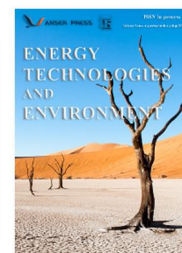




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Does Education Predict Women's Use of Unsustainable Biomass Cooking Technologies? Evidence from a Natural Experiment

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ABSTRACT

In developing countries, the dependence on traditional biomass for domestic energy consumption is one of the major causes of deforestation and environmental poverty. This paper investigates the impact of women's education on the probability of using Unsustainable Biomass Cooking Technologies (UBCT) as the household main fuel of cooking instead of clean energy. Combining data from four rounds of Nigeria DHS conducted between 2003 and 2018, we take advantage of a natural experiment, the implementation of Uni-versal Primary Education policies in 1970, to obtain an exogenous variation in women's education levels. Using an instrumental variable approach to control for the endogeneity issues, we find that women with higher levels of education are less likely to use UBCT as their primary source of cooking. This result implies that environmental policies in developing countries should rely not only on income transfers policies as suggested in the literature but also on increasing women's human capital to reduce women's dependence on unsustainable biomass cooking practices.

KEYWORDS

Education; Women; Biomass; Cooking; Nigeria

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1. Introduction

Unsustainable Biomass Cooking Technologies (UBCT)—mainly fuelwood, wood charcoal or dried animal dung—contributes to global climate change through forest degradation and deforestation (Mekonnen et al. 2022, Bluffstone et al., 2022, Orifah et al. 2019, Blanco et al. 2014, Wessels et al. 2013, Saad and Bugaje 2016). Yet, it remains a very important source of livelihood for the poor in developing countries (Mainimo et al. 2022, Singh 2019, Birundu et al. 2017, Bailey 2008). In developing countries, particularly in rural areas, this natural resource, collected for commercial purposes or mainly used for household cooking, provides a livelihood for an estimated 2.5 billion people (Tucho et al. 2022, Mekonnen et al. 2022, Bolaji 2012, Barbier, 2010).

Yet in recent years, forest cover in developing countries has declined due to a combination of increased climate stress and deforestation, seriously threatening the livelihoods of billions of people in developing countries. This global issue raises the specter of an environmental poverty trap—the vicious circle of dependence on traditional biomass, increased climate stress, forest degradation and deforestation. Evidence of such a trap has already been documented in the context of SSA, where 0.5% of forest cover is lost every year, the highest rate in the world (Tucho et al. 2022; Keenan et al. 2015). Moreover, unlike in other developing regions, mitigation, and adaptation efforts in SSA have slowed and even reversed, and, as a result, the level of dependence on this natural resource remains higher than the world average, at more than 80% depend on this fuel for cooking (Karimu and Dramani, 2021, D'Sa and Murthy 2010). Research in developing countries also show evidence that indoor air pollution and exposure to the byproduct of combustion of fuelwood results in various health issues for women (Oguntoke et al. 2013, Ingale et al. 2013, Ali et al. 2019).

The above notwithstanding, while in most developing countries women and men are vulnerable to climate change when highly dependent on traditional biomass for their energy and livelihoods, there is ample evidence that women in the developing world are disproportionately vulnerable to its adverse effects (Kasperson et al. 2022, Escalante and Maisonnave, 2022; Pérez-Peña, et al 2021, Arora-Jonsson, 2011; Demetriades and Esplen, 2010, Wong, 2009). First, in most developing countries, women and girls are responsible for collecting traditional fuels—a time-consuming and physically draining household chore. As a result, women have limited time to allocate to other household chores, engage in paid work, or in public activities. This intra-household allocation of tasks has also meant that girls have to help more in the household, and thus are kept home from school, leading to the persistence of poor education outcomes for women (Kaygusuz, 2011; Duflo et al. 2008). When coupled with unequal access to resources and to decision-making processes, poor education outcomes for women mean that they lack the ability to adapt to climate change, as switching to more efficient cooking technologies requires, not only that they have purchasing power to afford these new technologies, but also the agency to engage in rewarding income-generating activity. Child marriage—known from Field and Ambrus (2008) to be a barrier to girls' education—, high fertility, and poor health linked to women being traditionally responsible for collecting firewood—a physically draining activity—, and cooking—which involves hours of exposure to smoke from the cooking fire mean that women face social barriers to participation in paid employment. For SSA, therefore, it is feared that high dependence on traditional biomass—a contributor to global climate change—, whose own availability is under threat from increased climate stress, may entrench a vicious circle of climate stresses and social marginalization of women and girls (Duflo et al. 2008).

