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Adding fuel to human capital: Exploring the educational effects of cooking fuel choice from rural India

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ABSTRACT

The study examines the effect of household cooking fuel choice on educational outcomes of adolescent children in rural India. Using multiple large-scale nationally representative datasets, we observe household solid fuel usage to adversely impact school attendance, years of schooling and age-appropriate grade progression among children. This inference is robust to alternative ways of measuring educational outcomes, application of other datasets, specifications and estimation techniques. Importantly, the effect is found to be more pronounced for females in comparison to the males highlighting the gendered nature of the impact. On exploring possible pathways, we find that the direct time substitution on account of solid fuel collection and preparation can explain the detrimental educational outcomes that include learning outcomes as well, even though we are unable to reject the health channel. In the light of the micro and macro level vulnerabilities posed by the COVID-19 outbreak, the paper recommends interventions that have the potential to fasten the household energy transition towards clean fuel in the post-COVID world.

1. Introduction

A substantial proportion of households, especially across the Global South depends on solid fuel as a primary source of cooking fuel. The World Health Organization (WHO) in 2018 estimates about three million people not having access to clean fuel for household usage, emphasizing the need for a faster energy transition.[1] Literature has indicated attributes like wealth, income, fuel price, education, gender and preferences to be among the major determinants of household fuel choice (Behera et al., 2017; Muller and Yan, 2018; Rahut et al., 2020). Despite major gains in its adoption across the developing countries, the onset of the COVID-19 pandemic is likely to push households who had transitioned to clean fuel back to the usage of non-cleaner options because of reasons that include significant income reduction, job loss and cut in subsidy among others (Zhang and Li, 2021).[2] The reliance on solid fuel for cooking is related to negative externalities on the environment and health across developing countries. Accordingly, the Sustainable Development Goals (SDG) have recognized its importance and added “ensure universal access to affordable, reliable and modern energy services” as one of its goals to be achieved by 2030.

Literature has extensively established significant health benefits of using cleaner fuel for cooking purposes among household members. This paper adds and complements the existing evidence on the welfare effects of cooking fuel choice on an important albeit less explored dimension that is the human capital investments through education among adolescent children from rural India. Additionally, we also explore the extent to which these effects are gendered and the associated mechanism.

Cooking fuel choice and education may be linked in multiple ways and also depends on the context. In India, the majority of the households not using cleaner fuel depend on firewood or other natural resources that include cow dung or crop residues for cooking. Accordingly, a significant amount of time gets allocated for the collection of these resources. Studies have indicated that school-going children can potentially substitute their school time with activities involving the collection of these resources, which in turn can affect their school performance as well (Ndiritu and Nyangena, 2011; Levison et al., 2018). As resources get scarcer, the demand for these “environmental chores” increases, and

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[1] https://apps.who.int/iris/bitstream/handle/10665/274280/9789241513999-eng.pdf (accessed on May 31, 2021).
[2] https://www.eco-business.com/news/delhis-poor-return-to-dirty-fuel-in-covid-19-lockdown/ (accessed on May 12, 2021).

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as a result, parents may trade-off investment in human capital with higher labor requirements from the children. Extant literature has indicated a strong association of resource collection on school attendance and years of education in different contexts (Nankhuni and Findeis, 2004; Ndiritu and Nyangena, 2011; Levison et al., 2018). Importantly if these activities are placed alongside domestic responsibilities, the educational effects are likely to be gendered. This is because of a disproportionately higher time spent on collecting fuelwood by females, which is driven by the traditional division of labor and expected household roles (Nankhuni and Findeis, 2004; Choudhuri and Desai, 2021). In addition, it is also possible that the adverse health effects of solid fuel may affect schooling and academic performance of children. In this paper, apart from exploring the educational impact of solid fuel usage, we also assess the significance of these channels in driving our results.

Studying the implication of cooking fuel choice on educational outcomes in rural India is particularly important for multiple reasons. Firstly, India has among the largest population who are dependent on solid fuel for cooking purposes, many of whom are located in rural areas. Data from the Census of India, 2011 shows about 62.5 of rural households are dependent on firewood for cooking, followed by more than 12% who depend on crop residue. This has contributed to a higher concentration of household pollutants and has been recognized as one of the most important risk factors responsible for mortality and morbidity in India (WHO, 2018). Field experiment suggests that improvement in economic wellbeing is related to an increase in the energy consumption of poor households according to the energy ladder theory but does not necessarily shift the preferences towards clean cooking fuel (Hanna and Oliva, 2015). To accelerate the transition from dirty to clean fuel, the Pradhan Mantri Ujjwala Yojana (PMUY) that promised subsidized Liquefied Petroleum Gas (LPG) to poor households was implemented by the Government of India in 2016. Studies have found that the programme has been successful initially in the energy transition. However, they also found evidence in favor of fuel stacking and raised questions with respect to the extent and regular usage of LPG, with many households resorting to traditional fuel because of easy access, lower price, difficulties in refilling cylinders and lack of awareness (Kar et al., 2019; Swain and Mishra, 2020). Secondly, with respect to educational outcomes, while significant progress has been made in the attainment of primary education, completion of lower and higher secondary education remains elusive. In 2016–17, the gross enrolment ratio at the lower secondary level was found to be around 78.5%, while it was about 52% at the senior secondary level (Tilak, 2020). The same study also documents high dropout among children in secondary and higher secondary grades, which is more pronounced for females. Additionally, despite completion of eight years of schooling, a significant proportion is found to be unable to read a basic text and perform simple 3 by 1 division (World Bank, 2018; Government of India, 2019).

This paper uses multiple nationally representative datasets to assess the implication of cooking fuel choice and time allocation to free collection of firewood and other natural resources on educational outcomes. Firstly, to estimate the effects on school attendance and years of education, we use the fourth round of the National Family Health Survey (NFHS-4) conducted in 2015–16, which collects household data on cooking fuel use and education along with a host of socio-economic characteristics. To address the concerns revolving around unobservable confounders because of selection bias, we utilize exogenous variation in local forest cover in the lagged period that can be assumed to be highly correlated with cooking fuel choice but not directly related to educational outcomes. For this purpose, we use data from the Socio-economic High-resolution Rural-Urban Geographic Dataset (SHRUG) that records yearly forest cover using a vegetation continuous field, a Moderate Resolution Imaging Spectroradiometer (MODIS) product. For examining the implications of time allocation for resource collection linked with households using solid fuel for cooking, we use the Time-Use Survey (TUS) data collected in 2019. Further, we gauge the potential impact on learning outcomes using the Annual Status of Education Report (ASER) survey data conducted in 2016 among children.

We find significantly adverse educational effects of solid fuel use on adolescent children measured in terms of their likelihood of attending school, years of education and age-appropriate grade attainment. The results are found to be robust despite accounting for the potential unobservable confounders that we ensure through the usage of exogenous variation in past forest cover as instrumental variable (IV). Importantly, our causal inference stand even when we change the IV, the age cohorts considered or definition of solid fuel along with alternate estimations that allow for the IV to be "plausibly exogenous". Additionally, we observe that these educational effects are likely to be more adverse for females. On exploring the potential channels, we find time spent on schooling and homework to be significantly lesser among children who allocate more time for the collection of firewood. Notably, the substitution effects are disproportionately higher for females implying that household cooking fuel choice is likely to affect them more not only with respect to time spent in school but also that allocated for doing homework. If this is the case, it is possible that the learning outcomes would also be adverse. This is exactly what is observe as we find children from districts with a higher proportion of households using solid fuel to score worse, and these ill effects are again systematically higher for females. Notably, among the children considered, we observe that the female disadvantage is less prominent among younger children while the gender gap is higher for older children.

The paper has multiple contributions. Firstly, to our knowledge, this is among the first few papers to present robust empirical evidence of how cooking fuel choice is linked to educational outcomes. Despite previous studies documenting the impact of fuel poverty on education and children's wellbeing (Churchill et al., 2020; Choudhuri and Desai, 2021; Zhang et al., 2021), this paper estimates the educational effects on adolescent children and studies how these effects are gendered with age. Additionally, it provides evidence of direct substitution effects of time allocation for fuel resource collection. Secondly, the paper goes beyond the common determinants of educational outcomes that include individual, household and school level factors among others, and gives evidence on the adverse effects that may arise because of cooking fuel choice. Third, the paper complements the expanding literature that outlines the direct and indirect effects of solid fuel usage. Apart from the ill effects of solid fuel choice on the environment and health, it argues that dirty fuels may lead to detrimental human capital outcomes for children, which in turn may perpetuate intergenerational poverty. Additionally, because the educational effects are disproportionately higher for females, one can also link longer-term adverse effects that include lower age at marriage, female empowerment and labor participation among others, with solid fuel usage. Accordingly, the paper underscores the importance of implementing robust policies that incentivize households to switch from solid fuels to cleaner options.

The remainder of the paper is structured as follows. Section 2 discusses the background literature along with the relevance of our study. Sections 3 and 4 present the data and the empirical strategy, respectively. Section 5 presents the main results and associated robustness tests. Section 6 explores the possible explanations for the observed effects. Section 7 presents a discussion related to the economic impacts of the results, the importance of the findings in the light of the ongoing coronavirus pandemic and other policy implications. Finally, section 8 summarizes the finding and concludes the study.

2. Literature review and relevance of the study

Literature has indicated significant detrimental effects on health outcomes, especially among children who are exposed to household air pollution caused by solid fuel use. For instance, Edwards and Langpap (2012) use survey data from Guatemala and found a higher incidence of respiratory infection among children from households using firewood. Similarly, studies using Indian data found that household air pollution linked to fuel usage is associated with low birth weight, higher neonatal deaths and mortality among children under the age of five years. Other studies have shown evidence of an increased likelihood of health issues that include breathing problems, ophthalmic issues and blood pressure, among others, which are associated with higher household air pollution (Jagger and Shively, 2014; Arku et al., 2018; James et al., 2020). Further, the ability to cope with daily activities among the elderly reduces significantly in households owing to indoor air pollution (Liu et al., 2020).

Several studies have looked into the effect of fuel poverty on other welfare outcomes. For example, Churchill et al. (2020) use longitudinal data from Australia to find that fuel poverty is associated with a significant reduction in subjective wellbeing. A recent study by Nie et al. (2021) also finds that energy poverty reduces life satisfaction in China, which is more pronounced among males and the poor. Among children, energy poverty is found to be associated with their wellbeing, where academic performance is the important channel (Zhang et al., 2021). In another study, Mayer and Smith (2019) utilize data from 22 countries to argue that being worried about energy security reduces the chance of reporting "very good" self-rated health.

