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Impact of Cooking Energy Sources on Respiratory Health in Pakistan

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Abstract

Around 2.8 billion people worldwide utilize biomass energy sources, including firewood, animal dung, agriculture residue, kerosene, and coal, mainly for cooking. Ninety percent of this gigantic number lives in rural areas. Several studies have linked burning biomass fuels with respiratory diseases, the primary disease being asthma. However, most of these studies do not directly consider the endogeneity of choice of cooking energy sources by the household. To address this problem, this study applies the instrumental variable (IV) approach to estimate the correlation between cooking energy sources and respiratory health among household members by using Pakistan's Rural Household Panel Survey (RHPS). Results based on OLS estimates provide evidence for the impact of cooking energy sources on respiratory health particularly for asthma. Surprisingly, the results based on 2SSL suggest no significant relationship between using energy sources and asthma prevalence. This result can be because residences and cooking places in rural houses of Pakistan are generally open and airy compared to their urban counterparts, reducing the chances of lung disease prevalence due to cooking fuel use.

Keywords: Energy Consumption; Cooking Fuels; Respiratory Health; Instrumental Variable; Household Behaviour.

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1. INTRODUCTION

The developing world's access to efficient and clean energy sources remains inadequate (Kaygusuz, 2012). Households in developing countries rely on biomass fuels, including firewood, agriculture residue, and animal dung, for energy use (Mirza & Kemp, 2011). Although access to electricity has improved significantly in recent years, its usage is limited to lighting and running appliances such as fans and washing machines (Cozzi *et al.,* 2017; Fischer, 2008; Dubin & McFadden, 1984). For cooking, it is estimated that about 2.8 billion people across the world (about 90% of the rural population) still consume traditional biomass fuels (Cozzi *et al.,* 2017). Moreover, the transition to clean cooking fuels and technologies supports multiple SDGs (Rosenthal *et al.,* 2018). Similarly, most rural households in Pakistan also consume biomass fuels for cooking and heating purposes (Jan *et al.,* 2012; Mirza & Kemp, 2011; Moeen *et al.,* 2016; Ali et al. 2019; Imran & Ozcatalbas, 2020).

These biomass energy sources have several socioeconomic consequences, particularly for health and welfare (Pachauri *et al.,* 2013; Santana *et al.,* 2021; Qiu *et al.,* 2023). The use of biomass fuels for cooking is linked to various health hazards such as tuberculosis, cancers of the upper aerodigestive tract and the uterine cervix, low birth weight, and stillbirth due to the close exposure of household to air pollution from these sources (Smith *et al.,* 2014; Wylie *et al.,* 2014; Faizan *et al.,* 2019). It is especially pointed out that using biomass fuels impacts respiratory diseases, including asthma (Dutt *et al.,* 1996; Smith, 2006; Kim *et al.,* 2011; Qiu *et al.,* 2023). Asthma is a chronic respiratory disease, and around two hundred and thirty-five million people in the world currently have asthma. Three hundred and eighty-three thousand died due to its severity.[5]

Accordingly, many studies have been conducted to examine the impact of biomass fuels on respiratory health, including asthma. From the medical point of view, studies have found that biomass fuels have a severe effect on respiratory diseases (Robin *et al.,* 1996; Sümer *et al.,* 2004). It is argued that indoor household pollution due to biomass fuels can be a significant risk factor for asthma in children by analyzing asthma patients (Daigler *et al.,* 1991; Ehrlich *et al.,* 1996).

These studies discuss that the effect of pollution on human health arises

[5] http://www.who.int/respiratory/en/ accessed on March 1, 2024.

due to biomass fuels in the household, which are mainly harmful to respiratory health. This argument based on medical evidence is also supported by environmental studies, which claim that biomass fuels severely impact respiratory health (Smith *et al.,* 2014).

