Discussion Papers In Economics And Business

Information Frictions and the Transition to Clean Cooking Fuels in West Africa: Evidence from Instrumental Variables

Sanoh Yusuf

Discussion Paper 26-09

August 2026

Graduate School of Economics
The University of Osaka, Toyonaka, Osaka 560-0043, JAPAN

Information Frictions and the Transition to Clean Cooking Fuels in West Africa: Evidence from Instrumental Variables

Sanoh Yusuf†

Abstract

This paper examines the causal effect of informational access on household cooking fuel choices across seven West African countries using nationally representative Living Standards Measurement Study (LSMS) data covering 51,848 households in Burkina Faso, Côte d'Ivoire, Guinea-Bissau, Mali, Niger, Senegal, and Togo. Informational access is proxied by household television ownership, while endogeneity is addressed using a leave-one-out cluster-level television ownership instrument within IV-2SLS, IV-Probit, and nonlinear control-function frameworks. Results show that television exposure significantly increases the probability of LPG adoption by 16.3 percentage points and charcoal use by 17.7 percentage points, while reducing firewood dependence by 13.0 percentage points. IV estimates are substantially larger than corresponding OLS estimates, suggesting that conventional models underestimate the role of informational frictions in household energy transitions. Strong heterogeneity emerges across spatial and socioeconomic groups. Urban households exhibit much larger clean-fuel responses, while rural households remain constrained by weak infrastructure, limited LPG availability, and affordability barriers. Among low-income households, informational exposure increases charcoal use more strongly than LPG adoption, indicating movement toward intermediate fuels rather than full transition to clean energy. The findings suggest that informational access is an important but insufficient driver of clean cooking transitions in West Africa and highlight the need to combine behavioural communication strategies with infrastructure expansion and affordability-focused clean cooking policies.

JEL Classification: O13, Q41, D83, C26, O55.

Keywords: cooking fuel, television ownership, information access, instrumental variables, West Africa.

†Ph.D. Candidate, Graduate, School of Economics, The University of Osaka. u073302d@ecs.osaka-u.ac.jp

1. Introduction

Access to clean cooking fuels remains one of the most pressing development and public health challenges in sub-Saharan Africa, where approximately 970 million people continue to rely on traditional biomass fuels such as firewood and charcoal despite global progress in energy access (IEA, 2022). Dependence on biomass contributes to severe indoor air pollution, environmental degradation, and major time burdens associated with fuel collection, with women and children facing the greatest exposure to smoke-related health risks (Bruce et al., 2000; Smith et al., 2014; WHO, 2023). Women are particularly affected because of their central role in household cooking, creating broader implications for child health, gender inequality, and labor allocation (Cecelski, 2005; Rehfuess et al., 2006; Clancy et al., 2012). At the same time, extensive use of firewood and charcoal accelerates deforestation, weakens forest ecosystems, and contributes to carbon emissions, undermining both local livelihoods and climate objectives (Cooke et al., 2008; UNDP, 2019).

Existing explanations for low adoption of clean fuels emphasize affordability constraints, weak infrastructure, and limited market access, with studies consistently identifying income, education, electricity access, and urbanization as key determinants of cleaner fuel use (Hosier & Dowd, 1987; Farsi et al., 2007; Heltberg, 2004; Lewis & Pattanayak, 2012; Van der Kroon et al., 2013). The traditional energy ladder hypothesis argues that households progressively shift toward cleaner fuels as incomes rise, but growing evidence instead supports a fuel stacking framework in which households continue using biomass alongside modern fuels even after income gains (Masera et al., 2000; Heltberg, 2004). Although LPG adoption is widely recognized as a critical pathway out of energy poverty, major barriers remain, including high upfront stove and cylinder costs, weak distribution systems, and limited retail infrastructure, especially in sub-Saharan Africa (Kojima, 2011; Pachauri & Jiang, 2008; Khandker et al., 2012; Ravindra et al., 2019). Emerging research further suggests that informational barriers and behavioral frictions may independently slow energy transitions by limiting awareness of the health and efficiency benefits of modern fuels.

This paper examines whether informational access, proxied by television ownership, causally influences household cooking fuel choices across seven West African countries: Burkina Faso, Côte d'Ivoire, Guinea-Bissau, Mali, Niger, Senegal, and Togo. Using nationally representative LSMS data, the study investigates whether television ownership increases LPG adoption while reducing reliance on charcoal and firewood. Because television ownership is endogenous to wealth, education, infrastructure access, and urban residence, the analysis employs an instrumental variable strategy using leave-one-out cluster-level television ownership as an instrument for household television ownership. The empirical framework combines IV-2SLS and IV-Probit estimations with cluster-robust standard errors, alongside nonlinear control-function robustness checks. Results show that television ownership significantly increases LPG adoption and reduces firewood dependence, with IV estimates substantially larger than OLS estimates, implying that conventional models underestimate the role of information in household energy transitions. The findings also reveal strong urban-rural heterogeneity, with urban households responding more strongly due to fewer structural constraints. The study contributes to the literature by providing one of the first multi-country causal analyses of informational access and fuel transition in West Africa, introducing a robust methodological framework for addressing endogeneity in fuel-choice models, and highlighting the importance of integrating media access and behavioral interventions into clean cooking policy alongside infrastructure investment and fuel subsidies.

2. Literature Review

Research on household cooking fuel choice in developing countries has traditionally been guided by the energy ladder hypothesis, which argues that households progressively transition from biomass to cleaner modern fuels as incomes rise (Hosier & Dowd, 1987). However, later studies demonstrate that this transition is neither linear nor automatic. Heltberg (2004) shows that electrification, market access, and income jointly shape energy transitions, while Van der Kroon et al. (2013) find that urbanization and education consistently promote cleaner fuel use but that households often maintain multiple fuels simultaneously. This evidence gave rise to the fuel stacking framework, formally articulated by Masera et al. (2000), which argues that households accumulate rather than replace fuels because cooking practices, food preferences, risk management, and fuel availability all influence energy decisions. Similar patterns are observed in sub-Saharan Africa, where even households with access to electricity and LPG continue using charcoal and firewood as part of mixed-fuel strategies (Meng et al., 2021). Studies from Ghana further confirm that wealth, infrastructure access, and proximity to markets are among the strongest predictors of LPG adoption (Adjei-Mantey et al., 2021; Meng et al., 2021).

A large body of literature identifies affordability and infrastructure constraints as major barriers to clean fuel adoption. Farsi et al. (2007) show that income, education, and household composition significantly influence LPG adoption in urban India, while Pachauri and Jiang (2008) argue that household energy transitions are slower and more uneven than predicted by the energy ladder model because structural and behavioral constraints mediate the relationship between income and fuel choice. Kojima (2011) highlights the importance of LPG distribution systems, cylinder deposit costs, and refill accessibility, particularly in rural and peri-urban areas, while Khandker et al. (2012) demonstrate that energy poverty and income poverty are closely related but distinct. Evidence on subsidy programs is similarly mixed. Laan et al. (2010) show that fuel subsidies often disproportionately benefit wealthier urban households, while Troncoso and Soares da Silva (2017) find that LPG subsidies increase adoption mainly among middle-income groups. In West Africa, Bensch and Peters (2015) demonstrate that even when improved cookstoves are adopted, sustained use remains limited, underscoring the gap between technology availability and actual behavioral change.

