

Yang, Ruiliang et al.

Article

Different effects of main influence factors on household energy consumption in three typical rural villages of China

Energy Reports

Provided in Cooperation with:

Elsevier

Suggested Citation: Yang, Ruiliang et al. (2018) : Different effects of main influence factors on household energy consumption in three typical rural villages of China, Energy Reports, ISSN 2352-4847, Elsevier, Amsterdam, Vol. 4, pp. 603-618, <https://doi.org/10.1016/j.egyr.2018.09.006>

This Version is available at:

<https://hdl.handle.net/10419/243543>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



<https://creativecommons.org/licenses/by-nc-nd/4.0/>



Research paper

Different effects of main influence factors on household energy consumption in three typical rural villages of China

Ruiliang Yang^{*}, Jiangmin He, Sha Li, Wen Su, Yue Ren, Xinyu Li

Key Laboratory of Modern Electromechanical Equipment Technology, Tianjin Polytechnic University, Tianjin 300387, China

ARTICLE INFO

Article history:

Received 21 May 2018

Received in revised form 14 September 2018

Accepted 20 September 2018

Available online 11 October 2018

Keywords:

Energy consumption

Influence factor

Ordinary least squares (OLS)

Quantile regression (QR)

ABSTRACT

Three typical rural villages are chosen as study areas to study the different effects of main influence factors on rural household energy consumption using the ordinary least squares (OLS) model and the quantile regression (QR) model. Three typical rural villages include an affluent rural village in the richest province, a well-off rural village in the most energy-rich province and an out-of-poverty rural village in the most population province. The OLS results show family size and household income are significant at the 10 % level in all study areas, while air conditioner and refrigerator are only significant at the 5 % level of the affluent rural village. Family size has a positive effect on energy consumption, while household income has different effect in different areas. The QR results fluctuate around OLS results with large amplitude, indicating a different pattern of the effect of main independent variables on energy consumption using different models. The slopes are significantly different for all study areas at 10% significant level, which shows the distribution heterogeneity in studying the relationships between energy consumption and influence factors. This study is useful to develop more appropriate energy policy according to the main influence factors in different rural villages.

© 2018 Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

1. Introduction

With the rapid urbanization in China, the rural population was declining in recent years, whereas rural household energy consumption was rising sharply. Although the rural population declined from 745.4 million in 2005 to 603.5 million in 2015 (NBS, 2017), energy consumption of rural residents increased from 115.5 million tons coal equivalent (tce) in 2005 to 211.8 million tce in 2015 (NBS, 2016), with an annual growth of 6.6%. The average annual household energy consumption of rural residents increased from 155 kg coal equivalent (kgce) in 2005 to 351 kgce in 2015, approximately 226.5%. If China can maintain the average annual urbanization rate of 1% and reach an urbanization rate of approximately 70% by the end of 2030, there will still be more than 400 million rural population, which means enormous rural household energy consumption due to rising average annual household energy consumption of rural residents (Yu and Guo, 2016).

To reduce the enormous rural household energy consumption by the large rural population, it is necessary to further study the effect of main influence factors on rural household energy consumption. Some researchers analyzed the effect of main influence factors on household energy consumption at the macro-level, with the data came from the government statistics such as

China Statistical Yearbook. The stochastic impacts by regression on population, affluence and technology (STIRPAT) model is the most widely applied at the macro-level to research the relationship between household energy consumption and its influence factors (Ding et al., 2016). GDP per capita, average temperature, and population are the popular influence factors used in this model (Ding et al., 2016; Miao, 2017; Li, 2015). Logarithmic mean Divisia index (LMDI) technique is also frequently applied to the field of energy consumption (Nie and Kemp, 2014; Chung et al., 2011; Zhang and Guo, 2013), which can analyze the influence factors on energy consumption at the macro-level. Population, floor space, energy mix, appliance, and climate effect may be chosen as influence factors in the LMDI decomposition analysis. Residential energy model global (REMG) model (Daioglou et al., 2012), bottom-up model for residential energy use (van Ruijven et al., 2011), piecewise linear model (Liu et al., 2016), panel smooth transition regression (PSTR) model (Lee and Chiu, 2011), consumer lifestyle approach (CLA) (Wei et al., 2007), stochastic impacts by regression on population, affluence, and technology (STIRPAT) model (York, 2007), quantile regression (QR) model (Kaza, 2007), local area resource analysis (LARA) model (Druckman and Jackson, 2007) are also applied to research the influence factors on household energy consumption. However, due to the lack of detailed statistics on rural household energy consumption, researching the main influence factors on household energy consumption at the macro-level focuses on a province-level or city-level, and the conclusions are applied to

^{*} Corresponding author.

E-mail address: yangruiliang2001@sina.com (R. Yang).

Table 1
The summary of factors influencing the rural residential energy consumption in recent studies.

	Authors	Sample	Data period	Data source	Rural/urban	Influence factors	Methods	How do the factors act on the household energy consumption/ electricity consumption?
Macro-level	Ding et al. (2016)	30 provinces in China	1997–2013	China Energy Statistical Yearbook (1998–2014), China Statistical Yearbook (1998–2014), National Meteorological Information Center	Rural and urban	GDP per capita, urbanization level, annual average temperature	STIRPAT model	Significant positive impact (GDP per capita), significant negative impact (annual average temperature), uncertainty (urbanization level)
	Liu et al. (2016)	540 observations in 30 Chinese provinces	1995–2012	China Energy Statistical Yearbook (1996–2013), China Statistical Yearbook (1996–2013)	Rural and urban	Income	Piecewise linear model	Significant impact on residential electricity consumption (income)
	Li and Lin (2015)	A balanced panel data set of 73 countries	1971–2010	World Bank, UN	Rural and urban	Urbanization, industrialization	STIRPAT model	Significant impact (urbanization, industrialization)
	Nie and Kemp (2014)	China	2002–2010	China statistical yearbook 2011, China energy statistical yearbook (2003–2011)	Rural and urban	Population, floor space, energy mix, energy demand from appliances effect	LMDI technique	The most important factor (energy demand from appliances effect), the second most important factor (floor space), the third most important factor (population), negligible factor (energy mix)
	Zhang and Guo (2013)	China	1991 to 2010	China Statistical Yearbook, China Energy Statistical Yearbook	Rural	Population, energy intensity, per capita net income, energy mix	LMDI technique	The critical factor (per capita net income), dominant role (energy intensity), followed effect (population), very minor role (energy mix)
	Daioglou et al. (2012)	India, China, South East Asia, South Africa and Brazil	2007	World Development Indicators of the World Bank, World Bank, World Health Organization	Rural and urban	Population, household expenditure, population density, household size, temperature	REMG model	Primary drivers of energy use (population, household expenditure, population density, household size, temperature)
	van Ruijven et al. (2011)	India	1971–2003	OECD Environmental Outlook scenario, National Sample Survey Organization (NSSO) of the Ministry of Statistics	Rural and urban	Population, household size, income and temperature	Bottom-up model	Primary drivers of energy use (population, household size, income and temperature)
	Lee and Chiu (2011)	24 OECD countries	1978–2004	The World Development Indicators	Rural and urban	Real income, electricity price, and temperature	PSTR model	Significant impact (real income), negative or U-shaped relationship (temperature), no influence (electricity price)

(continued on next page)

the average situation rather than the actual rural village. Because rural resident is defined “the resident living outside of urban area”

(NBS, 2017), many non-farmer population are often classified as rural population in Chinese official statistics, which leads to great

Table 1 (continued).

Authors	Sample	Data period	Data source	Rural/urban	Influence factors	Methods	How do the factors act on the household energy consumption/ electricity consumption?
Kaza (2010)	4382 observations in USA	1987–2005.	Residential Energy Consumption Survey Data from the Energy Information Administration	Rural and urban	Heating degree days, heating area, cooling degree days, cooling area, housing size, household size, age of house, neighborhood density, income, price, ownership status, housing type	QR approach	Significant impact (heating degree days, heating area, cooling degree days, cooling area, housing size, household size, age of house, income, price)
Pachauri and Jiang (2008)	India, China	1999/2000	Various Indian official and ministerial publications, National Bureau of Statistics (NBS).	Rural and urban	Income, urbanization, energy access, energy price, geographic variation, climatic factors, local resource, availability, customs and tastes demographic factors	Comparison by figures or tables.	The most important factors (income, urbanization, energy access, energy price)
York (2007)	European Union Nations	1960–2000	World Bank	Rural and urban	Population size, age structure, economic development, urbanization	Elasticity STIRPAT model	Clear effect (population size, age structure), substantial contribution (economic development, urbanization)
Wei et al. (2007)	China	1999–2002	China Energy Statistical Yearbook, China Statistical Yearbook, China Industrial Statistical Yearbook, China Population Statistical Yearbook, China Rural Statistical Yearbook	Rural and urban	Home energy use; food, education, cultural and recreation services; personal travel; clothing, medicine and medical services; transport and communication services; household facilities and services; miscellaneous commodities and services	CLA	The most energy-intensive for urban residents (home energy use, food, education, cultural and recreation services), the most energy-intensive for rural residents (home energy use; food, education, cultural recreation services; personal travel)
Druckman and Jackson (2008)	7000 sampled households in the UK.	2004–2005	Expenditure and Food Survey (EFS),	Rural and urban	Income levels, type of dwelling, tenure, household composition and rural/ urban location, population	LARA	Strongly influenced (income levels), also extremely important (type of dwelling, tenure, household composition and rural/ urban location, population)

(continued on next page)

limitations of studying China's rural energy-related issues using the average situation.

Some researchers analyzed the effect of main influence factors on household energy consumption in China at the micro-level,

Table 1 (continued).

