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Factors Influencing Choice of Energy Sources in Rural Pakistan

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Modernisation of the agricultural and industrial sectors in Pakistan over the last thirty years, increased village electrification, increasing use of energy appliances by domestic users, and the usage of modern technology in all sectors, caused energy demand to increase more rapidly than energy supply. Sources of energy vary between urban and rural populations, across income groups, and by type of households. Pakistanis consume energy from both modern and traditional sources for different purposes, such as lighting, cooking, heating, and transportation. Modern sources of energy include electricity, oil, gas and coal, while traditional sources consist of animal/plant residue (firewood, crop residue and animal waste). Using a multinomial logit regression model, this study analyses how rural households make choices among different energy alternatives. The results suggest that because of the limited access to modern energy sources, households rely on traditional sources excessively, which may have a negative impact not only on human and animal health but also on the environment. These results suggest that the conversion of traditional energy sources into modern ones, such as, biogas, use of energy efficient appliances, etc. can have a positive impact on the environment and sustainable economic growth.

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Keywords: Rural, Households, Energy Consumption, Energy Sources, Environment

1. INTRODUCTION

Increasing demand and limited supply of modern energy sources is a major policy concern in Pakistan. Modernisation of agricultural and industrial sectors, increased village electrification, increasing use of energy appliances by domestic users, and the usage of modern technology in all sectors caused energy demand to increase more rapidly than supply. Sources of energy vary between urban and rural populations, across income groups, and by type of households. Most households use both modern (e.g., electricity, oil, gas and coal), and traditional energy sources (e.g., firewood, animal and plant

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residue) for different purposes, such as lighting, cooking, heating, and transportation. Because of large-scale village electrification in Pakistan, electricity is the major source for lighting. However, for cooking and heating, a majority of the rural population relies mostly on traditional sources of energy, of which firewood is the major source [Mirsa and Kemp (2009); Jan, *et al*. (2012)].

Traditional sources of energy are easily accessible and affordable for a majority of rural households. Their use, however, has serious implications for health, environment, and biodiversity. A higher demand for firewood can result in deforestation, loss of biodiversity, land erosion, and other types of harm to the environment [Heltberg, *et al*. (2000); Dewees (1989); Liu, *et al*. (2008)]. In addition, burning animal/plant residue creates indoor pollution that can cause several respiratory and lung diseases [Awan, *et al.* (2013)]. In addition to health and environmental problems, the use of animal/plant residue has several socioeconomic implications. For example, the collection of animal/plant residue increases the work load on women and children, who are prime collectors of animal/plant residue in rural areas. High deforestation can result in a wood shortage that may reduce the cooking frequency and/or the amount of cooked food, which has implications for the nutritional status of households [FAO (2008)].

The concept of household energy choice can be explained by either the ‘energy ladder’ or the ‘fuel-stacking’ models [Heltberg (2003)]. The energy ladder model explains the transition in energy consumption from traditional animal/plant residue to modern sources is caused by an improvement in income. This model is based on a three-stage fuel switching process. In the first stage, households rely on animal/plant residue. In the second stage, with improvement in income, households move to transition fuels such as kerosene, coal and charcoal. In the third stage, households adopt modern sources of energy with a further improvement in income. In the fuel-stacking model, households do not completely discard traditional sources of energy as their income rises. Instead, they simultaneously use both, traditional and modern energy sources. Earlier studies support the energy ladder model [Hosier and Dowd (1987); Leach (1992); Sathaye and Tyler (1991); Smith, *et al*. (1994); Reddy and Reddy (1994)]. However, several studies conducted after the 1990s found the fuel-stacking model is more appropriate [Barnes and Qian (1992); Hosier and Kipondya (1993); Davis (1998); Masera, *et al*. (2000); Heltberg (2005)]. Both these models assume income as the major determining factor of household choice about energy sources.[1] Recent studies point out that it is not only income but several socioeconomic, institutional, and market factors influence a household’s choice of energy source [Mirza and Kemp (2009); Jayaraj, *et al*. (2011); Nnaji, *et al*. (2012); Adepoju, *et al*. (2012); Jan, *et al*. (2012)].