Behavioral and socio-cultural factors further complicate household fuel transitions. Adjei-Mantey (2021) finds that risk-averse households in Ghana are significantly less likely to adopt LPG due to concerns about safety and supply reliability, while Mobarak et al. (2012) and Miller and Mobarak (2013) show that low demand for improved cookstoves is often driven by weak social marketing, intra-household preference differences, and women's limited decision-making power despite their disproportionate exposure to smoke-related health risks. Electrification also shapes broader energy transitions by increasing household integration into modern energy systems and reducing the time burden associated with biomass collection, particularly for women (Kooijman-van Dijk & Clancy, 2010; Cecelski, 2005; Clancy et al., 2012). Together, these studies demonstrate that cooking fuel decisions are influenced not only by income and infrastructure but also by trust, gender dynamics, cultural practices, and perceived reliability.

Recent literature increasingly emphasizes the role of information and behavioral frictions in slowing clean fuel adoption. Dendup and Arimura (2019), using a bivariate probit model instrumenting for television access in Bhutan, find that exposure to television significantly increases adoption of clean fuels while reducing firewood use, especially among less educated households. Related studies show that information can meaningfully alter household environmental and energy behavior: Jalan and Somanathan (2008) demonstrate that households informed about water contamination increase purification practices, while Jessoe and Rapson (2014) find that real-time energy feedback reduces household electricity consumption. Lewis and Pattanayak (2012) identify persistent informational and financing barriers in clean cookstove programs, and Sharma (2012), Malla and Timilsina (2014), and Ravindra et al. (2019) all conclude that awareness, socio-cultural norms, and information exposure significantly influence clean fuel adoption independently of income. Despite these advances, important gaps remain. Most existing studies are single-country analyses, few address the endogeneity of media exposure, and limited attention has been paid to urban-rural heterogeneity within a multi-country African framework. This study addresses these gaps by using nationally representative LSMS data from seven West African countries and an instrumental variable strategy based on leave-one-out cluster-level television ownership to identify the causal effect of informational access on household cooking fuel transitions.

3. Methodology

Theoretical Framework and Model Specification: Fuel Choice under Imperfect Information and Socioeconomic Constraints.

I model household energy adoption decisions as discrete choices over available fuel types, where the decision to adopt a clean cooking fuel reflects the outcome of a latent utility comparison between modern and traditional energy sources. Let household h derive indirect utility from choosing either a clean fuel (e.g., gas or electricity) or a polluting fuel (e.g., firewood). While actual utility is not observed, I assume that the household will choose clean fuel if and only if the perceived net benefit exceeds that of the alternative. Formally, let:

$$\mathrm{y_h} = \begin{cases} 1, \text{if} \mathrm{U_h(c) - U_h(t)} > 0 \\ 0 \text{ otherwise} \end{cases} \qquad (1)$$

Where $U_h(c)$ is the latent utility from adopting a modern (clean) fuel, and $U_h\ (t\ )$ is the utility from continuing with a traditional fuel. The difference in utilities, denoted $y_h^*$is not directly observed but is modeled as:

$$y_h^* = \theta_0 + \theta_1 \cdot I_h + X_h'\theta_2 + \varepsilon_h \qquad (2)$$

Where, I_h is a binary indicator equal to 1 if the household is exposed to information relevant for fuel switching—proxied in this study by predicted access to television—and X_h' is a vector of household-level covariates including education, household size, log per capita expenditure, electrification status, employment, gender, and urban residence. The error term $\varepsilon_h$captures unobservable determinants of the clean fuel adoption decision. A household adopts clean fuel if and only if $y_h^* \ > \ 0$. However, television ownership and thus information access is unlikely to be randomly distributed across households. Households with greater awareness, wealth, or progressive preferences may be more likely to both own a television and adopt clean fuel, introducing potential endogeneity. To address this concern, I specify a second latent equation governing television exposure:

$$I_h^* = \psi_0 + Z_h'\psi_1 + \nu_h \qquad (3)$$

where, $I_h = 1, if\ I_h^* > 0\ and$ 0 otherwise. The vector Z_h' includes instruments that affect information exposure but are excluded from the clean fuel decision equation. The primary instrument used in this study is the leave-one-out (LOO) cluster-level TV ownership rate, which reflects local diffusion of media while avoiding reflection bias from the household's own decision. For each household i within cluster c, I computed the mean TV ownership status of all other households in the same cluster, omitting household i from the calculation. This construction follows the logic of the peer effects literature, where valid instruments are derived from group-level averages that exclude the individual's own value to prevent mechanical correlation with the dependent variable (Angrist & Pischke (2009). The LOO IV was computed as below:

$$Z_{ic} = \left(\frac{1}{n_c-1}\right) \sum_{j \neq i} Tj_{jc} \qquad (4)$$

Where the Z_{ic} Leave-One-Out instrument for household i in cluster c, representing average exposure of peers to information through TV, n_c number of households in cluster c, Tjc, value of the treatment variable (e.g., TV ownership) for household j in cluster c. $j \neq i$ The summation excludes the target household i to avoid endogeneity. The two latent equations are jointly estimated via a bivariate probit model, allowing the error terms $(\varepsilon_h, \nu_h) \sim$ N(0,0,1,1,ρ) to be correlated. A statistically significant correlation $\rho \neq 0$ indicates the presence of endogeneity in , I_h validating the instrumental variable approach. To explore whether the effect of information varies across household types, I introduced interaction terms between, I_h and selected household characteristics. The extended latent utility equation is:

$$y_h^* = \theta_0 + \theta_1 \cdot I_h + X_h'\theta_2 + (I_h \cdot W_h')\theta_3 + \varepsilon_h \qquad (5)$$

Where $W_h \subset X_h$ includes moderators such as literacy, wealth, or location that are expected to condition how households respond to informational exposure. This specification captures heterogeneity in media influence, allowing for different marginal effects of I_h depending on a household's socioeconomic status.

$$\text{Average Partial Effect (APE)} = E[\Phi(\theta_0 + \theta_1 + X_h'\theta_2 + W_h'\theta_3) - \Phi(\theta_0 + X_h'\theta_2)] \quad (6)$$