The studies discussed that biomass fuels contained pollutants (particulate matter, Sulphur dioxide, benzene, and carbon monoxide), which severely impact respiratory health (see Chafe *et al.,* 2014; Smith *et al.,* 2013). It is also argued that the incomplete combustion of energy sources is associated with respiratory diseases (Kim *et al.,* 2011). According to studies with medical and environmental arguments, biomass fuels are related to respiratory diseases, but whether they have some negative impact also depends on socioeconomic conditions such as the house's structure, having a separate kitchen, and cooking stoves.

Several studies using econometric or statistical techniques examine the impact of cooking energy sources on respiratory health; however, these studies use a simple regression method. For example, Jamali *et al.,* (2017) analysed the effects of biomass fuels for cooking in the household by using multiple logistic regression models in Pakistan. They found a significant impact of biomass fuels on respiratory health. Boadi and Kuitunen (2006) also found a considerable negative effect of cooking energy sources on respiratory health in Accra, Ghana. Dutt et al. (1996) examines respiratory illness specifically for women among the two groups using biomass fuels for cooking compared to using kerosene and liquefied petroleum gas. They found a significant occurrence of respiratory disease among the women using biomass fuels for cooking. The studies also examine the impact of cooking energy sources on asthma (see Ehrlich *et al.,* 1996; van Gemerta *et al.,* 2011). They found that house pollutants arise due to biomass fuel smoke, a significant risk factor for asthma in sub-Saharan Africa.

Many studies also discussed the insignificant impact of biomass fuels on respiratory infections, including asthma (Desalu *et al.,* 2010; Schei *et al.,* 2004; Shah *et al.,* 1994). Desalu, Adekoya, and Ampitan (2010) conducted a correlation study based on a cross-sectional analysis of two hundred and sixty-nine adult women in Nigeria. They did not find a strong correlation between cooking energy sources and respiratory diseases, which include breathlessness, nasal symptoms, and chronic bronchitis, which could lead to asthma. Using simple regression, Schei et al. (2004) also found less evidence for asthma in childhood if the household uses firewood with a fireplace. Shah et al. (1994) did not find risk factors in the use of biomass fuels based on multivariate logistics regression analysis.

This paper contributes to the literature by examining the impact of energy sources on asthma prevalence in Pakistan. Unlike previous studies, this study uses an instrumental variable (IV) approach to consider the endogeneity in the choice of energy sources by the household. This study also conduct the analysis separately for adults and children to examine the differential impact of the cooking energy source on respiratory health. Further, this study also discuss the differential impact of cooking energy sources depending on the household structure.

The analysis is based on the Rural Household Panel Survey (RHPS), conducted by the International Food Policy Research Institute (IFPRI) and Innovative Development Strategies (IDS) in 2014. OLS estimates provided significant results for the causal relationship between asthma prevalence and the use of biomass energy sources with or without district-fixed effect[6]. However, 2SLS results found no impact on asthma prevalence from the use of energy sources. This study's findings contribute to the literature by discussing the impact of the use of energy sources on respiratory diseases.

The remaining part of the paper is organized as follows. Section two explains the data of RHPS. The identification strategy and econometric model are described in section three. Section four discusses the estimated results and the conclusion provided in the final chapter.

[6] Districts are third-order administrative divisions of Pakistan, and there are one hundred and fifty-four districts in Pakistan.

2. DATA

The paper utilizes data from the Rural Household Panel Survey (RHPS), Round III, conducted by the International Food Policy Research Institute (IFPRI), and Innovative Development Strategies (IDS), which was conducted in 2014. A multistage sampling methodology was used for the data collection. The data consists of nineteen districts of three provinces: twelve from Punjab, five from Sindh, and two from Khyber Pakhtunkhwa (KP). The total number of villages was seventy-six, with four villages from each district, and twenty-eight households were randomly selected from each village. Therefore, two thousand one hundred and twenty-four households were interviewed for the survey (Nazli & Haider, 2012).

This study used round three of RHPS because detailed information on household energy use was available. Round three data comprised 1,869 households, with 1,177 in Punjab, 486 in Sindh, and 206 in KP. After cleaning the data, 1,716 households remain in the sample, with 1,156 in Punjab, 483 in Sindh, and 77 in KP province for the analysis. Appendix Table 1 provides detailed summary statistics of the data.

