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Environmental Losses and the Lessons that Can Be Learnt from Energy Demand Elasticities: The Resultant Policy Implications

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Abstract
Environmental sustainability is deeply linked with household energy consumption decisions. Greater inclination towards cheap and pollution creating fuels can prove to be a major obstacle in having a clean environment. The governance decisions can make path towards cleaner and sustainable environment easier. Hence, this work has been executed to elucidate the impact of energy demand elasticities on the households living in rural as well as urban areas of Pakistan using a pool of four Pakistan Social and Living Standards Measurement Survey (PSLMs) data sets to estimate a Quadratic Almost Ideal Demand System (QUAIDS) and obtain the prices as well as expenditure elasticities. The first step probit estimates demonstrate the existence of fuel stacking in Pakistan. The results of estimated price elasticities show that electricity is least elastic with respect to own price for overall Pakistan as well as for rural-urban divide. Expenditure Elasticities for gas, firewood, kerosine oil and other fuels like coal and cow-dung etc. are higher in rural areas compared to urban ones. This might indicate a rising share of these more pollution creating goods in rural household budget. Inflation in prices of cleaner energy goods can be detrimental for environmental sustainability due to substitution with pollution creating energy goods. The results of this study are lucrative for effective policy formulations with respect to environment, taxation, and subsidies provision.

Keywords: Sustainable environment, Household energy demand, Elasticities, Policy, Pakistan

Introduction

Lifestyles elevation has historically been linked with growth in energy consumption and the provision of apt energy services has always been considered a prerequisite mandatory for development (Pachauri, 2007). With the increased use of energy goods, environmental sustainability is also threatened. Policy-framers, governments and scientific platforms have debated on the crucial issue of Climate change and global warming since the onset of this century (Balsalobre-Lorente et al., 2022). Consequently, the energy pricing policies of the government should be prudently designed as they may have deep rooted effects on the environment as well as the economic wellbeing of the consumers, specifically of those belonging to the middle class or below the middle class. The quantification of the impacts of energy goods price increase and purchasing power decrease can be lucrative for the precise and effective policy formulations. This is crucial for environmental sustainability as well due to being threatened by the fuel choices of the households. Therefore, when the household using modern energy sources like electricity and gas face affordability issue, the policymakers should work on expanding the fuel purchasing power of these consumers (Adusah-Poku and Takeuchi, 2019).

Within the arena of energy theories' literature, a plethora of research studies exist revolving around Energy ladder and Fuel Stacking hypotheses. The energy ladder focuses on changing household choices towards more efficient, cleaner, and expensive fuels like electricity with the elevation in its economic status (Van Der Kroon et al., 2013). Contrarily, the fuel stacking model puts forth multiple fuel utilization by household that includes cleaner as well as orthodox polluting fuels in its consumption basket (Masera et al., 2000). Fuel stacking can be regarded to be more realistic as pollution is still a major issue of the country. Recent electricity and gas prices elevation may even push consumers towards pollutant fuels.

The energy goods prices have proved to be regressive in Pakistan and hence affect poor the more (Ahmad et al., 2020). Consumer welfare is affected negatively due to energy goods price escalation like that of electricity, gas, and other fuels Beznoska (2014). Hence, income of consumers and market prices are crucial to the determination of consumers' demand (Aziz et al., 2016).

With the ill developed energy infrastructure of Pakistan and poor management, the country is the victim of acute crisis of energy. The scenario has turned gloomier due to power pilferage and transmission losses caused by obsolete infrastructure. The increased capacity has helped in removing problems at generation level, the prevalence of inefficiencies in transmission and distribution system have been a great hurdle in sustained energy supply (Pakistan Economic Survey, 2019-20).

Therefore, the country immediately needs an inclusive, futuristic, and viable energy policy. Regrettably, a prudent, all-embracing energy plan seems not to be forthcoming (Malik Naseem Abbas, 2015).
Table 1 from PSLMS (2018-19) reports the percentage distribution of monthly consumption expenditures per household on fuel and lighting according to income quintiles. On average a household spent RS: 2957.80 per month on energy goods during 2018-19 in Pakistan. The household spent 55.30 percent of its energy expenditure on electricity. Therefore, electricity is the major energy good for the household. 18.90 percent of household energy expenditures went to firewood, making it the second in the position with respect to household energy expenditures. 14.37 percent of the household energy expenditures were devoted to the gas expenses. Kerosine oil constituted 0.17 percent of household monthly expenditures.

Table 1: Percentage Distribution of Monthly Consumption Expenditure Per Household on Fuel and Lighting by Quintiles, 2018-19

Fuel and Lighting Items	Quintiles					
	Total	1st	2nd	3rd	4th	5th
Average Monthly Expenditure Per Household (Rs)	2957.80	1960.55	2388.33	2643.69	2988.13	4112.63
Percentage Expenditure	100	100	100	100	100	100
Firewood	18.90	32.76	30.14	25.10	19.74	7.40
Kerosine oil	0.17	0.43	0.28	0.21	0.14	0.05
Charcoal	0.31	0.75	0.47	0.42	0.19	0.14
Coal (hard / soft / peat)	0.04	0.06	0.05	0.06	0.03	0.02
Dung Cakes	3.23	6.07	5.85	4.60	2.91	1.01
Gas (piped/cylinder)	14.37	5.83	9.50	12.44	16.46	18.23
Electricity	55.30	35.27	41.03	47.96	54.89	69.94
Generator, etc.	0.90	0.27	0.18	0.44	0.74	1.66
Cotton Sticks	3.43	10.24	10.24	6.70	4.48	0.66
Other Agri. Wastes, Bagasse etc.	3.35	8.32	5.80	4.28	2.88	0.88

Source: PSLM Survey 2018-19

The government has always been subsidizing energy, especially electricity, to allay any problem and protests by public, but the issue of subsidies has always been debatable within economists' fraternity. Despite the relief given to the people, subsidies magnify the dead weight loss for economy and scale down welfare of consumers. Still, the sudden withdrawal of subsidies will hit the people at margins hardest. So, for a developing country like Pakistan, determination of optimal level of any energy subsidy is very crucial. It will have minimal adverse economic impact and consumer benefit for maximum users. A targeted program for subsidy will have more lucrative effects in forms of fiscal savings as well as welfare of marginal ones in Pakistan (Khalid & Salman, 2020). The recent Program of International Monetary Fund for Pakistan is conditional upon the removal of subsidies in energy sector of Pakistan to eliminate circular debt issue specially. Swift rise in energy prices and fast removal of subsidies can be detrimental for the ailing economy and consumers welfare. The fact that Tariff Differential Subsidy by the government benefits the urban consumer mainly, calls forth the need for targeted subsidies programs for poor (Haroon et al., 2019).
With the pacing of urbanization and population growth, the energy demand dynamics of the country may change. Hence, in such a critical need for comprehensive research on consumer demand in wake of surging prices and real income depletion, and after a deep perusal of existing literature specially pertaining to Pakistan, this study's objective is to estimate a Quadratic Almost Ideal Demand System (QUAIDS) by Incorporating Consistent two Step Estimator and a few demographic variables that impact the consumer preferences but are generally ignored by the fuel demand studies in Pakistan.
The organization of the paper is as follows; the materials and methods for obtaining results are elaborated in Section 2. Results are presented in section 3. Findings of the research are discussed in section 4. Conclusion and policy implications consequent upon findings in section 3 have been presented in section 5.