In light of these facts, the United Nations task force on Gender equality and empowerment of women has called for the identification of gender sensitive strategies to incentivize climate change's adaptation efforts in developing countries. This requires a clear understanding of factors that entrench women's dependence on traditional biomass either as a cooking fuel or as a source of livelihood. Surprisingly, despite the urgency of the situation in SSA, in the research front, the literature focusing on barriers to women's adaptation capacity in this region is very scant: is there a causal effect between women's individual characteristics and their dependence on traditional wood-based

biomass? How can this effect be identified properly in the context of SSA? These are the key questions that concern us in this paper research. Addressing them is important both to guide public policy actions that can enhance irreversible adaptation practices in SSA, and to put research at the forefront of efforts, by the international community, to detect and mitigate factors likely to slow the completion of SDGs, particularly SDGs 5 and 7. This paper focuses on women, as in SSA, as women are primary responsible for cooking (Duflo et al. 2008). The objective is to understand the extent to which a woman's individual characteristics (her level of education) predispose her and her household to depend on traditional biomass as a source of livelihood. According to a recent United Nations report, women are often the most marginalized in social, political and economic domains, and are overrepresented in the illiterate population. The report points to illiteracy as a manifestation of social marginalization of girls and women, as early marriage and pregnancy, gender-based violence in and around schools, as well as lack of gender-sensitive learning contents and environments force girls to drop out of school (UN 2019). Moreover, high female illiteracy rates have ramifications to women and children's health outcomes, further limiting their opportunities for earning an income. Indeed, evidence shows that maternal literacy correlates with better health outcomes for women and their children, reduced child mortality, greater enrolment of children in school, and reduced poverty at the family and household level (UN 2019).

This paper contributes to the literature on woman's individual characteristics (including education) as a factor of significant importance in household choice of cooking practices. In a study of rural Kenya, Pundo and Fraser (2006) find evidence that the education level of wife is associated with the probability of switching from fuelwood to charcoal or kerosene in rural Kenya. Likewise, in a study of rural India, Pandey and Chaubal (2011) find evidence that the number of educated females between 10 and 50 years of age and average household's level of education had a positive and significant correlation with the probability of using clean cooking fuels. What essentially distinguishes our proposed research from the existing literature is our strategy for identifying the causal effect of a woman's human capital—as measured by education and health—, in the face of well-documented endogeneity issues surrounding the use of human capital as explanatory variables of individual or household choices (e.g., Angrist and Krueger 1991). Addressing these endogeneity issues is paramount to consistent identification. Therefore, unlike the existing literature, this paper focuses on devising an empirical strategy that delivers a consistent estimation of the causal effect of women's education, by dealing with, potential endogeneity issues.

We use the Universal Primary education program in Nigeria in 1976, which creates an exogenous increase in women education levels (see Osili and Long, 2008 and Fenske, 2015) to control for the endogeneity of women's schooling. After applying an instrumental variable approach, the results indicate that one additional year of schooling significantly reduces a woman's probability of using UBCT.

The remainder of the paper is organized as follows. Section 2 reviews the literature while Section 3 describes the data. Section 4 outlines our empirical strategy. Section 5 presents estimation results. Section 6 concludes the paper.

2. Literature Review

The literature highlights multiple barriers to households' transition to more efficient cooking practices, as a climate change induced adaptation behavior. One such barrier is household income (Alem et al, 2016; Arthur et al. 2011; Bansal et al. 2013; Nlom and Karimov 2014). Campbell et al (2003) shows, that an energy transition from wood to kerosene to electricity occurred with increasing household incomes. Others include the price of more efficient biomass-specific cookstoves, and the area or region of residence, as these may determine the availability of better cooking technologies. If indeed these were the only or more important factors at play, price-based interventions that subsidize the use of more efficient cooking technologies would suffice to incentivize the transition away from traditional biomass cooking fuel. However, the results are mitigated as recent studies revealed

that income may have no impact on the choice of the cooking fuel. For example, Hiemstra-van der Horst and Hovorka (2008) in Botswana, and Brouwer and Falcão (2004) in Mozambique find evidence that households of all income levels use traditional wood-based biomass fuel. What is more, Davis (1998) in South Africa, Campbell et al. (2003) in Zimbabwe, and Brouwer and Falcão (2004) in Mozambique find evidence of the use of electricity for cooking by low-income households. In another study using Ghana microdata, Karimu (2015) also found that income has no effect on the choice for fuelwood.