As discussed earlier, rural households in Pakistan rely more on traditional sources of energy and face several socio-economic, health, and environmental issues. To overcome the negative effects of traditional energy sources on human health and the environment, and to improve living conditions of poor households in rural areas, there is a need for cleaner and efficient sources of energy that do not damage the environment and health of humans and

[1]The ordered probit model is used with the energy ladder model, and usually uses time series data, which is not available in our series. In our data, households simultaneously use different energy sources i.e. traditional sources (firewood, animal and crop residue) and modern sources (natural gas) for cooking and heating. This supports the fuel stacking model and multinomial logit model is appropriate.

animals. Understanding household energy choices is important to encourage policies that can support the provision of cleaner, efficient and cost effective sources of energy to rural households. For this, in-depth research is required that shows how different socioeconomic, institutional, and market factors influence a household's probability of choosing modern versus traditional sources of energy.

The issue of energy choice is not well-researched in Pakistan. The determinants of a household's energy choice are examined by Mirza and Kemp (2009) for rural Punjab, and Jan, *et al*. (2012) in rural KPK. Both studies support the fuel-stacking model and point out that the lack of resources at the household level, energy prices, and the unavailability of modern energy sources are the major reasons of households' dependence on traditional sources. Despite providing useful information, these studies suffer from estimation weaknesses. A household selects a source of energy over other available alternative varieties which maximise its welfare. Therefore, a simple descriptive analysis [Jan, *et al*. (2012) or a bivariate logit analysis of different energy sources [Mirza and Kemp (2009)] may give misleading results. Using a multinomial logit model, this paper examines the household decision making process for the choice of traditional and modern energy sources. This analysis is based on data from the Rural Household Panel Survey (RHPS), Round 3.0, conducted in 2014.

This paper is divided into seven sections. Details of sample design and survey process are given in Section II. Section III describes the data. The conceptual framework and empirical model are explained in Section IV. Section V discusses the results, while conclusions and policy recommendations are given in Section VI. Section VII provides an overview of the study limitations and gives suggestions for further research.

2. SAMPLE DESIGN AND SURVEY PROCESS

In response to a request to assess important economic policy priorities for the Government of Pakistan, the Pakistan Strategy Support Program (PSSP) launched a panel survey entitled the "Rural Household Panel Survey (RHPS)" in 2012. The sample universe included all households in rural areas of the provinces of Punjab, Sindh and Khyber-Pakhtunkhwa (KPK). Balochistan was dropped from the sample due to security reasons in 2012. The multistage stratified sampling technique was used. In the first stage, Probability Proportionate to Size (PPS)[2] was used to select districts. The proportion of rural households in each province determined the number of districts chosen from there. A total of 19 districts were selected from within the three provinces; 12 from Punjab, 5 from Sindh and 2 from KPK. Within each district, 4 mouzas as Primary Sampling Units (PSUs) were chosen using an equal probability systematic selection. The PPS at this stage would ensure each household had same probability of being in sample.

In each Mouza, the enumeration teams conducted reconnaissance. They prepared a map of the village. A Mouza is divided into enumeration blocks. Each block consists of maximum 200 households. One enumeration block was randomly selected. Households within each Mouza or Primary Sampling Units (PSU) have been considered as Secondary Sampling Units (SSU). A complete household listing was conducted in this block, and 28 households were randomly selected from this list. There was no replacement for households

[2]This method ensures that the districts with more rural households have a greater chance to be selected.

that refused to participate in the survey. Thus a total of 2,124 households were selected for the survey. Of these, 34 refused and the survey was conducted on 2,090 households.

Six survey modules were developed to collect information. These included three questionnaires for each household in the sample (one each for males, females and for a household member 18-35 years old) and a community (one per Mouza), schools (at least one per Mouza) and prices (one district, Union Council and Mouza) questionnaire.

The survey was conducted by nineteen teams, each comprising two males, two females and a supervisor. Monitoring of the whole survey process was conducted by a team of monitors, while a survey coordinator controlled all field operations. Our study used data from the third round of this survey, which was completed in June 2014. [For details one the first Round, see Nazli and Haider (2012)]. Detailed information on household energy sources, consumption of energy, and expenditure on energy was collected in this round. Because of attrition, Round 3 comprised of 1,869 households, with 1,177 in Punjab, 486 in Sindh, and 206 in KPK.

3. DATA

Data shows that households use different sources of energy for different purposes. A majority of households use a mix of different sources (see Table 1). Electricity is consumed by a majority of households (90 percent), which indicates that Pakistan has made significant progress in village electrification. Lighting is the main use of electricity, as nearly 98 percent of those households with electricity use it for this purpose. Firewood is the main source for cooking and heating, which is used by almost two-thirds of households. Animal and plant residue is another source for cooking and heating, and nearly 17 percent of households use this source for cooking, while 22 percent use residues for heating. A smaller percentage (15 percent) of households uses natural gas for cooking and heating.