2. Materials and Methods

2.1 Data

The data used is pool of four Pakistan Social and Living Standards Measurement Surveys conducted by Pakistan Bureau of Statistics, for the years 2001-02, 2007-08, 2013-14 and 2018-19. The demographic variables' data is extracted from the same data sets. These variables include family income proxied by total household monthly expenditures, age of household, family size, education proxied by if household can do and understand simple mathematics, and location i.e., rural, or urban. The research is conducted on household five energy goods used for cooking, lighting, and heating purposes, namely electricity, piped and cylinders' gas, Kerosine, firewood and other fuels used for same purposes. The data for the energy goods' prices is taken from Monthly Statistical Bulletin that Pakistan Bureau of Statistics (PBS) publishes for each month of each year. Enumeration time and date is given in PSLMS for every household. Pakistan Bureau of Statistics possess data on prices for different regions and months. These prices are taken from PBS for different provinces and months.
2.3 Econometric Model
Deaton and Muelbauer (1980) developed an Almost Ideal Demand System(AIDS). Banks et al. (1997) extended AIDs to allow the Engel curves to be quadratic. Their proposed model, Quadratic Almost Ideal Demand System (QUAIDS) has budget share quadratic in total expenditures in logarithmic form. The advantage of QUAIDS is that it has AIDs nested in it and has a rank three with respect to Engel curves which make it very flexible (Mittal 2006). According to Cranfield et al.

(2003), generally empirical results from in and out of sample comparisons favour rank three demand systems over those having rank two. The most important thing is this that it allows for the Engel curvature and the models that fail to account for it, present misguiding estimates of welfare changes due to tax alterations (Banks et al., 1997). The inclusion of Quadratic term in the model allows goods to be necessities at higher income level and luxuries at low-income level (Ecker and Qaim, 2008).
The QUAIDS model like AIDS is derived from Indirect Utility (V) Function as under

$$\ln V = \left\{\left(\frac{\ln x - \ln a(p)}{b(p)}\right)^{-1} + \lambda(P)\right\}^{-1} \quad \text{(i)}$$

Here x represents total household expenditures in our research, p is prices' vector, a (p) is a homogenous of degree one in prices function, whereas λ(p) and b (p) are homogenous of degree zero in prices functions.

Translog and Cob-Douglass equations specified originally in Deaton and Muellbauer's AIDS model are depicted by ln a (p) and ln b (p). Deaton and Muellbauer's AIDS model has λ(p) set equal to zero.

$$\ln a(p) = a_o + \sum_{i=1}^{n} a_i \ln p_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \gamma_{ij} \ln p_i \ln p_j \quad \text{(ii a)}$$

$$b(p) = \prod_{i=1}^{n} p_i^{B_i} \quad \text{(ii b)}$$

$$\lambda(p) = \sum_{i=1}^{n} \lambda_i \ln p_i \quad \text{(iii)}$$

i= 1, ... , n shows consumption goods.

In the study under discussion, the number of commodities is five as five household energy goods for cooking, heating, and lighting have been selected for analysis.

Substituting (ii a, ii b and iii) in (1) and applying Roy's Identity yields the QUAIDS represented in form of budget shares as

$$W_i = a_i + \sum_{i=n}^{n} \gamma_{ij} \ln p_i + \beta_i \ln\left(\frac{x}{a(p)}\right) + \frac{\lambda_i}{b(p)}\left[\ln\left(\frac{x}{a(p)}\right)\right]^2 + \varepsilon_i \quad \text{(iv)}$$

$$i = 1,2, \ldots \ldots \ldots, n$$

Here in (iv), w_i depicts budget share for ith commodity. Pi is the price of particular energy commodity consumed. Per-capita fuel expenditures 'x' will be deflated by stone's geometric price index, I. Stone's Geometric Price Index: lnI= ΣWilnp. Wi is the budget shares of individual energy good in total fuel expenditures; Lnp is Natural log of the prices of individual fuels. Parameters for estimation are given by αiγij and βi and error term is represented by εi. The consumer demand theory places some restrictions on the estimation of above given demand system namely adding up, homogeneity and symmetry. The adding up constraint is satisfied if for all X and P, $\sum_{i=1}^{n} Wi = 1$ i.e.

$$\sum_{i=1}^{n} a_i = 1, \quad \sum_{i=1}^{n} \beta_i = 0, \quad \sum_{i=1}^{n} \gamma_{ij} = 0, \quad \sum_{i=1}^{n} \lambda_i = 0 \quad \text{(v)}$$

$$\sum_{i=1}^{n} \gamma_{ji} = 0 \quad \text{(vi)}$$

$$\gamma_{ij} = \gamma_{ji} \quad \text{(vii)}$$

Equation (v) depicts adding up restriction, equation (vi) reflects homogeneity and equation (vii) is the Slutsky's symmetry. Provided that (v), (vi) and (vi) hold, estimated demand function add up to total expenditures (V), is homogeneous of degree zero in prices and income (vi) and satisfy Slutsky Symmetry (vii).
Since estimating all the equations together yields singular error covariance matrix, one equation is deleted from the demand system to proceed further. The parameters of deleted equation are recovered from parameters of other equations through restrictions on them.
Several demographic factors like age structure, population size, urbanization level can affect household energy demand (O'Neill and Chen, 2002). ÖZcan et al. (2013) found that income, age as well as dwelling (i.e., rural, or urban) of households affect their energy choices. Demographic translation method can be employed to incorporate the effects of the demographic variables in demand model (Pollak & Wales, 1981; Heien & Wessells, 1990).
The Constant term αi can be modelled as under:

$$a_i = \delta_i + \sum_{j=1}^{s} \delta_{ij} D_j, \quad \text{and} \quad \sum_{j=1}^{s} \delta_{ij} = 0, \quad i = 1,2,3, \ldots \ldots .., n$$

Here δi and δij depict the estimation parameters whereas Dj represents demographic characteristics like family income and household size etc.
Another issue encountered by cross-sectional or pooled data is that of corner solution or zero observation. Shonkwiler and Yen (1999) introduced their consistent two-step estimation method in which the issue of no-consumption has been modelled with limited dependent variables as

$$w_i^* = f(g_i, u_i + u_i) d_i^* = z_i \partial_i + v_i, \quad \text{(viii)}$$

$$d_i = \left[\begin{matrix} 1 & \text{if } d_i^* > 0 \\ 0 & \text{if } d_i^* \leq 0 \end{matrix}\right. w_{i=} d_i w_i^* > 0$$

Here wi represents ith commodity's budget share. di depicts a binary outcome which becomes 1 in case of consumption of commodity by household and zero contrarily. Correspondingly, wi* and di* depict the unobserved variables. The prices and expenditures of households are represented by gi. The demographics of households and related variables are shown by zi. Vectors of estimation parameters are depicted by μi and ∂i whereas ui and vi depict the random errors.