A recent study by Choudhuri and Desai (2021) has found adverse educational outcomes among rural Indian children from households that depend on the free collection of water and cooking fuel. It focuses on young children in the age cohort 8 to 14 years and looks at cognitive abilities for 8 to 11 years old children. Interestingly, they also document lower mathematical scores among boys because of higher psychosocial fragility due to a lack of motherly supervision. This childhood disadvantage may then result in further worsening of outcomes among adolescent males. Our study complements this study by examining the effect of fuel choice on adolescent children in the age cohort 12 to 18 years rather than focusing on children studying in the primary and upper-primary levels. As mentioned, because higher school dropout among children in India happens at the secondary and higher secondary levels, we argue the implications of cooking fuel choice can potentially be more pronounced for children in the 12–18 age group relevant for this educational level. More importantly, if the effect of education on job opportunities is non-linear in nature, educating children till primary level may not fetch superior labor market outcomes as against completing secondary or higher secondary education. With respect to time allocation for firewood and other natural resource collection, primary school-going children would be dependent on older family members who may substitute their time away from childcare, thus indirectly leading to deteriorated educational outcomes. In contrast, adolescent children are more likely to allocate this time themselves, directly impacting educational outcomes. Because women typically bear a greater burden of household chores that include fuel resource collection, it may result in disproportionately higher crowding out of schooling for females leading to worse outcomes among them. In terms of policy implications, our paper assumes significance as studies have found a direct causal link of higher educational outcomes among adolescent females on labor market opportunities apart from improving relative bargaining power, which can lead to an increase in age at marriage, higher autonomy in fertility decisions and agency among others (Field and Ambrus, 2008; Asadullah and Wahhaj, 2019).

3. Data

We employ the NFHS-4 conducted during January 2015 and December 2016 by the Ministry of Health and Family Welfare, Government of India, to analyze the effect of fuel type on educational outcomes.[3] The survey gathered information on 601,509 households across 640 districts and is one of the largest household surveys in India that is representative at the national, state and district level. The survey provides information related to cooking fuel type, educational attainment of individuals residing in the household, school attendance, age along with other characteristics like economic status, religious and caste affiliation of the households. Our estimation sample consists of 280,997 children in the age group of 12 to 18 years residing in rural India.

The forest cover data is obtained from the SHRUG India platform, which is an open dataset providing high resolution data on forest cover, night lights, employment and political outcomes among others at the village/ town level (Asher et al., 2021). The forest cover data starting from 2000 to 2019 is aggregated from Vegetation Continuous Fields at 250 m resolution using georeferenced location polygons generated from machine learning models.[4] The SHRUG database has been used by several studies ranging from the effect of road construction to the influence of political leaders on economic outcomes (Asher and Novosad, 2017; Lehne et al., 2018; Adukia et al., 2020).

Further, we use the TUS conducted in 2019 by the National Sample Survey Organization of India. The survey collects information about the time allocation of different activities undertaken by the members of the sampled households on the day prior to the survey. It gathers data from 518,751 individuals residing in 138,805 households and is representative at the national as well as at the state level.[5] This survey data in our paper is primarily used to examine the time substitution effects from schooling to that allocated for firewood and other natural resource collection in households using solid fuel for cooking purposes. For our analysis, we consider the sample of 37,220 rural children in the age cohort 12 to 18 years from this dataset.

To examine the implications of cooking fuel choice on learning outcomes, we employ household survey data from the ASER for the year 2016.[6] We particularly use the 2016 household survey data as we use it together with NFHS 4 data, which was also conducted in 2015–16. The survey is conducted to analyze the enrollment status as well as the basic learning levels among children from rural India and is representative at the district level. The survey covered about 17,473 villages across 589 rural districts and collected data from 350,232 households. Using well tested rigorous tools, the ASER survey collects information on basic mathematics and reading proficiency levels from all children in the age group 5 and 16 years, who are residing in the sampled households.[7] These outcomes have been used extensively by other studies (Chakraborty and Jayaraman, 2019; Lahoti and Sahoo, 2020). From this dataset, we utilize a sample of 197,178 rural children in the age group 12 to 16 years. The description of the variables used in the study is provided in Table 1.

4. Estimation strategy

We estimate the following equation to explore the educational effects of solid fuel usage:

$$Y_{is} = \alpha + \beta SF_{is} + \rho X_{is} + \mu_s + u_{is} \tag{1}$$

Here Y_{is} is the educational outcome for the child, i residing in the state, s. These outcomes include years of education and age-appropriate grade completion, among others, as defined in Table 1. SF_{is} is a binary variable that takes the value of 1 if the corresponding household of the

[3] More details about the survey is given in https://dhsprogram.com/data/dataset/India_Standard-DHS_2015.cfm?flag=1 (accessed on November 16, 2021).

[4] This data is retrieved from Dimiceli, C., Carroll, M., Sohlberg, R., Kim., D., Kelly, M., & Townshend, J. (2015). MOD44B MODIS/Terra Vegetation Continuous Fields Yearly L3 Global 250 m SIN Grid V006 [Data Set]. *NASA EOSDIS Land Process*.

[5] For more information on TUS, please refer http://mospi.nic.in/sites/default/files/README_TUS106.pdf (accessed on November 16, 2021).

[6] For more information, refer img.asercentre.org/docs/Publications/ASER Reports/ASER 2016/aser_2016.pdf (accessed on May 25, 2021).

[7] These tools can be accessed from http://www.asercentre.org/p/141.html (accessed on May 24, 2021).

Table 1
Variable definitions.

Variable	Description
NFHS-4 (2015–16)	
Outcome variables	
School attendance	Dummy variable = 1 for children who attended school during the survey year and 0 for others
Years of schooling	Standardized years of schooling
Grade progression	Ratio of actual years of schooling and expected years of schooling given age. Expected years of schooling = Current age- 6 years
Primary	Dummy variable = 1 for individuals who have completed at least 5 years of schooling and 0 for others
Secondary	Dummy variable = 1 for individuals who have at least 10 years of schooling and 0 for others
Interest variable	
Solid fuel	Dummy = 1 for households using firewood, animal dung, agricultural crop, straw/shrub/grass, coal/lignite or charcoal as cooking fuel and 0 if cooking fuel used is LPG, electricity, biogas or kerosene
Dirty fuel	Dummy = 1 for households using firewood, animal residue, crops or kerosene as cooking fuel and 0 if cooking fuel is LPG, electricity or biogas
District level solid fuel usage	Proportion of households using firewood, animal dung, agricultural crop, straw/shrub/grass, coal/lignite or charcoal as cooking fuel in the district
Instrumental variable	
Average forest cover	Average share of forest in the district 6 years before the survey year (2009 if survey year is 2015 and 2010 if survey year is 2016).
Other controls	
Age	Age of the child in years
Female	Dummy = 1 for girls and 0 for boys
Primary completed adults	Number of household members above 18 who have completed primary education
Household size	Number of household members
BPL card	Dummy = 1 if the household has a BPL card and 0 otherwise
Toilet	Dummy = 1 if the household has toilet facility in within premises and 0 otherwise
Water in home/ yard	Dummy = 1 if the household has access to piped drinking water in the house or yard and 0 otherwise
Mobile	Dummy = 1 if any member in the household owns a mobile and 0 otherwise
Religion	Categorical variable identifying the religious affiliation of the individual as Hindu, Muslim, Others
Upper caste	Dummy = 1 if the household does not belong to Scheduled castes, Scheduled Tribe or Other Backward caste and 0 otherwise
TUS (2019)	
Outcome variables	
Total school time (standardized)	Time allocated in hours (standardized) for School/ university attendance, Extra-curricular activities, breaks at place of formal education, self-study for distance education course work, other activities related to formal education
Total homework time (standardized)	Time allocated in hours (standardized) for homework, being tutored, course review, research and activities related to formal education
Interest variable	
Total fuel collection time	Time allocated in hours for Gathering firewood and other natural products used as fuel for own final use
Solid fuel usage	Dummy = 1 for households using firewood and chips, dung cake, coke or coal, or charcoal as primary source of energy for cooking during last 30 days preceding the date of survey and 0 if cooking fuel used is LPG, other natural gas, electricity, gobar gas, other biogas, kerosene or other sources.
Instrumental variable	
Average forest cover	Average share of forest in the district 6 years before the survey year (2013).
Other controls	
Age	Age of the child in years
Female	Dummy = 1 for girls and 0 for boys
Primary completed adults	Number of household members above 18 who have completed primary education
Household size	Number of household members
Household consumption expenditure	Usual monthly consumer expenditure (in Indian rupees- INR) for the household
Religion	Categorical variable identifying the religious affiliation of the individual as Hindu, Muslim, Others
Upper caste	Dummy = 1 if the household does not belong to Scheduled castes, Scheduled Tribe or Other Backward caste and 0 otherwise
ASER (2016)	
Outcome variables	
Reading scores (standardized)	Reading scores are as follows: 1: Unable to read; 2: Can identify letters; 3: can read a word; 4: can read a paragraph; 5: can read a story
Mathematics scores (standardized)	Mathematics scores are as follows: 1: Unable to do any math; 2: Can identify numbers 1–9; 3: can identify numbers 10–99; 4: can do a subtraction; 5: can do a division.
Controls	
Age	Age of the child in years
Female	Dummy = 1 for girls and 0 for boys
Cemented house	Dummy = 1 for cemented households (with walls and roofs made of brick and cement; 0 otherwise
Household toilet	Dummy = 1 if there is a toilet in the household; 0 otherwise
Television	Dummy = 1 if there is a television in the household; 0 otherwise
Computer usage	Dummy = 1 if anyone in the household knows how to use computers and 0 otherwise
Mobile	Dummy = 1 if anyone in the household has a mobile phone; 0 otherwise
Household size	Number of household members
Mother went to school	Dummy = 1 if the mother ever attended school; 0 otherwise

child, i uses solid fuel for cooking purposes and 0 otherwise. To gauge the educational impact of solid fuel usage, we are interested in the estimation of β. X_{is} is the set of individual and household level characteristics that can be hypothesized to determine educational outcomes as given in Table 1. μ_s is the vector of state level fixed effects that accounts for the state heterogeneities like differential state policies on education, female autonomy, or rural development, among others. u_{is} is the error term in the model.

As one may argue, direct Ordinary Least Squares (OLS) estimation may lead to biased estimates because unobserved factors may confound the causal estimates. It is possible that households located in areas with poorer administrative efficiency would have lower schooling owing to a greater distance to school and also have lower access to clean fuel. Further, households with higher bargaining power among women may be more likely to adopt clean fuel and simultaneously invest in higher human capital for children. To address these endogeneity concerns, we use exogenous variation in average forest cover at the district level that can be hypothesized to be correlated with solid fuel usage but not related to children's educational outcomes through channels other than solid fuel usage. Higher forest cover in the vicinity ensures better and easy access to firewood and may discourage households from adopting cleaner fuel (Bhatt and Sachan, 2004; Tembo et al., 2015). Accordingly, we argue that households situated in districts with higher forest cover are more likely to use firewood for cooking purposes. Of note is that firewood is the most popular choice of cooking fuel among households using the non-cleaner options. The NFHS-4 conducted in 2015–16 indicates 78% of rural households who use solid fuel are dependent on firewood.[8] This shows how overwhelmingly firewood dominates the cooking fuel space among households not using cleaner options, and hence average forest cover is likely to be strongly linked with its usage.

However, educational outcomes are unlikely to be related to forest cover once we account for other possible channels. One can still argue

[8] This is unweighted figure from the survey.

that households self-select and reside in locations with higher forest cover owing to unobservable factors, and these unobservables also influence educational outcomes. Notably, studies have indicated that spatial mobility is low in India because of which residential relocation should not be a major cause of concern in our case (Munshi and Rosenzweig, 2016; Roychowdhury, 2019). Nevertheless, we still allow for the possibility of the IV not meeting this exclusion criterion through the estimation strategy developed by Conley et al. (2012), which assumes the IVto be "plausibly" but not fully exogenous. This has been detailed out in section 5.3.2. Additionally, we also use Propensity Score Matching (PSM) with Rosenbaum bounds (section 5.3.3) to ensure that the estimates are not confounded by unobservables and hence are unbiased.