Table 1

Household Energy Consumption by Purpose in Rural Pakistan(Percentage)

Energy Sources	Lighting	Cooking	Heating
Electricity	97.72	0.00	0.00
Natural Gas	0.00	14.7	15.64
Firewood	1.66	68.32	62.37
Animal/plant Residue	0.00	16.98	21.99
Others	0.62	0.00	0.00
Total	100	100	100

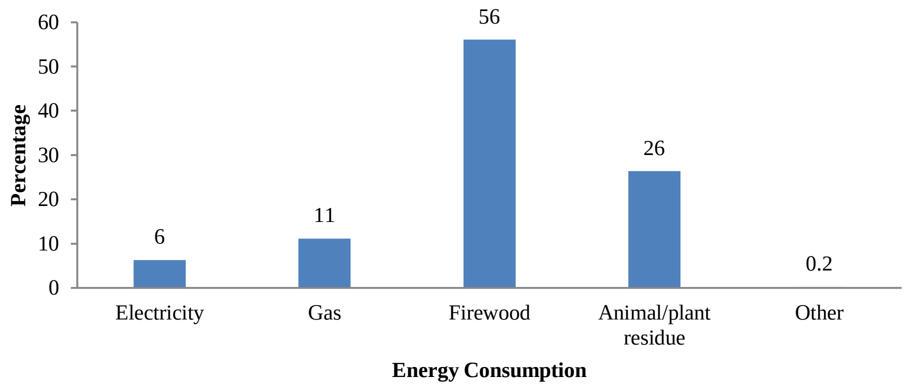
Source: Author's calculations from the Rural Household Panel Data Round – 3, PSSP-IDS.

To examine the consumption share of a particular source of energy in the total energy mix[3], we convert the quantity of consumption of all energy sources into heating values using Millions of British Thermal Units (MMBtu), which derives total energy consumption by each household. This enables us to calculate the consumption share of energy units in total energy consumption by each source. (See Annexure: Tables 1 and 2).

[3]Energy mix is defined total energy consumption by each energy sources consumed by the households.

The results of energy consumption in MMBtu compared with energy usage in rural Pakistan are shown in Figure 1, which shows that 90 percent of households used electricity in rural Pakistan. However, the share of consumption of electricity is only 6 percent. The use of natural gas is 10 percent and its share of consumption is 11 percent. Firewood is the major source of energy, and it accounts for more than 56 percent of total energy units consumed. Low share of energy units from electricity and gas explains the prevailing situation in rural Pakistan, where electricity is used only for lighting and the gas network is very thin in rural areas; as such, many villages do not have a supply of natural gas.

Fig. 1. Energy Consumption in Rural Pakistan



Source: Author's calculations from the Rural Household Panel Data Round – 3, PSSP-IDS.

The data also show that 43 percent of households use only a single source of energy for cooking and heating; 38 percent use two, and 19 percent households have more than two sources of energy for cooking and heating. These results show that households' depend largely on traditional sources of energy for cooking and heating and use them in combination. Similar trends were observed across provinces. However, the proportion of households using electricity is only 68 percent in Sindh. Usage of firewood is considerably higher in KPK where about 93 percent households use firewood for cooking and heating. This may be because of low temperatures during the winter, lower accessibility to modern sources of energy for heating and more forest cover in this province. As compared to other provinces, the use of animal/plant residue is higher in Punjab (44 percent) which may partly be explained by the higher proportion of livestock holders in this province.[4]

Households were also asked about outages/shortages of various energy sources during the last year and the usage of alternate sources in case of outages/shortage. Data shows that the average outage of electricity is 12.50 hours per day. A majority of households (35 percent) use emergency lights and (14 percent) candles as an alternative source. Households who use gas, face gas outages; on average, 2.30 hours per day in winter and 1.38 hours per day in summer. In case of gas outages, nearly one-third of

[4]In the sample, livestock holders are 76.58 percent in Punjab, 69 percent in Sindh and 71 percent in KPK.

households use firewood and 41 percent use other sources (e.g., petrol, diesel, or coal) as an alternative source (see Table 2). This indicates that firewood is the main substitute for gas. In case of firewood shortage, a majority of households (71 percent) use animal/plant residue, and some households (7 percent) use gas as an alternative source. When there is a shortage of animal/plant residue, most of the households depend on firewood (56 percent). This indicates that gas, firewood and animal/plant residues are substitutes of each other.