	Authors	Sample	Data period	Data source	Rural/urban	Influence factors	Methods	How do the factors act on the household energy consumption/ electricity consumption?
Micro-level	Ding et al. (2017)	187 valid questionnaires in Jiangsu province of China	Uncertainty	Questionnaire and interviews	Rural and urban	Energy-saving knowledge; environmental values; environmental responsibility; comfort preference; group psychology; low-carbon energy-saving willingness; habits and lifestyle; publicity, education and information; policies and regulations; economic cost, social technology	Linear regression model	The factor with the greatest influence for urban residents is low-carbon energy-saving willingness, the greatest influence on rural residents is publicity, education and information
	Yu and Guo (2016)	3404 households in 12 provincial units of China	2014	Questionnaires	Rural	Floor area, family member, No. of refrigerator, paid electricity bill monthly, household yearly income, dwelling age, No. of televisions, calculated electricity price, household head's education, TV labeling tier one, refrigerator labeling tier one, regional heterogeneity	Stochastic frontier model	Significant effect on electricity consumption (floor area, family member, No. of refrigerator, paid electricity bill monthly, household yearly income) Not Significant impact on electricity consumption (dwelling age, No. of televisions, calculated electricity price, household head's education, TV labeling tier one, refrigerator labeling tier one, regional heterogeneity)
	Niu et al. (2016)	1128 survey questionnaires in western China	2012	Questionnaires	Rural and urban	Price of electricity, per capita income, the price of electrical appliances, the diversity of appliances, household size	OLS and quantile regressions	Significantly effects on electricity consumption (per capita income, the price of electrical appliances, the diversity of appliances), little effects on electricity consumption (household size), no effects on electricity consumption (price of electricity)

(continued on next page)

with the data mainly from questionnaires. For example, based on 165 responses from the rural region of Zibo city in Shandong

province, Liu et al. regarded age, education, household size, income, and ownership of air conditioners as main influence factors

Table 1 (continued).

Authors	Sample	Data period	Data source	Rural/urban	Influence factors	Methods	How do the factors act on the household energy consumption/ electricity consumption?
Liu et al. (2013)	165 responses from Shandong province	2011	Questionnaire	Rural	Age, education, household size, income, ownership of air conditioners	Linear regression model	Positively correlated with the five explanatory variables at 10% significant level
Ping et al. (2013)	478 households in eastern part of Qinghai-Tibet Plateau	2004	Participatory Rural Appraisal (PRA), Physical Monitoring (PM)	Rural	Altitude, household size, annual income, education level and livelihood	Regression analysis	Important influence factors on energy consumption per capita (altitude, household size and annual income), Leading factors of electricity consumption (altitude, annual income, education level)
Niu et al. (2012)	719 sample data in the Western Loess Plateau of China	2009–2010	Questionnaire	Rural and urban	Income level, energy attributes	Cross-quadratic model	Main impact (the income level), litter impact (energy attributes)
Wang et al. (2002)	384 households in 12 villages of 4 towns in Jiangsu Province, China	1997	Questionnaire	Rural	Annual per capita income, per capita straw yield, number of persons and pigs per household, attitude towards energy consumption	Stratification sampling method	Main factors (annual per capita income, per capita straw yield, number of persons and pigs per household, attitude towards energy consumption)

on household energy consumption using the linear regression method ([Liu et al., 2013](#)). Based on 187 valid questionnaires from

Jiangsu province, Ding et al. studied the differences in the factors influencing energy-saving behavior of urban and rural residents



Fig. 1. The location of investigative areas.

using multiple regression analysis (Ding et al., 2017). Based on data from 1128 survey questionnaires in western China, Niu et al. analyzed six factors on residential electricity consumption using the QR approach (Niu et al., 2016). The greatest advantage of the micro-level is completely closed to the actual rural village instead of the average situation. However, the rural villages studied above were mostly randomly selected areas, and the conclusions were quite different, see Table 1.

Table 1 summarizes the factors influencing household energy consumption in recent studies. It can be seen from Table 1 that the main influence factors of rural household energy consumption (appear in one or more documents, and are generally considered to have a significant effect) are: household income (or GDP per capita or household expenditure), family size, household size, location (or annual average temperature, climatic factor), air conditioner, refrigerator, education level, price of electrical appliances, energy price, urbanization level, industrialization. The factors influencing household energy consumption in different documents were inconsistent, which means it is necessary to further study the factors in the typical rural area. For this propose, this paper analyzes the effect of main influence factors on rural household energy consumption in typical rural villages not only using the ordinary least squares (OLS) model, but also using the QR model, which can tease out the effects of various influence factors on the distribution on the energy consumption in different areas instead of focusing on the conditional average (Chung et al., 2011).

This paper differs from existing articles in three major respects. First, study areas are three typical rural villages in three typical provinces. Due to China's extensive territory, there is sharply different life styles among rural regions, which means there may be different influence factors in different rural regions. To distinguish real main influence factors on the energy consumption, the study areas must be typical areas. Three typical rural villages include an affluent rural village with a strongly developed agricultural economy in the richest province, a well-off rural village with a mixed economy of agriculture and local industry in the most energy-rich province, and an out-of-poverty rural village with an overwhelmingly agricultural economy in the most population province. Second, this paper not only analyzes the influence factors on energy consumption using the OLS and QR models, but also discusses the different effects of all independent variables and the significant

Table 2
Brief profiles of the household characteristics.

Item	Tianping Village	Dapu Village	Shihuiyao Village	All
Effective number of households	397	96	170	663
Effective population	1821	396	778	2995

variables using these models. Third, the Kruskal–Wallis test is used in this paper to compare the differences of energy consumption and six influence factors in study areas.

2. Survey

2.1. Investigative areas

This study was undertaken in three typical rural villages: Tianping Village, Dapu Village and Shihuiyao Village (see Fig. 1). The three selected villages are far apart to reduce the impact of cities on rural areas. Because the villages in the same province always have similar energy policy and energy consumption habit, one village is chosen from one province. Tianping Village is an affluent rural village with a strongly developed agricultural economy in northwest Tianjin, the richest province with the highest per capita gross domestic product in China (NBS, 2017). Tianping Village has the distinctive features of nursery stock production, and almost all residents lived by stock cultivation and transportation. Dapu Village is a well-off rural village in central Shanxi province, China's largest coal producing and storage province. Like most of China's rural villages, Dapu Village has a mixed economy with agriculture and local industry. Almost all Dapu Village residents lived by farmland and coal industry. Shihuiyao Village is an out-of-poverty rural village in southern Henan province, the most population province. Shihuiyao Village has an overwhelmingly agricultural economy, and almost all Shihuiyao Village residents lived by farmland. To pursue a better life, many adults of Shihuiyao Village township went to coastal boomtown for work, the old men and children stayed at home as “empty nest”.

2.2. Sample selection and data acquisition

Survey on residential energy consumption in the rural village was undertaken by a survey team in January 2016. Half of total household was chosen in each village as samples. The questionnaires were applied by home visits with the help of the local government and the local junior high school. Questionnaire topics include: energy type, energy consumption, household information, house information and other energy related information. Incomplete or obviously false samples were abandoned. Table 2 shows brief profiles of household characteristics.

2.3. Energy type and influence factors

Energies used by the residents in this survey include electricity, liquefied petroleum gas (LPG), coal, gasoline, diesel, biogas, solar energy, stalk, and fireweed. To allow convenient energy consumption comparison, all energies are indicated by their standard coal equivalent (China Nation Standardization Management Committee, 1998).

Fig. 2 shows the average annual energy consumption for study regions. The average annual energy consumption for a household in Tianping Village, Dapu Village, Shihuiyao Village are 2301.0, 2363.7, 1030.1 kgce, respectively. The main energies used in Tianping Village, Dapu Village, and Shihuiyao Village are coal and gasoline, coal and stalk, and stalk and diesel, respectively.

3. Methodology

General statistical characteristics of energy consumption in study areas are shown in Table 3. The average annual energy consumption in Shihuiyao Village is obviously below than that in Tianping Village and Dapu Village. The skewness and kurtosis of energy consumption in study areas are larger than zero, meaning energy consumption in study areas is right advergence and relatively centralized. The kurtosis coefficients of energy consumption in investigative regions are all lower than 3, meaning less outliers (Joanes and Gill, 1998). Fig. 3 shows the kernel densities of household energy consumption.

3.1. The main influence factors

The main influence factors in this paper are chosen from analyzed main influence factors in Table 1, i.e., household income (or GDP per capita or household expenditure), family size, household size, air conditioner, refrigerator, education level, price of electrical appliances, energy price, urbanization level, industrialization, location (or annual average temperature, climatic factor). However, for study areas, the above factors may be modified according to the actual situation. First, due to universal nine-year compulsory education in China from 1986, the investigative homeowners were junior high school education or slightly lower than junior high school education, though some homeowners appeared to be illiterate for a long time without reading and writing. Thus, the education levels of the homeowners are basically the same, and are not considered in this study. Second, the electrical appliances and commercial energy were all purchased from the market, with prices fluctuating in different periods, which meant it is meaningless to research the effect of electrical appliances prices and commercial energy price on energy consumption using the electrical appliances and commercial energy from different sources. Thus, the price of electrical appliances and energy price are not considered in this study. Third, urbanization level and industrialization are very effective to discuss urban-related issues, but failed to study the rural problems. Thus, urbanization level and industrialization are not considered in this study. Fourth, three study areas are considered separately rather than together, so the location is not considered as the main influence factor in this study. In summary, the main influence factors in this study are household size, household income, family size, household age, air conditioner and refrigerator.

Table 4 shows the brief profiles of six influence factors of residential energy consumption. The average house areas, family size, household age and the percentage of refrigerator in three investigative areas are close, whereas household income and the percentage of air conditioner in three investigative areas are significantly different. The average household income of Tianping Village residents, Dapu Village residents and Shihuiyao Village residents are 41.9 ± 34.4 , 27 ± 20.2 , 18.4 ± 12.3 thousand Yuan, respectively. The average household income of the surveyed Tianping Village residents was significantly higher than that of the other two regions, while the average household income of the surveyed Shihuiyao Village residents is significantly lower than that of the other two regions. The percentages of air conditioner in Tianping Village, Dapu Village and Shihuiyao Village are 58.9%, 8.3% and 67.1%. The percentage of air conditioner in Dapu Village is significantly lower than that of the other two regions.