In RHPS, the household has reported asthma prevalence in the health module for each household member. The asthma prevalence in the household is defined as 1 if at least one of the household members has asthma. The households can choose between natural gas, firewood, animal dung, and plant residue for cooking. Natural gas is a modern energy source, whereas other sources are traditional. Household characteristics, including gender and education of the household head, number of household members in the household, size of cultivated area, ownership of livestock, tobacco smoking of the household member, and structure of the house, are also reported in the data. The village-level characteristics, such as the distance of the village to the nearest city, the type of internal road, and gas availability at the villages, were taken from a community survey of the RHPS. Most importantly, the study employed Global Positioning

System (GPS) data on the household location using DIVA-GIS[7] to construct the distance variable from the household to the nearest forest. Footnote: Figure 1 shows the location of the sample household.

Table 1 presents the household energy consumption sources for cooking. Data shows that households use several energy sources for cooking, such as gas, firewood, agriculture residue, animal dung, and other biomass. Firewood was consumed by most households (sixty-nine percent), followed by agriculture residue (fourteen percent). Natural gas is an efficient and modern energy source, but it is only consumed by 9.79 percent of households for cooking in rural Pakistan. Overall, 90 percent of households consumed traditional energy sources for cooking, with a significant contribution made by firewood.

Table 2 summarizes the prevalence of asthma in the household with each energy source. The data shows that overall, 14 percent of households suffer from asthma. While 9.5 percent of households with modern energy sources have asthma prevalence, 14.5 percent of households who consume traditional energy sources for cooking suffer from asthma.

3. IDENTIFICATION STRATEGY AND MODEL

The main challenge for estimating the causal effect of traditional energy sources on asthma prevalence in households is the endogeneity of the household's choice of cooking energy sources. This section describes the identification strategy to deal with this problem. Since the main dependent and explanatory variables are in binary form, this study used a linear probability model (LPM), which can be expressed as:

$$\mathrm{Y}_i = \beta_0 + \mathrm{X}_i\beta_1 + \acute{\gamma}K_i + \mathrm{U}_i \qquad \ldots (1)$$

The index i (i=1, 2, 3 …n) denotes household. Y_i represents an indicator variable that equals one if any member has asthma in household i. X_i, the variable of that

[7] http://www.diva-gis.org/ accessed on February 25, 2024.

equals one if the primary energy source is the traditional energy source used for cooking in households. K_i is a vector of various household-level characteristics. The estimated coefficient $\tilde{\beta}$ themselves are the marginal effects.

Households endogenously determine their energy sources for cooking from natural gas, firewood, animal dung, and plant residue. To circumvent this problem, an instrumental variable (IV) approach is appropriate. The instrumental variables include the distance from the household to the nearest bushes and forest, gas availability at the village, and household ownership of livestock. This study also includes the district-fixed effect to control for all region-specific changes.

4. RESULTS AND DISCUSSION

4.1. First-stage Estimates

The first-stage estimates are shown in Appendix Table 2. As discussed, the instruments are the distance from the household to the nearest bushes or forest, gas availability in the village, and livestock ownership by the household. The estimation model includes each instrument separately from columns one to three and all three instruments together in columns four for a specification that includes household characteristics, village characteristics, and district fixed effect. Household characteristics include smoking of household members, number of females in the household, number of rooms in the house, the structure of the house, gender and education of household head, cultivated area, and household expenditures. The village characteristics, such as distance from the village to the nearest city and the developed road, also include the robustness check. The village-level variable is used for the robustness check. Therefore, cluster standard error at the village is used for the estimates.

The first-stage estimates show a strong correlation between the instruments and the choice of energy sources for cooking. Distance from each household to the nearest bushes or forest and gas availability have a significant negative correlation with traditional energy sources for cooking. However, livestock ownership has a strong positive correlation with using traditional energy sources for cooking. These results suggest that if the distance from the household to bushes or forest increases, the household is less likely to use traditional energy sources. Similarly, if gas is available in the village, the probability of using traditional energy sources for cooking decreases. However, if a household has livestock, it is more likely to increase the use of traditional energy sources for cooking.