5. Results

5.1. Descriptive statistics

Table 2 presents the summary statistics for the selected variables for the entire sample and for solid and non-solid fuel users. Notably, the educational outcomes for solid fuel users are poorer than non-solid fuel users, and this difference is statistically significant at a 1% level. Further, the solid fuel users have a larger household size, fewer adult household members with completed primary schooling, and are less likely to have access to piped drinking water or toilet facility at home than non-solid fuel users. As one would expect, these households are also less likely to own mobile and are poorer, as indicated by the share of households owning a Below Poverty Line (BPL) card.

Fig. 1 presents the distribution of years of education for the 12 to 18 years old children based on the type of cooking fuel. Visual inspection suggests that the average years of schooling are higher for children from non-solid fuel user households in comparison to those belonging to solid-fuel user households. Given that other confounders may drive this difference between the groups, we further explore using a regression framework.

5.2. Main results

Table 3 presents the baseline association between solid fuel and educational outcomes. As mentioned, we use three primary outcomes: school attendance, years of schooling, and age-appropriate grade progression, and regression estimations of these three indicators are given in columns 1 to 3, respectively. The findings reveal that the usage of solid fuel is related to a lower likelihood of attending school (Column 1), lesser years of schooling on average (column 2), and also lower average grade progression (column 3). Therefore, the preliminary analysis suggests a negative and statistically significant relationship between solid fuel use and the educational outcomes among children in India.

As acknowledged earlier, the solid fuel variable can be endogenous because of self-selection bias wherein households who use solid fuel can also have lower human capital investment for reasons other than those related to cooking fuel. Accordingly, endogeneity corrected 2SLS estimation is used to obtain the causal inference. Columns 4–6 presents the corresponding results for the three outcome variables using average forest cover six years before the survey year at the district level as an IV. Specifically, we find that usage of solid fuel leads to a reduction in the likelihood of attending school by 18.2 percentage points for the rural children in the age-cohort 12 to 18 years (column 4).[9] Further, solid fuel is also found to be associated with 1.01 standard deviations lower years of schooling for these adolescent children on average, which is found to be statistically significant at 1% level (column 5). Complementary to these findings, we observe a 0.31 slower grade progression of children from solid fuel using households compared to non-solid fuel users (Column 6), ceteris paribus. These results indicate a discernible educational loss among rural adolescent children because of cooking fuel choice. Notably, the first stage regression suggests a positive and significant relationship between average forest cover and solid fuel use. The first stage F-statistic is much higher than the commonly accepted threshold of 10 in all the specifications, suggesting that the IV is not weak. Because we find the marginal effects from the OLS regression to be much smaller than those from the 2SLS regression, the naïve OLS estimates without accounting for the endogeneity bias could have possibly underestimated the adverse educational effects of solid fuel use.

The results for the covariates are in line with the existing literature and holds for rural households in India (Drèze and Kingdon, 2001; Tilak, 2020).[10] Girls are found to be less likely to attend school and have lower years of schooling. As one would expect, the household educational outcome is positively related to the child's educational outcomes. Larger family size is associated significantly with low educational attainment and this is also true for Muslim children. The children from upper caste households and households possessing mobile phones have significantly better educational outcomes on average.

5.3. Robustness checks

We perform a battery of robustness checks to ensure that our results capture the negative effect of solid fuel use on educational attainment and are not confounded by other factors that we are unable to capture.

5.3.1. Time use survey

The TUS survey allows us to study the implications of solid fuel usage on time allocated to formal education by the children. Apart from that being an additional indicator of educational outcome, this survey, conducted in 2019 enables us to revisit the relationship using more recently gathered household data. Accordingly, we use time allocation to schooling (in standardized form) as outcome variable and estimate the OLS along with the 2SLS regression with average forest cover six years back (year: 2013) as the IV. The control scheme is kept similar to that used for earlier regressions, with the only difference being the introduction of household monthly consumption expenditure instead of possession of BPL card. Information on BPL card possession is not collected in the TUS dataset, and hence we add consumption expenditure as the latter is a well-accepted indicator of household economic conditions (Deaton, 2005). Findings from the regression are presented in appendix table A3. We observe a robust adverse influence of household solid fuel usage on time spent in formal education.

5.3.2. Plausibly exogenous

One may argue that the IV we use does not satisfy the strict exogeneity condition, and the 2SLS estimation results are biased due to the violation of this assumption. In our context, for example, it is possible that districts with higher past average forest cover may systematically experience rapid deforestation and industrialization, which may potentially improve employment opportunities. This, in turn, may increase the opportunity cost of schooling among adolescent children. To avert these possibilities confounding our estimates, Conley et al. (2012) suggest ways to draw causal inference when the IV is only 'plausibly exogenous'. In this framework, we consider the equation below:

$$Y_i = \beta SF_i + \gamma Z_i + \varnothing X_i + \varepsilon_i \tag{2}$$

Where Y_i are the three educational outcome variables for child, *i*. SF_i refers to the endogenous solid fuel variable, Z_i is the IV (past average forest cover) and X_i is the vector of controls. The main results discussed in section 5.2 assume that γ=0. If the parameter γ is close to zero, but not necessarily zero, the IV can still be 'plausibly exogenous' and it is

[9] The reported effect is an approximation of the true effect as it is based on LPM models in both first and second stages. The IV probit estimates are also presented in appendix table A1.

[10] The regression results for all the covariates are given in appendix table A2.

Table 2
Summary statistics.

	All households	Non-solid fuel users (a)	Observations	Solid fuel users (b)	Observations	Mean difference (a-b)
School attendance (share)	0.777	0.892	51,563	0.752	242,684	0.140***
Years of schooling (in years)	7.382	0.939	51,511	0.815	242,386	0.123***
Grade progression (ratio)	0.837	8.387	51,511	7.165	242,386	1.222***
Age (in years)	14.921	14.994	51,569	14.905	242,731	0.089***
Female (share)	0.487	0.478	51,569	0.489	242,731	−0.011***
Primary completed adults	1.527	2.111	51,569	1.403	242,731	0.708***
Household size	6.165	5.655	51,569	6.273	242,731	−0.619***
BPL (share)	0.472	0.323	51,431	0.503	242,444	−0.180***
Upper caste (share)	0.17	0.271	48,064	0.149	232,897	0.122***
Toilet (share)	0.467	0.804	51,569	0.395	242,731	0.409***
Water in yard (share)	0.186	0.367	51,569	0.147	242,731	0.219***
Mobile (share)	0.914	0.982	51,569	0.899	242,731	0.083***
Hindu	0.751	0.681	51,519	0.766	242,585	−0.085***
Muslim	0.131	0.154	51,519	0.126	242,585	0.028***
Others	0.118	0.166	51,519	0.108	242,585	0.057***

Note: Standard *t*-test is used to compare the difference in group means. *indicates significance at 1% level. The sample is rural children from 12 to 18 years of age.

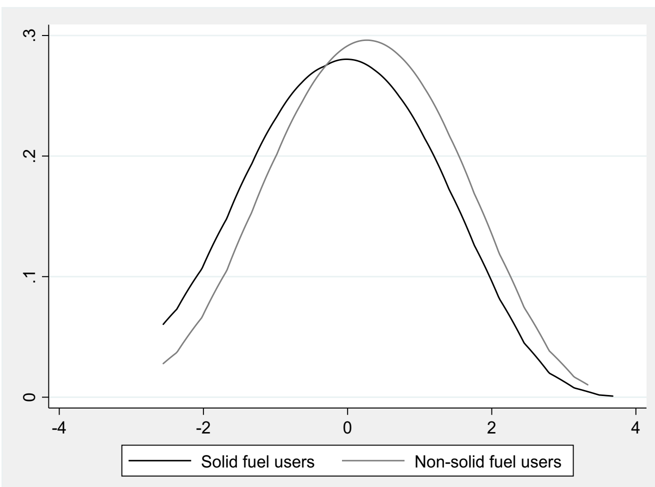


Fig. 1. Schooling for solid and non-solid fuel users.
Note: Figure presents the kernel density of years of education (standardized) of rural children from 12 to 18 years of age from solid fuel and non-solid fuel user households.

possible to consistently estimate the effect of the endogenous variable on the outcome variable for certain values of γ. Extant literature has used this in different contexts (McArthur and McCord, 2017; Azar et al., 2020; Das, 2021). Following Azar et al. (2020), we estimate the reduced form equation of educational outcomes on the IV and other control variables, but excluding the endogenous solid fuel variable and obtain the lower bound for $\hat{\gamma}$ (Table 4). Using values of γ in the range of $\hat{\gamma}$ to zero, we obtain the bounds for the effect of solid fuel in the second stage. Further, we also report the maximum value of γ (γ_{max}) for which the estimated bound for β is strictly less than zero. Our estimated γ_{max} values indicate that solid fuel usage will have adverse effects on the educational outcomes, even if the direct effect of the IV is up to 36%–75% of the reduced form effect. The results we obtain are robust to a greater degree of the IV exogeneity assumption relaxation for standardized years of schooling and grade progression variables and to a lesser extent for school attendance.

5.3.3. *Propensity score matching (PSM)*

As an additional robustness check, we employ PSM to compare the difference in the educational outcomes of children between solid and non-solid fuel users. PSM can be employed to address endogeneity and draw causal inferences using observational data in a non-experimental setup (Dehejia and Wahba, 2002). Importantly, the existing literature examining the effects of cooking fuel/ energy poverty on welfare outcomes has extensively used PSM either as the main econometric method to decipher the effects or as a part of robustness exercise (Churchill et al., 2020; Liu et al., 2020). The treatment here is solid fuel use, and the matching is performed using a set of observed covariates. We consider the nearest neighbor matching method as proposed by Rosenbaum and Rubin (1985) with a caliper of 0.01 and obtain the average treatment effect on the treated. Table 5 suggests that post-matching, the likelihood of attending school, average educational attainment, and age-appropriate grade progression among children from solid fuel user households are lower than those from the non-solid fuel users at 1%

Table 3
Effect of solid fuel on educational outcomes.

	Probit	OLS		IV		
	School attendance	Years of schooling	Grade progression	School attendance	Years of schooling	Grade progression
	(1)	(2)	(3)	(4)	(5)	(6)
Solid fuel	−0.060***	−0.066***	−0.019***	−0.182***	−1.011***	−0.311***
	(0.002)	(0.004)	(0.001)	(0.061)	(0.142)	(0.045)
Other controls	Y	Y	Y	Y	Y	Y
State FE	Y	Y	Y	Y	Y	Y
Month of survey FE	Y	Y	Y	Y	Y	Y
First stage F-stat				253.250	253.250	253.250
Observations	280,339	280,011	280,011	280,339	280,011	280,011
R-squared		0.346	0.206	0.187	0.247	0.092

Note: The regression coefficients are the average marginal effects. All regressions control for the covariates including sex of the child, current age, number of primary completed adults, household size, BPL card, toilet, water in yard, mobile, upper caste, religion, month of survey and state fixed effects. The IV is the average share of forest in the district 6 years before the survey year (2009 if survey year is 2015 and 2010 if survey year is 2016). The sample is rural children from 12 to 18 years of age. Regression output is based on robust standard errors. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 4
Plausibly exogenous instrumental variable regressions.