Table 2

Alternative Source of Energy in Case of Outages/Shortages of an Energy Sources (Percentage)

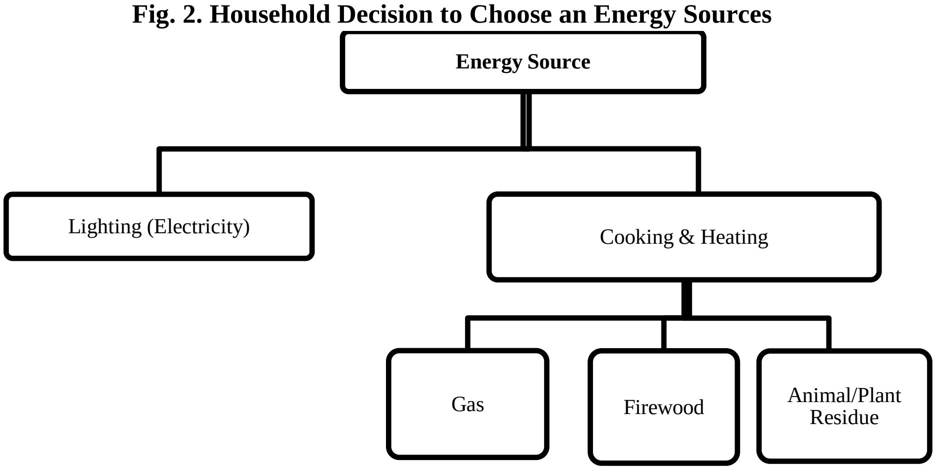
	Alternative Source of Energy				
Main Source of Energy	No Alternative	Gas	Firewood	Animal/Plant Residue	Others
Gas	20.10	0.00	35.41	1.05	43.44
Firewood	16.66	7.18	0.00	70.73	5.43
Animal/Plant Residue	4.60	0.00	55.51	29.72	10.17
Others	17.92	0.00	0.00	0.00	82.08

Source: Author's calculation from the Household Panel Data Round – 3, PSSP-IDS. Note: For other sources of energy, the major alternate source is petrol.

4. CONCEPTUAL FRAMEWORK

These results indicate that households use electricity solely for lighting with almost no alternative except candles. However, for cooking and heating, they have a choice between natural gas, firewood, and animal/plant residue. Therefore our analysis will be based on the three sources of energy that are potential alternatives and on which households can make decisions. A household's decision to choose energy sources is explained in Figure 2.

Fig. 2. Household Decision to Choose an Energy Sources



Source: Author's Construction.

4.1. Empirical Model

The discussion above indicates that a household has a choice of alternative energy sources and, presumably, selects one that gives the highest utility. Such behaviour can be explained by multinomial logit models [McFadden (1974); Maddala (2001); Greene (2008)]. These models[5] are used to model the relationships between a polytomous response variable (with more than 2 categories of responses) and a set of explanatory variables, when responses are unordered.[6]

Consider a household's choice of available energy sources, and assume that utility depends on choices made from a set C, which includes all possible energy sources. The household is assumed to have a utility function of the form

$$U_{ij} = U(Z_{ij}) \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (1)$$

Where, for any household *i*, a given level of utility will be associated with any alternative energy source *j*, where j=1…k. The k is the number of energy sources. The random utility model is the theoretical basis for integrating the choice behaviour of a household. In this model, the utility of a choice is comprised of a systematic (explainable or deterministic) component, V_{ij}, and an error (unexplainable or random) component, e_{ij}, which is independent of the deterministic part and follows a predetermined distribution.

$$U_{ij} = V_{ij} + e_{ij} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (2)$$

The deterministic part can be written as:

$$V_{ij} = X_i \gamma_j \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (3)$$

Where γ_j are parameters, and X_i are explanatory variables; the e_{ij} is a random disturbance reflecting intrinsically random choice behaviour, measurement or specification error, or other unobserved attributes of the alternatives. The error terms are also assumed to be identically and independently distributed across alternative activities. Also let P_{ij} denote the probability associated with the choice of a particular energy source *j* (*g*, *f*, *r*) for household *i*, where *g* denotes gas, *f* is firewood, and *r* is animal/plant residue such that P_{ij}= 1 if the *i*th individual selects *j*th source, P_{ij} =0 otherwise. The multinomial logit model with unordered choice set (*j*=1, 2, 3) is given by:

$$P_{ij} = \frac{\exp(X_i^{`}\gamma_j)}{\sum_{j=0}^{3} \exp(X_i^{`}\gamma_j)} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (4)$$