With the assumption that the disturbance terms (ui and vi) follow bivariate normal distribution and have cov(ui, vi) =ϕ , for every taken good, Shonkwiler and Yen (1999) corrected for demand system inconsistency via specification of regression at second stage as;

$$w_i^* = \emptyset(z_i\,\partial_i) f(g_i, u_i) + \delta_i \varphi(z_i\,\partial_i) + e_i \quad \text{(ix)}$$

Here ' ϕ(zi ∂i) and φ (zi∂i) represent the probability density function (PDF) and the cumulative distribution function, respectively. Theoretically these can be obtained via a probit model using equation (viii) for each energy good at first stage.

$$w_i^* = a_i \emptyset(z_i\,\partial_i) + \sum_{i=1}^{n} \gamma_{ij} \ln p_j \emptyset(z_i\,\partial_i) + \beta_i \emptyset(z_i\,\partial_i) \ln\left[\frac{x}{a(p)}\right] + \left[\frac{\lambda_i}{b(p)}\right] \emptyset(z_i\,\partial_i) [\ln\left[\frac{x}{a(p)}\right]]^2 + \sum_{j=1}^{s} \delta_{ij} D_j \emptyset(z_i\,\partial_i) + \delta_i\, \emptyset(z_i\,\partial_i) + \varepsilon_i \quad \text{(x)} \quad i=1,2,3,\ldots\ldots\ldots\ldots\ldots,n$$

For deriving energy price and conditional expenditure elasticities, equation (x) is differentiated with respect to lnpj and lnx, as under.

$$\Psi_i = \frac{\partial w_i^*}{\partial \ln x} = \emptyset(z_i\,\partial_i) \left[\beta_i + \frac{2\lambda_i}{b(p)} \{\ln *[\frac{x}{a(p)}]\}\right] \quad \text{(xi)}$$

$$\Psi_{ij} = \frac{\partial w_i^*}{\partial \ln p_j} = \emptyset(z_i\,\partial_i) \left[\gamma_{ij} - \Psi_i \left[a_j + \sum_{k=1}^{n} \gamma_{jk} \ln p_k\right] - \frac{2\lambda_i \beta_j}{b(p)} \{\ln[\frac{x}{a(p)}]\}^2\right] \quad \text{(xii)}$$

Here price index Pk is calculated by taking arithmetic mean of all k (energy goods) prices. The calculation of conditional expenditure elasticities hence can be done as:

$$e_i = (\Psi_i / w_i^*) + 1 \quad \text{(xiii)}$$

The equation (xiv) gives the conditional, Marshallian price elasticities as under

$$e_{ij}^u = (\Psi_{ij} / w_i^*) - \vartheta_{ij} \quad \text{(xiv)}$$

Here ϑ_{ij} represents Kronecker delta which equals unity when i=j, and zero contrarily. The conditional compensated elasticities with respect to prices can be calculated using slutsky's equation, as under

$$e_{ij}^c = (\Psi_{ij} / w_i^*) + e_i w_j \quad \text{(xv)}$$

3. Results

3.1 Probit estimates

The research estimates a probit model at the first stage to gauge household fuel choices for cooking heating and lighting purposes as a part of two step estimation process for tackling zero consumption issue either due to abstention or any other reason like that of corner solution. It has a binary dummy that turns zero when the household doesn't consume a particular energy good and one otherwise. The estimated results unmask a divergence in fuel choices due to number of determinants including demographic ones. The outcome of probit estimates at national level as well as for rural and urban areas are given in Table A1, Table A2 and Table A3 respectively of Appendix. The results illustrate that the price of electricity is highly significant in determining the electricity as well as all other taken energy goods choices at national level as well as in rural and urban regions. The results of current study also divulge that an increase in electricity price causes an elevation in inclination towards gas selection by household at aggregate as well as rural and urban levels. It has also been depicted that with a rise in electricity price, there is decreased tendency to choose firewood, kerosine oil and other fuels at all levels.

The demographic variables are also influential in household fuel choices. Except for the electricity choice for urban households, there is a decrease in tendency towards electricity and gas consumption at all levels with the rise in household size. Contrary is the case with kerosine oil, firewood, and other fuels. The education variable is proxied by simple mathematics, understanding in this study which is different from other studies' conventional way of categorizing household into educational levels like matric, intermediate etc. The reason for doing so is that a household bears a significant level of wisdom. If he/she can do simple mathematics, can manage energy goods consumption calculations effectively according to the budget. This variable is only significant for other fuels for national level. The total expenditure variable is highly significant for all energy goods at all levels except for firewood in urban and other fuels in rural areas. Though electricity and gas consumption have rising tendency to be chosen with expenditure increase, firewood in rural areas and other fuels in urban areas have also upward propensity for selection by household.

3.2 QUAIDS estimates

Once the household fuel choices are finalized by household in the previous section, we now move towards QUAIDS estimates that illustrate share of a particular fuel good in energy mix of consumer, used for cooking, heating, and lighting purposes. The results of aggregate Pakistan and its rural and urban areas are presented respectively in Table A4, Table A5 and Table A6 of the Appendix. Most of the estimated coefficients are significant at one percent level which means a good deal of policy relevance. All the intercept coefficients are significant at one percent level. Except for the other fuels in rural areas, all the coefficients of total fuel expenditures and squared total fuel expenditures are significant at one percent in share equations of all the taken five goods. This also hints at the importance of quadratic specification of the model. The expenditures on cleaner energy goods are declining with total fuel expenditures across the rural and urban regions specifically, and these are rising for relatively polluting energy goods. The results of squared fuel expenditures show that the shares of electricity and gas are rising with squared fuel expenditures and those of kerosine oil and firewood are declining at national, rural as well as urban levels.

Electricity consumption is decreasing with household size for all levels. The consumption of firewood is increasing with family size at aggregate as well as at rural and urban levels. The age variable is significant for the share equation of each energy good at national level and rural and urban levels except for the gas and other fuels in urban areas, and electricity and kerosine oil in rural areas. Electricity consumption is rising with age at aggregate level as well as in rural areas. Kutortse (2022) also found rising electricity consumption with age in Ghana.

3.3 Own and Cross-Price Marshallian (Uncompensated) Demand Elasticities

The parameters estimated via QUAIDS have been used to derive the elasticities. Table 2 shows the Marshallian demand elasticities for overall Pakistan with respect to price. All own price elasticities are negatively signed as well as highly significant even at one percent level. The principal diagonal of this table depicts own price elasticities. The demand for electricity is the least elastic among all own price elasticities. Apart from other fuels, kerosine oil is the most inelastic fuel commodity among all own and cross price demand elasticities at national level used for cooking heating and lighting purposes by consumers of Pakistan. Gas, kerosine oil and firewood are most inelastic with respect to the prices of electricity and other fuels.