3.2. Methodology

The OLS and QR models are used to estimate the effect of six influence factors (household income, family size, household size, air conditioner, refrigerator, and household age) on energy consumption.

The linear model takes the following form:

$$y_i = x_i' \beta + \varepsilon_i \quad (1)$$

where y_i is the dependent variable, representing household energy consumption; x_i is six chosen independent variables, including household area (HA), household income (HI), family size (FS), household age (HHA), air conditioner (AC), and refrigerator (RE). HA, HI, FS, HHA are normal variables, while AC and RE are dummy variables. $AC = 1/RE = 1$ means air conditioner/refrigerator is used by investigative resident, while $AC = 0/RE = 0$ means air conditioner/refrigerator is not used. ε_i is error term. β is unknown parameter, and can be estimated by the OLS model:

$$\min \sum_{i=1}^n (y_i - x_i' \beta)^2 \quad (2)$$

β can also be estimated for any quantile τ by the QR model (Niu et al., 2016):

$$\min \left[\sum_{i \in \{i: y_i \geq x_i' \beta\}} \tau |y_i - x_i' \beta| + \sum_{i \in \{i: y_i < x_i' \beta\}} (1 - \tau) |y_i - x_i' \beta| \right] \quad (3)$$

where $0 \leq \tau \leq 1$.

4. Results

4.1. The results of OLS and QR models

The results of OLS and QR models using six independent variables are presented in Table 5. The OLS results indicate that the significant variables at 10% significant level in Tianping Village, Dapu Village, Shihuiyao Village and all investigative area are HI, FS, AC, RE; HI, FS; HI, FS; and HI, FS, respectively. FS is a significant variable, and has a positive effect on energy consumption. HI is also a significant variable, and has a positive effect on energy consumption of Tianping Village residents, but has a negative effect on energy consumption of Dapu Village residents and Shihuiyao Village residents. There were many migrant workers with more money but less time at home in Dapu Village and Shihuiyao Village, which made income and energy consumption different trend. For Tianping Village residents, owning an air conditioner or refrigerator can result in a significant increase of household energy consumption.

Different to the OLS model, the QR model seeks to estimate the conditional quantile function models in which quantiles of the conditional distribution of the response variable are expressed as functions of observed covariates (Niu et al., 2016). The 5th, 10th, 20th ... 80th, 90th and 95th quantiles are estimated in Table 6, which helps to better understand the effects of the distribution of independent variables. Fig. 4 represents a summary of QR results for the six independent variables in investigative rural villages. In Fig. 4, the solid line shows the QR estimates for the quantiles ranging from 0.05 to 0.95, the shaded area denotes 90% confidence interval for the QR estimates, the dashed lines and the dotted lines denotes the coefficient and 90% confidence band of the OLS estimates, respectively. It can be seen from Fig. 4 and Table 5 that the QR results can change across the quantiles, and fluctuate around the QLS results with large amplitude, indicating a different pattern of the effect of six independent variables on energy consumption using two models.

The effects of HI on energy consumption are significant positive at all quantiles for Tianping Village residents and all investigative residents, while are negative and statistically significant at most quantiles for Dapu Village residents and Shihuiyao Village residents. For Tianping Village residents, the positive effects of HI are low at bottom quantiles, and high at top quantiles. For Dapu Village

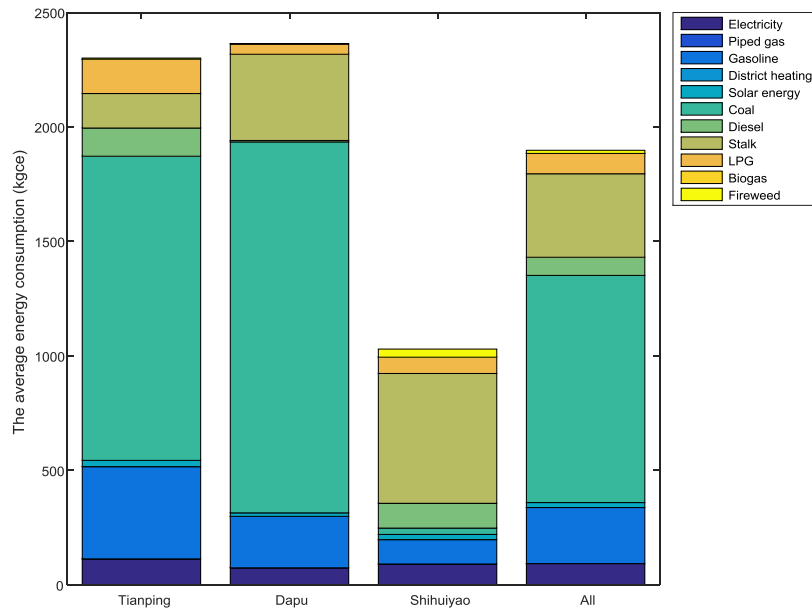


Fig. 2. The average annual energy consumption in study regions.

Table 3
General statistical characteristics of energy consumption in study areas.

	Sample	Maximum (kgce)	Minimum (kgce)	Mean (kgce)	25th percentile (kgce)	Median (kgce)	75th percentile (kgce)	Skewness	Kurtosis
Tianping Village	397	4589.6	824.6	2301	1693.5	2104.8	2852	0.53822	2.6232
Dapu Village	96	3962.0	606.8	2363.7	1823.6	2331.7	2722.8	0.11074	2.9132
Shihuiyao Village	170	3335.6	79.3	1030.1	393.0	763.7	1622.6	0.74486	2.8243
All	663	4589.6	79.3	1984.2	1306.1	1889.9	2599.2	0.22873	2.6229

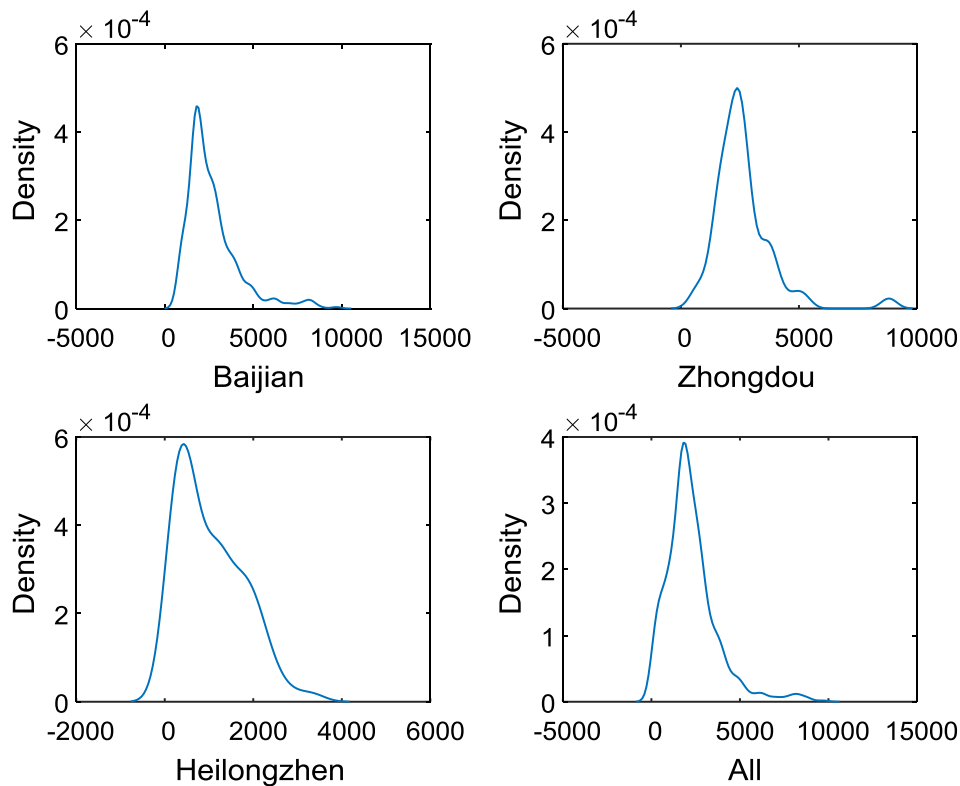
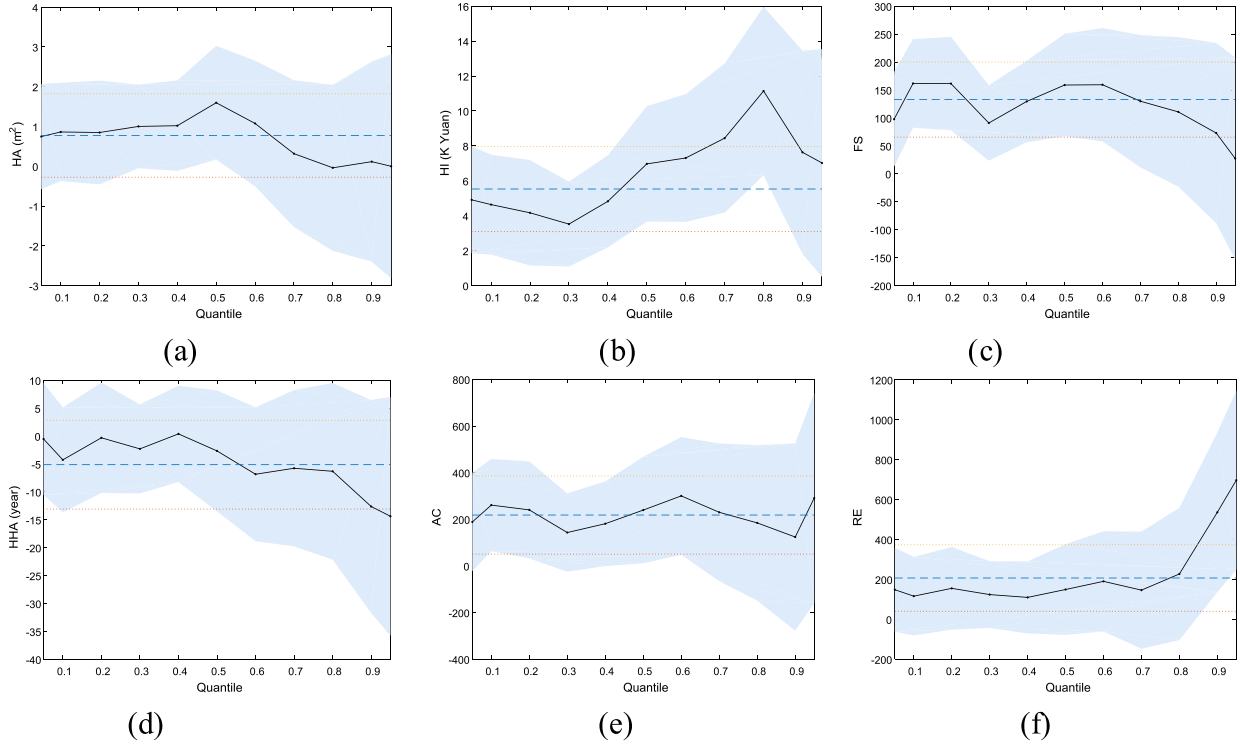