Besides income, recent papers have attempted to capture the influence of human capital on household's decision on the choice of cooking fuel. For instance, Ali et al. (2019) used multinomial logit results show that household heads with higher education are more likely to use modern fuel such as natural gas, and are less likely to use fuelwood and, dung cake and crop residues in Pakistan. In Ghana, previous studies such as Karimu (2015) and Mensah and Adu (2015) indicated that education, is one of the key factors influencing household's choice of the main cooking fuels (fuelwood, charcoal and liquefied petroleum gas). A similar result was found in China (Hou et al. 2017). Using a comprehensive data set from the Living Standard Measurement Study from four African countries (Ethiopia, Malawi, Tanzania and Uganda), Behera et al (2017) applied a multinomial logit model and an ordered probit model and found that demographic characteristics, a household's human capital accelerate a household's use of electricity for light and cooking.

Our study is not the first to advance the idea that women's individual characteristics are a significantly important factor in the choice of household cooking practices. Indeed, in a study of rural Kenya (Kisumu), Pundo and Fraser (2006), use a multinomial logit model to investigate the factors that determine households' choice of cooking fuel between firewood, charcoal and kerosene.

Yet, this paper contributes to this literature by accounting for the endogeneity in education levels to capture robust estimation of the relationship between education and the choice of cooking fuel.

3. Data

3.1. Data sources

This study use data collected in Nigeria during four rounds of DHS namely DHS 2003, DHS 2008, DHS 2013, and DHS 2018. DHS are nationally representative data that contains information about individual characteristics such as level of education, ethnic group, religion, region of residence, and the area of residence. We define a woman's use of UBCT is built as a dummy variable equals 1 if the female report usually using fuelwood, wood charcoal or dried animal dung as her main source of cooking and 0 if she reported using clean energy as electricity. The woman level of education is measured in single years of schooling completed.

3.2. Regional disparities

Nigeria displays large significant cross-regional disparities both in the average number of years of schooling completed and in the biomass energy use. For observational evidence, we match each married man and his characteristics to a local government area and plot the prevalence of biomass use and women's mean years of schooling by local government area. Figure 1a represents the geographic variation in the prevalence of biomass use while Figure 1b represents the geographic variation in women's educational attainments. Thus, Figure 1 provides a visual test of the hypothesized negative correlation between women education and the UBCT use. Dark blue areas are those where the use of UBCT is highest (Figure 1a), and more women are educated (Figure 1b). The lighter the color of an area, the lower the prevalence of the UBCT and the less educated the married men.

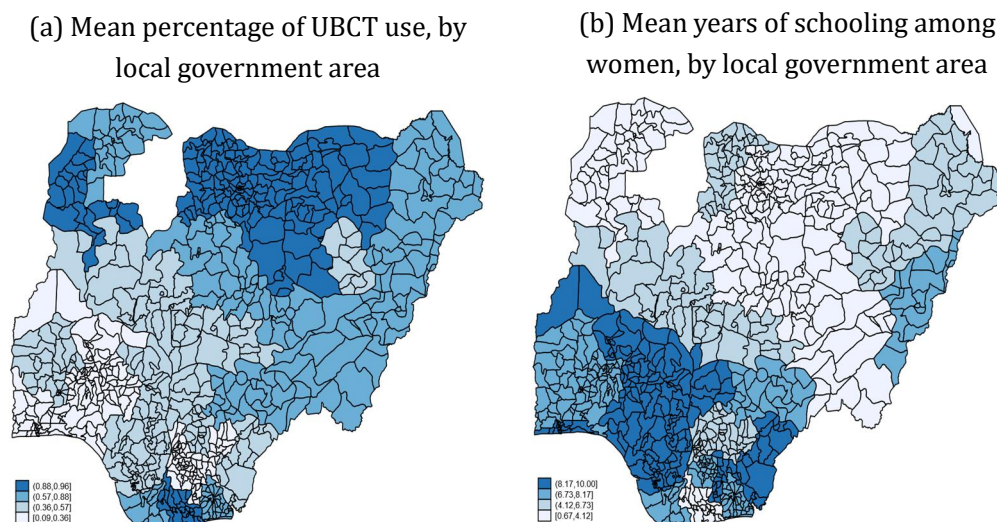


Figure 1. Years of education and UBCT use in Nigeria, by area of residence.