	School attendance	Years of schooling	Grade progression
	(1)	(2)	(3)
$\hat{\gamma}$	−0.042***	−0.235***	−0.072***
	(0.014)	(0.030)	(0.010)
Controls	Y	Y	Y
State FE	Y	Y	Y
Month of survey FE	Y	Y	Y
Observations	280,375	280,047	280,047
R-squared	0.200	0.345	0.256
$\hat{\beta}$ (UB)	0.115	0.246	0.076
$\hat{\beta}$ (LB)	−0.301	−1.289	−0.389
γ_{max}	−0.015	−0.177	−0.054

Note: All regressions control for the covariates including sex of the child, current age, number of primary completed adults, household size, BPL card, toilet, water in yard, mobile, upper caste, religion, month of survey and state fixed effects. The IV is the average share of forest in the district 6 years before the survey year (2009 if survey year is 2015 and 2010 if survey year is 2016). The sample is rural children from 12 to 18 years of age. Regression output is based on robust standard errors. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5
Propensity score matching.

	Treated	Control	Difference	T-statistic	Rosenbaum bounds
	(1)	(2)	(3)	(4)	(5)
School attendance	0.753	0.809	−0.056	−9.23***	1.38–1.39
Years of schooling	−0.071	0.082	−0.153	−9.36***	1.28–1.29
Grade progression	0.816	0.859	−0.043	−10.44***	1.29–1.30

Note: Matching is performed after controlling for covariates including sex of the child, current age, number of primary completed adults, household size, BPL card, toilet, water in yard, mobile, upper caste, religion, districts, month of survey and state fixed effects. The sample is rural children from 12 to 18 years of age.

level of significance. This corroborates our findings from the 2SLS estimation method that we presented.

One of the key drawbacks of the PSM method is it accounts for endogeneity only due to observed covariates, while omitted variables that affect both solid fuel adoption and educational attainment may still confound the estimates. Accordingly, we report the Rosenbaum bounds indicating that the PSM results are robust in the presence of hidden bias up to a threshold. Rosenbaum (2002) developed an approach to assess the effect of bias on test statistic if the treatment assignment is not random owing to unobservable factors using a non-parametric Wilcoxon signed-rank test. Column 4 indicates that the Rosenbaum bounds are in the range of 1.28–1.39 for the various outcome variables.[11] Specifically, it suggests that hidden bias up to 28–39% will still yield a significant difference in educational outcomes among solid and non-solid fuel users.

5.3.4. Additional sensitivity analysis

Next, instead of district level forest cover six years before the survey, we consider the five-year pre-survey forest cover as IV. This alternate IVyields qualitatively similar results in the 2SLS regression (columns 1–3, appendix table A4). The results are also robust if we consider 11 to 18 as adolescent children, respectively, and re-estimate equation 1 (columns 4–6). Finally, we reclassify kerosene as a source of dirty fuel and re-estimate the 2SLS regression. This is because studies indicate that kerosene is less polluting than other solid fuels like coal or firewood but is not as clean as modern fuels like LPG or electricity (Smith et al., 2000; Thoday et al., 2018). The findings from all these regressions indicate a robust and significant but negative effect of dirty fuel use on educational outcomes of adolescent children (columns 7–9).

6. Mechanisms and further analysis

6.1. Is there a gendered effect?

Our regression results establish an educational loss for an average adolescent child that is linked with the household cooking fuel choice. However, are these effects similar for boys and girls? Who among the children is more likely to be disproportionately affected due to solid fuel usage? We explore these questions by examining the impact separately for the females and males in our sample. Fig. 2 presents the 2SLS IV regression results for children of the same age cohort (12 to 18 years). The marginal effects associated with the solid fuel variable are negative and significant at a 5% level for both females and males in all the specifications; however, the results are most striking for years of schooling and grade progression variables with a discernible disadvantage for the females. These systematically higher adverse effects observed for females indicate a definite gendered pattern in fuel type and education relationship among children in India.

6.2. Time substitution

If female education suffers disproportionately in comparison to the males because of household cooking fuel choice, one key channel can be through time substitution of that allocated to educational activities. Literature has pointed out that activities, including collecting firewood and processing dung cakes for cooking and other household use, are common in rural India (Hirway and Jose, 2011; Choudhuri and Desai, 2021). Since women are mainly responsible for these activities, it is possible that the allocation of time on educational activities gets substituted more for females, systematically affecting their schooling outcomes relative to the males. This has been discussed extensively in the developing country context, including India (Nankhuni and Findeis, 2004; Ndiritu and Nyangena, 2011).

The TUS data allows us to examine these effects for children aged 12 to 18 years. Here we consider the time spent in school and that for doing homework as the outcome variables, with total time allocated for firewood and other natural resource collection as the primary variable of interest. To ensure we can get close to the unbiased causal estimates of time allocation to fuel resource collection on the mentioned outcomes, we use three specifications to control for all possible confounders. In the first specification, we include the complete set of control variables as indicated earlier. In the second one, we include time allocated for the collection of fuel resources by others in the household. This would account for the indirect effects, if any, on children's schooling that may emanate because of time substitution away from child care due to firewood and other cooking resource collection by other members of the household (Choudhuri and Desai, 2021). Further, because of this, it is possible that the adolescent children then have to substitute time away from school for domestic chores that include caring for the elderly and the kids. Consequently, in the third specification, we control for time allocation for caring activities by the corresponding child. Please note that only rural children in the age cohort 12 to 18 years from households using solid fuel are considered since the free collection of firewood and other natural resources would only be relevant for households using solid fuel and not for those using the cleaner options.

We first analyze the marginal effects from regressions using the male sample, following it up with the female sample, the results of which are given in appendix figs. A5 and A6, respectively. We observe a significant reduction in school and homework time as the time allocated for fuel

[11] Liu et al. (2020) find Rosenbaum bounds in a similar range.

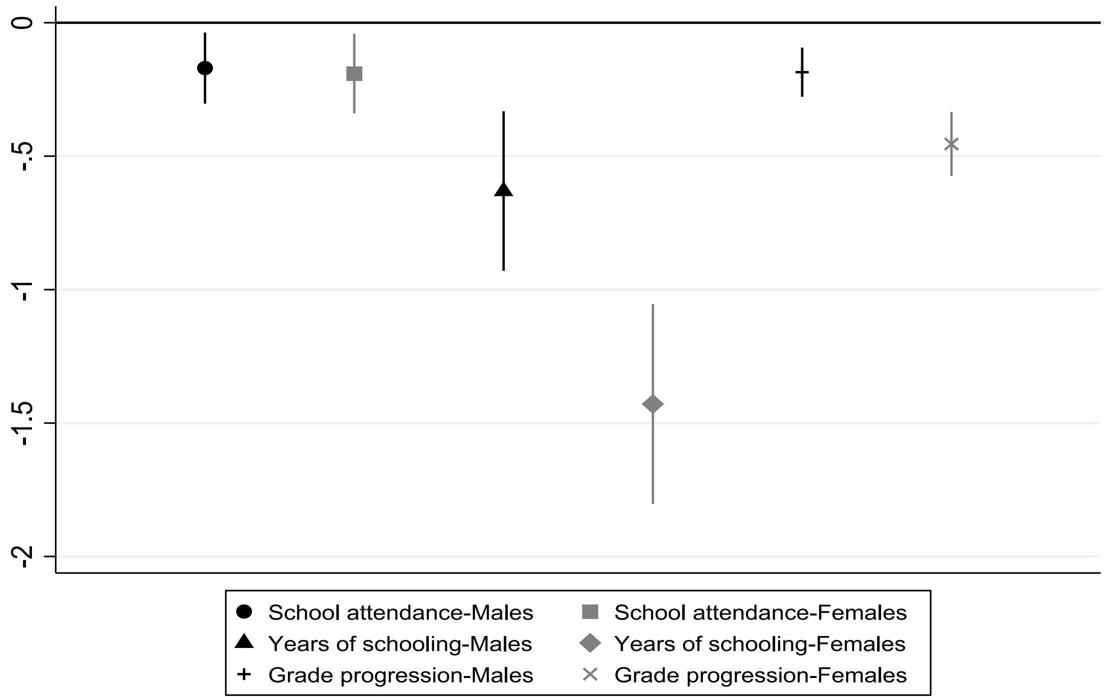


Fig. 2. Effect of solid fuel on educational outcomes – Males and females.
Note: The average marginal effects are plotted along with the 90% confidence intervals. All regressions control for the covariates including current age, number of primary completed adults, household size, BPL card, toilet, water in yard, mobile, upper caste, religion, month of survey and state fixed effects. The IV is the average share of forest in the district 6 years before the survey year (2009 if survey year is 2015 and 2010 if survey year is 2016). The sample is rural children from 12 to 18 years of age. Regression output is based on robust standard errors.

collection increases for males and females. Nevertheless, the effect size indicates that the females are likely to be more affected with the time substitution because of fuel collection. We check this through a regression of school and homework time on an interaction variable of the female dummy with the solid fuel dummy (Fig. 3). The negative and statistically significant association between the two indicates that female children are more likely to be systematically affected relative to male children. Importantly, this relationship remains intact across all three specifications with no discernible changes in the effect size.

6.3. *What about performance?*

If school and homework time get substituted because of higher time allocation for collecting firewood and other natural resources, learning outcomes or cognitive abilities among children are also likely to suffer. While NFHS-4 or TUS do not directly collect information on learning outcomes, the ASER dataset collects relevant data on this, as mentioned earlier. Accordingly, we use this dataset to infer the potential association of cooking fuel choice on children learning outcomes. The reading skill assessment that ASER administers has the following four levels, which are ordinal in nature: recognition of letters, reading of words, reading a short paragraph (a grade 1 level text), and reading a short story (a grade 2 level text). The arithmetic skill assessment also has four ordinal levels: recognition of single-digit numbers, recognition of double-digit number recognition, subtraction of two-digit numbers with a carryover, and division of a three-digit by one-digit division. We use standardized scores of these variables as our outcome indicators.

However ASER does not collect data on cooking fuel usage at the household level. Accordingly, we use district level share of rural households using solid fuel for cooking purposes from NFHS-4 and merge it with the ASER dataset at the district level conducted in 2016, the same year NFHS-4 was conducted. This district level solid fuel usage is used as the primary variable of interest along with a female dummy that takes the value of 1 if the child is female and 0 otherwise. This allows us to derive indicative evidence on the potential effect of solid fuel usage on learning outcomes among rural children.