Fig. 3. Kernel density estimate of energy consumption in study areas after eliminating outliers.

residents, HI has a positive effect on energy consumption below 10th, then has more and more negative effects from 10th to 95th.

The effects of HI on energy consumption for Dapu Village residents are statistically significant at 5th, 70th to 95th. For Shihuiyao

Tianping Village



Dapu Village

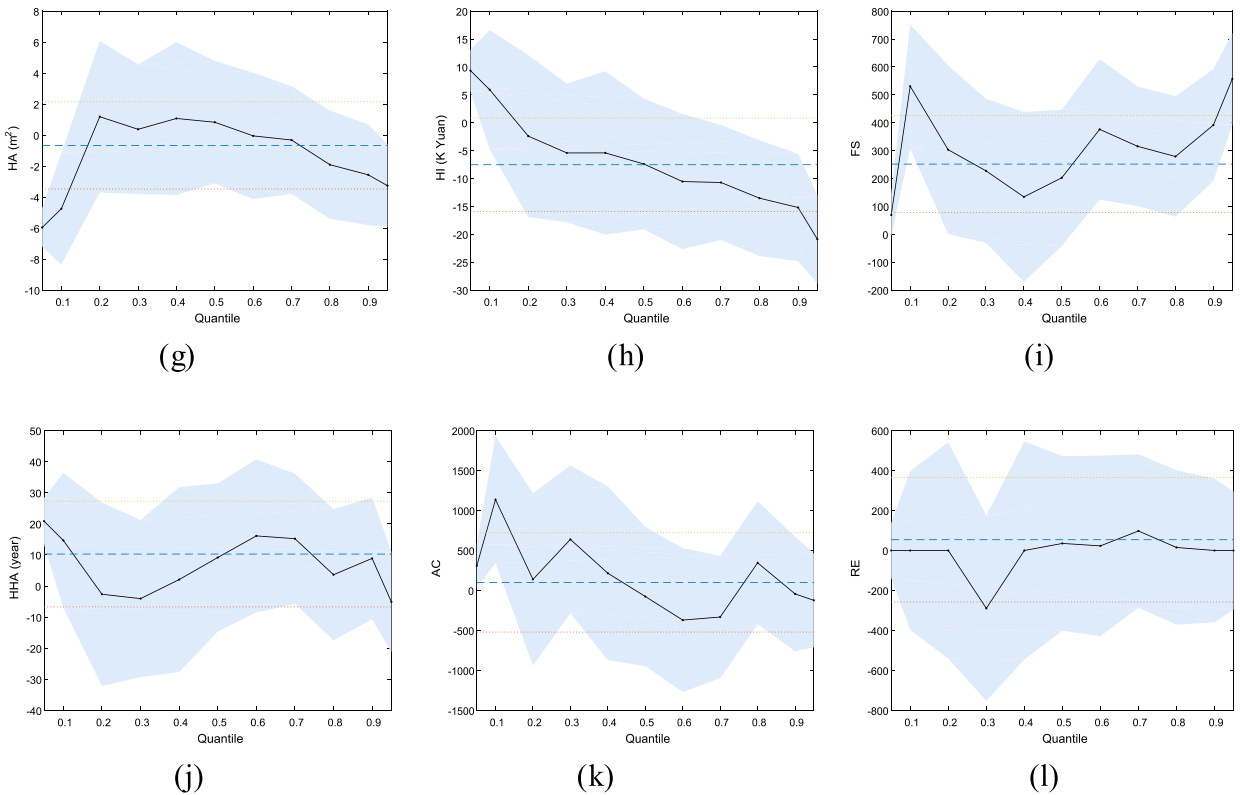


Fig. 4. The QR results for six independent variables in the investigative rural villages. Note: The solid line shows the QR estimates for the quantiles ranging from 0.05 to 0.95; the shaded area denotes 90% confidence interval for the QR estimates; the dashed lines and the dotted lines denote the coefficient and 90% confidence band of the conventional OLS estimates, respectively. (a)~(f) denote the QR results in Tianping Village, (g)~(l) denote the QR results in Dapu Village, (m)~(r) denote the QR results in Shihuiyao Village, (s)~(x) denote the QR results in all investigative area.

Shihuiyao Village

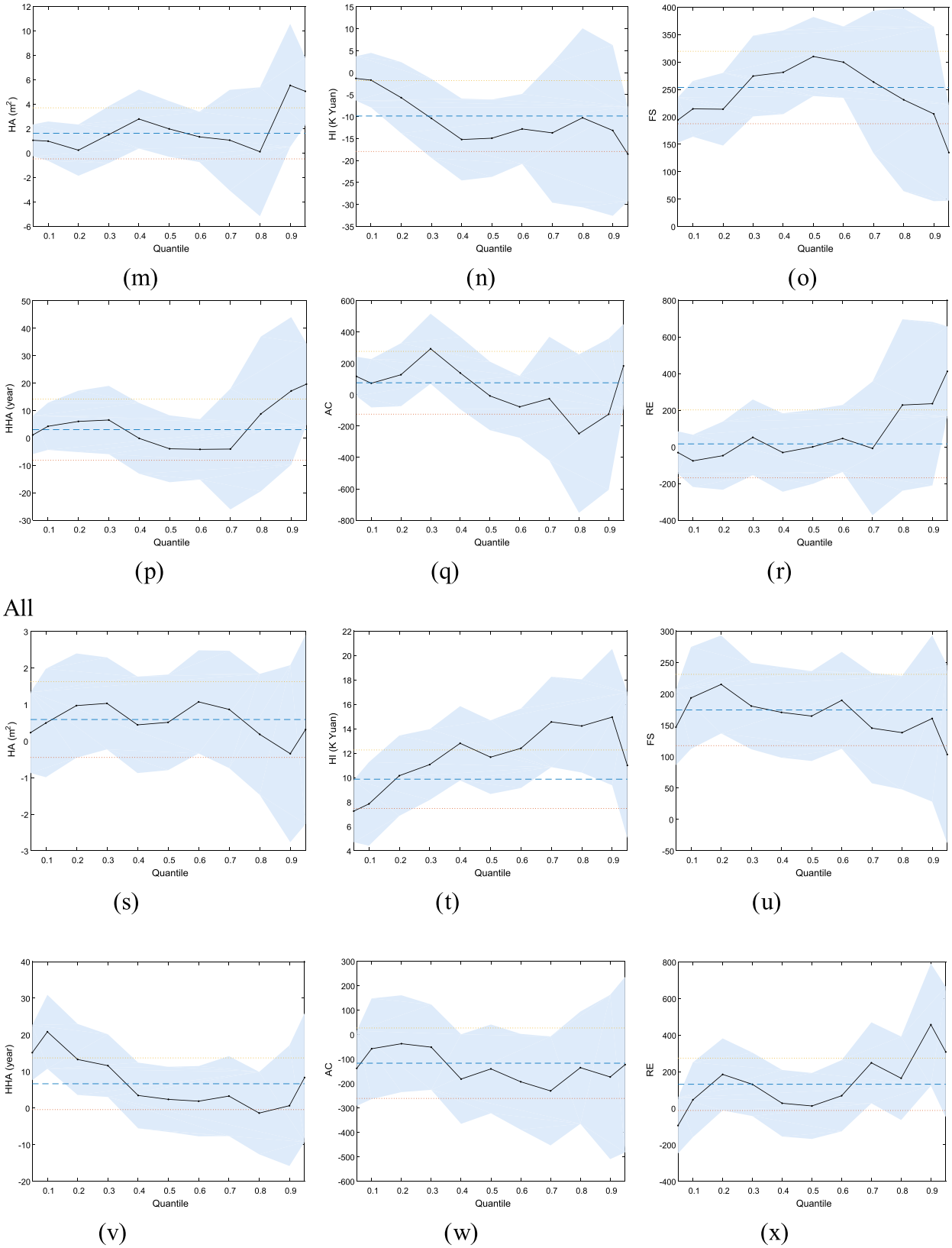


Fig. 4. (continued).

Village residents, the negative effects of HI are low at bottom quantiles, and high at top quantiles. The effects of HI on energy

consumption for Shihuiyao Village residents are statistically significant from 30th to 60th, and 95th. For all investigative residents,

Table 4
Brief profiles of six influence factors of the residential energy consumption.