The results remain stable and consistent, moving similarly across the various specifications. The first-stage F-statistics for the excluded instruments remain over ten from columns one to four. Thus, the estimates are not biased by weak instruments.

4.2. Estimation Results for the Impact of Cooking Energy Sources on Asthma Prevalence in the Household

Table 3 shows the estimation results of the impact of cooking energy sources on asthma prevalence in the household. The results of OLS and 2SLS are shown in columns one to four. Column one reports the correlation estimates between using energy sources for cooking and asthma prevalence in the household with and without district fixed effect. In column one, the coefficient of the primary explanatory variable is 0.059 and is statistically significant at a one percent p-value. The result implies that households tend to use traditional energy sources, which has a probability of an increase in asthma prevalence by six percent. The results remain significant in column two after adding controlling for the district fixed effect. OLS estimates suggest there is a statistically significant impact of traditional cooking energy sources on the prevalence of asthma.

The 2SLS estimates in columns three and four of Table 3 are based on three IVs. According to the estimates, the results found a statistically insignificant correlation between cooking energy sources and asthma prevalence in the household. Comparing 2SLS estimates with OLS, the direction of 2SLS estimates remains like OLS, but the results are insignificant.

The reduced form of instruments shown in columns five and six reports estimates by including controls with similar variables as reported from columns one to four. Here, the leading independent variables are the distance from the household to the nearest bushes or forest, gas availability in the village, and household ownership of livestock, which are all insignificant, suggesting that there is no correlation between instrumental variables and asthma prevalence in the household. The results remain stable for the reduced form estimates across all the specifications.

4.3. Estimation Results on the Impact of Cooking Energy Sources and House Structure on Asthma Prevalence in the Household

The estimates in Table 4 report the effect of cooking energy sources with an interaction term of the household improved structure. This is because one may argue that the improved structure of the house may reduce the effect of indoor emissions on the respiratory health of the household members. The improved house structure implies that the outer wall, roof, and floor are made of cement, bricks, and stones. The results report adding household and village characteristics along with district fixed effect. The OLS results in columns one and two report a significant correlation with a positive sign between cooking energy sources and asthma prevalence in the household. The coefficient is around two-thirds of the standard deviation of the asthma prevalence in the household, implying that the impact of using traditional energy sources is significant to increase the probability of asthma in the household. The coefficient of the interaction term also reported a significant correlation with a negative sign, implying that if the house structure had improved, the household could have reduced the probability of asthma prevalence.

The 2SLS estimates with an interaction term show an insignificant correlation between cooking energy sources and household asthma prevalence. This suggests that cooking energy sources do not affect the severity of asthma prevalence in the household.

4.4. Estimation Results on the Impact of Cooking Energy Sources on Asthma Prevalence for Adults and Children in the Household

This study also estimates the results of the separate impact of cooking energy sources on asthma prevalence for adults and children in the household. The results estimates are shown in Table 5, which follows a similar identification strategy that reports estimates for asthma prevalence in the household. From columns one to four, the OLS estimates for the effect of cooking energy sources on asthma prevalence in adults and children report a significant impact across all the specifications with or without district-fixed effect. The coefficient of the primary explanatory variable is about one-fourth of the standard deviation of the asthma prevalence of adults and children in the household.

On the other hand, the 2SLS results show that cooking energy sources do not affect asthma prevalence in the household's adults and children. The results are consistent for all household members without distinguishing adults and children.

5. CONCLUSION

Access to efficient modern energy sources is a requirement for human development. This study examines the impact of cooking energy sources on respiratory health. To address the endogeneity of the household's choice of cooking energy sources, this study estimated IV models by using the distance from the household to the nearest bushes and forest, gas availability at the village, and livestock ownership as IV.

OLS estimates suggest there is a statistically significant impact on the positive sign of traditional cooking energy sources on the prevalence of asthma. The positive sign of the coefficient suggests that use of biomass cooking fuels have a significant positive impact in terms of asthma prevalence at the household level. OLS estimates from found consistency when adding control variables for district fixed effect, village characteristics, and household characteristics.

