The impact of indoor air pollution on the incidence of life threatening respiratory illnesses: Evidence from young children in Peru

Gissele Gajate-Garrido
IFPRI

This paper analyzes the impact of indoor air pollution on boys and girls health, and the validity of various mitigation strategies using a panel of Peruvian children younger than six years old. It controls for unobserved child heterogeneity and important confounding variables established in the literature, but seldom available in surveys. I find a negative, statistically significant and considerable impact of indoor air pollution on child respiratory health. This impact is stronger and only significant for boys. To discard a spurious correlation I show diarrhea, a priori not related to pollution, is not affected by cooking fuel choice.

Key words: Latin America; Peru; indoor air pollution; child health; mitigation strategies.

I. Introduction

The vast majority of those who cook with unprocessed biomass fuels, such as wood, crop residues and cow dung - about half of the world's population - live in developing countries (Bruce, Perez-Padilla and Albalak 2000). These fuels have been shown (Dasgupta et al. 2004a) to produce high levels of indoor air pollution (IAP), which in turn is believed to be a major cause for mortality and disability in both rural and urban settings in developing countries.

Indoor air pollution is, for example, the 10th most important risk factor in terms of its global burden of disease (World Health Reports 2001-2002),[1] and is believed to generate twice as many deaths (1.6 million, of which two thirds are among children; Dasgupta et al. 2004b) and four times the number of disability adjusted life years produced by urban outdoor air pollution (Smith and Mehta 2003). Indoor air pollution is also linked to acute respiratory infections, which are the leading cause of worldwide mortality in children five years old or younger (Bruce, Perez-Padilla and Albalak 2000; Duflo, Greenstone and Hanna 2008). In Peru, the country of study, the average annual health cost of biomass fuels is estimated to be about 0.27 billion dollars (0.8 billion soles), of which one third is attributed to mortality from respiratory infections in children and another third to acute respiratory illnesses in children (World Bank 2007).

Despite the magnitude of such impacts the literature that rigorously establishes the link between the use of biomass fuels and poor health outcomes has a number of significant gaps. In particular, while the literature has established a definite negative relationship between this environmental hazard and health, it has failed clearly to address issues of causality - in particular to deal with potential observed and unobserved variables that could confound the correlation between air pollution and health outcomes - and to rigorously examine the differential impact of air pollution by gender. Furthermore the literature has not achieved a consensus around the effectiveness of different mitigation strategies.

In this paper, I address these shortcomings using a panel data set of Peruvian children that provides information about children aged one to six and records both indoor air pollution levels (use of biomass fuels) and health outcomes. The panel structure of the data allows me to control for household-level unobserved variables by first-differencing the data, and the richness of the data allows me to take into account detailed measures of household structure (for example, the presence of other adult women in the household), and construction materials used within the home (with impermeable materials believed to mitigate the impact of pollution). In addition I am able to examine the heterogeneity of the effect with respect to child gender (Dezateux and Stocks 1997; Falagas, Mourtzoukou and Vardakas 2007). I measure pollution using a dichotomous variable equal to one when the household uses a hazardous cooking material and evaluate the incidence of life threatening respiratory-related illnesses.

While household fixed effects cleanse the results of time-invariant unobserved variables, my identification relies on within-household variation in the use of cooking fuel, a change which could be associated with other (time-varying) shocks. I address this concern by showing that the type of cooking fuel, conditional on the controls used in this study, does not affect the incidence of intestinal symptoms, a health outcome that a priori should not be related to indoor air pollution but which would be expected to be affected by time-varying household shocks to income or health. As a further robustness check, I also show that a change in cooking fuel is not associated with a household relocating, another possible confounding shock.

I find that indoor air pollution has a negative, statistically significant and considerable impact on child respiratory health. Neither the presence of other adult women in the household, nor the permeability of construction materials appears to attenuate this impact. I also confirm that the impact is stronger for boys and that these results are not driven by an under-diagnosis for girls.

The paper is organized as follows. The next section briefly reviews the literature on the relationship between child health outcomes and indoor air pollution. Section 3 presents the conceptual framework, a discussion of the identification strategy and the estimation procedure, while section 4 describes the data. The fifth section presents the main results including an examination of the existence of gender differences. I conclude with a discussion of the implications of the findings.

II. Child Health and Indoor Air Pollution

I begin with a review of the literature linking air pollution, health, and later-life outcomes, highlighting both key results and the shortcomings this paper aims to fill. I then discuss the literature related to type of fuel used, choice of construction material within the home, and duration of exposure to cooking and indicate how the findings from this work inform my specifications.

2.1 The Link between Air Pollution, Health, and Later-Life Outcomes

There is an extensive literature linking indoor air pollution generated by the incomplete combustion of biomass fuel to negative health outcomes. These range from middle ear infection to asthma and cataracts.

Acute respiratory infections are the most widely researched outcomes of exposure to high levels of indoor air pollution (Bruce, Perez-Padilla and Albalak 2000; Smith et al. 2000; Smith 2000; Ezzati and Kammen 2001a, b; Smith et al. 2007). Indoor air pollution can raise the occurrence of acute respiratory infections by damaging respiratory tract defenses and rendering children more vulnerable to pathogens (Smith et al. 2000)[2]. Consequently, respiratory infections can cause a vicious cycle of malnutrition and illness[3] (Ehiri and Prowse 1999).Women and young children are most affected by this problem due to their proximity to stoves (Dasgupta et al. 2004b). Young children are especially vulnerable to IAP due to the immaturity of their respiratory defense mechanisms and the structure of their airways (Smith et al. 2000).