Table 2: Uncompensated/ Marshallian Own and Cross Price Demand Elasticities Aggregate Pakistan

Prices	Elasticities				
	Electricity	Gas	Kerosine Oil	Firewood	Other Fuels
Electricity	-0.753*** (0.000)	-0.131*** (0.000)	0.037*** (0.000)	-0.193*** (0.000)	-0.021*** (0.000)
Gas	-0.089*** (0.000)	-1.078*** (0.000)	0.355*** (0.000)	-0.200** (0.021)	-0.029*** (0.000)
Kerosine Oil	0.073*** (0.000)	0.444*** (0.000)	-1.631*** (0.000)	0.222*** (0.000)	-0.018*** (0.000)
Firewood	-0.105*** (0.000)	-0.175*** (0.000)	0.232*** (0.000)	-0.997*** (0.000)	0.018*** (0.000)
Other Fuels	0.019*** (0.000)	-0.009*** (0.000)	-0.010*** (0.000)	-0.005*** (0.000)	-0.999*** (0.000)

P-Values in parentheses.
***p < 0.01, **p < 0.05, *p < 0.1

Probing deep into the rural-urban divide gives a clearer picture about uncompensated price elasticities of demand in Table 3 and Table 4 respectively.

Table 3: Uncompensated Marshallian own and cross price elasticities across rural regions

Prices	Elasticities				
	Electricity	Gas	Kerosine Oil	Firewood	Other Fuels
Electricity	-0.681*** (0.000)	-0.109*** (0.000)	0.050*** (0.000)	-0.264*** (0.000)	-0.024*** (0.000)
Gas	-0.092*** (0.000)	-1.048*** (0.000)	0.286*** (0.000)	-0.137** (0.021)	-0.034*** (0.000)
Kerosine Oil	0.068*** (0.000)	0.314*** (0.000)	-1.647*** (0.000)	0.342*** (0.000)	-0.016*** (0.000)
Firewood	-0.220*** (0.000)	-0.121*** (0.000)	0.316*** (0.000)	-1.047*** (0.000)	0.058*** (0.000)
Other Fuels	0.007*** (0.000)	-0.028*** (0.000)	-0.013*** (0.000)	0.048*** (0.000)	-0.997*** (0.000)

P-Values in parentheses.
***p < 0.01, **p < 0.05, *p < 0.1.

The electricity is more inelastic with respect to own price in rural areas compared to urban areas of the country in absolute terms with elasticity values of -0.681 and -0.819 respectively. The same is not the case with gas. The own price elasticity value of -1.009 in urban areas is lower in absolute terms than that of -1.048 in rural areas. It is worth noting that the electricity demand is also the least elastic among all own price elasticities across rural urban divide as well. The own price elasticities of kerosine oil and Firewood are lower in urban areas with values -1.349 and -0.954 compared to rural ones having values -1.647 and -1.047, respectively.

Table 4: Uncompensated Marshallian own and cross price elasticities across urban regions

Prices	Elasticities				
	Electricity	Gas	Kerosine Oil	Firewood	Other Fuels
Electricity	-0.819*** (0.000)	-0.159*** (0.000)	-0.020*** (0.000)	-0.039*** (0.000)	-0.042*** (0.000)
Gas	-0.100*** (0.000)	-1.009*** (0.000)	0.220*** (0.000)	-0.184** (0.021)	0.078*** (0.000)
Kerosine Oil	-0.013*** (0.000)	0.308*** (0.000)	-1.349*** (0.000)	0.164*** (0.000)	-0.012*** (0.000)
Firewood	-0.023*** (0.000)	-0.222*** (0.000)	0.156*** (0.000)	-0.954*** (0.000)	-0.009*** (0.000)
Other Fuels	-0.029*** (0.000)	0.110*** (0.000)	-0.011*** (0.000)	-0.014*** (0.000)	-1.022*** (0.000)

P-Values in parentheses.
***p < 0.01, **p < 0.05, *p < 0.1.

Evaluating the cross-price Marshallian demand elasticities yields interesting results. The demand for electricity is most inelastic with respect to price of kerosine oil and most elastic with respect to the gas price for urban consumers. Gas, kerosine oil and firewood are most elastic with respect to prices of kerosine oil, gas, and gas respectively and most inelastic with respect to other fuels' prices for urban users. The results are a bit diverse for rural consumers. Electricity demand elasticity is smallest with respect to the price of other fuels and greatest with respect to price of firewood. Forest cover is relatively greater in peri-urban and rural areas, hence substitution with firwood is easier. Gas, kerosine oil and firewood are most elastic with respect to prices of kerosine oil, firewood and kerosine oil correspondingly, and most inelastic with respect to other fuels' prices.

Table 5: Compensated/ Hicksian Own and Cross Price Demand Elasticities Aggregate Pakistan

Prices	Elasticities				
	Electricity	Gas	Kerosine Oil	Firewood	Other Fuels
Electricity	-0.563*** (0.000)	0.084*** (0.000)	0.266*** (0.000)	0.070*** (0.000)	0.214*** (0.000)
Gas	0.066*** (0.000)	-0.909*** (0.000)	0.537*** (0.000)	0.009** (0.021)	-0.160*** (0.000)
Kerosine Oil	0.256*** (0.000)	0.646*** (0.000)	-1.414*** (0.000)	0.475*** (0.000)	0.206*** (0.000)
Firewood	0.059*** (0.000)	0.009** (0.041)	0.429*** (0.000)	-0.771*** (0.000)	0.221*** (0.000)
Other Fuels	0.181*** (0.000)	0.169*** (0.000)	0.182*** (0.000)	0.216*** (0.000)	-0.801*** (0.000)

P-Values in parentheses
***p < 0.01, **p < 0.05, *p < 0.1

3.4 Own and cross-price Hicksian (compensated) demand elasticities: The Hicksian demand elasticities lack the income effect consequent upon price variations, and solely bank on the substitution effect of price changes. Therefore, the compensated/Hicksian price elasticities are expected to be of lower magnitude than those of the Uncompensated/ Marshallian ones. The results of aggregate Pakistan in Table 5 also confirm this proposition except for some cases of kerosine oil and other fuels. All own price compensated demand elasticities represented by principal diagonal, bear expected negative signs and are significant even at one percent level. The analysis of the elasticities is again in absolute terms concentrating only on the magnitude of the values. Identical to the case of uncompensated elasticities, the electricity demand is most inelastic due to own-price changes, among all own price elasticities.

Aggregate Pakistan estimates uncover that electricity, gas and firewood are most elastic with respect to kerosine oil price, whereas kerosine oil is having greatest elasticity with respect to gas price. The Cross-price elasticities in all the cases except for other fuels with respect to gas price, bear positive signs implying that goods are substitutes for each other denying any complementarity. Gas, firewood and kerosine oil are substitutes for electricity. The current study found that the

compensated electricity price elasticity of demand with respect to firewood price equal to 0.059 which means that a percent rise in firewood prices result in 0.059 percent increase in electricity demand. Though the relationship according to this study is that of substitution between the two, the magnitude of substitution is relatively smaller. Probing vice versa, a percent escalation in electricity price results in 0.070 increase in firewood demand which is very small.
Table 6 and Table 7 contain the compensated own and cross price demand elasticities across rural and urban divides respectively.