The regression results are presented in Fig. 4. We run four regressions, out of which the first two indicate if children from districts with a higher share of solid fuel usage score lesser in reading tests separated by gender, and the next two present the effects for mathematics scores. We run two more regressions to understand if female children from districts with higher share of solid fuel usage perform worse on average than the males. This is obtained by examining the marginal effects of the interaction term of the female dummy and the share of solid fuel usage at the district level. As one would expect, we observe that females from these districts are more likely to fare worse than the males in both reading and arithmetic outcomes. The lower dedicated time that children can give to schooling and homework because of solid fuel usage may manifest with lower learning abilities, where females, on average, find themselves in a disadvantageous position. Further, this finding is important as Choudhuri and Desai (2021) find detrimental mathematics scores for males in their early childhood because of lesser time dedicated by mothers due to time substitution for firewood and water collection. In fact, our finding suggests a reversal at an adolescent stage wherein the gender gap among females increases in regions with a higher prevalence of solid fuel being used as cooking fuel and possibly within households that use it. Nevertheless, further in-depth study on the implications of household solid fuel use on differentiated learning outcomes is required, and our paper only gives indicative evidence of this, which can serve as a motivation for future research.

6.4. *Gendered effect for younger and older children*

Our results suggest that for households using solid fuel, the time substitution is stronger for adolescent females putting them at a more disadvantageous position relative to males. If this is true, older adolescent females who are likely to allocate higher time for free collection of

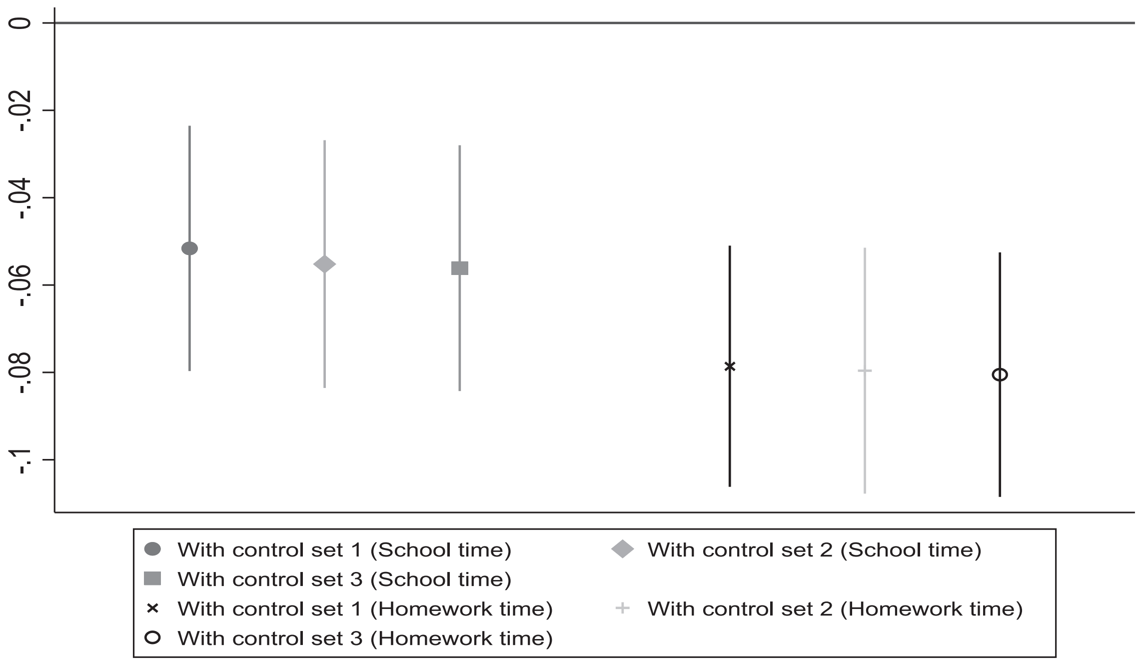


Fig. 3. Gendered effects of time allocated to firewood and natural resource collection.
Note: The average marginal effects are plotted along with the 90% confidence intervals. Control set 1 includes of time taken for firewood and other natural resource collection, sex of the child, current age, number of primary completed adults, household size, usual monthly household consumption expenditure (in INR), upper caste, religion, month of survey and state fixed effects. Control set 2 includes all the above as well as the time allocated by others in the household for firewood and other natural resource. Control set 3 includes all those included in control set 2 along with the time allocated for care giving. The sample is rural children from 12 to 18 years of age. Regression output is based on robust standard errors.

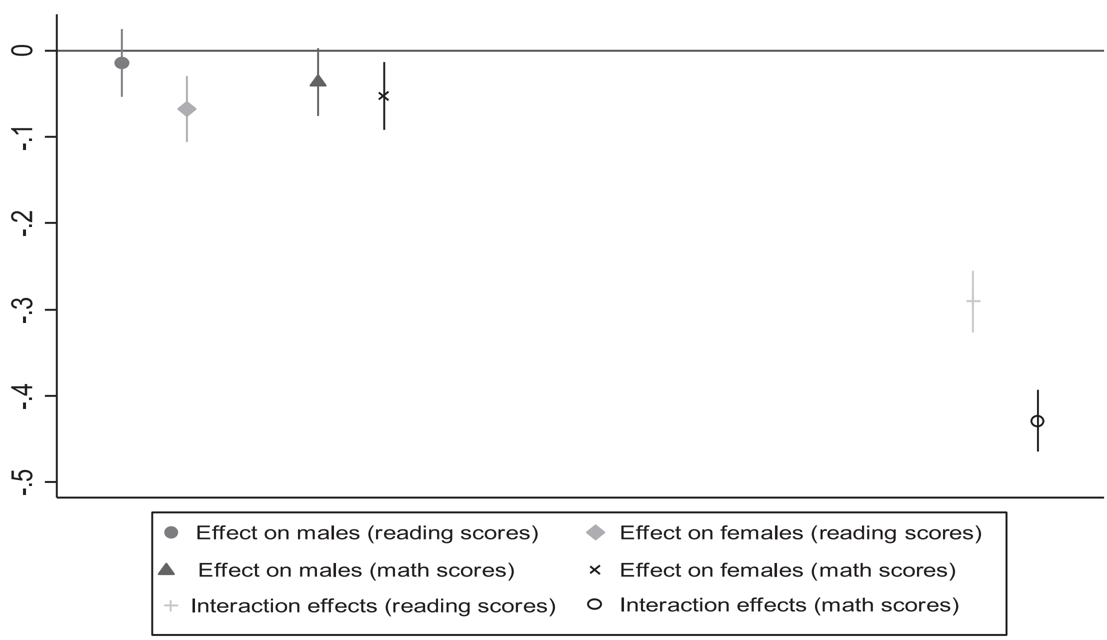


Fig. 4. Association of district level solid fuel use and performance using ASER data.
Note: The average marginal effects are plotted along with the 90% confidence intervals. All regressions control for the covariates including current age, household possession of television and toilet, household size, whether the household is cemented or not, whether anyone in the household knows computer usage, whether anyone in the household has a mobile phone, whether the mother attended school or not and state fixed effects. The sample is rural children from 12 to 16 years of age. Regression output is based on robust standard errors.

firewood and other resources may have to suffer disproportionately more in terms of educational outcomes. This comes from well-established literature, especially in the developing country context on traditional household roles that older adolescent females are expected to perform (Edmonds, 2006; Kambhampati and Rajan, 2008). These, among other things, include domestic chores, care activities, and the collection of water or firewood. From the TUS data, we find the time allocated by older adolescent females (16 to 18 years) for collection of firewood among rural households using solid fuel for cooking purposes is significantly higher in comparison to the females in the lower age cohort (12 to 15 years) and also boys. An older adolescent female is likely to spend about an average of 0.17 h (95% CI: 0.15–0.19) a day as against 0.11 h for the younger ones (95% CI: 0.1–0.13).[12] The corresponding figures for males are 0.065 (95% CI: 0.05–0.08) and 0.047 (95% CI: 0.036–0.058) respectively.

Accordingly, we examine if the relative disadvantage of female children compared to male children widens with age or remains stable over time. To assess this, we split the sample into younger (12–15 years) and older cohort (16–18 years) children and then study the effect of solid fuel across gender separately for the different age cohorts. In addition to the three educational outcomes variables, we also consider primary school completion as an additional outcome for the younger cohort. Primary completion takes the value of 1 if the child has completed at least five years of schooling and 0 otherwise. Additionally, we analyze the effect of fuel use on secondary completion for children aged 17–18 years since the outcome variable is relevant for children of this age group and not for the younger ones. Secondary completion takes the value of 1 if the child has completed at least ten years of schooling and 0 otherwise. Fig. 5 presents the second stage 2SLS marginal effects for these age groups.

Solid fuel is negatively related to school attendance for the younger cohort, with no apparent difference across gender; however, for children in the older cohort, we do not find any discernible effect of household solid fuel usage on school attendance (Fig. 5a). Further, older females appear to be more adversely affected as the solid fuel usage is found to be significantly negative for years of schooling, while no such effects are observed for the males (Fig. 5b). Next, we observe that younger females are likely to be marginally more affected when grade progression is considered, and this gender gap gets magnified in the older age group (Fig. 5c). Finally, using solid fuel reduces the likelihood of primary and secondary school completion for both males and females, though the effect size is more prominent for females, especially in the 17–18 years age group (Fig. 5d). Given that secondary education is more closely linked to future earnings ability, the striking effect of solid fuel use on secondary completion, grade progression, and schooling for females compared to males can potentially contribute further to the gender gap in labor force participation as well as wages. Additionally, lower educational attainment of girls on the whole is likely to fetch detrimental outcomes for them in terms of their relative bargaining, fertility decisions, and autonomy, among others. Because the gendered effect of solid fuel on educational outcomes of children gets magnified in the older age group, it can potentially have larger implications on labor market outcomes, marital decisions and empowerment.

6.5. Health as an additional channel

Extant literature, as indicated earlier, documents adverse health impacts of solid fuel among children as well as adults. The negative effect of solid fuel use on years of schooling can also be driven by the poor health of adolescent children, in addition to the time substitution channel. Studies suggest that intricate health condition often lead to reduced school absenteeism and affects school enrolment, literacy rate and lower academic achievement (Miguel and Kremer, 2004; Bleakley, 2007; Ding et al., 2009). Further, adverse health may have differential effects on males and females owing to gender discrimination. First, women and young adolescent females are predominantly involved in cooking and are more likely to be affected due to direct and longer exposure to smoke due to the combustion of solid fuel (Chen and Modrek, 2018). Secondly, evidence suggests that adverse health shocks may affect the education of females more relative to males owing to gender bias in resource allocation (Maccini and Yang, 2009). In other words, given the relatively lower returns to female education, parents may reallocate resources from education spending of females to meet health expenses. Finally, as females are more likely to be involved in caregiving for sick members of the households than males (Hirway and Jose, 2011), poor health of a household member owing to solid fuel use may have a larger detrimental effect on female's education.