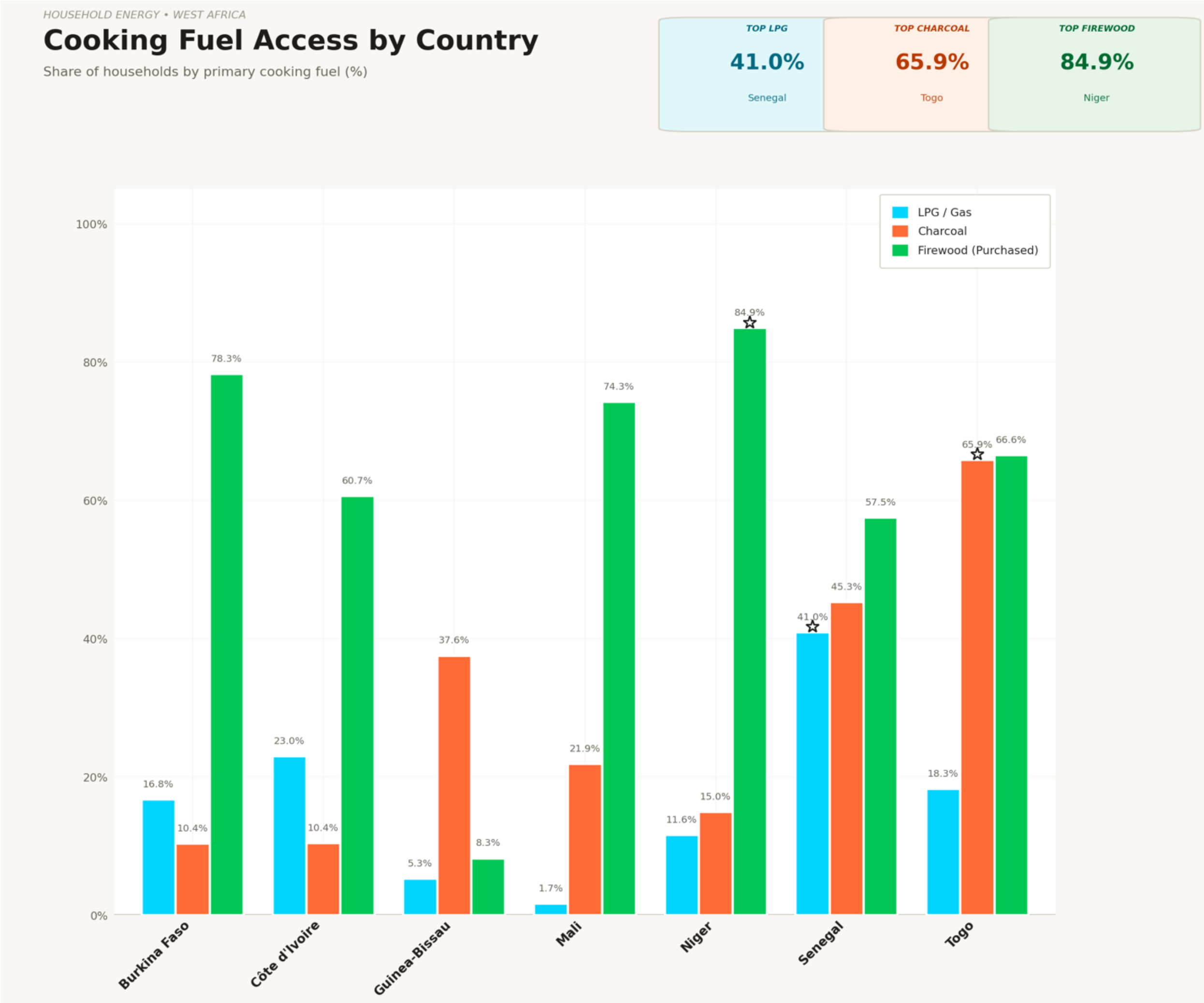
where Φ denotes the standard normal cumulative distribution function (CDF), which provides an estimate of how information exposure shifts the probability of clean fuel adoption, averaging over the population distribution of covariates. A valid instrument must satisfy both relevance and the exclusion restriction: the leave-one-out cluster TV ownership rate must affect household cooking fuel choices only through its effect on household television ownership, and not through any independent channel. The relevance condition is strongly satisfied by the partial F-statistic of 2,006 reported in Table 3.2. The exclusion restriction, while untestable in a strict sense, is supported on several grounds. The most plausible threat is that high-TV-penetration clusters may also enjoy better energy infrastructure or market access that independently facilitates clean fuel adoption. This concern is addressed directly by the inclusion of household electricity connection status, travel time to the nearest permanent market, presence of a permanent market in the community, and travel time to the nearest paved road as controls, which absorb the infrastructure and market access pathways most likely to confound the instrument-to-outcome relationship. Household-level log per capita expenditure and the principal component asset index further absorb the possibility that cluster TV penetration simply proxies for local aggregate wealth. Conditional on these controls, the residual variation in cluster-level TV penetration most plausibly reflects local social diffusion of media technology — peer effects, neighborhood norms, and community-level availability of television sets — rather than underlying differences in infrastructure quality or economic development, lending credibility to the exclusion restriction.

3.1. Data

The pooled dataset used in this study is drawn from the 2021 World Bank Living Standards Measurement Study (LSMS) surveys for seven West African countries: Burkina Faso, Côte d'Ivoire, Guinea-Bissau, Mali, Niger, Senegal, and Togo. After harmonization and cleaning, the final sample consists of 51,848 household-level observations. The dataset contains detailed information on household cooking fuel use, television ownership, electricity access, socioeconomic characteristics, financial inclusion, and infrastructure accessibility. Table 1 shows substantial heterogeneity in both informational access and cooking fuel use across the region. Approximately 36.2% of households own a television, although ownership rates differ sharply across countries, ranging from 17.3% in Niger to 56.2% in Senegal. Similarly, electricity access averages 72.8% across the pooled sample, while urban households account for 42.8% of observations. Household heads are predominantly male (80.0%), only 16.7% have completed at least secondary education, and the average household size is 6.25 members.

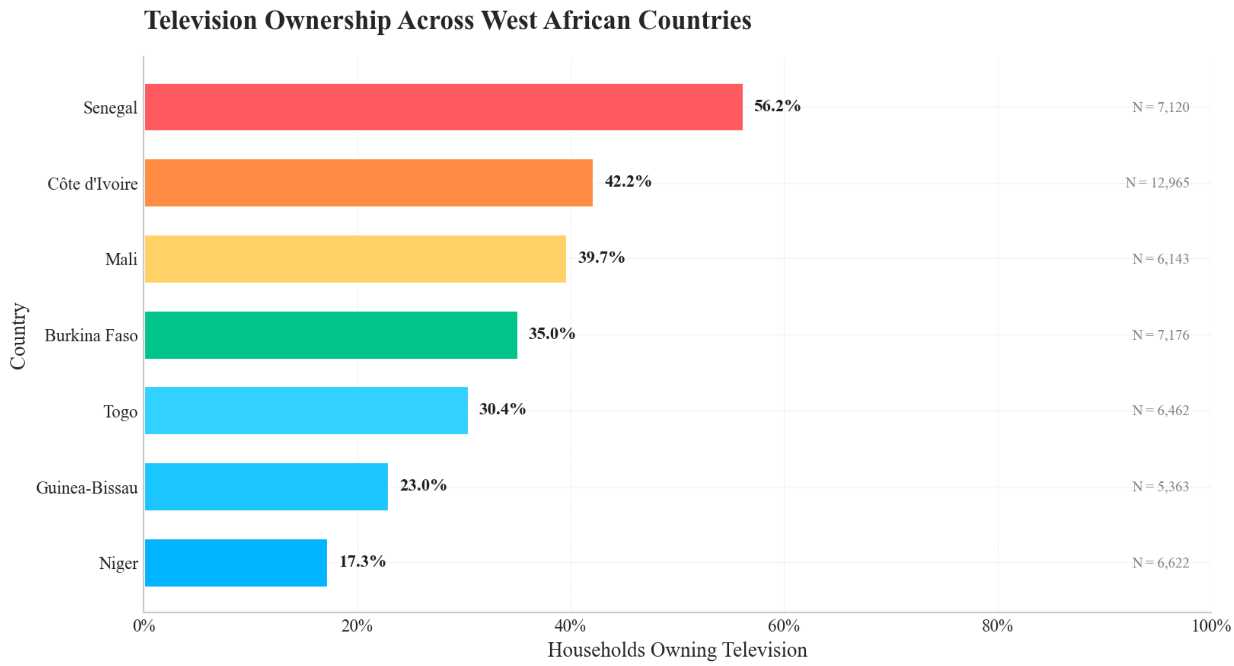
Cooking fuel patterns continue to reflect heavy reliance on traditional biomass fuels despite ongoing clean energy transition efforts. Across the pooled sample, 62.7% of households use firewood for cooking, 24.8% use charcoal, and only 17.6% use LPG or gas. However, strong cross-country disparities emerge in fuel adoption. Senegal records the highest LPG usage rate at approximately 41.0%, while LPG adoption remains extremely limited in Mali (1.7%) and Guinea-Bissau (5.3%). Firewood dependence is particularly severe in Niger, where nearly 85% of households rely on firewood, whereas charcoal use is most prevalent in Togo at roughly 66%. The descriptive evidence also highlights important infrastructural constraints, with households requiring an average of 56 minutes to reach the nearest permanent market and nearly 49 minutes to access a paved road. Overall, the data reveal that household cooking fuel choices in West Africa are shaped by substantial disparities in informational access, infrastructure, and socioeconomic conditions across countries and households.