Table 6: Compensated/ Hicksian own and cross price demand elasticities for rural areas of Pakistan

	Elasticities				
Prices	Electricity	Gas	Kerosine oil	Firewood	Other Fuels
Electricity	-0.487*** (0.000)	0.097*** (0.000)	0.259*** (0.000)	-0.043*** (0.000)	0.187*** (0.000)
Gas	0.092*** (0.000)	-0.851*** (0.000)	0.485*** (0.000)	0.072*** (0.000)	0.166*** (0.000)
Kerosine Oil	0.270*** (0.000)	0.529*** (0.000)	-1.429*** (0.000)	0.571*** (0.000)	0.203*** (0.000)
Firewood	-0.040*** (0.000)	0.071*** (0.000)	0.511*** (0.000)	-0.843*** (0.000)	0.254*** (0.000)
Other Fuels	0.164*** (0.000)	0.154*** (0.000)	0.172*** (0.000)	0.242*** (0.000)	-0.811*** (0.000)

P-Values in parentheses
***p < 0.01, **p < 0.05, *p < 0.1

Table 7: Compensated/ Hicksian own and cross price demand elasticities for urban areas of Pakistan

	Elasticities				
Prices	Electricity	Gas	Kerosine oil	Firewood	Other fuels
Electricity	-0.576*** (0.000)	0.079*** (0.000)	0.226*** (0.000)	0.213*** (0.000)	0.205*** (0.000)
Gas	0.051*** (0.000)	-0.859*** (0.000)	0.375*** (0.000)	-0.025*** (0.000)	0.233*** (0.000)
Kerosine Oil	0.191*** (0.000)	0.511*** (0.000)	-1.140*** (0.000)	0.378*** (0.000)	0.198*** (0.000)
Firewood	0.167*** (0.000)	-0.035*** (0.000)	0.349*** (0.000)	-0.757*** (0.000)	0.184*** (0.000)
Other Fuels	-0.029*** (0.000)	0.110*** (0.000)	-0.011*** (0.000)	-0.014*** (0.000)	-1.022*** (0.000)

P-Values in parentheses
***p < 0.01, **p < 0.05, *p < 0.1

The results are in consensus with theory as all own price elasticities are negatively signed with high significance at one percent. The results of rural-urban division support the results of Marshallian demand elasticities. Electricity in long run is more elastic in urban areas with value -0.576 compared to rural areas of Pakistan whose value is -0.487. Firewood is complementary to electricity in rural areas. Electricity, kerosine oil and other fuels have resulted to be substitutes for gas in rural as well as in urban areas, whereas firewood has proved to be substitute for gas only in rural areas. Electricity, gas, firewood, .and other fuels all have proved to be substitutes for kerosine oil in rural as well as in urban areas.
3.5 Expenditure elasticities: Lastly, the expenditure elasticities for aggregate Pakistan and across rural-urban divide have been reported in Table 8.

Table 8: Expenditure Elasticities

Expenditure	Elasticities		
	Overall Pakistan	Urban Pakistan	Rural Pakistan
Electricity	0.854*** (0.000)	0.985*** (0.000)	0.932*** (0.000)
Gas	0.949*** (0.000)	0.973*** (0.000)	0.993*** (0.000)
Kerosine Oil	1.017*** (0.000)	1.004*** (0.000)	1.008*** (0.000)
Firewood	1.173*** (0.000)	1.028*** (0.000)	1.059*** (0.000)
Other Fuels	1.048*** (0.000)	1.008*** (0.000)	1.014*** (0.000)

P-Values in parentheses
***p < 0.01, **p < 0.05, *p < 0.1

Expenditure elasticity tells that how much change is produced in demand in percentage terms due to a percentage variation in expenditure/income of the user (Gostkowski, 2018). The electricity has proved to be least elastic with respect to income proxied by total expenditures for aggregate as well as rural Pakistan. For urban Pakistan, gas followed by electricity have proved to be least elastic with respect to total expenditures on fuel. One of the important aspects of the results is that none of the elasticities bear negative signs, hence there is no inferior good among all these five goods. Apart from electricity, all the fuels' expenditure elasticities are bit higher in rural areas comparatively. The elasticity of firewood is highest with respect to expenditures for whole Pakistan as well as for rural-urban division. The expenditure elasticities of electricity and gas are lower in magnitude than that of the firewood, kerosine oil and other fuels at all levels.

4. Discussion

The first step probit estimates in Table A1, Table A2 and Table A2 demonstrate a great significance of electricity price in determining choices for all the taken fuels' including electricity itself at national level as well as across rural-urban division. This result is in contrast with that of Waleed and Mirza (2020), who obtained an insignificant electricity price variable for the choice of electricity. The divergent result may be underpinned by the choice of single time cross-sectional data by that study. It has also been depicted that with a rise in electricity price there is decreased tendency to choose firewood, kerosine oil and other fuels at all levels. The provision of these fuels is not monopolized by the government like that of electricity. Hence the compulsory electricity bills payment might increase electricity share in household budget and leave less money in pocket for spending on kerosine oil, firewood, and other fuels.

The probit estimates also reveal a rising tendency for choice of relatively pollutant fuels i.e. Kerosine oil, firewood, and other fuels with the rise in household size. Similar results were obtained by Waleed and Mirza (2020). Rahut et al. (2019) also found the rising inclination towards dung cake and crop residue with increase in household size. The results of Kutortse (2022) also conceded a decreased likelihood for using modern fuels for large sized households in Ghana. The sustainable development goal number 11 stresses on making human settlements safe and sustainable. Larger household sizes pose affordability problems compelling households to use orthodox fuels and threaten environmental safety as well as the sustainability of human dwellings. From policy perspective, government may prioritize families with larger household sizes in providing subsidized alternates of government provided energy services like that of solar panels. Awareness campaigns for environmental sustainability must target large sized families.

The monthly expenditures' variable in probit regression results at national level depict a rising tendency for the selection of electricity, gas, and firewood. Manzoor et al. (2022) and Awan et al. (2023) also obtained positive impact of income/expenditures on clean fuel adoption i.e., for electricity and gas. To the extent of electricity and gas, the results of this study are in line with these studies, but these go beyond to support energy stacking in Pakistan rather than climbing the ladder towards cleaner fuels. The age of household head also has positive impact on cleaner fuel (electricity and gas) adoption for rural and national level households. Kutortse (2022) also observed an elevated likelihood for consuming modern fuels for older household heads. People learn the importance of cleaner fuels and the cleaner environment with age and experience.