Setting $\gamma_0 = 0$, the model can be written as:

$$P_{ij} = \frac{\exp(X_i^{`}\gamma_j)}{1+\sum_{j=1}^{3} \exp(X_i^{`}\gamma_j)} \ (j = 1,2,3) \text{ and } P_{i0} = \frac{1}{1+\sum_{j=1}^{3} \exp(X_i^{`}\gamma_j)} \qquad \ldots \quad \ldots \qquad (5)$$

[5]See footnote 2. The ordered probit model, suggested by participants in our session, works for the energy ladder model, but usually uses time series data. In this analysis we assume households use simultaneously different energy sources and with sufficient income, can switch between sources. Thus the multinomial model is appropriate. In the conclusions, however, we suggest several other possible approaches.

[6]Dependent variables are arbitrary numerical values because the ranking does not imply that outcome 1 is less than outcome 2, which in turn is less than outcome 3.

Where X_i is the vector of explanatory variables, γ_i represents are the parameters to be estimated. This model can be estimated using the maximum likelihood estimation method.

To describe results, the average marginal effects are computed by differentiating the conditional expected value of the dependent variable with respect to explanatory variables. When the explanatory variable is a discrete variable, the marginal (or incremental) effect is an arithmetic difference, E(y|x1 = 1) E - (y|x1 = 0), rather than a derivative [Sui and Zhihao Yu (2012)]. In the estimation process, gas is considered as the referent/base case. All results are explained in comparison with the reference category. We estimated two models, one for heating and the other for cooking.

5. RESULTS

Before presenting the results of estimated model, we look at the unit costs of different energy sources which are calculated in terms of PKR per MMBtu, and which indicates that gas is the most cost effective source of energy at Rs 250 per MMBtu (see Table 3). Firewood is the most expensive source of energy with a unit cost of 330 PKR/MMBtu, followed by animal/plant residue (316 PKR/MMBtu). Disaggregation by per capita expenditure quintile shows a positive association between unit cost and expenditure quintile. This means as income improves, expenditure on energy sources increases. This table shows that the unit cost of gas is higher than the other two sources for households in highest income group. This may be due to the fact that households move to more efficient sources of energy with an improvement in income. In Pakistan, the gas tariff is tiered, and so rises with the household consumption level, as seen in Table 3. However, traditional sources do not have formal markets and they are largely collected, not purchased, at least among lower income households. This informal market does not have standard prices because of the un- regulated market structure. The table shows that the unit cost of firewood and animal/plant residue varies across expenditure quintile which supports the argument regarding the market structure of traditional sources.

Table 3

Unit Cost of Energy by Expenditure Quintile

(PKR/MMBtu)

Sources of Energy	1(Poorest)	2	3	4	5(Richest)	Total
Gas	152	198	223	256	387	251
Firewood	300	326	325	353	355	330
Animal/Plant Residue	298	301	335	360	303	316

Source: Author's calculation from Rural Household Panel Data Round – 3, PSSP-IDS.

5.1. Explanatory Variables

The sample comprised of 1,869 households, 70 percent from Punjab, 20 percent from Sindh and 10 percent from KPK. Explanatory variables include various household, energy use and community specific factors, with their definition and summary statistics reported in Table 4. This table shows that the average age of the household head was 47.90 years. Half of households have some education. Female headed households are very few in the sample. On average, a household has 2.8 dependents. A majority of household heads are involved in nonfarm activities. Average number of females and children involved in firewood collections is less than 1. The average distance between villages and nearest city is 15.5 kilometre. Internal road structure in most of the villages is not well developed.

Table 4

Summary Statistics

Variable	Mean	Standard Deviation
Household characteristics		
Age of household head (years)	47.86	13.20
Education of household head (1=if any schooling)	0.49	0.50
Gender of household head (=1 if male)	0.95	0.22
Number of Dependents (number)	2.79	2.12
Farm household (yes=1)	0.44	0.50
Household labour supply		
Number of females involved in collecting firewood (number)	0.34	0.61
Number of children involved in collecting firewood (number)	0.17	0.54
Household income groups		
First Income Quantile (yes=1)	0.20	0.40
Second Income Quantile (yes=1)	0.20	0.40
Third Income Quantile (yes=1)	0.20	0.40
Forth Income Quantile (yes=1)	0.20	0.40
Fifth Income Quantile (yes=1)	0.20	0.40
Energy consumption		
Energy Consumption (MMBTu)	2.78	3.12
Community variable		
Distance to Nearest Market (kilometer)	15.51	14.47
Type of internal roads (developed=1)	0.42	0.49
Location variables		
Punjab (yes=1)	0.67	0.47
Sindh (yes=1)	0.24	0.43
KPK (yes=1)	0.09	0.29

Source: Author's own estimation by using Rural Household Panel Data Round – 3, PSSP-IDS.