Figure 1: Different Cooking Fuel Access by Country



Sources: Author`s estimation from 2021 LSMS data

Figure 2: TV Ownership



Source: Author's calculations using LSMS household survey data.

Table 1: Summary Statistics

Variable	Definition	Mean	Std. Dev.	Min	Max	Obs.
A. Outcome Variables						
LPG/Gas Use	=1 if household uses LPG/gas for cooking	0.176	0.381	0.000	1.000	51,848
Charcoal Use	=1 if household uses charcoal as cooking fuel	0.248	0.432	0.000	1.000	51,848
Firewood Use	=1 if household uses firewood as cooking fuel	0.627	0.484	0.000	1.000	51,848
B. Treatment and Instrument						
Television Ownership	=1 if household owns a television	0.362	0.480	0.000	1.000	51,848
Leave-One-Out TV Instrument	Cluster-level mean TV ownership, excluding own observation	0.362	0.334	0.000	1.000	51,848
C. Household Head Characteristics						
Secondary Education or Higher	=1 if head completed at least secondary education	0.167	0.373	0.000	1.000	51,848
Literate	=1 if household head can read and write	0.500	0.500	0.000	1.000	51,848
Male Head	=1 if household head is male	0.800	0.400	0.000	1.000	51,848
Employed	=1 if household head has any form of employment	0.875	0.331	0.000	1.000	51,848
Age	Age of the household head in years	48.139	14.432	14.000	114.000	51,848
D. Household-Level Variables						

Household Size	Total number of household members	6.248	3.994	1.000	60.000	51,848
Log Per Capita Expenditure	Log of annual per capita consumption expenditure	12.928	0.632	10.451	16.117	51,848
Urban Residence	=1 if household is located in an urban area	0.428	0.495	0.000	1.000	51,848
Electricity Access	=1 if household has access to electricity	0.728	0.445	0.000	1.000	51,848
Household Owns Dwelling	=1 if household lives in its own dwelling	0.256	0.436	0.000	1.000	51,848
Asset Index (PCA)	Principal component index of household assets	−0.001	0.970	−1.233	13.834	51,848
Dependency Ratio	Ratio of dependents to working-age members	0.732	0.851	0.000	20.000	51,848
E. Infrastructure and Market Access						
Time to Permanent Market	Travel time to nearest permanent market (minutes)	56.069	480.402	0.000	9,999	51,848
Time to Bank or MFI	Travel time to nearest bank or microfinance institution (mins)	45.168	80.344	0.000	1,240	51,848
Time to Paved Road	Travel time to closest paved road (minutes)	48.679	433.581	0.000	9,999	51,848
Permanent Market in Community	=1 if a permanent market exists within the community	0.382	0.486	0.000	1.000	51,848

Notes: Summary statistics are computed over the full pooled sample of 51,848 households from seven West African countries (Burkina Faso, Côte d'Ivoire, Guinea-Bissau, Mali, Niger, Senegal, and Togo), drawn from the 2021 Living Standards Measurement Study (LSMS). All binary variables take values of 0 or 1. The Leave-One-Out TV Ownership Instrument is the cluster-level mean of television ownership excluding the household's own observation, used as the instrument for TV ownership in the IV estimations.

4. First Stage IV Results, Instrument Relevance: Predicting TV Ownership Using Leave-One-Out (LOO) Cluster TV Access

The first-stage analysis assesses the relevance of the instrument by examining whether the leave-one-out cluster-level TV ownership rate significantly predicts household-level TV ownership. The leave-one-out instrument (tv_loo) was constructed from the cluster-level television ownership rate excluding the household's own observation in order to preserve exogeneity and minimize mechanical correlation. Clusters correspond to localized enumeration areas comprising 5,666 clusters and 51,848 households in total, thereby ensuring substantial within-cluster variation in television exposure and peer-driven information diffusion. The first-stage OLS results reported in Table 2 confirm the strong relevance of the instrument. The coefficient on the leave-one-out TV ownership measure is positive and highly statistically significant (coefficient = 0.446, $p < 0.01$), indicating that households residing in clusters with higher television penetration are substantially more likely to own a television themselves. The associated partial F-statistic of 2006.0 far exceeds conventional weak-instrument thresholds, including the Stock–Yogo benchmark value of 10, strongly rejecting concerns regarding weak instrument bias. The first-stage model also exhibits substantial explanatory power, accounting for approximately 49.3 percent of the variation in household television ownership ($R^2 = 0.493$). Several covariates display statistically significant associations with TV ownership, particularly asset ownership, household income, literacy, educational attainment, electricity access, and market connectivity, consistent with the broader literature linking media access to household socioeconomic status and infrastructure availability in developing-country settings.

Table 2: First Stage IV results

Variables	Linear First Stage (OLS)	Bivariate Probit Treatment
Constant	-0.484*** (0.052)	-2.077*** (0.289)
Household connected to electricity	0.026*** (0.004)	-0.052** (0.021)
Household head secondary education	0.024*** (0.005)	-0.010 (0.026)
Household head literate	0.021*** (0.004)	0.011 (0.018)
Male household head	0.026*** (0.004)	0.160*** (0.022)
Household head employed	0.000 (0.005)	-0.002 (0.027)
Household size	0.009*** (0.001)	0.026*** (0.002)
Household head age	-0.001*** (0.000)	-0.002*** (0.001)
Log per capita expenditure	0.043*** (0.004)	0.073*** (0.022)
Urban residence	0.015*** (0.006)	-0.116*** (0.025)
Time to permanent market	0.000** (0.000)	0.000** (0.000)
Time to bank/microfinance	-0.000*** (0.000)	-0.001*** (0.000)
Asset index (PCA)	0.204*** (0.006)	1.694*** (0.047)
Dependency ratio	0.025*** (0.002)	0.135*** (0.010)
Household lives in own house	0.016*** (0.004)	0.150*** (0.024)
Time to paved road	0.000** (0.000)	0.000*** (0.000)
Permanent market exists	0.053*** (0.003)	0.251*** (0.018)
Instrument: TV leave-one-out mean	**0.446*** (0.010)	**1.475*** (0.045)**
Observations	51,848	51,848
Clusters	5,666	5,666
R-squared / Pseudo R-squared	0.493	0.527
Instrument t/z-statistic	44.790	32.740
Partial F-statistic	2006.000	—
Wald test of ρ = 0	—	p = 0.000
Estimated ρ	—	0.158*** (0.024)
Covariance estimator	Cluster-robust	Cluster-robust