The NFHS-4 survey does not provide information on health indicators of all the respondents but collects information on disease burden in addition to reporting the blood pressure and glucose level for males and females in the age group of 15–49 years.[13] Hence, we are unable to explore the effect of solid fuel on the health outcomes of adolescent children, which in turn can potentially have a negative impact on education. However, the survey asks the question, "whether any household member suffers from tuberculosis?"[14] We use this question to measure tuberculosis (TB) incidence at the household level and use it as a health indicator. The TB variable takes the value 1 if any household member suffers from TB and 0 otherwise. Notably, only 1.8% of the households reported someone suffering from TB. We estimate a household level regression of TB on solid fuel as the outcome variable is not at the child level. In this specification, we exclude child characteristics but additionally control for the sex of the household head and household head's age along with other household factors included in the baseline model. Columns 1 of Table A7 of the appendix suggest that solid fuel usage is positively associated with the likelihood of TB at a 1% level of significance; however, in the IV result reported in column 2, the coefficient of solid fuel is positive but no longer significant (p-value: 0.2). This could be because of the skewed distribution of the TB variable. However, there appears to be a positive albeit weak correlation between TB and solid fuel use, as suggested in the literature (Lin et al., 2008). Next, to establish TB as a possible channel, following Alesina and Zhuravskaya (2011) and Zhang et al. (2021), we re-estimate the effect of solid fuel on educational outcomes for males and females separately after including TB as an additional control. The IV results presented in columns 3–8 indicate that the coefficient of TB is negatively related to educational outcomes for both males and females and the coefficient of solid fuel in these specifications is marginally lower than those presented in Fig. 2. The evidence does not allow us to rule out health as a channel through which solid fuel leads to inferior educational outcomes. We also do not observe any noteworthy differences across males and females. Consequently, whether poor health due to solid fuel usage contributes to the gendered effect on education remains inconclusive and is an area for future research.

7. Discussion

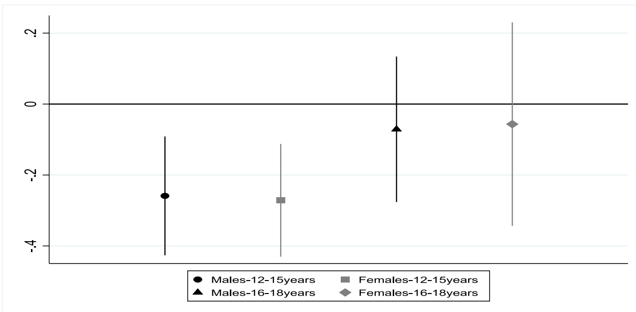
7.1. Economic impact

This section briefly discusses the cost-effectiveness of clean fuel transition purely in terms of educational gains. There are two types of costs associated with clean fuel transition: upfront costs and regular

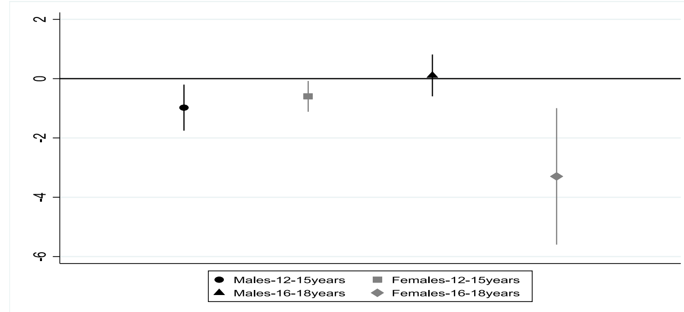
[12] CI stands for Confidence Interval.

[13] The survey collects biomarkers and other health outcomes for men and women in the age-group of 15–54 years and 15–49 years, respectively.

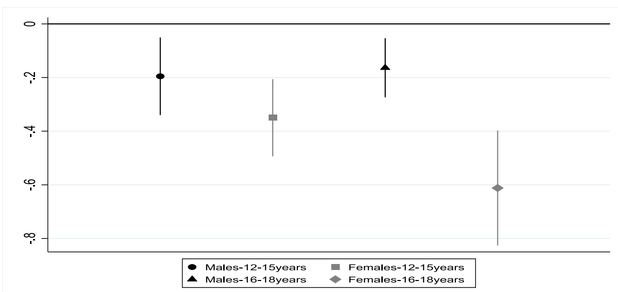
[14] Survey also captures whether the individual suffers from tuberculosis, since less than 0.1% children have tuberculosis we do not consider this.



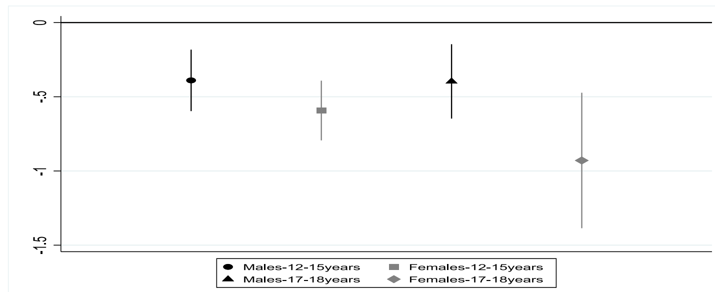
5a: School attendance



5b: Years of schooling



5c: Grade progression



5d: Primary and secondary completion

Fig. 5. Age-cohort wise effect on educational outcomes for males and females.
Note: The average marginal effects are plotted along with the 90% confidence intervals. All regressions control for the covariates including current age, number of primary completed adults, household size, BPL card, toilet, water in yard, mobile, upper caste, religion, month of survey and state fixed effects. The IV is the average share of forest in the district 6 years before the survey year (2009 if survey year is 2015 and 2010 if survey year is 2016). The sample is rural children from 12 to 18 years of age. Regression output is based on robust standard errors.

costs. The former refers to the cost of purchasing an LPG connection, which is approximately \$21.5,[15] and the price of an LPG compatible stove, which amounts to an additional \$20. Hence, the upfront transition cost per household is around \$41.5. The regular cost comprises the price of refilling cylinders and traveling expenses incurred in the process. Studies suggest that an average Indian household needs one refill of 14.2 kg LPG cylinder per month (Sharma et al., 2020; Gould and Urpelainen, 2018), amounting to another \$11.5 monthly cost, and transportation cost is considered as \$0.41 per trip, assuming that the LPG distributor is within a distance of 5 km–10 km (Sharma et al., 2020). The regular annual cost amounts to \$142.92, and the total transition cost (sum of upfront and variable cost) is approximately \$184.42.

Our main results indicate that households using solid fuel are likely to have 1.01 standard deviations lower educational attainment, which translates into 2.92 years lower years of education on average.[16] We examine the cost-effectiveness of clean fuel transition by looking at the ratio of the average effect size to the total annual costs.[17] A back-of-the-envelope calculation motivated from the above calculation suggests that transitioning from solid to clean fuel is associated with 0.016 years per dollar spent per child educational gain in a year. Further, in terms of school attendance, we find that children from households using solid fuel are 18.2 percentage points less likely to attend a school, indicating fuel transition effectiveness of 0.01 percentage points per dollar spent per child. Additionally, the effects are more pronounced for females since we observe a higher gain of 0.023 years per dollar spent per female child for a year. Similarly, solid fuel is related to a lower likelihood of school attendance by 19.3 percentage points for females, which indicate that shifting to clean fuel can increase the likelihood of attending school by 0.104 percentage points per dollar per female child. It is worth noting that these educational gains, especially for females, can be substantial for a country like India, where dropout rates for females at the secondary level remain high.

7.2. Discussion in the light of the COVID-19 pandemic

The findings from the paper establish the associated ill effects of solid fuel usage on human capital investment, which appears to be disproportionately more adverse for females. These inferences call for actions to ensure a faster transition to cleaner fuel options. The understanding and the need for higher adoption of cleaner fuel and its effect on education becomes even more pertinent in the present scenario. The outbreak of the COVID-19 across the world may not only reduce the pace of clean fuel adoption but also threaten to reverse the initial gains in the energy transition. Recent studies in Africa find that the pandemic-induced income shocks led to the substitution of LPG with cheaper polluting fuels like coal and kerosene by households (Shupler et al., 2021a). Given that solid fuel use is mainly concentrated in the Global South, any further movement down the energy ladder can potentially widen the energy gap between the low and middle income and high-income countries apart from increasing inequality between rich and poorer within these developing economies. Further, studies find that job loss in paid work was higher for women compared to men (Desai et al., 2021; Dang and Nguyen, 2021). This gendered pattern of unemployment may reduce women's intra-household bargaining power, and households may end up reducing expenditure on cooking fuel (an activity typically performed by women) by shifting to the free collection of firewood.

The COVID-19 induced lockdown and school closures have already

[15] 1600 Indian rupees based on break-up obtained from https://www.pmuy.gov.in/ (accessed on November 16, 2021).

[16] The regression of years on education on solid fuel and other factors are available upon request.

[17] The economic impact will be larger if we consider the ratio of educational gains to annual regular costs alone instead of total transition costs.

aggravated the educational gap between the rich and the poor, and it may further widen the educational gap between girls and boys (Alvi and Gupta, 2020).[18] Parental job loss, social norms and gender digital divide can also potentially lead to higher school dropout among children, especially adolescent girls, as limited financial resources are more likely to be redirected towards human capital investments for boys (World Bank, 2020). In addition, due to the pandemic, the increased domestic unpaid work and care work has disproportionately fallen on women and girls (Seck et al., 2021; World Bank, 2020). The higher demand for care tasks and the shift to solid fuel may further endanger the continuation of girls' education. Consequently, the gendered effect of the pandemic on females may reverse the fragile gains in reducing gender inequality in education achieved in the past few decades.

Further, at a macroeconomic level, the pandemic led to budget tightening, especially in the worst-hit countries, including India (Hosseini, 2020), and the risk of budgetary reallocation from clean fuel subsidies to more pressing demands looms large. This, along with a significant fall in global fossil fuel prices, especially during 2020, can possibly become a major hurdle for clean energy adoption as the relative price of using clean energy sources has gone up significantly (Hoang et al., 2021). While Smith et al. (2021) argue that the fall in the price of fossil fuel and the COVID-19 pandemic may not affect the climate change mitigation efforts by the countries, both macro and microeconomic evidence largely indicates that the pandemic poses a real threat of delaying energy transition to cleaner fuel in the Global South (Ravindra et al., 2021; Shupler et al., 2021a). However, it is worth noting that a recent study by Shupler et al. (2021b) finds that the Pay As You Go LPG (PAYGL) users in Kenya were less likely to reduce cooking time during lockdown than conventional LPG cylinder users. In the PAYGL scheme, cylinders are fitted with smart meters that allow households to refill cylinders partially, using mobile money. This finding highlights the possibility of deploying technology-based solutions to ensure that the fragile gains towards clean energy adoption do not get reversed amidst financial constraints and, in fact, the household energy transition trajectory gets accelerated in the post-COVID recovery period.[19]

7.3. Other policy implications

Recognizing the benefits of using clean cooking fuel over the last decade, a number of interventions have been initiated in India to increase the use of LPG that includes the *Rajiv Gandhi Gramin LPG Vitaran Yojana (RGGLVY)* in 2009 and the *Pratyaksh Hastantrit Labh (PAHAL)* in 2015. More recently, under the PMUY, implemented since 2016, LPG connections are provided to poor households in the name of a woman household member who is above 18 years of age. While there has been a considerable expansion of coverage and distribution network over the recent years with evidence of a socially inclusive transition to cleaner fuel, its usage over time does not yield encouraging feedback (Swain and Mishra, 2020). Apart from issues related to targeting, studies have indicated that higher prices discourage LPG refills among the beneficiaries of the program, and hence they often transition back to solid fuels (Kar et al., 2019; Gould and Urpelainen, 2020; Swain and Mishra, 2020). Additionally, subsidizing alternative fuels like kerosene or lower transaction cost of accessing biomass and firewood increase the possibility of crowding out of the more expensive fuels like LPG. This underscores the need for policy interventions that call for higher and regular subsidization of cleaner fuel in the short run to reduce fuel stacking by rural households.