	House area (m ²)				Household income (k Yuan)				Family size				Household age (years)				AC (percentage)	RE (percentage)
	Max	Min	Mean	Std.	Max	Min	Mean	Std.	Max	Min	Mean	Std.	Max	Min	Mean	Std.		
	504	48	140.7	80.7	500	5	41.9	34.4	10	2	4.6	1.2	57	2	21.6	10.8	58.9%	63.0%
Dapu	360	48	129.6	64.9	120	10	27	20.2	6	2	4.1	0.9	37	2	16.8	9.9	8.3%	45.8%
Shihuiyao	336	60	138.2	52.1	60	2	18.4	12.3	10	2	4.6	1.5	37	2	16.9	8.5	67.1%	55.3%
All	504	48	138.4	72.2	500	2	33.7	30.2	10	2	4.5	1.3	57	2	19.7	10.4	53.7%	58.5%

Note: AC denotes air conditioner, RE denotes refrigerator.

HI has more and more positive effect on energy consumption from 5th to 90th, then quickly declines. While HI changes with one thousand Yuan, holding other variables constant, according to the OLS model the annual household energy consumption of Tianping Village residents, Dapu Village residents, Shihuiyao Village residents and all investigative residents' changes 5.5327, -7.5224 , -9.8728 , and 9.8649 kgce, respectively. But when using the QR model, the energy consumption of Tianping Village residents, Dapu Village residents, Shihuiyao Village residents' changes from 3.5232 , -20.8706 , -18.5398 , 7.2471 kgce to 11.1429 , 9.3442 , -1.3206 , 14.9489 kgce, respectively.

The effects of FS on energy consumption are positive at all quantiles for residents in study areas. For Tianping Village residents, the effects of FS reach peak at the 20th and 60th, and not statistically significant at the 80th, 90th, and 95th. For Dapu Village residents, the effects of FS become wave-like strong, and reach peak at top quantiles, and not statistically significant from 30th to 50th. For Shihuiyao Village residents, the effects of FS reach peak at 50th, and statistically significant at all quantiles. For all investigative residents, the effects of FS reach peak at 20th, then fluctuate from 20th to 95th, and statistically significant at all quantiles. While FS changes with one person, holding other variables constant, according to the OLS method the annual household energy consumption of Tianping Village residents, Dapu Village residents, Shihuiyao Village residents and all investigative residents' changes 132.9606 , 251.6976 , 253.4163 , and 174.2487 . But when using the QR model, the energy consumption of Tianping Village residents, Dapu Village residents, Shihuiyao Village residents' changes from 27.5248 , 69.1377 , 134.7795 , 103.3531 kgce to 161.8098 , 557.0521 , 309.9580 , 215.0476 kgce, respectively, with the range of 5.8787 , 8.0571 , 2.2997 and 2.0807 times.

The effects of AC on energy consumption are positive at all quantiles for Tianping Village resident, which indicates owning an air conditioner can promote energy consumption. The coefficients of AC range from 124.1993 to 300.5054 , but the effects of AC are only significant at some bottom quantiles and some median quantiles. The effects of AC on energy consumption for other residents except Tianping Village are only statistically significant at very few points. Similar to AC, the effects of RE on energy consumption are positive at all quantiles for Tianping Village residents, which indicate owning RE can promote energy consumption. The coefficients of RE change slowly below 80th, then quickly rise to top. However, the effects of RE are only significant at 90th. For other residents except Tianping Village, the effects of RE on energy consumption are only statistically significant at very few points.

The effects of HA on energy consumption are not statistically significant at all quantiles for all the residents, but statistically significant at 50th for Tianping Village residents, 5th, 10th, 95th for Dapu Village residents, and 40th, 90th, 95th for Shihuiyao Village residents.

The effects of HHA on energy consumption are not statistically significant at all quantiles for the residents in Tianping Village, but statistically significant at low quantiles for Dapu Village and all the residents, 95th for Shihuiyao Village residents.

4.2. The slope equality test

The slope equality test used to quantify whether coefficients are significantly different across the quantiles. The null hypothesis is $b_{\tau=h} = b_{\tau=k}$, where $b_{\tau=h}$ and $b_{\tau=k}$ are slope coefficients in the neighboring quantiles. Rejection of the null hypothesis implies that the slopes are significantly different. Table 6 displays p values of the null hypothesis for quantile slope equality test. The null hypothesis of slope equality is only rejected at $b_{0.2} = b_{0.3}$ of FS, $b_{0.8} = b_{0.9}$ of RE for the Tianping Village residents; $b_{0.8} = b_{0.9}$ of HA for Shihuiyao Village residents; $b_{0.3} = b_{0.4}$ of HHA and AC, $b_{0.6} = b_{0.7}$ and $b_{0.8} = b_{0.9}$ of RE for all residents. The rejection of the null hypothesis of slope equality at most quantiles suggested that the slopes are not significantly different in neighboring quantiles of the response variable distribution. However, the slopes for all coefficients are significantly different for Dapu Village residents, Shihuiyao Village residents and all the residents at 5% significant level, and for Tianping Village residents at 10% significant level. Therefore, it is important to consider the distribution heterogeneity in studying the relationships between energy consumption and influence factors.

5. Discussions

5.1. Six independent variables and the significant variables

To ensure the accuracy of the regression, significant variables should be chosen as independent variables when the OLS method is used. But the QR model is robust to outliers, which may make some insignificant coefficients become significant at some quantiles. Thus, the insignificant independent variables may be used in the QR model (Niu et al., 2016; Zhu et al., 2016).

To compare the different effects of all independent variables and the significant variables, stepwise regression is used to choose the significant independent variables. By the forward selection at 5% significant level, significant independent variables in the linear model in study areas can be chosen as Table 7. HI, FS, AC, RE; HI, FS; HI, FS; and HI, FS are significant at 5% significant level for Tianping Village residents, Dapu Village residents, Shihuiyao Village residents and all investigative residents, respectively.

Both HA and HHA do not affect the energy consumption directly in the investigative areas at most quantiles, which differs from existing studies (Yu and Guo, 2016; Daioglou et al., 2012; van Ruijven et al., 2011; Kaza, 2010). China's rural per capita residential area was 39 square meters in 2014, and would remain unchanged in the next few years. But the per capita housing areas of the rural region were quite different, and many people did not mean a large household area (Tsinghua University Building Energy Conservation Research Center, 2016) which results in HA does not affect energy consumption directly in the investigative areas. HHA in the investigated areas varies from 0 to 55 years old, but the building materials are generally made of brick and concrete, and are not much changed, which results in HHA has no significant effect on energy consumption directly in the study areas.

AC and RE are significant at 5% significant level for Tianping Village residents, but are not significant for Dapu Village residents,

Table 5
The QR and OLS model estimates for energy consumption.

Variables	Location	HA	HI	FS	HHA	AC	RE	Intercept
OLS	Tianping	0.7755 (0.5331)	5.5327**** (1.2346)	132.9606**** (34.2246)	-5.1054 (4.0482)	218.4098** (85.2301)	207.3721** (84.7642)	1201.4670**** (222.0780)
	Dapu	-0.6629 (1.4173)	-7.5224* (4.2074)	251.6976*** (87.5366)	10.2798 (8.5527)	100.6384 (312.4496)	54.0018 (156.8321)	1409.1040*** (400.5097)
	Shihuiyao	1.6115 (1.0578)	-9.8728** (4.0853)	253.4163**** (33.4502)	3.0483 (5.6576)	75.9554 (101.3105)	16.1783 (93.8059)	-281.8392 (213.3745)
	All	0.5913 (0.5285)	9.8649**** (1.2192)	174.2487**** (28.9229)	6.6370* (3.5952)	-117.1371 (73.3635)	130.8666* (72.9309)	638.2119**** (171.1619)
Quantiles								
0.05	Tianping	0.7484 (0.6720)	4.9134*** (1.5562)	97.7839** (43.1412)	-0.5049 (5.1029)	188.7508* (107.4353)	148.7397 (106.8480)	233.0646 (279.9364)
	Dapu	-5.9578**** (0.6300)	9.3442**** (1.8701)	69.1377* (38.9088)	20.8452**** (3.8016)	308.1948** (138.8796)	0 (69.7098)	1046.7710**** (178.0211)
	Shihuiyao	1.04341 (0.6605)	-1.3206 (2.5508)	194.1513**** (20.8858)	1.1188 (3.5325)	116.7847* (63.2568)	-31.2249 (58.5711)	-777.0010**** (133.2280)
	All	0.2324 (0.5624)	7.2471**** (1.2975)	146.9364**** (30.7819)	15.1398**** (3.8264)	-138.1951* (78.0790)	-94.7674 (77.6187)	-571.4082*** (182.1635)
0.1	Tianping	0.8640 (0.6283)	4.6403*** (1.4549)	161.8098**** (40.3336)	-4.2457 (4.7708)	261.0276*** (100.4435)	116.3973 (99.8944)	153.7446 (261.7184)
	Dapu	-4.7453** (1.8093)	5.9138 (5.3710)	530.7569**** (111.7463)	14.6535 (10.9181)	1136.2758*** (398.8628)	0.0000 (200.2067)	-667.2573 (511.2774)
	Shihuiyao	0.9733 (0.8139)	-1.7061 (3.1436)	214.4850**** (25.7394)	4.2748 (4.3534)	72.9619 (77.9568)	-76.3785 (72.1822)	-804.4355**** (164.1884)
	All	0.4958 (0.7551)	7.8405**** (1.7419)	193.5103**** (41.3256)	20.8281**** (5.1370)	-57.9627 (104.8232)	46.0880 (104.2051)	-781.8100**** (244.5593)
0.2	Tianping	0.8503 (0.6620)	4.1702*** (1.5331)	161.5526**** (42.5000)	-0.2917 (5.0270)	240.5192** (105.8385)	155.5460 (105.2599)	330.3918 (275.7758)
	Dapu	1.1887 (2.4598)	-2.3973 (7.3019)	303.3522** (151.9189)	-2.6515 (14.8431)	138.6860 (542.2534)	0.0000 (272.1807)	362.3958 (695.0809)
	Shihuiyao	0.2360 (1.0608)	-5.7024 (4.0969)	213.8601**** (33.5456)	6.0623 (5.6737)	127.1127 (101.5993)	-48.0283 (94.0733)	-563.6930*** (213.9827)
	All	0.9718 (0.7261)	10.1519**** (1.6751)	215.0476**** (39.7387)	13.2702*** (4.9397)	-37.3657 (100.7979)	184.9135* (100.2036)	-593.3193** (235.1683)
0.3	Tianping	1.0031* (0.5338)	3.5232*** (1.2361)	91.0295*** (34.2670)	-2.2782 (4.0532)	143.3511* (85.3358)	124.3274 (84.8693)	982.7148**** (222.3534)
	Dapu	0.3747 (2.1061)	-5.4126 (6.2520)	227.5701* (130.0743)	-4.0488 (12.7088)	638.8784 (464.2822)	-289.2571 (233.0435)	1262.2118** (595.1344)
	Shihuiyao	1.5011 (1.1782)	-10.4113** (4.5503)	274.3387**** (37.2576)	6.5642 (6.3015)	292.7096** (112.8419)	51.8158 (104.4831)	-946.8592**** (237.6613)
	All	1.0323 (0.6400)	11.0609**** (1.4764)	180.5045**** (35.0268)	11.5813*** (4.3540)	-51.5647 (88.8462)	130.6183 (88.3224)	-159.8641 (207.2842)
0.4	Tianping	1.0214* (0.5774)	4.8272**** (1.3370)	129.6012**** (37.0638)	0.4064 (4.3840)	181.1876* (92.3008)	110.1938 (91.7962)	838.8226**** (240.5015)
	Dapu	1.0749 (2.4803)	-5.4059 (7.3627)	134.1921 (153.1836)	2.0754 (14.9667)	215.4676 (546.7676)	0.0000 (274.4466)	1581.6075** (700.8674)
	Shihuiyao	2.7848** (1.2205)	-15.2204*** (4.7137)	281.1569**** (38.5958)	-0.1324 (6.5279)	138.2494 (116.8948)	-30.9522 (108.2358)	-638.2950*** (246.1973)
	All	0.4453 (0.6714)	12.8047**** (1.5489)	170.4596**** (36.7450)	3.4398 (4.5676)	-182.0326* (93.2045)	27.0866 (92.6549)	444.0173** (217.4522)
0.5	Tianping	1.5984** (0.7260)	6.9707**** (1.6812)	158.9553**** (46.6079)	-2.6423 (5.5129)	239.6707** (116.0686)	149.7197 (115.4341)	746.6181** (302.4316)
	Dapu	0.8320 (1.9879)	-7.4013 (5.9010)	202.5907 (122.7725)	9.1712 (11.9954)	-74.9822 (438.2196)	35.3735 (219.9616)	1511.5260*** (561.7265)
	Shihuiyao	1.9760* (1.1536)	-14.9191**** (4.4555)	309.9580**** (36.4815)	-3.9242 (6.1703)	-7.8048 (110.4913)	0.0000 (102.3067)	-402.2600 (232.7107)
	All	0.5134 (0.6655)	11.6686**** (1.5351)	164.5760**** (36.4191)	2.3745 (4.5271)	-140.3564 (92.3778)	12.2584 (91.8331)	743.8391**** (215.5235)