Significance levels**:** *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

5. Second Stage Results: Effect of Information Access on Household Fuel Adoption

Before interpreting the IV estimates, two clarifications should be made. First, under the standard assumptions of relevance, exclusion, and monotonicity, the IV-Probit and IV-2SLS estimates recover a local average treatment effect (LATE) for households whose television ownership responds to variation in local television penetration (Imbens & Angrist, 1994). The estimated effects are therefore most relevant for policies that expand community-level media access, such as rural electrification, broadcasting diffusion, or shared community viewing infrastructure, rather than for universal television subsidies.

Second, the policy relevance of the estimates depends on the likely characteristics of these responsive households. Drawing on the first-stage results in Table 2, television ownership is positively associated with asset wealth, literacy, market access, and household expenditure, while the leave-one-out instrument retains substantial predictive power conditional on these characteristics. This pattern suggests that the IV estimates are most likely capturing households on the margin of television adoption rather than households facing either minimal or severe structural constraints to ownership. In practical terms, the estimated effects are therefore particularly relevant for households whose media access may be influenced by local diffusion and community-level exposure effects. At the same time, the exclusion restriction should be understood as a maintained identifying assumption, and the estimates may still reflect residual cluster-level socioeconomic factors correlated with both television diffusion and household energy behavior.

Table 3 reports the OLS, IV-2SLS, and IV-Probit average marginal effect estimates examining the impact of access to information — proxied by instrumented television ownership — on household cooking fuel choice across the full sample as well as the urban and rural subsamples. The three dependent variables represent the adoption of LPG/gas, charcoal, and firewood, capturing clean, transitional, and traditional fuel types, respectively. Across all three specifications, the estimated effects of instrumented TV access are directionally consistent with the hypothesis that information exposure influences household energy decisions. The IV-Probit average marginal effects indicate that instrumented TV access increases the probability of LPG adoption by 16.3 percentage points and the likelihood of charcoal use by 17.7 percentage points, while reducing firewood dependence by 13.0 percentage points, with all three effects statistically significant at the 1 percent level. These findings are consistent with the theoretical framework of this study, which posits that informational frictions constrain household fuel transitions: when such frictions are alleviated through media exposure, households may update their beliefs about the health, economic, and safety attributes of modern fuels and reallocate toward cleaner alternatives. The corresponding OLS linear probability estimates for the same outcomes — 5.5, 8.8, and −3.9 percentage points for LPG, charcoal, and firewood, respectively — are substantially smaller in magnitude than the IV-Probit average marginal effects, a pattern consistent with attenuation arising from omitted variables, measurement error, or selection into TV ownership. The IV-2SLS results, reported as a robustness check under a linear probability specification, similarly indicate positive and statistically significant effects on LPG (0.292) and charcoal (0.395) adoption alongside a negative though statistically insignificant coefficient on firewood (−0.010), the latter likely reflecting the limitations of the linear probability model in capturing nonlinear binary outcome relationships. The broad convergence in directional findings across the three estimators, together with the statistically significant Wu-Hausman tests and the control-function residual diagnostics reported in Table 3, strengthens confidence in the interpretation that information access constitutes an important constraint on household energy transitions in this setting, and that its relaxation through television exposure is associated with meaningful behavioral shifts toward cleaner and transitional fuels across the region.

The urban–rural disaggregation reported in Table 3 further reveals substantial spatial heterogeneity in household responsiveness to television-mediated information, underscoring the important role of complementary market infrastructure in translating informational exposure into behavioral change. Among urban households, instrumented TV access increases the probability of LPG adoption by 24.8 percentage points and reduces firewood reliance by 26.3 percentage points, both statistically significant at the 1 percent level. The effect on charcoal use, at 16.5 percentage points, is also statistically significant at the 1 percent level, yet the magnitude of the firewood reduction suggests that LPG adoption rather than a transition to intermediate fuels constitutes the dominant behavioral response among urban households exposed to television-based information. These results are broadly consistent with the energy ladder hypothesis and align with the expectation that urban markets — characterized by better LPG distribution networks, functioning retail infrastructure, and higher household liquidity — are more capable of enabling informed households to act on updated fuel preferences. In rural areas, by contrast, instrumented TV access increases LPG adoption by a more modest 8.3 percentage points and increases charcoal use by 12.3 percentage points, with both effects statistically significant at the 1 percent level. However, the IV-Probit coefficient on firewood use is positive and statistically insignificant (0.010), a finding further supported by the failure to reject the null of exogeneity for the rural firewood equation (CF residual $p = 0.164$). This result suggests that the causal effect of television exposure on rural firewood dependence is weak or statistically indistinguishable from zero, potentially reflecting supply-side constraints such as sparse LPG distribution channels, limited retail access, and binding liquidity barriers that prevent rural households from acting on newly acquired information. The urban–rural contrast therefore indicates that information and infrastructure may function as complementary inputs in the energy transition process: media campaigns may be necessary but not sufficient conditions for clean fuel adoption in areas where market access remains structurally deficient, pointing to the importance of spatially differentiated policy interventions to narrow the gap between informational exposure and actual behavioral change.

Table 4 presents the income-disaggregated IV-Probit estimates, while Table 5 reports the corresponding education-disaggregated results, together revealing meaningful heterogeneity in the effectiveness of television-based information exposure across socioeconomic strata, with all reported IV-Probit effects statistically significant at the 1 percent level unless otherwise indicated. Among high-income households — defined as those above the median log per capita expenditure of 12.88 — instrumented TV access increases the probability of LPG adoption by 26.3 percentage points and reduces firewood use by 22.9 percentage points, while the corresponding low-income estimates are 8.9 and 8.3 percentage points, respectively. Although formal statistical tests of coefficient differences are not reported, the point estimates suggest that higher-income households may be better positioned to translate information into actual adoption decisions because they face fewer financial barriers to acquiring cleaner fuels. Notably, among low-income households, television exposure is associated with a relatively large increase in charcoal use (14.9 percentage points), suggesting that when LPG adoption remains financially constrained, information access may still facilitate movement away from the most polluting traditional fuels toward less harmful transitional alternatives — an outcome that carries meaningful health co-benefits even in the absence of full clean energy adoption. Turning to educational heterogeneity in Table 5, the IV-Probit average marginal effects indicate that instrumented TV access increases LPG adoption by 20.2 percentage points among households with secondary education or above, compared to 15.3 percentage points among households with below-secondary education. Similarly, the negative effect on firewood use is larger in absolute magnitude among the secondary-educated group (−16.4 versus −12.3 percentage points). These patterns are consistent with the hypothesis that formal schooling may enhance household receptivity to health and environmental messaging disseminated through television. The first-stage instruments are strong across all subgroups, with F-statistics of 570.62 and 1,772.90 for the secondary-educated and below-secondary subsamples reported in Table 5, and 1,590.63 and 703.45 for the high- and low-income subsamples reported in Table 4. In addition, the Wu-Hausman tests uniformly reject the null of exogeneity ($p = 0.000$) across all subgroup specifications, indicating that OLS estimates are likely affected by endogeneity bias throughout. Taken together, these findings suggest that while information access through television is associated with increased clean fuel adoption across the household distribution, the magnitude of the estimated effects tends to be larger among households with higher income and educational attainment, pointing to the importance of complementary income support and literacy-enhancing interventions alongside media-based behavioral campaigns to ensure that the clean energy transition reaches more vulnerable households across the region.