Both Figures 1a and 1b show a great deal of variation across local government areas for both the percentage of UBCT use and the years of schooling. Southern local government areas seem to have relatively more educated women than those located in the North (see Figure 1b). By contrast, the UBCT use seems to be more prevalent in northern local government areas (see Figure 1a). Consequently, Figure 1 clearly shows a pattern of negative correlation between women education and the use of UBCT in Nigeria. Indeed, the use of UBCT appears to be more prevalent in local government areas where women have lower educational attainments.

3.3. Descriptive Statistics

In this subsection, we present summary statistics on women's educational attainments and the use of UBCT. Table 1 presents the summary statistics by UBCT use, religion, area of residence, and ethnic group. In terms of UBCT, 78.3% of women tend to use UBCT as the main fuel of cooking. The average level of education among women who use UBCT is 4.83 years of schooling. The corresponding figure for those who use clean energy for cooking is nearly double at 9.274 years of education. In Nigeria, UBCT use appears more prevalent among women living in rural areas. In fact, nearly 89% of women using UBCT reside in rural areas. This fact suggests that UBCT is predominantly used in rural areas. Regarding the distribution by ethnic group, the use of UBCT is also unequally distributed. Finally, among Nigerian women who use UBCT, 17.6% were exposed to the UPE reform. This figure is slightly higher among those who are using clean energy (19.6%)

Table 1. Summary Statistics.

VARIABLES	Clean energy		UBCT		All	
	mean	sd	mean	sd	mean	sd
UBCT					0.783	0.195
Years of schooling	9.274	5.338	4.830	5.411	6.728	5.812
Religion						
<i>Traditionalist and other</i>	0.0320	0.176	0.0542	0.226	0.0447	0.207
<i>Muslim</i>	0.355	0.479	0.722	0.448	0.565	0.496
<i>Christians</i>	0.613	0.487	0.224	0.417	0.390	0.488
Ethnic group						
<i>Haussa</i>	0.128	0.334	0.441	0.497	0.307	0.461

<i>Ibo</i>	0.190	0.392	0.0369	0.189	0.102	0.303
<i>Yoruba</i>	0.145	0.352	0.0326	0.178	0.0807	0.272
<i>Others</i>	0.537	0.499	0.489	0.500	0.510	0.500
Area of residence						
Rural residence	0.111	0.499	0.889	0.408	0.678	0.467
UPE Reform	0.196	0.397	0.176	0.381	0.185	0.388
High intensity state	0.681	0.466	0.914	0.281	0.814	0.389

4. Econometric model

4.1. One equation model

In this section, we study the correlation between a woman's level of education and the probability of using UBCT. First, we estimate this correlation using the following OLS regression:

$$UBCT_{iar} = \beta YearsOfSchooling_{iar} + X^i\gamma + \epsilon_{iar} \quad (1)$$

In Equation (1), $UBCT_{iar}$ is an indicator for whether a woman i belonging to a birth cohort a , and residing in area r predominantly use UBCT as her main fuel for cooking. $YearsOfSchooling_{iar}$ denotes the number of years of schooling she completed. X^i is a vector containing the individual and geographic controls, including age, a dummy for whether she lives in a rural area, and, in different specifications, fixed effects for country-round, sub-national region, and survey cluster. Standard errors are clustered by survey cluster. Based on the visual tests presented in Figures 1, we expect the sign of β to be negative. We are interested in uncovering the magnitude of this correlation coefficient and the extent to which it is sensitive to different controls.

If education were exogenous, then the effect estimated from in Equation (1) could be interpreted as causal. However, in Nigeria settings, there is likely to be an omitted variable that increases/decreases a woman's number of years of schooling completed but has a negative/positive partial effect on her probability of using UBCT. For example, in Nigeria, where colonization exposed coastal regions to western styles of living, admiration for such styles can positively be associated with a woman being educated but negatively affects the probability of using UBCT. Not accounting for this omitted variable can lead to a negative bias.

4.2. Instrumental variable approach

As argued above, our primary concern is that ordinary least squares (OLS) estimates of β in Eq.(1) are biased due to the endogeneity of the education variable. When observational data is available, one commonly used solution to resolve these biases is to find an exogenous source of identifying variation in men's levels of education. Therefore, to test whether education reduces UBCT use probabilities, we exploit a natural experiment that have exogenously exposed some cohorts of men to additional education in Nigeria. The Universal Primary Education (UPE) in Nigeria has been the backbone of several empirical studies, including by (Osili and Long, 2008) and (Fenske, 2015). It was introduced in September 1976, by the Federal Government of Nigeria, as a nationwide program designed to increase educational attainment. At the time of its inception, the federal government intended to use education as a lever of rapid national development and social cohesion in a multi-ethnic and religiously diverse country split by civil war (Csapo, 1983). This large-scale program provided tuition-free primary education and increased the number of primary school classrooms and teacher-training institutions throughout the country, marking a significant change in the educational opportunities available to young Nigerian children. Before its end in 1981, the UPE was credited for substantially increasing enrollment in primary education (Osili and Long, 2008).