(continued on next page)

Shihuiyao Village residents and all investigative residents. Rural residents of Tianjin, the richest provincial level in China, were generally rich. Therefore, rural residents in Tianping Village purchased

more air conditioner and refrigerator, and more inclined to use air conditioning and refrigerator than residents in other areas, which

Table 5 (continued).

Variables	Location	HA	HI	FS	HHA	AC	RE	Intercept
0.6	Tianping	1.0779 (0.8027)	7.3090**** (1.8587)	159.4485*** (51.5276)	-6.8229 (6.0948)	300.5054** (128.3203)	190.6122 (127.6188)	1058.5605** (334.3549)
	Dapu	-0.0484 (2.0519)	-10.5390* (6.0911)	376.2512*** (126.7275)	16.1251 (12.3818)	-370.4488 (452.3361)	23.0363 (227.0473)	1174.8754** (579.8215)
	Shihuiyao	1.3235 (1.0427)	-12.8122*** (4.0272)	299.6031**** (32.9746)	-4.1359 (5.5771)	-77.2865 (99.8698)	45.8004 (92.4720)	-165.3539 (210.3403)
	All	1.0734 (0.7180)	12.3946**** (1.6564)	189.6223**** (39.2961)	1.8792 (4.8847)	-193.1298* (99.6755)	68.2738 (99.0878)	765.3860*** (232.5495)
0.7	Tianping	0.3187 (0.9380)	8.4451**** (2.1720)	129.9750** (60.2118)	-5.7494 (7.1220)	230.1383 (149.9467)	146.5787 (149.1270)	1596.7324**** (390.7054)
	Dapu	-0.3149 (1.7459)	-10.7127** (5.1827)	315.5237*** (107.8275)	15.2236 (10.5352)	-331.9955 (384.8752)	97.6125 (193.1857)	1552.3216*** (493.3476)
	Shihuiyao	1.0543 (2.0833)	-13.7082* (8.0461)	263.3742**** (65.8809)	-4.0239 (11.1427)	-25.2956 (199.5331)	-8.4968 (184.7527)	179.3773 (420.2456)
	All	0.8674 (0.8169)	14.5555**** (1.8844)	145.3313*** (44.7057)	3.2720 (5.5571)	-230.4759** (113.3970)	248.3643** (112.7284)	1083.5167**** (264.5627)
0.8	Tianping	-0.0366 (1.0597)	11.1429**** (2.4539)	110.8519 (68.0268)	-6.2948 (8.0464)	184.7438 (169.4084)	227.6133 (168.4823)	1955.6271**** (441.4154)
	Dapu	-1.9071 (1.7569)	-13.5243** (5.2155)	278.8751** (108.5102)	3.6375 (10.6019)	345.8004 (387.3121)	15.1231 (194.4089)	2386.7093**** (496.4713)
	Shihuiyao	0.1086 (2.6689)	-10.2744 (10.3077)	231.0222*** (84.3989)	8.7785 (14.2747)	-247.8641 (255.6185)	228.2235 (236.6836)	612.1114 (538.3694)
	All	0.1854 (0.8421)	14.2252**** (1.9426)	138.1971*** (46.0854)	-1.3723 (5.7286)	-135.4369 (116.8966)	163.8436 (116.2074)	1656.1731**** (272.7275)
0.9	Tianping	0.1180 (1.2781)	7.6342** (2.9596)	73.0562 (82.0468)	-12.6055 (9.7047)	124.1993 (204.3228)	536.4136*** (203.2059)	2635.7834**** (532.3893)
	Dapu	-2.5618 (1.6344)	-15.1910*** (4.8518)	391.6120**** (100.9446)	8.8823 (9.8627)	-42.7612 (360.3077)	0.0000 (180.8542)	2153.3578**** (461.8561)
	Shihuiyao	5.5341** (2.5464)	-13.1622 (9.8345)	205.2575** (80.5243)	17.1797 (13.6194)	-124.5296 (243.8833)	235.3861 (225.8177)	176.1961 (513.6536)
	All	-0.3434 (1.2324)	14.9489**** (2.8430)	160.7227** (67.4465)	0.6505 (8.3839)	-173.4410 (171.0794)	456.9056*** (170.0707)	1829.0640**** (399.1396)
0.95	Tianping	0.0013 (1.4328)	7.0240** (3.3179)	27.5248 (91.9788)	-14.3584 (10.8795)	291.1356 (229.0565)	697.3974*** (227.8043)	3072.3610**** (596.8361)
	Dapu	-3.2598** (1.3433)	-20.8706**** (3.9875)	557.0521**** (82.9617)	-5.0973 (8.1057)	-123.2790 (296.1204)	0 (148.6358)	2169.7023**** (379.5783)
	Shihuiyao	5.0525**** (1.4062)	-18.5398**** (5.4309)	134.7795*** (44.4677)	19.6476*** (7.5210)	183.5430 (134.6791)	411.7273**** (124.7028)	505.7647* (283.6537)
	All	0.3167 (1.3163)	10.9952**** (3.0366)	103.3531 (72.0399)	8.3333 (8.9549)	-122.9924 (182.7306)	307.7261* (181.6532)	2536.0661**** (426.3226)

Note:
 *p < 0.1.
 **p < 0.05.
 ***p < 0.01.
 ****p < 0.001.

results in more electricity. Tianping Village households, Dapu Village households, Shihuiyao Village households and all investigative households consumed 1050.27 ± 332.91 , 668.43 ± 234.48 , 743.77 ± 276.13 and 916.39 ± 347.80 kWh/year. Tianping Village residents used more electricity consumption than other residents did. Due to the highest average temperature in three investigative areas, Shihuiyao Village residents owned relatively more air conditioner and refrigerator, but consumed less electricity than Tianping Village residents because of poor economic conditions. Thus, AC and RE are only significant for Tianping Village residents.

Table 8 shows the comparison of computed coefficient for Tianping Village residents by the QR model using six independent variables and the significant variables. The maximum difference percentage is 106.68%, but the coefficient at that quantile is not statistically significant. Considering the 5% significant level, the maximum difference percentage is 30.43%. The trend of computed coefficient using two methods is basically the same, although there

are certain differences at some quantiles. The comparison shows the QR model using six independent variables is reasonable and can be used to study the effect of influence factors on energy consumption.

5.2. Regional difference

To compare the differences of energy comparison in three rural regions by the statistical theory, the Kruskal–Wallis test is used by the software SPSS 22.0 (see Table 9). Coal usage (the major energies in Tianping Village and Dapu Village) in Tianping Village is close to that in Dapu Village, but significantly different to that of Shihuiyao Village. There is a significant difference between three rural villages in other main energies including stalk (the main energy in Shihuiyao Village and Dapu Village), diesel (the main energy in Shihuiyao Village) and gasoline (the main energy in Tianping Village).