Table 3: Fuel Choice Results — Full Sample, Urban, and Rural

IV-Probit AME = average marginal effect from control-function probit. Rural firewood CF residual p = 0.164 (exogeneity not rejected).

	Full sample			**Urban**			**Rural**		
Outcome	**OLS**	**IV-2SLS**	**IV-Probit AME**	**OLS**	**IV-2SLS**	**IV-Probit AME**	**OLS**	**IV-2SLS**	**IV-Probit AME**
LPG / Gas	0.0553*** (0.006)	0.2921*** (0.024)	0.1625*** (0.008)	0.0801*** (0.009)	0.0627 (0.032)	0.2479*** (0.017)	0.0174*** (0.006)	0.4240*** (0.041)	0.0831*** (0.006)
Charcoal	0.0883*** (0.007)	0.3952*** (0.030)	0.1767*** (0.011)	0.0714*** (0.011)	0.0258 (0.041)	0.1649*** (0.022)	0.0456*** (0.008)	0.5246*** (0.051)	0.1227*** (0.012)
Firewood	−0.0387*** (0.007)	−0.0096 (0.020)	−0.1295*** (0.014)	−0.0967*** (0.010)	−0.4533*** (0.040)	−0.2626*** (0.021)	0.0483*** (0.010)	−0.0457 (0.061)	0.0102 (0.021)
Observations	51,848	51,848	51,848	22,199	22,199	22,199	29,649	29,649	29,649
Clusters	5,666	5,666	5,666	2,620	2,620	2,620	3,078	3,078	3,078
First-stage F-stat	—	2,006.99	—	—	1,146.90	—	—	667.91	—
First-stage Z-stat	—	—	32.74	—	—	24.43	—	—	21.79
Wu-Hausman p-value	—	0.000	—	—	0.000	—	—	0.001	—
CF residual p-value	—	—	0.000	—	—	0.000	—	—	0.164 (FW)
First-stage pseudo R^2	—	—	0.5266	—	—	0.4423	—	—	0.5125
Outcome pseudo R^2 (LPG)	—	—	0.3844	—	—	0.2460	—	—	0.3566

Outcome pseudo R² (Charcoal)	—	—	0.2109	—	—	0.0879	—	—	0.1640
Outcome pseudo R² (Firewood)	—	—	0.2877	—	—	0.2228	—	—	0.1797

Cluster-robust standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. *IV-Probit reports average marginal effects (AME). Wu-Hausman p-value tests exogeneity of TV ownership. Dashes indicate statistic not applicable for that estimator.*

Table 4: Fuel Choice Results by Income Group — OLS, IV-2SLS, and IV-Probit AME
Income split at median log per capita expenditure (12.88). Diff = High minus Low income.

	OLS		**IV-2SLS**		**IV-Probit AME**	
Outcome	**High income**	**Low income**	**High income**	**Low income**	**High income**	**Low income**
LPG / Gas	0.1014*** (0.008)	0.0223*** (0.006)	0.3745*** (0.031)	0.2634*** (0.027)	0.2632*** (0.0146)	0.0891*** (0.0073)
Charcoal	0.0739*** (0.009)	0.0623*** (0.009)	0.2722*** (0.033)	0.6741*** (0.054)	0.1755*** (0.0164)	0.1485*** (0.0155)
Firewood	−0.0879*** (0.009)	0.0123 (0.010)	−0.4015*** (0.034)	−0.1955*** (0.056)	−0.2292*** (0.0181)	−0.0834*** (0.0226)
Observations	25,924	25,924	25,924	25,924	25,924	25,924
Clusters	5,129	4,678	5,129	4,678	5,129	4,678
First-stage F-stat	—	—	1,590.63	703.45	—	—
First-stage Z-stat	—	—	—	—	27.37	24.72
Wu-Hausman p-value	—	—	0.000	0.000	—	—
Outcome pseudo R² (LPG)	—	—	—	—	0.2842	0.2815
Outcome pseudo R² (Charcoal)	—	—	—	—	0.1531	0.2635

Outcome pseudo R² (Firewood)	—	—	—	—	0.2734	0.2369

Cluster-robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. *IV-Probit reports average marginal effects (AME). Wu-Hausman p-value tests exogeneity of TV ownership. Dashes indicate statistic not applicable for that estimator*

Table 5: Fuel Choice Results by Education Group — OLS, IV-2SLS, and IV-Probit AME

Secondary+ = completed secondary education or above. Below sec. = below secondary. Diff = Secondary+ minus Below secondary.

	OLS		**IV-2SLS**		**IV-Probit AME**	
Outcome	**Secondary+**	**Below sec.**	**Secondary+**	**Below sec.**	**Secondary+**	**Below sec.**
LPG / Gas	0.0514*** (0.012)	0.0577*** (0.006)	0.3289*** (0.050)	0.2869*** (0.024)	0.2022*** (0.023)	0.1534*** (0.007)
Charcoal	0.0907*** (0.014)	0.0856*** (0.007)	0.3948*** (0.060)	0.3902*** (0.030)	0.2608*** (0.027)	0.1554*** (0.011)
Firewood	−0.0245 (0.013)	−0.0428*** (0.008)	−0.4258*** (0.056)	−0.2648*** (0.034)	−0.1642*** (0.028)	−0.1233*** (0.015)
Observations	8,653	43,195	8,653	43,195	8,653	43,195
Clusters	3,193	5,634	3,193	5,634	3,193	5,634
First-stage F-stat	—	—	570.62	1,772.90	—	—
Wu-Hausman p-value	—	—	0.000	0.000	—	—
CF residual p-value	—	—	—	—	0.000	0.000
Outcome pseudo R² (LPG)	—	—	—	—	0.3079	0.3867
Outcome pseudo R² (Charcoal)	—	—	—	—	0.1435	0.2178
Outcome pseudo R² (Firewood)	—	—	—	—	0.2546	0.2696

Cluster-robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. *IV-Probit reports average marginal effects (AME). Wu-Hausman p-value tests exogeneity of TV ownership. CF residual p-value tests the null of exogeneity (control function approach). Dashes indicate a statistic not applicable for that estimator.*

6. Discussion of Results

The findings of this study suggest that informational access constitutes an important component of household energy transition dynamics in West Africa. Across the various estimation strategies, television exposure is consistently associated with increased adoption of LPG and reduced dependence on firewood, supporting the argument that informational frictions represent a meaningful barrier to cleaner fuel adoption in low-income settings. Television exposure may influence household fuel choices by increasing awareness of the health consequences of biomass smoke, improving knowledge of the convenience and efficiency advantages of modern fuels, and shifting social norms surrounding cooking practices and energy use. At the same time, the positive charcoal responses observed among some household groups indicate that household energy transition in the region often occurs through "fuel stacking" rather than through an immediate shift from biomass fuels to LPG. These patterns are broadly consistent with previous studies emphasizing the behavioral and informational dimensions of household fuel decisions in developing economies.