We use Osili and Long (2008) research design to estimate the impact of women's educational attainment on UBCT use probabilities. Because of the regional disparities, UPE was not equally distributed across the regions. To account for this disparity, Osili and Long (2008) design two levels of impacts: high intensity regions where the impact of UPE were higher than the low intensity states. We follow a similar design and therefore estimate the following two regression equations:

$$UBCT_{iar} = 1[\beta_0 + \beta_1 YearsOfSchooling_{iar} + \gamma X_{iar} + \epsilon_{iar} > 0] \quad (2)$$

$$YearsOfSchooling_{iar} = \alpha_0 + \lambda X_{iar} + \alpha_1 (UPECohort_{ia} \times UPEIntensity_r) + \alpha_2 UPECohort_{ia} + \alpha_3 UPEIntensity_r + \mu_{iar} \quad (3)$$

Where α_1 capture the overall impact of UPE, taking into account regional disparities. We estimate this system jointly allowing to test for the presence of endogeneity issues.

5. Results

5.1. OLS Results

Table 2 below reports the result of the OLS estimation. When we include no control (column 1, Table 2), we find that an additional year of schooling predicts a 2.1 percentage point reduction in a woman's probability of using UBCT. This effect decreases slightly to 1.7 percentage point as we add religion, ethnic group, and DHS rounds' fixed effect (column 2). Adding a geography fixed effect among the controls (column 3) leads to a drop of 0.7 percentage points in magnitude compared to the no control baseline, which is still a relatively small change. These results suggest that the correlation between a woman's level of education and UBCT use is negative and robust in Nigeria.

Table 2. OLS results.

VARIABLES	Model 1	Model 2	Model 3
<i>Years of education</i>	-0.0213*** (0.00061)	-0.0168*** (0.0006)	-0.0139*** (0.0006)
<i>Ethnic group FE</i>	N	Y	Y
<i>Religion FE</i>	N	Y	Y
<i>Rural dummy FE</i>	N	N	Y
<i>DHS round FE</i>	N	Y	Y
<i>Observations</i>	26,612	26,576	26,576

Note: FE = fixed effects. Y=yes, N=No. Standard errors in parentheses are clustered at the survey cluster. * $p < .10$, ** $p < .05$, *** $p < .01$.

5.2. IV estimation results

Table 3 reports the result of the estimation using the instrumental variable approach. The correlation coefficient between errors in the women UBCT use and education equations is strictly, large in magnitude, and highly statistically significant. This indicates the presence in Nigeria of unobserved characteristics that increase a man's number of years of schooling completed and have a positive partial effect on the probability that she uses UBCT. As argued above, not accounting for this type of omitted variable leads to a positive bias. However, because the estimated effect of a woman's level of education on UBCT probability is negative, this positive bias amounts to underestimating this impact in absolute value. Comparisons with OLS estimates confirm that not accounting for

endogeneity indeed leads to overestimation of the effect of education in absolute value. First-stage results show that the UPE reform increased the number of years of schooling of those treated by at least 30% relative to the untreated. When we include all controls (Table 3, column 6), we find that an additional year of schooling decreases a woman's probability of using UBCT by 1.35 percentage points, and the result is highly statistically significant. These results also show that OLS (Table 2, column 3) overestimates the effect of education on a man's probability of taking a bride by 0.03 percentage points. These results also show that OLS (Table 2, column 3) overestimates the effect of education on a man's probability of taking a bride by 0.03 percentage points.

Table 3. IV results.

VARIABLES	IV Model 1		IV Model 2		IV Model 3	
	CM.eqn	E.eqn	CM.eqn	E.eqn	CM.eqn	E.eqn
Years of schooling	-0.0169*** (0.00165)		-0.0158*** (0.00264)		-0.0135*** (0.00399)	
Reform Cohort*High intensity		0.421*** (0.1522)		0.522*** (0.1523)		0.307*** (0.1272)
Religion FE	Y	Y	Y	Y	Y	Y
Ethnic group FE	N	N	Y	Y	Y	Y
Rural dummy FE	N	N	N	N	Y	Y
Wealth Index FE	N	N	N	N	Y	Y
DHS round FE	N	N	N	N	Y	Y
Observations	26,612		26,576		26,576	
Endogeneity test corr(E.eqn, CM.eqn)	0.701***		0.614***		0.525***	

Note: FE = fixed effects. Y=yes, N=No. Standard errors in parentheses are clustered. * $p < .10$, ** $p < .05$, *** $p < .01$.