However, 2SLS estimates found no correlation between cooking energy sources and asthma prevalence at the household level. This insignificant relationship is consistent with previous studies, which found that cooking energy sources do not impact respiratory diseases with the main disease of asthma (Desalu *et al.,* 2010; Schei *et al.,* 2004; Shah *et al.,* 1994).

These results can cast doubt on the effectiveness of policy for providing clean energy sources to reduce health hazards caused by indoor emissions. One limitation of this study is that the RHPS data reports that only 9.5 percent of households use natural gas for cooking energy sources. Also, the provision of modern energy sources for cooking should not be discussed from the perspective of health hazards. Further study is needed to investigate the impact of cooking energy sources on respiratory health. This investigation may require a large dataset to address the limitations of the current study. The authors intended to explore this issue with a larger dataset, but the study nevertheless contributed significantly due to its robust methodology.

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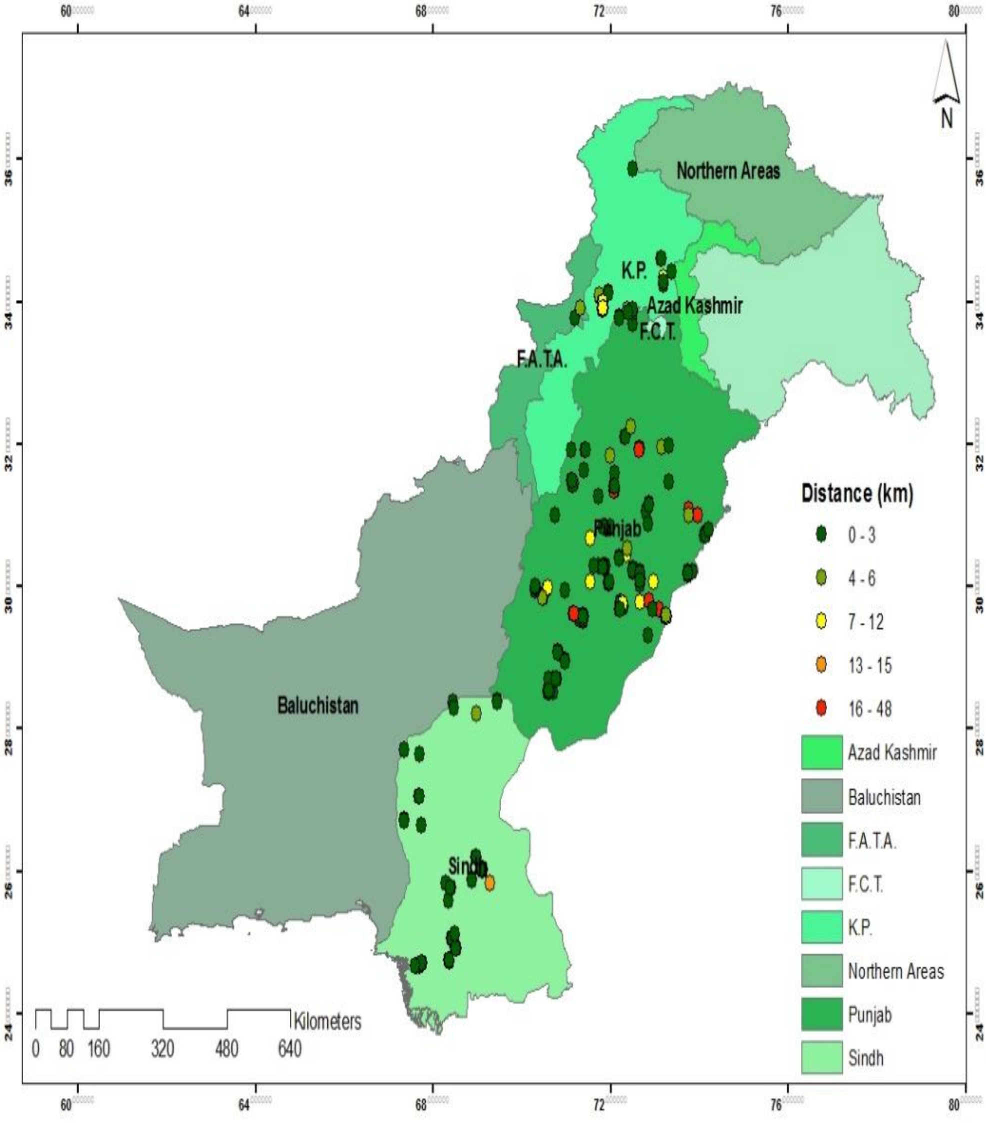
Figure 1. Distance from Household to Nearest Bushes and Forest for RHPS