The lumpiness of LPG is one reason that limits the use of clean fuel by poor households. The LPG cylinders in India come in standard sizes of either 14.2 kg or 5 kg, whereas firewood can be collected for free or very low cost and in small quantities. In addition, the steep upfront cost of purchasing an LPG connection (that includes security deposit money, cost of hose, regulator, and other ancillary costs) and stove also remains a critical barrier. Interventions like providing loans to women through microfinance institutions have been found to increase the uptake and sustained use of LPG in Kenya (Hsu et al., 2021). The introduction of smaller size cylinders by oil marketing companies or encouraging microfinance institutions to provide loans for cylinder refills in addition to existing clean fuel subsidies can be ways to ensure sustained usage of LPG. Notably, Nayak et al. (2015) find that community-based resource pooling at regular monthly intervals may also help households alleviate the issue of affordability associated with fuel transitioning. Important to note in this context is that the evidence indicates women Self Help Groups (SHGs) have been effective in creating income-generating activities while improving women's empowerment and their ability to make decisions (Pitt and Khandker, 1998; Holvoet, 2005; Swain and Wallentin, 2009). Because marginal benefits of clean fuel adoption are disproportionately higher for women, SHGs can also be utilized to encourage its usage and overcome the cost constraints.

Further, schemes like PAYGL discussed in section 7.2 can be initiated to reduce the per-time refill costs, thereby easing the liquidity constraint faced by poor households. Evidence from some East African countries indicates the considerable success of the scheme in fastening the adoption and usage of clean fuel in rural households. Additionally, studies reveal that there is a perception among many that the choice of cooking fuel affects the taste of food and such beliefs favor the use of solid fuel (Sharma et al., 2020; Martínez et al., 2020; Williams et al., 2020). This highlights the need for behavioral intervention to address the cultural beliefs surrounding cooking practices using solid fuel. Utilizing the social capital of communities by leveraging trust and cooperation through the SHGs, apart from implementing awareness generation programs regarding the negative impacts of dirty fuel, can be encouraged to improve clean fuel adoption and ensure its consistent usage in the longer run.

8. Conclusion

Reliance on solid fuel for cooking and its adverse impact on health because of the pollutants emitted by the fuel is well documented in the literature. This paper complements the literature on the welfare-reducing effects of solid fuel use by exploring its impact on human capital investments among rural adolescent children from India. Our findings indicate a robust and significant deterioration in educational outcomes among children from households using solid fuel. We find these effects not only on school attendance but also on years of education and age-appropriate grade progression. Importantly, we are able to account for the potential bias arising because of self-selection, which allows us to draw causal inferences from our regression estimates. Additionally, we find a significant female disadvantage in terms of the educational outcomes. While we do not rule out the possibility of these effects emanating indirectly from the adverse impact on health, we consider the direct time substitution due to the free collection of firewood and other natural resources as a significant channel. We show that time spent in schools decreases significantly as time allocation for environmental chores like the collection of fuel resources increase in households using solid fuel for cooking. We further find that the extent of the substitution to be disproportionately higher for females. In fact, among the adolescent children, the gender difference is found to be marginal for the younger age cohort, but this gap diverges for the older group indicating that the older adolescent females bear most of the brunt.

Despite important and policy relevant findings, our study has limitations and opens up possibilities for future research. Firstly, in the absence of recent longitudinal data at the household level, we are unable to track the changes in educational outcomes with the transition to cleaner fuel. Longitudinal data would have allowed us to obtain more

[18] https://sdgs.un.org/goals/goal4 (accessed on May 31, 2021).

[19] Refer https://www.paygoenergy.co/about for more information (accessed on May 31, 2021).

precise causal estimates. Secondly, as mentioned, the ASER dataset that we use does not gather information on the cooking fuel used by the surveyed households. Therefore, we are able to present only suggestive evidence linking district level prevalence of solid fuel usage with learning outcomes among children. Rigorously studying the relationship between household level cooking fuel choice and learning abilities among the children can be taken up for future research. Finally, while we are able to give evidence of time allocation for natural resources directly hindering educational outcomes in households using solid fuel, we are not able to reject the possibility of an indirect role of adverse health outcomes as well. Exploring the educational implication of solid fuel usage through the health channel can also be considered for future research.

Despite these limitations, our paper has important policy implications. The findings underscore the importance of policies that encourage household adoption to LPG or other cleaner options. Apart from the detrimental effects on health and the environment, our study finds complementary evidence of adverse effects on human capital investments. This has enormous relevance as literature has established the significant role played by education on labor market opportunities and earnings. It is particularly important in a country like India, where a considerable proportion of the population does not have adequate education or skills, thus reducing their employability (Blom and Saeki, 2011; Unni, 2016). From the perspective of rural India, literature has documented substantial income gains in the agrarian sector linked with higher education (Duraiswamy, 1992). Accordingly, incentivizing households to move up the energy ladder and adopt cleaner fuel in rural India assumes significance due to positive spillovers on education in addition to health concerns.

The paper also presents evidence of an educational disadvantage, which is disproportionately higher for females, especially at the later period of adolescence. This is pertinent in the context of India, which already suffers from low female labor participation (Chowdhury, 2011; Neff et al., 2012). Apart from this, it is also found to bestow a number of non-market benefits, especially for females that include, among others, marital decisions, fertility choices, and empowerment emanating through higher relative bargaining power because of education and alteration of gender norms. Consequently, policy actions which include subsidization, behavioral interventions, community-based resource pooling, and schemes like PAYGL that can enhance the adoption of cleaner cooking fuel become imminent.

Inclusion and diversity statement

One or more of the authors of this paper self-identifies as an underrepresented ethnic minority in science. While citing references scientifically relevant for this work, we also actively worked to promote gender balance in our reference list. The author list of this paper includes contributors from the location where the research was conducted who participated in the data collection, design, analysis, and/or interpretation of the work.

Credit author statement

Shreya Biswas: Data curation, Methodology, Formal analysis, Investigation, Software, Visualization, Writing – original and revised draft, preparation of response sheet, reviewing.

Upasak Das: Conceptualization, Methodology, Formal analysis, Investigation, Software, Visualization, Writing – original and revised draft, preparation of response sheet, reviewing.

The order of the author names are given in alphabetic order of their surnames.

Declaration of Competing Interest

There are no known conflicts of interest associated with this publication among the authors, and there has been no financial support for this work that could have influenced its outcome.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2021.105744.

References

Adukia, A., Asher, S., Novosad, P., 2020. Educational investment responses to economic opportunity: evidence from Indian road construction. Am. Econ. J. Appl. Econ. 12 (1), 348–376.
Alesina, A., Zhuravskaya, E., 2011. Segregation and the quality of government in a cross section of countries. Am. Econ. Rev. 101 (5), 1872–1911.
Alvi, M., Gupta, M., 2020. Learning in times of lockdown: how Covid-19 is affecting education and food security in India. Food Secur. 12 (4), 793–796.
Arku, R.E., Ezzati, M., Baumgartner, J., Fink, G., Zhou, B., Hystad, P., Brauer, M., 2018. Elevated blood pressure and household solid fuel use in premenopausal women: analysis of 12 demographic and health surveys (DHS) from 10 countries. Environ. Res. 160, 499–505.
Asadullah, M.N., Wahhaj, Z., 2019. Early marriage, social networks and the transmission of norms. Economica 86 (344), 801–831.
Asher, S., Novosad, P., 2017. Politics and local economic growth: evidence from India. Am. Econ. J. Appl. Econ. 9 (1), 229–273.
Asher, S., Lunt, T., Matsuura, R., Novosad, P., 2021. Development research at high geographic resolution: an analysis of night lights, firms and poverty in India using the SHRUG open data platform. World Bank Econ. Rev. https://doi.org/10.1093/wber/lhab003.
Azar, J., Marinescu, I., Steinbaum, M., 2020. Labor market concentration. J. Hum. Resour. 1218-9914R1 (Forthcoming).
Behera, B., Ali, A., Marenya, P., 2017. A ladder within a ladder: understanding the factors influencing a household's domestic use of electricity in four African countries. Energy Econ. 66, 167–181.
Bhatt, B.P., Sachan, M.S., 2004. Firewood consumption pattern of different tribal communities in Northeast India. Energy Policy 32 (1), 1–6.
Bleakley, H., 2007. Disease and development: evidence from hookworm eradication in the American south. Q. J. Econ. 122 (1), 73–117.
Blom, A., Saeki, H., 2011. Employability and skill set of newly graduated engineers in India. In: The World Bank. Available at. https://openknowledge.worldbank.org/bitstream/handle/10986/3404/WPS5640.pdf?sequence=1 (accessed on May 31, 2021).
Chakraborty, T., Jayaraman, R., 2019. School feeding and learning achievement: evidence from India's midday meal program. J. Dev. Econ. 139, 249–265.
Chen, C., Modrek, S., 2018. Gendered impact of solid fuel use on acute respiratory infections in children in China. BMC Public Health 18 (1), 1–7.
Choudhuri, P., Desai, S., 2021. Lack of access to clean fuel and piped water and children's educational outcomes in rural India. World Dev. 145, 105535.
Chowdhury, S., 2011. Employment in India: what does the latest data show? Econ. Polit. Wkly. 46 (32), 23–26.
Churchill, S.A., Smyth, R., Farrell, L., 2020. Fuel poverty and subjective wellbeing. Energy Econ. 86, 104650.
Conley, T.G., Hansen, C.B., Rossi, P.E., 2012. Plausibly exogenous. Rev. Econ. Stat. 94 (1), 260–272.
Dang, H.A.H., Nguyen, C.V., 2021. Gender inequality during the COVID-19 pandemic: income, expenditure, savings, and job loss. World Dev. 140, 105296.
Das, U., 2021. Rural employment guarantee programme in India and its impact on household educational decisions: a focus on private coaching. J. Int. Dev. 1-21 https://doi.org/10.1002/jid.3546.
Deaton, A., 2005. Measuring poverty in a growing world (or measuring growth in a poor world). Rev. Econ. Stat. 87 (1), 1–19.
Dehejia, R.H., Wahba, S., 2002. Propensity score-matching methods for non-experimental causal studies. Rev. Econ. Stat. 84 (1), 151–161.
Desai, S., Deshmukh, N., Pramanik, S., 2021. Precarity in a Time of Uncertainty: Gendered Employment Patterns during the Covid-19 Lockdown in India. Fem Econ. 27 (1-2), 152–172.
Ding, W., Lehrer, S.F., Rosenquist, J.N., Audrain-McGovern, J., 2009. The impact of poor health on academic performance: new evidence using genetic markers. J. Health Econ. 28 (3), 578–597.
Drèze, J., Kingdon, G.G., 2001. School participation in rural India. Rev. Dev. Econ. 5 (1), 1–24.
Duraiswamy, P., 1992. Effects of education and extension contacts on agricultural production. Indian J. Agric. Econ. 47 (2).

Edmonds, E.V., 2006. Understanding sibling differences in child labor. J. Popul. Econ. 19 (4), 795–821.

Edwards, J.H., Langpap, C., 2012. Fuel choice, indoor air pollution and children's health. Environ. Dev. Econ. 17 (4), 379–406.

Field, E., Ambrus, A., 2008. Early marriage, age of menarche, and female schooling attainment in Bangladesh. J. Polit. Econ. 116 (5), 881–930.