6. Robustness check

A primary concern is the robustness of the results in relation to the availability of alternative cooking methods. One might argue that there are significant differences between rural households where very few alternative cooking methods (such as electricity) exist and urban households where electricity is often available. The table 4 shows the estimated impact of education separately for rural and urban households. The results clearly show that the impact of education on UBCT use is negative and significant in both rural and urban households, but that the effect is much greater in rural areas.

Table 4. IV results.

VARIABLES	Rural Area		Urban Area	
	CM.eqn	E.eqn	CM.eqn	E.eqn
Years of schooling	-0.0194*** (0.0032)		-0.011*** (0.00125)	
Reform Cohort*High intensity		0.71*** (0.124)		0.286*** (0.117)
Religion FE	Y	Y	Y	Y
Ethnic group FE	Y	Y	Y	Y
Wealth Index FE	Y	Y	Y	Y
DHS round FE	Y	Y	Y	Y
Observations	18,043		8569	
Endogeneity test corr(E.eqn, CM.eqn)	0.711***		0.486***	

The second concern is the ethnical disparity that could affect social habits such as cooking. Table 5 analyzes the sensitivity of the results to the three main ethnic groups: Hausa, Igbo and Yoruba. The results show that the effect of education on UBCT use is robust for all ethnic groups, with a stronger effect for the Hausa.

Table 5. IV results.

VARIABLES	Haoussa		Igbo		Yoruba		Others	
	CM.eqn	E.eqn	CM.eqn	E.eqn	CM.eqn	E.eqn	CM.eqn	E.eqn
Years of schooling	-0.0166*** (0.00142)		-0.0120*** (0.00208)		-0.014*** (0.00311)		-0.0101*** (0.00410)	
Reform Cohort*High intensity		0.443*** (0.1482)		0.492*** (0.1443)		0.328*** (0.1328)		0.395*** (0.1054)
Religion FE	Y	Y	Y	Y	Y	Y	Y	Y
Rural dummy FE	Y	Y	Y	Y	Y	Y	Y	Y
Wealth Index FE	Y	Y	Y	Y	Y	Y	Y	Y
DHS round FE	Y	Y	Y	Y	Y	Y	Y	Y
Endogeneity test corr(E.eqn, CM.eqn)	0.586***		0.623***		0.577***		0.729***	

7. Discussion and Conclusion

This paper provides a robust estimation of the effect of education on the choice of cooking method, especially the use of UBCT in Nigeria. In order to obtain consistent estimates, we exploit the exogenous gap in the years of women's education created by the Universal Primary Education program introduced in 1996. Combining data from the four waves of DHS and controlling for endogeneity, the results show that women with higher levels of education have a lower probability to use UBCT as their primary source of cooking. This result therefore shows that in addition to household income identified in the previous literature (Alem et al, 2016; Arthur et al. 2011; Bansal et al. 2013; Nlom and Karimov 2014), individual characteristics such as education are also important predictors of women's adoption of clean energy. This implies that environmental policies in developing countries should not only focus on income transfers policies as suggested in the previous literature (Boute, 2009) but also focus on women's human capital as drivers of women's choice of cooking technologies. This result implies that investing in girls schooling is crucial to breaking the vicious cycle of dependence on traditional unsustainable cooking practices and social marginalization of women and girls.

More broadly, our findings echo the fact that adaptation strategies to anthropogenic climate change likely to succeed in SSA must be socially inclusive. In many SSA's rural communities, both women and men are highly dependent on biomass, such as wood, agricultural crops, wastes and forest resources for their energy and livelihoods, but women and girls remain disproportionately affected by climate change (UN, 2019). They are primarily responsible for collecting traditional fuels—a time-consuming and a physically draining chore—and cooking—a household chore that exposes them to indoor air pollution, with adverse consequences for their health. As a result, women and girls have limited opportunities for learning or acquiring productive and other skills, earning an income, engaging in politics or other public activities (UN Women Watch 2018). It is therefore clear that adaptation strategies that do not consider account for women's vulnerabilities and access to resources are less likely to succeed.

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Conflict of interest

All the authors claim that the manuscript is completely original. The authors also declare no conflict of interest.

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