The strong urban-rural differences further suggest that information and infrastructure operate as complementary inputs in the clean energy transition process. Urban households are more likely to possess the market access, LPG distribution networks, electrification, road connectivity, and household liquidity necessary to translate informational exposure into sustained LPG adoption. In contrast, persistent supply-side and affordability constraints in many rural areas may limit households' ability to act on updated fuel preferences even when awareness increases. The relatively stronger charcoal responses observed in some rural areas further suggest that when modern fuels remain inaccessible, informational exposure may still encourage movement toward intermediate fuels rather than direct transitions to LPG. The findings therefore imply that information-based interventions are likely to be most effective when accompanied by complementary improvements in fuel distribution systems, market integration, transportation infrastructure, and household purchasing power.

The positive and statistically significant charcoal effects across several subgroups require more careful interpretation than a simple fuel-stacking explanation alone provides. Among low-income households, television exposure increases charcoal use by 14.9 percentage points — a larger effect than the LPG response of 8.9 percentage points — suggesting that for financially constrained households, informational exposure does not primarily drive a direct transition to clean fuels but instead facilitates a partial shift away from the most polluting fuel (raw firewood) toward an intermediate alternative. A similar pattern emerges in rural areas, where the charcoal response exceeds the LPG response and firewood use shows no statistically significant decline. The welfare implications of this intermediate transition are ambiguous and context-dependent. On the health side, charcoal combustion generally produces lower concentrations of particulate matter and carbon monoxide than traditional firewood use, implying that a transition from firewood to charcoal may reduce household exposure to indoor air pollution, particularly for women and children. On the environmental side, however, charcoal production in West Africa is predominantly artisanal and highly inefficient in wood-to-charcoal conversion, making it a major contributor to deforestation and forest degradation across the region. An information-induced increase in charcoal demand could therefore exacerbate environmental pressures even while improving some household-level health outcomes. These findings suggest that informational campaigns promoting clean cooking should avoid implicitly framing charcoal as a desirable long-term substitute for firewood. Instead, policies targeting low-income and rural households should combine informational interventions with measures that improve the affordability and accessibility of LPG, including subsidized starter packages, lower cylinder deposit requirements, and expanded community-level distribution systems.

The socioeconomic heterogeneity documented across income and education groups further clarifies the mechanisms through which information affects household fuel behavior. Higher-income and more educated households appear better positioned to process information and absorb the upfront and recurring costs associated with modern fuel adoption, including stove purchases, cylinder deposits, refill expenditures, and transportation costs. These findings suggest that informational exposure alone may generate unequal benefits when substantial financial and structural constraints remain in place. Although the instrumental-variable strategy substantially strengthens causal interpretation, the exclusion restriction should still be understood as a maintained identifying assumption, and some residual confounding related to unobserved household aspirations, modernization preferences, or broader cluster-level socioeconomic conditions cannot be fully excluded. Nevertheless, the consistency of the findings across multiple estimation strategies provides substantial evidence that informational access plays an important role in shaping household fuel choices across the region.

7. Policy Implications

The findings carry several policy implications for clean cooking strategies in West Africa. First, informational barriers appear to constitute a meaningful and potentially addressable constraint on household fuel transitions, even in settings where modern fuels are physically available. Governments and development partners could therefore integrate behavioural communication campaigns into national clean cooking strategies using television and related media platforms to increase awareness of the health, convenience, and long-term economic advantages of LPG. Because television campaigns carry relatively low marginal dissemination costs once broadcasting infrastructure exists, they may represent a cost-effective complement to more capital-intensive energy investments. In this respect, the findings align closely with Sustainable Development Goal (SDG) 7, particularly Target 7.1 on universal access to affordable, reliable, and modern energy services, as well as ongoing regional initiatives led by the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) and the West African Clean Cooking Alliance aimed at expanding access to modern cooking energy across the region.

Second, the results indicate that information and infrastructure operate as complements rather than substitutes in the energy transition process. Informational exposure appears to increase LPG adoption primarily where households already possess sufficient market access, purchasing power, electrification, and fuel availability. In many rural and low-income settings, however, informational exposure is associated with increased charcoal use rather than full transition to LPG, suggesting that financially constrained households may shift toward intermediate fuels when cleaner alternatives remain unaffordable or inaccessible. This finding carries important environmental implications because inefficient charcoal production is a major driver of deforestation and forest degradation across West Africa. Policies promoting clean cooking should therefore avoid implicitly framing charcoal as a desirable long-term substitute for firewood and instead combine informational campaigns with subsidized LPG starter packages, lower cylinder deposit requirements, improved rural distribution networks, and transportation infrastructure investments. These policy priorities are directly relevant to SDG 13 on climate action and SDG 15 on sustainable forest management and ecosystem protection.

8. Conclusion

In conclusion, this study examined the causal effect of informational access on household cooking fuel choices across seven West African countries using nationally representative LSMS data and an instrumental-variable framework designed to address the endogeneity of television ownership. The findings provide new multi-country causal evidence that media-based informational exposure significantly increases LPG adoption and reduces dependence on traditional biomass fuels, although the magnitude of these effects varies substantially across socioeconomic and spatial groups. Urban and higher-income households respond more strongly to informational exposure, while rural and poorer households remain constrained by weak infrastructure, limited fuel availability, and affordability barriers, often shifting toward intermediate fuels such as charcoal rather than fully transitioning to clean energy. These results suggest that informational frictions represent an important but incomplete explanation for slow clean cooking transitions in sub-Saharan Africa. The study contributes to the literature by demonstrating that information and infrastructure operate as complementary inputs in household energy transitions and by highlighting the limitations of relying solely on behavioural communication strategies in structurally constrained environments. The findings further imply that achieving progress toward SDG 7 and related health, gender, and environmental objectives will require integrated policies combining media outreach with expanded LPG distribution systems, affordability support, and regionally coordinated clean cooking initiatives across West Africa.

Reference:

Adjei-Mantey, K. (2021). Essays on household cooking energy in Ghana (Doctoral dissertation, Kobe University). https://doi.org/10.24546/81009071

Angrist, J. D., & Pischke, J.-S. (2009). Mostly harmless econometrics: An empiricist's companion. Princeton University Press.

Bensch, G., & Peters, J. (2015). The intensive margin of technology adoption—Experimental evidence on improved cooking stoves in rural Senegal. Journal of Health Economics, 42, 44–63. https://doi.org/10.1016/j.jhealeco.2015.03.006

Bruce, N., Perez-Padilla, R., & Albalak, R. (2000). Indoor air pollution in developing countries: A major environmental and public health challenge. Bulletin of the World Health Organization, 78(9), 1078–1092.

Cecelski, E. (2005). Energy, development and gender: Global correlations and trends. UNDP Energy for Development Research Brief.