5.2. Regression Results

For both cooking and heating, energy consumption (MMBTu), gender of household head, farm household and female collection of firewood are positive and significantly affect the choice of the firewood and animal/plant residue relative to gas. More literate households tend to use gas as source of energy for cooking and heating relative to firewood and animal/plant residue. Distance to nearest market is positive and only significantly affects the choice of firewood relative to gas. Internal road development and higher income quintiles are negative and significantly affect the choice of gas relative to firewood and animal/plant residue for cooking and heating.

The coefficients from the estimated model are difficult to interpret because they are relative to the base outcome. Another way to evaluate the effect of covariates is to examine the average marginal effect of changing their values on the probability of observing an outcome. The average marginal effects of cooking and heating are presented in Tables 5 and 6, respectively. Results shows that the probability of choosing gas as source of cooking or heating increases if head of the household is male, with some education, belongs to a higher income group, and the community infrastructure is developed. Because the rows sum to zero, it is possible to see the substitution into and out of an energy source. So, for example, if a household head shifts to literate, the probability of using gas for cooking rises by about 5 percent, and there is no particular shift out of either firewood or residues. In contrast, the same improvement in education for heating leads to a significant movement of about 3.8 percent out of animal/plant residue use (see Table 5).

Table 5

Average Marginal Effects for Cooking

Variable	Gas	Firewood	Animal/Plant Residue
Household characteristics			
Household Head Age (years)	0.002	-0.001	0.001
Dummy Household Head Education (1=literate)	0.050***	-0.026	-0.024
Dummy Household Head Gender (=1 if male)	-0.058***	0.072	-0.014
Number of Dependents (number)	2.800	2.100	0.013**
Dummy for Farm Household (yes=1)	-0.064***	-0.012	0.076
Household labour supply			
Number of Females Involved in collecting firewood (number)	-0.215***	0.112***	0.103***
Number of Children Involved in collecting firewood (number)	-0.035	0.006	0.028
Household income groups			
Dummy for Second Income Quintile (yes=1)	0.020	-0.070	0.050
Dummy for Third Income Quintile (yes=1)	0.020	-0.031***	0.011**
Dummy for Fourth Income Quintile (yes=1)	0.062	-0.088	0.026
Dummy for Fifth Income Quintile (yes=1)	0.075***	-0.074**	-0.001
Energy consumption			
Energy Consumption (MMBTu)	-0.001	0.115***	-0.114***
Community variable			
Distance to Nearest Market (kilometer)	-0.001	0.004***	-0.003**
Dummy for Developed Internal Mouza Road (developed=1)	0.147***	-0.175***	0.028
Location variables			
Dummy for Punjab Province (yes=1)	-0.044	-0.083	0.127**
Dummy for KPK Province (yes=1)	-0.107**	0.216***	-0.108*

Source: Source: Author's own estimation by using Rural Household Panel Data Round – 3, PSSP-IDS.
Notes: Standard errors are in parenthesis and robust; *** p<0.01, ** p<0.05, * p<0.1

The presence of females involved in the collection of firewood and higher distance to market reduce the probability of choosing gas. These results are substantiated by the average marginal effects of firewood and animal/plant residue for both cooking and heating. Raising the number of females involved in collecting firewood by one person decreases gas use by 21.5 percent but of course, an increase in females involved in collecting firewood is highly correlated with the use of firewood. If those females increase, a higher dependence on animal/plant residue also arises, suggesting that firewood and residues are perhaps equal complements in use, at least for cooking. They appear to be less symmetric in heating choices. Similarly, developing internal Mouza roads tends to increase the probability of using gas by 14.7 percent, and most of this appears to be a shift from using firewood, as the latter probability decreased by 17.5 percent with more developed Mouza roads, but no effect is seen on animal/plant residue. The same magnitudes were seen for both cooking and heating, although they were not significant in the heating analysis. Households tend to use more gas and less firewood with higher income.