The QUAIDS results in Table A5 and Table A6 demonstrate that expenditures on cleaner energy goods are declining with total fuel expenditures across the rural and urban regions and these are rising for relatively polluting energy goods. The results of squared fuel expenditures are totally in contradiction with these results as the shares of electricity and gas are rising with squared fuel expenditures and those of kerosine oil and firewood are declining at national, rural as well as urban levels. Consequently, at higher expenditure levels, the consumption of cleaner energy goods is rising. This causatum highlights the importance of elevating the income levels of households for attaining environmental sustainability as well as Sustainable Development Goals. The consumption of firewood is increasing with family size at aggregate as well as at rural and urban levels. Resultantly. decreased family size can be lucrative for curbing deforestation. Waleed and Mirza (2020) also obtained the same results for electricity and firewood. However, their LPG consumption is decreasing at National as well as rural and urban levels.

The Marshallian demand elasticities in Table 2 show that, electricity is most inelastic with respect to the prices of kerosine oil and other fuels for the whole Pakistan in absolute terms. Hina et al. (2022) also obtained the same results of electricity with respect to the kerosine oil price in absolute terms, using Linearized Almost Ideal Demand System (LA-AIDS) and PSLMS 2013-14. Other fuels and kerosine oil have very low budget shares, and hence changes in the prices of these goods may not affect electricity demand much. The own price Marshallian elasticity value of gas in urban areas is lower in absolute terms than that of rural areas as shown in Table 4 and Table 3 respectively. The gas contains piped as well as cylinder's gas. Prices of both have increased in recent years. This surge has affected the low income and rural consumers more as these usually dwell in areas without gas pipeline coverage. Cylinder's gas is relatively expensive in distant areas with huge transportation costs. Subsequently, it is easier for rural consumers to switch to firewood or other fuels like Dung cake etc., which are readily available and easier to use in these areas. Rural areas must be prioritized in providing cleaner energy goods at subsidized rates if the budget is not a constraint. Otherwise taxing the ruralites on cutting wood or burning wood and other fuels like coal etc. might be an option. This option may not be viable for poor ruralites. Hence monetary incentives can be introduced for the areas having lowest pollution indexes values. The absolute own price elasticity values of gas in both regions are greater than one hinting that escalated gas prices have compelled consumers to switch to gas economizing appliances along with modification in behaviour towards thriftiness to avoid excessive gas bills.

Table 3 and Table 4 of uncompensated and Table 6 and Table 7 of compensated demand elasticities with respect to prices are in consensus with respect to electricity as it is in long run more elastic in urban areas compared to rural areas of Pakistan. The rationale is that in longer run i.e., twenty years of analysis period of this research, consumers in urban areas have reduced demand for electricity more due to better utilization of electricity economizing inventions and innovations. There is one important factor as well. The urban consumers get better technology and information about it rapidly and are more flexible towards change. Thus, their demand for electricity may be more elastic due to these factors.

The other side of picture is this that the electricity supply in rural areas is far below than that of urban areas. Electricity load shedding increases to 14-16 hours in rural areas so use of electric appliances is also very low (Ahmar et al., 2022). Hence the demand for electricity is less elastic in rural areas due to the factor that it captures lesser budget share in rural households' income and hence demand is not affected much by price variation as is affected in urban areas. Another factor is that the power pilferage is more prevalent in rural or peri-urban areas of Pakistan. An increase in electricity price may not affect rural consumers much also due to more illegal options like that of under billing and bribing the lineman available.

According to Table 5, gas, firewood and kerosine oil are substitutes for electricity at national level. Waleed and Mirza (2020) also obtained same results for overall Pakistan. They found a compensated price elasticity of electricity demand with respect to firewood price as 0.38. The current study found that the compensated electricity price elasticity of demand with respect to firewood price equal to 0.059 which means that a percent rise in firewood prices result in too less than a percent increase in electricity demand. Though the relationship according to this study is that of substitution between the two, the magnitude of substitution is relatively smaller. Probing vice versa, a percent escalation in electricity price results in very little increase in firewood demand. Hence, electricity price increase and resultant firewood demand elevation might have little impact on environmental pollution creation due to burning of wood. Raising electricity prices may not lead to firewood burning to a greater extent but can lead to economization of exorbitantly costly produced service.

According to the results of expenditure elasticities in Table 8, the elasticity of firewood is highest with respect to expenditures for whole Pakistan as well as for rural-urban division. Hence Energy Ladder Hypothesis cannot be ratified by these results.

Electricity is a cleaner fuel, and all other fuels are pollution creating. Piped gas is also a cleaner fuel, but cylinders' gas cannot be totally regarded as a cleaner fuel like electricity due to poor quality of provision. The expenditure elasticities of electricity and gas are lower in magnitude than that of the firewood, kerosine oil and other fuels. Aziz et al. (2020), also obtained lower electricity and gas expenditure elasticities compared to other fuels. The logic given by them is that supply constraints dominate the provision system of the gas and electricity services. Hence excess demand is met easily by the consumer via utilization of other fuels like fossils fuels. The expenditure elasticity for electricity is higher in urban areas and lower in rural areas which expresses the importance of cleaner fuel in expenditure shares for the urbanites. Hence for sustainable development urbanites are playing a better role.

5. Conclusion and policy implications

The study has examined the household demand for fuels used for cooking heating and lighting purposes for aggregate Pakistan as well as across its rural-urban division. The outcomes of QUAIDS at aggregate level divulge that all the demographic variables are highly significant for households in Pakistan. Simple mathematics cognizance of household head can impact the spending pattern. The squared expenditures are highly significant at one percent and rising for gas and electricity for overall Pakistan as well as for rural-urban division while these are shrinking for kerosine oil and firewood. This means consumers are trying to avoid pollution creating fuels at higher expenditure level. The government policies of appreciating such consumer behaviour can further fasten the drive towards cleaner fuels' consumption. It also must strategize for provision of cleaner fuels in wake of rising expenditures and to prevent consumers from switching back to traditional fuel goods. Reliance on thermal and hydel electricity can be exorbitant for the economy due to mushrooming circular debt.

The elasticities are also bearing crucial repercussions. Except electricity, all other goods' expenditure elasticities are higher for rural areas. This might indicate a rising share of gas, firewood, kerosine oil and other fuels like coal and cow dung etc. in household budget as we move from urban to rural areas. Though according to QUAIDS findings, the share of pollution creating fuel goods is diminishing with exponential rise in consumer expenditures, still rural areas are contributing more towards pollution, environmental degradation, and slower move towards sustainable development. Government must move with muti-pronged strategy to achieve sustainable development. Low-income group, large sized families, younger household heads and ruralites specifically must be focused on in policy targeting for having cleaner environment. Different policies with respect to expenditure levels, demographic determinants and rural-urban segregation should be adopted to meet the goals which would otherwise be prone to conflicting outcomes and achievements leading to ten miles towards sustainable development and twenty miles away from it.