Gould, C.F., Urpelainen, J., 2018. LPG as a clean cooking fuel: adoption, use, and impact in rural India. Energy Policy 122, 395–408.

Gould, C.F., Urpelainen, J., 2020. The gendered nature of liquefied petroleum gas stove adoption and use in rural India. J. Dev. Stud. 56 (7), 1309–1329.

Government of India, 2019. Draft National Policy on Education 2019. Ministry of Human Resource for Development, New Delhi. Available at. https://www.education.gov.in/sites/upload_files/mhrd/files/Draft_NEP_2019_EN_Revised.pdf (accessed on May 31, 2021).

Hanna, R., Oliva, P., 2015. Moving up the energy ladder: the effect of an increase in economic wellbeing on the fuel consumption choices of the poor in India. Am. Econ. Rev. 105 (5), 242–246.

Hirway, I., Jose, S., 2011. Understanding women's work using time-use statistics: the case of India. Fem. Econ. 17 (4), 67–92.

Hoang, A.T., Nižetić, S., Olcer, A.I., Ong, H.C., Chen, W.-H., Chong, C.T., Nguyen, X.P., 2021. Impacts of COVID-19 pandemic on global energy system and the shift progress to renewable energy: opportunities, challenges, and policy implications. Energy Policy 154, 112322.

Holvoet, N., 2005. The impact of microfinance on decision-making agency: evidence from South India. Dev. Chang. 36 (1), 75–102.

Hosseini, S.E., 2020. An outlook on the global development of renewable and sustainable energy at the time of Covid-19. Energy Res. Soc. Sci. 68, 101633.

Hsu, E., Forrougi, N., Gan, M., Muchiri, E., Pope, D., Puzzolo, E., 2021. Microfinance for clean cooking: what lessons can be learned for scaling up LPG adoption in Kenya through managed loans? Energy Policy 154, 112263. https://doi.org/10.1016/j.enpol.2021.112263.

Jagger, P., Shively, G., 2014. Land use change, fuel use and respiratory health in Uganda. Energy Policy 67, 713–726.

James, B.S., Shetty, R.S., Kamath, A., Shetty, A., 2020. Household cooking fuel use and its health effects among rural women in southern India—a cross-sectional study. PLoS One 15 (4), e0231757.

Kambhampati, U.S., Rajan, R., 2008. The 'nowhere'children: patriarchy and the role of girls in India's rural economy. J. Dev. Stud. 44 (9), 1309–1341.

Kar, A., Pachauri, S., Bailis, R., Zerriffi, H., 2019. Using sales data to assess cooking gas adoption and the impact of India's Ujjwala programme in rural Karnataka. Nat. Energy 4 (9), 806–814.

Lahoti, R., Sahoo, S., 2020. Are educated leaders good for education? Evidence from India. J. Econ. Behav. Organ. 176, 42–62.

Lehne, J., Shapiro, J.N., Eynde, O.V., 2018. Building connections: political corruption and road construction in India. J. Dev. Econ. 131, 62–78.

Levison, D., DeGraff, D.S., Dungumaro, E.W., 2018. Implications of environmental chores for schooling: Children's time fetching water and firewood in Tanzania. Eur. J. Dev. Res. 30 (2), 217–234.

Lin, H.H., Murray, M., Cohen, T., Colijn, C., Ezzati, M., 2008. Effects of smoking and solid-fuel use on COPD, lung cancer, and tuberculosis in China: a time-based, multiple risk factor, modelling study. Lancet 372 (9648), 1473–1483.

Liu, Z., Li, J., Rommel, J., Feng, S., 2020. Health impacts of cooking fuel choice in rural China. Energy Econ. 89, 104811.

Maccini, S., Yang, D., 2009. Under the weather: health, schooling, and economic consequences of early-life rainfall. Am. Econ. Rev. 99 (3), 1006–1026.

Martínez, N.N., Mäusezahl, D., Hartinger, S.M., 2020. A cultural perspective on cooking patterns, energy transfer programmes and determinants of liquefied petroleum gas use in the Andean Peru. Energ. Sustain. Dev. 57, 160–167.

Mayer, A., Smith, E.K., 2019. Exploring the link between energy security and subjective wellbeing: a study of 22 nations. Energ. Sustain. Soc. 9 (1), 1–13.

McArthur, J.W., McCord, G.C., 2017. Fertilizing growth: agricultural inputs and their effects in economic development. J. Dev. Econ. 127, 133–152.

Miguel, E., Kremer, M., 2004. Worms: identifying impacts on education and health in the presence of treatment externalities. Econometrica 72 (1), 159–217.

Muller, C., Yan, H., 2018. Household fuel use in developing countries: review of theory and evidence. Energy Econ. 70, 429–439.

Munshi, K., Rosenzweig, M., 2016. Networks and misallocation: insurance, migration, and the rural-urban wage gap. Am. Econ. Rev. 106 (1), 46–98.

Nankhuni, F.J., Findeis, J.L., 2004. Natural resource-collection work and children's schooling in Malawi. Agric. Econ. 31 (2–3), 123–134.

Nayak, B.P., Werthmann, C., Aggarwal, V., 2015. Trust and cooperation among urban poor for transition to cleaner and modern cooking fuel. Environ. Innov. Soc. Transit. 14, 116–127.

Ndiritu, S.W., Nyangena, W., 2011. Environmental goods collection and children's schooling: evidence from Kenya. Reg. Environ. Chang. 11 (3), 531–542.

Neff, D., Sen, K., Kling, V., 2012. Puzzling Decline in Rural women's Labor Force Participation in India: A Reexamination, GIGA Working Paper No. 196. German Institute of Global and Area Studies, Hamburg.

Nie, P., Sousa-Poza, A., Li, Q., 2021. Neff Energy Poverty and Subjective Wellbeing in China: New Evidence from the China Family Panel Studies. In: Discussion Paper Series No. 14429. IZA Institute of Labor Economics, Bonn, Germany.

Pitt, M.M., Khandker, S.R., 1998. The impact of group-based credit programs on poor households in Bangladesh: does the gender of participants matter? J. Polit. Econ. 106 (5), 958–996.

Rahut, D.B., Ali, A., Mottaleb, K.A., Aryal, J.P., 2020. Understanding households' choice of cooking fuels: evidence from urban households in Pakistan. Asian Dev. Rev. 37 (1), 185–212.

Ravindra, K., Kaur-Sidhu, M., Mor, S., Chakma, J., Pillarisetti, A., 2021. Impact of the COVID-19 pandemic on clean fuel programmes in India and ensuring sustainability for household energy needs. Environ. Int. 147, 106335.

Rosenbaum, P.R., 2002. Sensitivity to Hidden bias. In Observational Studies. Springer, New York, NY, pp. 105–170.

Rosenbaum, P.R., Rubin, D.B., 1985. Constructing a control group using multivariate matched sampling methods that incorporate the propensity score. Am. Stat. 39 (1), 33–38.

Roychowdhury, P., 2019. Peer effects in consumption in India: an instrumental variables approach using negative idiosyncratic shocks. World Dev. 114, 122–137.

Seck, P.A., Encarnacion, J.O., Tinonin, C., Duerto-Valero, S., 2021. Gendered impacts of COVID-19 in Asia and the Pacific: early evidence on deepening socioeconomic inequalities in paid and unpaid work. Fem. Econ. 27 (1–2), 117–132.

Sharma, D., Ravindra, K., Kaur, M., Prinja, S., Mor, S., 2020. Cost evaluation of different household fuels and identification of the barriers for the choice of clean cooking fuels in India. Sustain. Cities Soc. 52, 101825 https://doi.org/10.1016/j.scs.2019.101825.

Shupler, M., O'Keefe, M., Puzzolo, E., Nix, E., de Cuevas, R.A., Mwitari, J., Pope, D., 2021a. Pay-as-you-go liquefied petroleum gas supports sustainable clean cooking in Kenyan informal urban settlement during COVID-19 lockdown. Appl. Energy 292, 116769.

Shupler, M., Mwitari, J., Gohole, A., de Cuevas, R.A., Puzzolo, E., Čukić, I., Pope, D., 2021b. COVID-19 impacts on household energy & food security in a Kenyan informal settlement: the need for integrated approaches to the SDGs. Renew. Sust. Energ. Rev. 144, 111018.

Smith, K.R., Uma, R., Kishore, V.V.N., Zhang, J., Joshi, V., Khalil, M.A.K., 2000. Greenhouse implications of household stoves: an analysis for India. Annu. Rev. Energy Environ. 25 (1), 741–763.

Smith, L.V., Tarui, N., Yamagata, T., 2021. Assessing the impact of COVID-19 on global fossil fuel consumption and CO2 emissions. Energy Econ. 97, 105170.

Swain, S.S., Mishra, P., 2020. Determinants of adoption of cleaner cooking energy: experience of the Pradhan Mantri Ujjwala Yojana in rural Odisha, India. J. Clean. Prod. 248, 119223.

Swain, R.B., Wallentin, F.Y., 2009. Does microfinance empower women? Evidence from self-help groups in India. Int. Rev. Appl. Econ. 23 (5), 541–556.

Tembo, S., Mulenga, B., Sitko, N., 2015. Cooking Fuel Choice in Urban Zambia: Implications on Forest Cover (No. 202883). Michigan State University, Department of Agricultural, Food, and Resource Economics.

Thoday, K., Benjamin, P., Gan, M., Puzzolo, E., 2018. The mega conversion program from kerosene to LPG in Indonesia: lessons learned and recommendations for future clean cooking energy expansion. Energ. Sustain. Dev. 46, 71–81.

Tilak, J.B., 2020. Universal Secondary Education in India: Issues, Challenges and Prospects. Springer, Singapore.

Unni, J., 2016. Skill gaps and employability: higher education in India. J. Dev. Pol. Pract. 1 (1), 18–34.

Williams, K.N., Thompson, L.M., Sakas, Z., Hengstermann, M., Quinn, A., Díaz-Artiga, A., Harvey, S.A., 2020. Designing a comprehensive behaviour change intervention to promote and monitor exclusive use of liquefied petroleum gas stoves for the household air pollution intervention network (HAPIN) trial. BMJ Open 10 (9), e037761.

World Bank, 2018. World Development Report 2018: Learning to Realize Education's Promise, vol. 2018. The World Bank, Washington DC.

World Bank, 2020. The COVID-19 Pandemic: Shocks to Education and Policy Responses. Available at. http://www.itspa.edu.mx/wp-content/uploads/2020/09/covid1.pdf (accessed on May 31, 2021).

WHO, 2018. Opportunities for transition to clean household energy: application of the household energy assessment rapid tool (ʿHEARTʾ: India.

Zhang, Y., Li, Z., 2021. COVID-19's Impact on the Transition to Clean Cooking Fuels. Available at. https://documents1.worldbank.org/curated/en/326471615352029248/pdf/COVID-19-s-Impact-on-the-Transition-to-Clean-Cooking-Fuels-Initial-Findings-from-a-Case-Study-in-Rural-Kenya.pdf.

Zhang, Q., Appau, S., Kodom, P.L., 2021. Energy poverty, children's wellbeing and the mediating role of academic performance: evidence from China. Energy Econ. 97, 105206.