Table 6
p values of the null hypothesis for quantile slope equality test.

Regions	Variable	$b_{0.1} = b_{0.2}$	$b_{0.2} = b_{0.3}$	$b_{0.3} = b_{0.4}$	$b_{0.4} = b_{0.5}$	$b_{0.5} = b_{0.6}$	$b_{0.6} = b_{0.7}$	$b_{0.7} = b_{0.8}$	$b_{0.8} = b_{0.9}$	All coefficients
Tianping	HA	0.9835	0.7866	0.9725	0.2828	0.2368	0.1048	0.6251	0.8798	0.0554
	HI	0.3733	0.2220	0.7137	0.3831	0.8812	0.6846	0.3886	0.1676	
	FS	0.9937	0.0124	0.1863	0.3320	0.9876	0.4233	0.6747	0.5706	
	HHA	0.3142	0.5070	0.3482	0.3700	0.3264	0.8242	0.9228	0.3196	
	AC	0.8045	0.1508	0.5501	0.3897	0.4179	0.5026	0.7085	0.6840	
	RE	0.6335	0.6374	0.8242	0.5773	0.5953	0.6260	0.4309	0.0290	
Dapu	HA	0.1452	0.8555	0.6576	0.8040	0.3772	0.7903	0.3075	0.7067	0.0002
	HI	0.0528	0.9982	0.9982	0.4039	0.1910	0.9404	0.2986	0.5747	
	FS	0.2384	0.6991	0.3735	0.4654	0.0817	0.4364	0.6951	0.3158	
	HHA	0.0787	0.9010	0.5268	0.4498	0.4931	0.9092	0.3818	0.7248	
	AC	0.2179	0.5237	0.1971	0.3177	0.3435	0.8666	0.0743	0.3444	
	RE	1.0000	0.1293	0.0775	0.7988	0.9327	0.6108	0.5943	0.9301	
Shihuiyao	HA	0.5377	0.2634	0.2349	0.4007	0.4924	0.7730	0.5065	0.0065	0.0099
	HI	0.1593	0.0648	0.1205	0.9142	0.4281	0.7733	0.6277	0.7471	
	FS	0.9874	0.0883	0.8384	0.3153	0.7063	0.1759	0.4301	0.6808	
	HHA	0.7268	0.9179	0.2516	0.4753	0.9682	0.9851	0.2133	0.4661	
	AC	0.5806	0.0832	0.0918	0.2837	0.2036	0.6461	0.2647	0.6039	
	RE	0.7216	0.1617	0.2187	0.6405	0.4936	0.4646	0.1176	0.9729	
All	HA	0.4740	0.9132	0.2073	0.8854	0.3138	0.7303	0.2470	0.4477	0.0042
	HI	0.4114	0.5813	0.3999	0.5873	0.7388	0.3135	0.8823	0.8303	
	FS	0.5161	0.1302	0.6550	0.8100	0.3887	0.1502	0.8506	0.6753	
	HHA	0.0694	0.6078	0.0059	0.7118	0.8651	0.7000	0.2848	0.7060	
	AC	0.7996	0.8254	0.0304	0.4775	0.4022	0.6037	0.3877	0.8395	
	RE	0.0903	0.4197	0.0891	0.7936	0.3452	0.0057	0.2734	0.0105	

Note: Bold p value denotes rejection of the null hypothesis of slope equality.

Table 7
Significant independent variables by the forward selection at significant level of 5%.

	HA	HI	FS	HHA	AC	RE
Tianping	No	Yes	Yes	No	Yes	Yes
Dapu	No	Yes	Yes	No	No	No
Shihuiyao	No	Yes	Yes	No	No	No
All	No	Yes	Yes	No	No	No

Tianping Village, located in northwest Tianjin, is an affluent rural village with a strongly developed agricultural economy. Furthermore, Tianjin with the highest per capita gross domestic product is the richest province level in China, and can provide a lot of energy subsidy to its residents. In 2015, National Development and Reform Commission of Tianjin collected 600 million Yuan for coal subsidies to Tianjin rural residents for lower pollution coal. Tianjin rural residents can buy subsidized coal from local government for approximately 550 Yuan/t in 2015. At the same time, the Tianjin Rural Work Committee planned to promote uptake of 1.2 million advanced coal stoves into Tianjin rural villages from 2014 to 2017. Every high combustion efficiency coal stove was subsidized 2100 Yuan (market price of the coal stove) by the government, so Tianjin rural residents could obtain new coal stoves for free, once they applied. Due to higher household income, developed agricultural economy and higher government energy subsidy, Tianping Village residents consume more relatively clean energy. Dapu Village, located in central Shanxi province, is a well-off rural village with a mixed economy of agriculture and local industry. Furthermore, Shanxi province is China's largest coal producing and storage province. The government of Shanxi province supplied 1 ton of coal to low income rural households (approximately 90% of rural households) in winter from 2011 to 2014. From 2015 to now, the government of Shanxi province provided each low-income rural household 300 Yuan to buy coal on the market every year. Due to rich coal resources, Dapu Village residents consumed more coal. Shihuiyao Village, located in southern Henan province, is an out-of-poverty rural village with an overwhelmingly agricultural economy. Henan province is the most population province in China. In contrast to Tianjin and Shanxi provinces, Henan province provides no energy subsidy to its residents. Due to the poor economy, Shihuiyao Village residents consume less energy.

Table 10 shows the comparisons of six influence factors by Kruskal–Wallis test followed by all pairwise multiple comparisons. There are significant differences in HI between three investigative rural regions, whereas there are no significant differences in HA between three investigative rural regions. FS of the Tianping Village resident is close to that of Shihuiyao Village resident, but significantly different to that of Dapu Village resident. HHA of the Tianping Village resident is significantly different to that of Shihuiyao Village resident and Dapu Village resident, but HHA of Shihuiyao Village resident is close to that of Dapu Village resident. AC and RE of the Tianping Village resident are close to that of Shihuiyao Village resident, but is different to that of Dapu Village. AC of Dapu Village resident is different to that of the Shihuiyao Village resident, whereas RE of the Dapu Village resident is close to that of the Shihuiyao Village resident.

As one of significant independent variables for three study regions, HI has a positive effect on energy consumption for Tianping Village residents and all investigative residents, but has a negative effect for Dapu Village residents and Shihuiyao Village residents. Thus, it is unreasonable to research the effect of HI on energy consumption using the overall data instead of separate regions. As one of significant independent variables for three study regions, the effects of FS on energy consumption are positive at all quantiles for residents in three investigative areas and all residents. The results of the quantile model are around the OLS results with considerable fluctuation range, which means it is instructive to research the effect of household income on the different quantiles.

6. Conclusions and energy implications

In this article, we assess the relationship between the household energy consumption and six influence factors (household

Table 8
Comparison of computed coefficient for Tianping Village residents by QR model using the six independent variables and the significant variables.

Variables HI	FS			AC			RE					
	QR model using the six independent variables	QR model using the significant variables	Difference percentage (%)	QR model using the six independent variables	QR model using the significant variables	Difference percentage (%)	QR model using the six independent variables	QR model using the significant variables	Difference percentage (%)			
OLS	5.5327**** (1.2346)	6.0244**** (1.2173)	8.89	132.9606**** (34.2246)	137.6406**** (34.2496)	3.52	218.4098** (85.2301)	229.2016*** (85.2300)	4.94	207.3721** (84.7642)	206.707** (85.1041)	0.32
Quantiles												
0.05	4.9134*** (1.5562)	5.1149*** (1.6529)	4.10	97.7839** (43.1412)	104.8899** (46.5054)	7.27	188.7508* (107.4353)	185.5213 (115.7284)	-1.71	148.7397 (106.8480)	169.4997 (115.5576)	13.96
0.10	4.6403*** (1.4549)	4.916*** (1.4819)	5.94	161.8098**** (40.3336)	152.74**** (41.6951)	-5.61	261.0276*** (100.4435)	282.84*** (103.7581)	8.36	116.3973 (99.8944)	113.16 (103.605)	-2.78
0.20	4.1702*** (1.5331)	4.3763*** (1.3700)	4.94	161.5526**** (42.5000)	170.0762**** (38.5468)	5.28	240.5192** (105.8385)	250.3893*** (95.9235)	4.10	155.5460 (105.2599)	105.7 (95.7819)	-32.05
0.3	3.5232*** (1.2361)	3.9015*** (1.2221)	10.74	91.0295*** (34.2670)	113.9696**** (34.3852)	25.20	143.3511* (85.3358)	129.8391 (85.5675)	-9.43	124.3274 (84.8693)	67.2696 (85.4411)	-45.89
0.4	4.8272**** (1.3370)	5.0364**** (1.3718)	4.33	129.6012**** (37.0638)	142.35**** (38.5953)	9.84	181.1876* (92.3008)	133.4727 (96.0442)	-26.33	110.1938 (91.7962)	59.2273 (95.9024)	-46.25
0.5	6.9707**** (1.6812)	7.8317**** (1.6729)	12.35	158.9553**** (46.6079)	171.5833**** (47.0683)	7.94	239.6707** (116.0686)	238.8667** (117.1292)	-0.34	149.7197 (115.4341)	173.7 (116.9563)	16.02
0.6	7.3090**** (1.8587)	8.5382**** (1.9602)	16.82	159.4485*** (51.5276)	174.3088*** (55.1521)	9.32	300.5054** (128.3203)	296.8706** (137.2457)	-1.21	190.6122 (127.6188)	290.0647** (137.0431)	52.18
0.7	8.4451**** (2.1720)	9.5586**** (2.1143)	13.19	129.9750** (60.2118)	138.8777** (59.4868)	6.85	230.1383 (149.9467)	242.5075 (148.0327)	5.37	146.5787 (149.1270)	169.1504 (147.8142)	15.40
0.8	11.1429**** (2.4539)	12.4580**** (2.3244)	11.80	110.8519 (68.0268)	122.3387* (65.3983)	10.36	184.7438 (169.4084)	184.8048 (162.7433)	0.03	227.6133 (168.4823)	237.8971 (162.5031)	4.52
0.9	7.6342** (2.9596)	9.9575**** (2.6384)	30.43	73.0562 (82.0468)	53.475 (74.2312)	-26.80	124.1993 (204.3228)	57.275 (184.724)	-53.88	536.4136*** (203.2059)	561.85*** (184.4513)	4.74
0.95	7.0240** (3.3179)	9.0411**** (2.6613)	28.72	27.5248 (91.9788)	56.8889 (74.8782)	106.68	291.1356 (229.0565)	191.4 (186.3341)	-34.26	697.3974*** (227.8043)	503.6444*** (186.0591)	-27.78

Note:
*p < 0.1.
**p < 0.05.
***p < 0.01.
****p < 0.001.