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Appendix

Table A1: Probit Estimates of First Step Estimation at Aggregate Level

	Electricity	Gas	Kerosine Oil	Firewood	Other Fuels
Ln Electricity Price	0.274*** (0.00)	0.763*** (0.00)	-0.343*** (0.00)	-0.571*** (0.00)	-0.167*** (0.00)
Ln Gas Price	0.997*** (0.00)	1.674*** (0.00)	-0.832*** (0.00)	-1.441*** (0.00)	-0.481*** (0.00)
Ln Kerosine oil Price	-0.048 (0.68)	-1.281*** (0.00)	1.752*** (0.00)	1.742*** (0.00)	0.658*** (0.00)
Ln Firewood Price	-0.851*** (0.00)	-0.422*** (0.00)	-1.638*** (0.00)	-0.473*** (0.00)	-0.085 (0.18)
Ln other Fuels Price	0.002*** (0.00)	0.019*** (0.00)	0.004*** (0.00)	-0.001** (0.03)	-0.024*** (0.00)
Ln fuel expenditures	-0.000 (0.11)	-0.000*** (0.00)	0.000*** (0.00)	0.000*** (0.00)	0.000*** (0.00)
Region	-0.522*** (0.00)	-1.275*** (0.00)	0.587*** (0.00)	1.080*** (0.00)	1.107*** (0.00)
Family Size	-0.005** (0.03)	-0.015*** (0.00)	0.022*** (0.00)	0.019*** (0.00)	0.007*** (0.00)
Age	0.002*** (0.00)	0.002*** (0.00)	0.000 (0.60)	-0.000 (0.42)	-0.000 (0.22)
Math Simple	-0.002 (0.91)	0.007 (0.57)	-0.019 (0.32)	0.015 (0.22)	-0.027** (0.04)
Monthly Expenditures	$1.29X10^{-6}$*** (0.00)	$4.43X10^{-6}$*** (0.00)	$-7.40 X 10^{-6}$*** (0.00)	$2.12X10^{-6}$*** (0.00)	$-4.63X10^{-6}$** (0.04)
Gender	0.171*** (0.00)	0.129*** (0.00)	-0.052* (0.07)	0.028 (0.14)	-0.199 (0.30)
Constant	-0.145 (0.50)	0.174 (0.21)	-2.856*** (0.00)	-2.026*** (0.00)	-2.471*** (0.00)

P-Values in parentheses.
***p < 0.01, **p < 0.05, *p < 0.1

Table A2: Probit estimates of first step estimation across rural areas

	Electricity	Gas	Kerosine Oil	Firewood	Other Fuels
Ln Electricity Price	0.244*** (0.00)	0.696*** (0.00)	-0.215*** (0.00)	-0.428*** (0.00)	-0.088*** (0.00)
Ln Gas Price	0.854 *** (0.00)	1.367*** (0.00)	-0.278*** (0.00)	-0.857*** (0.00)	-0.198*** (0.00)
Ln Kerosine oil Price	0.069 (0.62)	-1.077*** (0.00)	1.388*** (0.00)	1.601*** (0.00)	0.045 (0.64)
Ln Firewood Price	0.821*** (0.00)	-0.396*** (0.00)	-1.855*** (0.00)	-0.936*** (0.00)	0.326*** (0.00)
Ln other Fuels Price	0.003** (0.03)	0.024*** (0.00)	0.005*** (0.00)	0.002*** (0.00)	-0.073*** (0.00)
Ln fuel expenditures	-0.000 (0.19)	-0.000*** (0.00)	0.000** (0.04)	0.000* (0.06)	0.000*** (0.00)
Family Size	--0.006 ** (0.04)	-0.013*** (0.00)	0.022*** (0.00)	0.019*** (0.00)	0.002 (0.22)
Age	0.002*** (0.00)	0.003*** (0.00)	0.000 (0.51)	-0.000 (0.57)	-0.001** (0.02)
Math Simple	-0.009 (0.67)	0.006 (0.69)	-0.028 (0.22)	0.002 (0.89)	-0.021 (0.18)
Monthly Expenditures	$1.05X10^{-6}$ ** (0.01)	$5.24X10^{-6}$*** (0.00)	$-5.15X10^{-6}$*** (0.00)	$3.3X10^{-6}$*** (0.00)	$-3.61X10^{-6}$ (0.19)
Gender	0.206*** (0.00)	0.175*** (0.00)	-0.077** (0.03)	0.052** (0.03)	-0.029 (0.22)
Constant	-1.202*** (0.00)	-2.171*** (0.00)	-1.989*** (0.00)	-0.850*** (0.00)	0.868*** (0.00)

P-Values in parentheses.
***p < 0.01, **p < 0.05, *p < 0.1

Table A3: Probit Estimates of first Step Estimation across Urban areas

	Electricity	Gas	Kerosine Oil	Firewood	Other Fuels
Ln Electricity Price	0.413*** (0.00)	0.909*** (0.00)	-0.709*** (0.00)	-0.976*** (0.00)	-0.403*** (0.00)
Ln Gas Price	1.312*** (0.00)	2.120*** (0.00)	-1.729*** (0.00)	-2.222*** (0.00)	-1.285*** (0.00)
Ln Kerosine oil Price	-0.147 (0.51)	-1.516*** (0.00)	1.835*** (0.00)	1.609*** (0.00)	1.192*** (0.00)
Ln Firewood Price	-1.121*** (0.00)	-0.559*** (0.00)	-0.617*** (0.00)	0.596*** (0.00)	0.137 (0.25)
Ln other Fuels Price	0.000 (0.81)	0.012*** (0.00)	-0.002 (0.27)	-0.007*** (0.00)	0.002*** (0.00)
Ln fuel expenditures	-0.000** (0.04)	-0.000*** (0.00)	0.000*** (0.00)	0.000*** (0.00)	0.000*** (0.00)
Family Size	-0.007 (0.19)	-0.198*** (0.00)	0.024*** (0.00)	0.026*** (0.00)	0.017*** (0.00)
Age	0.001 (0.38)	0.000 (0.37)	-0.000 (0.62)	-0.000 (0.28)	0.001 (0.14)
Math Simple	0.024 (0.57)	0.007 (0.77)	-0.010 (0.78)	0.035 (0.10)	-0.021 (0.40)
Monthly Expenditures	$2.18X10^{-6}$** (0.02)	$2.16X10^{-6}$*** (0.00)	-0.000*** (0.00)	$3.37X10^{-7}$ (0.38)	$1.11X10^{-6}$*** (0.00)
Gender	0.052 (0.43)	0.035 (0.30)	0.006 (0.92)	-0.024 (0.47)	-0.004 (0.90)
Constant	-0.982** (0.02)	-1.42*** (0.00)	-0.444 (0.16)	1.261*** (0.00)	-1.167*** (0.00)