Clancy, J., Winther, T., Matinga, M., & Oparaocha, S. (2012). Gender equity in access to and benefits from modern energy and improved energy technologies. World Bank.

Cooke, P., Köhlin, G., & Hyde, W. (2008). Fuelwood, forests and community management—Evidence from household studies. Environment and Development Economics, 13(1), 103–135. https://doi.org/10.1017/S1355770X0700397X

Dendup, N., & Arimura, T. H. (2019). Information leverage: The adoption of clean cooking fuel in Bhutan. Energy Policy, 125, 181–195. https://doi.org/10.1016/j.enpol.2018.10.057

Farsi, M., Filippini, M., & Pachauri, S. (2007). Fuel choices in urban Indian households. Environment and Development Economics, 12(6), 757–774. https://doi.org/10.1017/S1355770X07003932

Greene, W. H. (2012). Econometric analysis (7th ed.). Pearson Education.

Gupta, G., & Köhlin, G. (2006). Preferences for domestic fuel: Analysis with socio-economic factors and rankings in Kolkata, India. Ecological Economics, 57(1), 107–121. https://doi.org/10.1016/j.ecolecon.2005.03.010

Heltberg, R. (2004). Fuel switching: Evidence from eight developing countries. Energy Economics, 26(5), 869–887. https://doi.org/10.1016/j.eneco.2004.04.018

Hosier, R. H., & Dowd, J. (1987). Household fuel choice in Zimbabwe: An empirical test of the energy ladder hypothesis. Resources and Energy, 9(4), 347–361. https://doi.org/10.1016/0165-0572(87)90003-X

Imbens, G. W., & Angrist, J. D. (1994). Identification and estimation of local average treatment effects. Econometrica, 62(2), 467–475. https://doi.org/10.2307/2951620

International Energy Agency. (2022). Africa Energy Outlook 2022. IEA, Paris. https://www.iea.org/reports/africa-energy-outlook-2022

Jalan, J., & Somanathan, E. (2008). The importance of being informed: Experimental evidence on demand for environmental quality. Journal of Development Economics, 87(1), 14–28. https://doi.org/10.1016/j.jdeveco.2007.10.002

Jensen, R., & Oster, E. (2009). The power of TV: Cable television and women's status in India. Quarterly Journal of Economics, 124(3), 1057–1094. https://doi.org/10.1162/qjec.2009.124.3.1057

Jessoe, K., & Rapson, D. (2014). Knowledge is (less) power: Experimental evidence from residential energy use. American Economic Review, 104(4), 1417–1438. https://doi.org/10.1257/aer.104.4.1417

Khandker, S. R., Barnes, D. F., & Samad, H. A. (2012). Are the energy poor also income poor? Evidence from India. Energy Policy, 47, 1–12. https://doi.org/10.1016/j.enpol.2012.01.048

Kojima, M. (2011). The role of liquefied petroleum gas in reducing energy poverty. World Bank.

Kooijman-van Dijk, A. L., & Clancy, J. S. (2010). Impacts of electricity access to rural enterprises in Bolivia, Tanzania and Vietnam. Energy for Sustainable Development, 14(4), 45–52. https://doi.org/10.1016/j.esd.2010.09.003

Laan, T., Beaton, C., & Presta, B. (2010). Strategies for reforming fossil-fuel subsidies: Practical lessons from Ghana, France and Senegal. IISD–GSI.

Lewis, J. J., & Pattanayak, S. K. (2012). Who adopts improved fuels and cookstoves? A systematic review. Environmental Health Perspectives, 120(5), 637–645. https://doi.org/10.1289/ehp.1104194

Malla, S., & Timilsina, G. R. (2014). Household cooking fuel choice and adoption of improved cookstoves in developing countries: A review. World Bank Policy Research Working Paper No. 6903.

Masera, O. R., Saatkamp, B. D., & Kammen, D. M. (2000). From linear fuel switching to multiple cooking strategies: A critique and alternative to the energy ladder model. World Development, 28(12), 2083–2103. https://doi.org/10.1016/S0305-750X(00)00076-0

Meng, T., Florkowski, W. J., Sarpong, D. B., Chinnan, M., & Resurreccion, A. V. A. (2021). Cooking fuel usage in sub-Saharan urban households: Evidence from Ghana. Energies, 14(15), 4629. https://doi.org/10.3390/en14154629

Miller, G., & Mobarak, A. M. (2013). Gender differences in preferences, intra-household externalities, and the low demand for improved cookstoves. NBER Working Paper No. 18964. https://doi.org/10.3386/w18964

Mobarak, A. M., Dwivedi, P., Bailis, R., Hildemann, L., & Miller, G. (2012). Low demand for nontraditional cookstove technologies. Proceedings of the National Academy of Sciences, 109(27), 10815–10820. https://doi.org/10.1073/pnas.1115571109

Pachauri, S., & Jiang, L. (2008). The household energy transition in India and China. Energy Policy, 36(11), 4022–4035. https://doi.org/10.1016/j.enpol.2008.06.016

Ravindra, K., Kaur-Sidhu, M., Mor, S., & John, S. (2019). Trend in household energy consumption pattern in India: A case study on the influence of socio-cultural and demographic factors. Environmental Research, 172, 13–22. https://doi.org/10.1016/j.envres.2019.02.002

Rehfuess, E. A., Mehta, S., & Prüss-Üstün, A. (2006). Assessing household solid fuel use: Multiple implications for the Millennium Development Goals. Environmental Health Perspectives, 114(3), 373–378. https://doi.org/10.1289/ehp.8482

SEforALL. (2021). Tracking SDG 7: The Energy Progress Report. Washington, DC: World Bank.

Sharma, R. (2012). Determinants of cooking fuel choice in India: An analysis using multinomial logit model. Journal of Environmental Planning and Management, 55(5), 669–686. https://doi.org/10.1080/09640568.2011.619885

Smith, K. R., Bruce, N., Balakrishnan, K., et al. (2014). Millions dead: How do we know and what does it mean? Methods used in the comparative risk assessment of household air pollution. Annual Review of Public Health, 35, 185–206. https://doi.org/10.1146/annurev-publhealth-032013-182356

Troncoso, K., & Soares da Silva, A. (2017). LPG fuel subsidies in Latin America and the use of solid fuels to cook. Energy Policy, 107, 188–196. https://doi.org/10.1016/j.enpol.2017.04.046

UNDP. (2019). Human Development Report 2019: Beyond income, beyond averages, beyond today. New York: United Nations Development Programme.

United Nations. (2015). Transforming our world: The 2030 Agenda for Sustainable Development. https://sdgs.un.org/2030agenda

Van der Kroon, B., Brouwer, R., & Van Beukering, P. J. (2013). The energy ladder: Theoretical myth or empirical truth? Results from a meta-analysis. Renewable and Sustainable Energy Reviews, 20, 504–513. https://doi.org/10.1016/j.rser.2012.11.045

Wooldridge, J. M. (2010). Econometric analysis of cross-section and panel data (2nd ed.). MIT Press.

World Bank. (2023). Tracking SDG 7: The Energy Progress Report 2023. Washington, DC: World Bank.

World Health Organization. (2023). Clean household energy policy and programme planning guide. https://www.who.int/publications/i/item/9789240070202