Source: Pakistan Administrative and Natural Data from DIVA-GIS.

Table 1. Household Cooking Energy Sources in Rural Pakistan (RHPS)

Energy Source	Freq.	Percent
Gas	168	9.79
Firewood	1,189	69.29
Agriculture Residue	243	14.16
Animal Dung	110	6.41
Another Biomass	6	0.35
Total	1,716	100

Source: Author's Rural Household Panel Data Round – 3 Calculations, IFPRI-IDS.

Table 2. Summary of Asthma Prevalence in the Household (RHPS)

Energy Source for Cooking	Mean	Std. Dev.	Freq.	*t-value*
Gas	0.095	0.294	168	
Firewood	0.134	0.341	1,189	
Agriculture Residue	0.156	0.364	243	
Animal Dung	0.236	0.427	110	
Another Biomass	0.167	0.408	6	
Total	0.140	0.347	1,716	3.30***
Modern	0.095	0.294	168	
Traditional	0.145	0.352	1,548	
Total	0.140	0.347	1,716	1.76*

Source: Author's Rural Household Panel Data Round – 3 Calculations, IFPRI-IDS.

Table 3. The Effect of Cooking Energy Sources on Asthma Prevalence in the Household.

Variables	OLS Estimates		2SLS Estimates		Reduced Form Estimates	
	(1)	(2)	(3)	(4)	(5)	(6)
Energy sources for cooking (1=traditional, otherwise 0)	0.059* (0.030)	0.076* (0.041)	0.045 (0.115)	0.081 (0.157)		
Distance from household to nearest bushes or forest (km)					0.001 (0.002)	-0.001 (0.003)
Gas availability at the village (1=yes)					-0.001 (0.028)	-0.002 (0.022)
Household ownership of livestock (1=yes)					0.015 (0.021)	0.007 (0.019)
District fixed effect	No	Yes	No	Yes	No	Yes
Household characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Village Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,716	1,716	1,716	1,716	1,716	1,716
R^2	0.015	0.048	0.015	0.048	0.014	0.046

Note: Cluster robust standard errors at village level in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 4. The Effect of Cooking Energy Sources and House Structure on Asthma Prevalence in the Household.

Variables	OLS estimates		2SLS estimates	
	(1)	(2)	(3)	(4)
Energy sources for cooking (1=traditional, otherwise 0)	0.183** (0.0263)	0.240** (0.0435)	-0.0220 (0.771)	-0.302 (0.662)
Improved structure of house (1=yes)	0.125** (0.0268)	0.184** (0.0452)	-0.0826 (0.749)	-0.310 (0.631)
Energy sources for cooking (1=traditional, otherwise 0) × Improved structure of House (1=yes)	-0.131** (0.0343)	-0.177** (0.0490)	0.0737 (0.760)	0.344 (0.636)
District fixed effect	No	Yes	No	Yes
Household characteristics	Yes	Yes	Yes	Yes
Village Characteristics	Yes	Yes	Yes	Yes
Observations	1,716	1,716	1,716	1,716
R^2	0.016	0.049	0.015	0.039

Note: Cluster robust standard errors at village level in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 5. The Effect of Cooking Energy Sources on Asthma Prevalence in the Adults and Children of the Household.