P-Values in parentheses.
***p < 0.01, **p < 0.05, *p < 0.1

Table A4: QUAIDs Estimates of Second Step Estimation at Aggregate Level

	Electricity	Gas	Kerosine Oil	Firewood	Other Fuels
Ln Electricity Price	0.065*** (0.00)	-0.014*** (0.00)	0.004*** (0.00)	-0.043*** (0.00)	-0.011*** (0.00)
Ln Gas Price	-0.014*** (0.00)	-0.059*** (0.00)	0.090*** (0.00)	-0.024*** (0.00)	0.008*** (0.00)
Ln Kerosine oil Price	0.004*** (0.00)	0.090*** (0.00)	-0.144*** (0.00)	0.048*** (0.00)	0.002*** (0.00)
Ln Firewood Price	-0.043*** (0.00)	-0.024*** (0.00)	0.048*** (0.00)	0.019*** (0.00)	0.000*** (0.00)
Ln other Fuels Price	-0.011*** (0.00)	0.008*** (0.00)	0.002*** (0.00)	0.000*** (0.01)	0.00*** (0.00)
Ln fuel expenditures	-0.145*** (0.00)	0.037*** (0.00)	0.031*** (0.00)	0.072*** (0.00)	0.005** (0.04)
Ln fuel expenditures Square	0.047*** (0.00)	0.011*** (0.00)	-0.010*** (0.00)	-0.053*** (0.00)	0.005*** (0.00)
Region	0.144*** (0.00)	0.044*** (0.00)	-0.003 (0.00)	-0.072*** (0.00)	-0.005*** (0.00)
Family Size	-0.006*** (0.00)	-0.000*** (0.00)	-0.000*** (0.00)	0.000*** (0.00)	-0.000*** (0.00)
Age	0.001*** (0.00)	0.000*** (0.00)	0.000*** (0.00)	0.000*** (0.00)	0.000*** (0.00)
Math Simple	0.033*** (0.00)	0.004*** (0.00)	0.007*** (0.00)	0.011*** (0.00)	0.002*** (0.00)
Monthly Income	$5.26X10^{-8}$ (0.11)	$1.32X10^{-7}$ *** (0.00)	$2.53 X 10^{-7}$ *** (0.00)	$4.44X10^{-7}$*** (0.00)	$2.55 X 10^{-8}$*** (0.00)
Constant	0.387*** (0.00)	0.043*** (0.00)	0.231*** (0.00)	0.166*** (0.00)	0.172*** (0.00)

P-Values in parentheses.
***p < 0.01, **p < 0.05, *p < 0.1.

Table A5: QUAIDs estimates of second step estimation across rural regions

	Electricity	Gas	Kerosine Oil	Firewood	Other Fuels
Ln Electricity Price	0.063*** (0.00)	-0.024*** (0.00)	0.012*** (0.00)	-0.046*** (0.00)	-0.004*** (0.00)
Ln Gas Price	-0.024*** (0.00)	-0.008*** (0.00)	0.062*** (0.00)	-0.023*** (0.00)	-0.006*** (0.00)
Ln Kerosine oil Price	0.012*** (0.00)	0.062*** (0.00)	-0.140*** (0.00)	0.068*** (0.00)	-0.001*** (0.00)
Ln Firewood Price	-0.046*** (0.00)	-0.023*** (0.00)	0.068*** (0.00)	-0.010*** (0.00)	0.011*** (0.00)
Ln other Fuels Price	-0.004*** (0.00)	-0.006*** (0.00)	-0.001*** (0.00)	0.011*** (0.00)	0.00*** (0.00)
Ln fuel expenditure	-0.037*** (0.00)	-0.024*** (0.00)	0.013*** (0.00)	0.044*** (0.00)	0.003** (0.04)
Ln fuel expenditures Square	0.004*** (0.00)	0.004*** (0.00)	-0.001*** (0.00)	-0.006*** (0.00)	0.000 (0.44)
Family Size	-0.056*** (0.00)	-0.006*** (0.00)	-0.009*** (0.00)	0.014*** (0.00)	-0.002*** (0.00)
Age	0.000 (0.67)	-0.000* (0.05)	-0.000 (0.66)	-0.003*** (0.00)	0.000*** (0.00)
Math Simple	0.064* (0.05)	0.012 (0.12)	0.016** (0.02)	0.019 (0.39)	0.000 (0.99)
Monthly Income	$1.66X10^{-6}$ ** (0.03)	$3.53X10^{-7}$ (0.16)	$2.66X10^{-6}$ *** (0.00)	$2.65X10^{-6}$ *** (0.00)	$9.84X10^{-8}$ (0.13)
Gender	0.177*** (0.00)	-0.019 (0.13)	0.076*** (0.00)	-0.031 (0.37)	0.011*** (0.00)
Constant	0.304*** (0.00)	0.195*** (0.00)	0.261*** (0.00)	0.062*** (0.00)	0.177*** (0.00)

P-Values in parentheses
***p < 0.01, **p < 0.05, *p < 0.1

Table A6: QUAIDs estimates of second step estimation across urban regions

	Electricity	Gas	Kerosine Oil	Firewood	Other Fuels
Ln Electricity Price	0.043*** (0.00)	-0.026*** (0.00)	-0.004*** (0.00)	-0.006*** (0.00)	-0.007*** (0.00)
Ln Gas Price	-0.026*** (0.00)	-0.001 (0.53)	0.045*** (0.00)	-0.034*** (0.00)	0.016*** (0.00)
Ln Kerosine oil Price	-0.004*** (0.00)	0.045*** (0.00)	-0.072*** (0.00)	0.032*** (0.00)	-0.002*** (0.00)
Ln Firewood Price	-0.006*** (0.00)	-0.034*** (0.00)	0.032*** (0.00)	0.009*** (0.00)	-0.002*** (0.00)
Ln other Fuels Price	-0.007*** (0.00)	0.016*** (0.00)	-0.002*** (0.00)	-0.002*** (0.00)	0.000*** (0.00)
Ln fuel expenditures	-0.014*** (0.00)	-0.014*** (0.00)	0.003*** (0.00)	0.017*** (0.00)	0.008*** (0.00)
Ln fuel expenditures Square	0.003*** (0.00)	0.002 (0.00)	-0.000*** (0.00)	-0.003*** (0.00)	-0.001*** (0.00)
Family Size	-0.025*** (0.00)	0.001 (0.23)	-0.001*** (0.00)	0.002*** (0.00)	-0.000*** (0.00)
Age	0.002* (0.05)	-0.000 (0.24)	0.000*** (0.00)	0.000* (0.09)	0.000 (0.21)
Math Simple	0.072** (0.01)	-0.007 (0.38)	0.003 (0.34)	-0.024*** (0.00)	0.002*** (0.00)
Monthly Income	$2.11X10^{-6}$ *** (0.00)	$1.73X10^{-6}$ *** (0.00)	$8.45X10^{-8}$ *** (0.00)	$5.30X10^{-8}$ (0.69)	$-2.26X10^{-8}$** (0.02)
Gender	0.056 (0.19)	-0.056*** (0.00)	-0.016*** (0.00)	-0.02* (0.09)	-0.000 (0.66)
Constant	0.299*** (0.00)	0.105*** (0.00)	0.233*** (0.00)	0.174*** (0.00)	0.189*** (0.00)

P-Values in parentheses.
***p < 0.01, **p < 0.05, *p < 0.1.