Table 9
Energy comparisons in three rural regions by Kruskal–Wallis test.

Region 1	Region 2	Electricity	Gasoline	Solar energy	Coal	Diesel	Stalk	LPG	Fireweed	Energy consumption
Tianping	Dapu	⊗	⊗	⊗	●	⊗	⊗	⊗	●	●
	Shihuiyao	⊗	⊗	●	⊗	⊗	⊗	⊗	⊗	⊗
Dapu	Shihuiyao	●	●	●	⊗	⊗	⊗	●	⊗	⊗

Note: ● denotes no significant difference at 5% significant level; ⊗ denotes significantly difference at 5% significant level.

size, household income, family size, household age, air conditioner and refrigerator) in three typical townships (Tianping Village, an affluent rural village; Dapu Village, a well-off rural village; Shihuiyao Village, an out-of-poverty rural village) using the OLS and QR models.

The OLS results indicate that the significant variables at the 10% level in Tianping Village, Dapu Village, Shihuiyao Village and all investigative villages are household income, family size, air conditioner, refrigerator; household income, family size; household income, family size; and household income, family size, respectively. The QR results fluctuate around the QLS results with large amplitude, indicating a different pattern of the effect at different quantiles.

As the significant variable in three study villages, household income in three investigative rural regions is significantly different, while family size of the Tianping Village resident is close to that of Shihuiyao Village resident, but significantly different to that of Dapu Village resident. Air conditioner and refrigerator of the Tianping Village resident, significant variables for Tianping Village resident, are close to that of the Shihuiyao Village resident, but different to that of Dapu Village.

Table 10
The comparisons of six influence factors by Kruskal–Wallis test.

Region 1	Region 2	HA	HI	FS	HHA	AC	RE
Tianping	Dapu	●	⊗	⊗	⊗	⊗	⊗
	Shihuiyao	●	⊗	●	⊗	●	●
Dapu	Shihuiyao	●	⊗	●	●	⊗	●

Note: ● denotes no significant difference at 5% significant level; ⊗ denotes significantly difference at 5% significant level.

The out-of-poverty rural village consumed more biomass energy and less total energy, and energy consumption is positively correlated with family size, but negatively correlated with household income. The reason is migrant workers mean higher incomes and less energy consumption. Thus, local governments should rationally arrange energy supply according to the local population, further encourage farmers to continue to use bio-energy on an existing basis, and improve the cleanliness and convenience of bio-energy. At the same time, local governments should strive to create local jobs and reduce migrant workers.

The well-off rural village consumed more coal due to local abundant coal resources, and energy consumption is positively correlated with family size and household income. Thus, local governments should guide rational energy consumption, use cleaner energy sources such as bio-energy and solar energy, and reduce dependence on heavily polluting coal. Moreover, the local government should provide a more rational energy subsidy program based on the rural population, guide farmers to local employment, in particular, allow local farmers to enjoy the benefits of the local energy industry.

The affluent rural village consumed more commercial energy and cleaner coal owing to high income, more air conditioner and refrigerator, and government benefits. The energy consumption is positively correlated with family size, household income, air conditioner and refrigerator. Thus, the affluent local government should rationally guide the local population's energy consumption, strengthen energy education for local farmers, provide market access standards for high-energy equipment, and encourage more affluent farmers to buy more energy efficient products. Moreover, local government should supply clean energy with low pollution instead of energy with high pollution, and energy equipment with high combustion efficiency instead of low combustion efficiency.

The energy consumption in all investigative area is positively correlated with family size and household income, which is different to that in Dapu Village and Shihuiyao Village. So, it is unreasonable to use the overall data instead of separate regions. To control the rapid growth of rural energy consumption, the central government should guide residents to rational energy consumption when improving rural household income.

Furthermore, because climate has a great influence on energy consumption, three study areas in this paper are all within or close to the cold zone climate region. Further studies will extend these conclusions and corresponding policy implications to other climate zones.

Acknowledgments

This research is supported by Tianjin Natural Science Foundation, China (No. 16JCZDJC31400) and the China Scholarship Council, China (File No. 201808120029).

References

- China Nation Standardization Management Committee, 1998. General principles for calculation of the comprehensive energy consumption. China Standard Press, Beijing, China, p. GB/T 2589.
- Chung, W., Kam, M.S., Ip, C.Y., 2011. A study of residential energy use in hong kong by decomposition analysis, 1990–2007. *Appl. Energy* 88, 5180–5187.
- Daigoglou, V., van Ruijven, B.J., van Vuuren, D.P., 2012. Model projections for household energy use in developing countries. *Energy* 37, 601–615.
- Ding, Y., Qu, W., Niu, S., Liang, M., Qiang, W., Hong, Z., 2016. Factors influencing the spatial difference in household energy consumption in China. *Sustainability* 8, 1285.
- Ding, Z., Wang, G., Liu, Z., Long, R., 2017. Research on differences in the factors influencing the energy-saving behavior of urban and rural residents in China—a case study of Jiangsu Province. *Energy Policy* 100, 252–259.
- Druckman, A., Jackson, T., 2008. Household energy consumption in the UK: A highly geographically and socio-economically disaggregated model. *Energy Policy* 36, 3177–3192.
- Joanes, D.N., Gill, C.A., 1998. Comparing measures of sample skewness and kurtosis. *J. R. Stat. Soc. D Stat.* 47, 183–189.
- Kaza, N., 2010. Understanding the spectrum of residential energy consumption: A quantile regression approach. *Energy Policy* 38, 6574–6585.
- Lee, C., Chiu, Y., 2011. Electricity demand elasticities and temperature: Evidence from panel smooth transition regression with instrumental variable approach. *Energy Econ.* 33, 896–902.
- Li, K., Lin, B., 2015. Impacts of urbanization and industrialization on energy consumption/CO₂ emissions: Does the level of development matter? *Renew. Sust. Energy. Rev.* 52, 1107–1122.
- Liu, Y., Gao, Y., Hao, Y., Liao, H., 2016. The relationship between residential electricity consumption and income: A piecewise linear model with panel data. *Energies* 9, 831.
- Liu, W., Spaargaren, G., Heerink, N., Mol, A.P.J., Wang, C., 2013. Energy consumption practices of rural households in north China: Basic characteristics and potential for low carbon development. *Energy Policy* 55, 128–138.
- Miao, L., 2017. Examining the impact factors of urban residential energy consumption and CO₂ emissions in China – Evidence from city-level data. *Ecol. Indic.* 73, 29–37.
- NBS, 2016. China Energy Statistical Yearbook 2016. China Statistical Press, Beijing.
- NBS, 2017. China Statistical Yearbook 2017. China Statistical Press, Beijing.
- Nie, H., Kemp, R., 2014. Index decomposition analysis of residential energy consumption in China: 2002–2010. *Appl. Energy* 121, 10–19.
- Niu, S., Jia, Y., Ye, L., Dai, R., Li, N., 2016. Does electricity consumption improve residential living status in less developed regions? An empirical analysis using the quantile regression approach. *Energy* 95, 550–560.
- Niu, S., Zhang, X., Zhao, C., Niu, Y., 2012. Variations in energy consumption and survival between rural and urban households: a case study of the western loess plateau, china. *Energy Policy* 49, 515–527.
- Pachauri, S., Jiang, L., 2008. The household energy transition in India and China. *Energy Policy* 36, 4022–4035.
- Ping, X., Li, C., Jiang, Z., 2013. Household energy consumption patterns in agricultural zone, pastoral zone and agro-pastoral transitional zone in eastern part of Qinghai-Tibet Plateau. *Biomass Bioenerg.* 5 (8), 1–9.
- van Ruijven, B.J., van Vuuren, D.P., de Vries, B.J.M., Isaac, M., van der Sluijs, J.P., Lucas, P.L., Balachandra, P., 2011. Model projections for household energy use in India. *Energy Policy* 39, 7747–7761.
- Tsinghua University Building Energy Conservation Research Center, 2016. 2016 Annual Report on China Building Energy Efficiency. China Construction Industry Press, Beijing, China.
- Wang, X., Dai, X., Zhou, Y., 2002. Domestic energy consumption in rural china: a study on sheyang county of jiangsu province. *Biomass Bioenerg.* 22, 251–256.
- Wei, Y., Liu, L., Fan, Y., Wu, G., 2007. The impact of lifestyle on energy use and CO₂ emission: An empirical analysis of China's residents. *Energy Policy* 35, 247–257.
- York, R., 2007. Demographic trends and energy consumption in European Union Nations, 1960–2025. *Soc. Sci. Res.* 36, 855–872.
- Yu, Y., Guo, J., 2016. Identifying electricity-saving potential in rural China: Empirical evidence from a household survey. *Energy Policy* 94, 1–9.
- Zhang, M., Guo, F., 2013. Analysis of rural residential commercial energy consumption in China. *Energy* 52, 222–229.
- Zhu, H., Guo, Y., You, W., Xu, Y., 2016. The heterogeneity dependence between crude oil price changes and industry stock market returns in China: Evidence from a quantile regression approach. *Energy Econ.* 55, 30–41.