The results for heating and cooking have the same directions and magnitudes, but the significance levels of some variables change. For example, the probability of the number of dependents, distances to the nearest market and energy consumption (MMBTu) are significant for animal /plant residue in cooking but not heating. Similarly, the Household Head Gender and farm household are significant for animal/plant residue. The number of children involved in collecting firewood is also significant for firewood (see Table 6).

Table 6

Average Marginal Effects for Heating

Variable	Gas	Firewood	Animal/Plant Residue
Household characteristics			
Household Head Age (years)	0.0005	-0.001	0.0003
Dummy Household Head Education (1=literate)	0.054***	-0.016	-0.038*
Dummy Household Head Gender (=1 if male)	-0.086***	0.048	0.037
Number of Dependents (number)	-0.007*	-0.001	0.007
Dummy for Farm Household (yes=1)	-0.056***	0.0004	0.056*
Household labour supply			
Number of Females Involved in collecting firewood (number)	-0.141***	0.052*	0.089***
Number of Children Involved in collecting firewood (number)	-0.035	0.013***	0.021**
Household income groups			
Dummy for Second Income Quintile (yes=1)	-0.002	-0.046	0.048
Dummy for Third Income Quintile (yes=1)	0.035***	-0.036**	0.0002
Dummy for Fourth Income Quintile (yes=1)	0.074***	-0.095	0.021
Dummy for Fifth Income Quintile (yes=1)	0.075	-0.058	-0.017**
Energy consumption			
Energy Consumption (MMBTu)	-0.009	0.095*	-0.086
Community variable			
Distance to Nearest Market (kilometer)	-0.001***	0.004***	-0.003
Dummy for Developed Internal Mouza Road (developed=1)	0.148	-0.165	0.016*
Location variables			
Dummy for Punjab Province (yes=1)	-0.054	-0.084***	0.138**
Dummy for KPK Province (yes=1)	-0.080	0.331	-0.250

Source: Source: Author's own estimation by using Rural Household Panel Data Round – 3, PSSP-IDS.
Notes: Standard errors are in parenthesis and robust; *** p<0.01, ** p<0.05, * p<0.1

5.3. Health and Environment Impact

Use of traditional energy sources has a serious impact on health and the environment, especially when these traditional sources are used in un-controlled levels and with un-controlled appliances. In Pakistan, and especially in rural areas, these traditional sources are often used in an un-controlled way. These traditional energy sources produce various pollutants such as Nitric Oxide (NOX), Carbon Mono Oxide (CO) and Carbon Dioxide (CO2) which have serious environment and health risks (see Table 7).

Table 7

Health and Environment Impact in Case of Using Traditional Energy Sources in Uncontrolled Measure

		Un-Controlled		
Pollutant	Name of Pollutant	1 Kg Firewood per MMBtu	1 Kg Animal and Plant Residue per MMBtu	Health and Environment Impact
NOX	Nitric Oxide and Nitrogen Dioxide	0.49	0.67	Water Quality Deterioration, Global Warming, Toxic Chemicals, Visibility Impairment
CO	Carbon Monoxide	1.33	27.56	Dull headache, Weakness, Dizziness, Vomiting, Shortness of breath, Confusion, Blurred vision, Loss of consciousness
SO2	Sulfur Dioxide	0.06	n/a	Inhalation and TOXIC, Skin and Eye Contact (CORROSIVE), Ingestion Effects of Long-Term (Chronic), Exposure, Carcinogenicity
VOC	Volatile Organic Compound	0.04	1.78	Acetone, Benzene, Ethylene glycol, Formaldehyde, Methylene chloride, Perchloroethylene, Toluene, Xylene , 1,3-butadiene
PM	Particulate Matter	1.27	2.89	Heart or lung disease, nonfatal heart attacks irregular heartbeat, aggravated asthma, decreased lung function, coughing or difficulty breathing
CO2	Carbon Dioxide	460	476	Cardiovascular Effects, Nerve Damage, Asphyxiation

Source: Department for Environment Food and Rural Affairs (UK) and Global Change Impact Studies Centre (GCISC), Pakistan.

Nitric Oxide affects water quality and is thought to be a cause of global warming, toxic chemicals and visibility impairment. Similarly, Carbon monoxide and carbon dioxide have many health risks: headaches, weakness and dizziness, vomiting, shortness of breath, confusion, blurred vision, and a loss of consciousness, skin and eye contact (corrosive), ingestion, cardiovascular effects, nerve damage and asphyxiation. The use of traditional energy sources in controlled measures, with improved stoves, will reduce the amount of smoke, indoor air pollution and put less pressure on energy consumption. The use of traditional energy sources with improved stoves could reduce pollutants more than fifty percent compared to use of traditional energy sources in an un-controlled way. Improved stoves are fuel efficient and also reduce the household labour effort going to collecting firewood.