Variables	OLS estimates				2SLS estimates			
	Adult		Children		Adult		Children	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Energy sources for cooking (1=traditional, otherwise 0)	0.052** (0.027)	0.070** (0.040)	0.043** (0.019)	0.063** (0.029)	0.032 (0.101)	0.079 (0.121)	0.018* (0.083)	-0.022 (0.116)
District fixed effect	No	Yes	No	Yes	No	Yes	No	Yes
Household Characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Village Characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,716	1,716	1,716	1,716	1,716	1,716	1,716	1,716
R^2	0.014	0.041	0.017	0.047	0.013	0.041	0.016	0.043

Note: Cluster robust standard errors at village level in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Appendix-1. Summary Statistics

Variables	Obs.	Mean	SD
Asthma prevalence of members in household (1=yes)	1,716	0.140	0.347
Asthma prevalence of adults in household (1=yes)	1,716	0.129	0.335
Asthma prevalence of children in household (1=yes)	1,716	0.080	0.272
Energy sources for cooking (1=traditional, otherwise 0)	1,716	0.902	0.297
Energy sources for cooking (1=traditional, otherwise 0) × Improved structure of House (1=yes)	1,716	0.535	0.498
Improved structure of house (1=yes)	1,716	0.868	0.338
Distance from household to nearest bushes or forest (km)	1,716	4.136	4.203
Gas availability at village (1=yes)	1,716	0.573	0.495
Household ownership of livestock (1=yes)	1,716	0.797	0.403
Gender of household Head (1=Male)	1,716	0.980	0.139
Household head Educated (1= any level of schooling)	1,716	0.478	0.500
Number of total Member of household	1,716	7.197	3.271
Number of males in the household	1,716	1.958	1.227
Number of females in a household	1,716	1.990	1.253
Number of children in a household	1,716	3.208	2.248
Tobacco smoking (1=any member of household)	1,716	0.371	0.483
Cultivated area (acre)	1,716	1.798	4.963
The annual total expenditure of household (PKR 000)	1,716	250	176
Number of rooms in House	1,716	2.291	1.399
Distance from the village to the nearest city (km)	1,716	12.373	8.212
Type of internal roads (developed=1)	1,716	0.346	0.475

Source: Author's Rural Household Panel Data Round – 3 calculations, IFPRI-IDS.
Note: The asthma prevalence in the household is equal to one if any household member has asthma. A similar approach applies to the asthma prevalence for adult members and children in the household.
The improved structure of the household is equal to one if the outer wall, roof, and floor of the house are made of cement, stones, and bricks; otherwise, it is zero, which implies that the house structure is made of mud.

Appendix 2. First Stage Estimates

Dependent Variable: Energy sources for cooking (1=traditional, otherwise 0)				
Variables	(1)	(2)	(3)	(4)
Distance from household to nearest bushes or forest (km)	-0.012** (0.006)	-0.069* (0.037)	-0.093** (0.027)	-0.011** (0.005)
Gas availability at the village (1=yes)				-0.053** (0.030)
Household ownership of livestock (1=yes)				-0.084** (0.026)
District fixed effect	Yes	Yes	Yes	Yes
Household Characteristics	Yes	Yes	Yes	Yes
Village Characteristics	Yes	Yes	Yes	Yes
Weak identification test (F-Statistics)	76	25	51	46
Overidentification test (p-value)				0.557
Observations	1,716	1,716	1,716	1,716
R^2	0.540	0.530	0.533	0.556

Cluster robust standard errors at village level in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Note: The results report first-stage estimates to explain the correlation between a set of instruments and an endogenous variable. IVs are the distance from the household to the nearest forest, gas availability at the village, and household involved in livestock. First-stage estimates from columns 1-4 report the correlation between each instrument and cooking energy sources, which is found to be strongly correlated with an endogenous variable. Column four reports the relationship between all three instruments and cooking energy sources. After adding control for district fixed effect and village and household characteristics, the results remain significant. F-statistics for weak identification test reports that instruments are unlikely to bias with weakness. The p-value of the overidentification test is larger than 0.05, and the null hypothesis is that the overidentification restrictions are valid.