6. CONCLUSIONS

The development of the energy sector and management of supply side factors has proven to be a difficult task for the government of Pakistan in the last 30 years. Resolving problems within the energy sector is vital for the future of Pakistan, as energy limitations affect growth of the economy and agriculture and other rural non-form sectors, which in turn impacts poverty. Yet to date, most of the focus for policy makers and research institutions has been on developing solutions for the supply of energy, with an emphasis on providing electricity to urban locations. Little attention is given to increasing the efficiency of the energy sources used in rural areas. Using data from RHPS, collected in 2014, and applying a multinomial logit model, this study attempts to fill this research gap by identifying the factors that impact the choice of energy sources in rural areas of Pakistan.

The results support the fuel stacking model, as rural households use different sources of energy simultaneously. Firewood is preferred for both cooking and heating, while plant residue is mostly used for heating. The likelihood of using traditional energy sources is positively associated with labour supply and has negative association with distance to market. The lesser use of gas arises because of its limited supply in rural areas, although it is affordable by households who are better educated and well-off. A developed infrastructure increases the probability of using gas. However, implementing policies to effect this change will not be that simple, as we have identified education and roads as important factors, which require large financial outlays. Also, the impact of such investments can only be seen in the long term.

This paper also shows that traditional energy sources have harmful effects on the environment and human and animal health. In view of the limited supply and existing shortage of gas in the country, this study proposes two solutions that not only fulfill the demand for efficient energy source but also minimise the harmful effects on environment and health: (1) to generate gas from animal/plant residue; (2) encourage rural households to use energy-efficient appliances. These suggestions would help the Government of Pakistan in the implementation of Vision 2025.

7. STUDY LIMITATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

Finally, there are several suggested areas for further research. One might be to consider the use of an ordered probit model, where the ordering is found in the cost per MMBtu. In that case, there might be a natural ordering in terms moving up in costs per Btu. If in fact households are making decisions on those costs, this could be an appropriate approach. A second possibility is to look more directly at an optimisation approach. In this case, household might want to minimise the full costs of providing energy for a variety of uses, given their locations, options and costs of energy (including harvesting in the case of traditional sources). For this research, some kind of household production model could shed light on a range of policy options, and be a logical extension to the work done in this research and in the data available in the RHPS.

Also, it is worth noting that one of this study's limitations is that it focused exclusively on choice of energy source of rural households in Pakistan using data from the Rural Household Panel Survey (RHPS). Corresponding data from urban households is currently not available, and it might be worth examining the same relationship in an urban or overall context. Additionally, Balochistan was excluded from the sample of this study for security reasons.

ANNEXURE

Table 1

Heating Value of Energy Sources

Fuel	kJ/Kg	MMBtu/Kg
Dung Cake	7,000	0.007
Coal	29,000	0.027
Petrol	45,000	0.043
Kerosene	45,000	0.043
Diesel	45,000	0.043
LPG	45,000	0.043
Biogas	45,000	0.043
Electricity Unit	3,600	0.003

Source: Energy Year Book 2015.

Table 2

Calculation of Heating Value of Animal/Plant Residue and Firewood

Animal/plant Residue		Firewood	
1 tone	1000 Kg	1 Tone	1000 Kg
1 Maund	40 Kg	1 Maund	40 Kg
	15.48 MMBtu/Tone		16.93 MMBtu/Tone
Heating Value	0.015 MMBtu/Kg	Heating Value	0.016 MMBtu/Kg
	0.62 MMBtu/Maund		0.67 MMBtu/Maund

Sources:

(1) http://www1.eere.energy.gov/biomass/feedstock_databases.html

(2) Jenkins, B., Properties of Biomass, Appendix to Biomass Energy Fundamentals, EPRI Report TR-102107, January, 1993.

(3) Jenkins, B., Baxter, L., Miles, T. Jr., and Miles, T., Combustion Properties of Biomass, Fuel Processing Technology 54, pg. 17-46, 1998.

(4) Tillman, David, Wood as an Energy Resource, Academic Press, New York, 1978.

(5) Bushnell, D., Biomass Fuel Characterisation: Testing and Evaluating the Combustion Characteristics of Selected Biomass Fuels, BPA report, 1989.

(6) http://www.ecn.nl/phyllis

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