Early experiences are an important factor in the physiological development of children (Knudsen et al. 2006; Heckman 2007). Exposure during childhood will affect lung growth into puberty, even after exposure levels have been reduced (Gauderman et al. 2004) and weakened lung development could predispose children to chronic obstructive pulmonary disease (Bruce, Perez-Padilla and Albalak 2000). Furthermore, biological insults during infancy affect the development of diverse skills as well as biological processes[4], which in turn will determine cognitive outcomes in adulthood.

Negative health outcomes in turn affect school attendance and child productivity (Bobonis, Miguel and Puri-Sharma 2004; Miguel and Kremer 2004; Duflo and Hanna 2006) as well as adult stature, which is related to socioeconomic status (Case, Lubotsky and Paxson 2002; Currie and Stabile 2003; Case, Fertig and Paxson 2005; Alderman, Hoddinott and Kinsey 2006; Oreopoulos et al. 2008).

2.2 Type of fuel used

According to Dasgupta et al. (2004a), dung is the biomass fuel that generates the highest levels of emissions (291 ug/m^3). Other fuels such as firewood and sawdust are also above the 200 ug/m^3 level (263 and 237, respectively). Similarly, straw, jute, as well as twigs and branches are between the 170 and 200 ug/m^3 level. In contrast natural gas and kerosene have very low levels of emissions (101 and 134, respectively). The United States Environmental Protection Agency's standards for 24-hour average PM_{10} and $PM_{2.5}$ concentrations are 150 mg/m^3 and 65 mg/m^3 respectively (Bruce, Perez-Padilla and Albalak 2000). According to the environmental country analysis carried out for Peru by the World Bank in 2007, indoor concentration of particles dramatically exceed these levels in homes using biomass fuels. PM_4 (ug/m^3)[5] concentrations exceeded 500 mg/m^3 in 40% of the households monitored, exceeded 1000 mg/m^3 in over 20% of these homes, and surpassed the standards of 65 mg/m^3 in almost 90% of the homes (World Bank 2007). Accordingly in the specification below I define a household as suffering from indoor air pollution if they used any cooking fuel other than kerosene, gas or electricity.

2.2.1 Cooking methods in Peru

According to Environmental Health Module of the Peruvian Continuous Demographic and Health Survey for 2006 (Rustein and Klescovich 2009) a considerable percentage of households use smoke-producing fuels (42%). This is a major concern in rural areas where 88% use hazardous cooking materials compared to 15% in urban ones. Moreover, the highlands have the higher usage of smoky fuels (70%) followed by the jungle (59%) and the coast (16%). Both in rural areas and in the highlands firewood is the most popular choice of cooking fuel. The fuel usage of households belonging to different socioeconomic levels shows even more striking disparities. 98% of households at the lowest economic level use hazardous cooking materials, compared to 0% in the highest wealth quintile[6]. Less than 12% of households using harmful fuels have stoves with chimneys. Furthermore, kitchens are poorly ventilated. In urban areas only 65% of kitchens have windows, while in rural areas barely 44% have a window.

2.3 Construction materials

Ventilation due to roof and wall permeability can affect how much smoke will be dispersed from a fire. Using particulate concentration monitors, Dasgupta et al. (2004a, b) found that ventilation is a very important determinant of particulate density. Hence wall and roof permeability could decrease the harmful effect of hazardous cooking fuels smoke. On the other hand Pitt, Rosenzweig and Hassan (2005) found no effect of wall or roof permeability. I test these differing hypotheses in the results below.

2.4 Duration of exposure to pollution

Women are usually the ones in charge of cooking, which means they are the ones exposed most frequently to high levels of indoor air pollution. Since cooking and child care are joint activities, the mother’s exposure to a hazardous environment while cooking necessarily implies that young children are exposed to high levels of indoor air pollution too (Dasgupta et al. 2004b). The Peruvian Continuous Demographic and Health Survey for 2006 (Rustein and Klescovich 2009) calculated that 29% of Peruvian mothers with children younger than five years old keep them close to the stove or at least in the kitchen when they cook (25% in urban areas and 33% in rural locations). Authors such as Pitt, Rosenzweig and Hassan (2005) have argued that the presence of other women in the household, such as grandmothers or aunts, could diminish the amount of time mothers with young children spend close to the stove. Hence it would reduce the impact of indoor air pollution on child health. This hypothesis will also be tested below.

III. Conceptual Framework, Identification Strategy, and Specification

3.1 Conceptual Framework

I consider the health status of a child to be a choice that results from the household's efforts to maximize its utility (Becker 1965; Grossman 1972; Gronau 1977; Wolfe and Behrman 1982; Strauss and Thomas 1998; Currie 2000; Mwabu 2008). These choices are made subject to financial constraints, time-constraints, and the child's health outcome production function. Child health (H_t) is a result of indoor air pollution (IAP_t)[7], the time the mother invests to produce a better health outcome (for example time used to teach the child to wash his/her hands), the goods purchased to produce a better health outcome (for example vaccines), child characteristics such as nutritional status (X_t^c), parental characteristics (X_t^M) such as maternal education, household characteristics such as wall permeability (X_t^i), community characteristics (X_t^L), including access to immunization programs, and unobserved attributes related to both the mother and the child (μ_t) such as resilience and maternal initiative and determination. The choice of cooking fuel is similarly a function of child, parental and household characteristics such as the child's frailty (represented by his/hers nutritional status), maternal education and construction materials permeability. Community characteristics such as the price of cooking fuels[8], the availability of cooking fuels[9], the level of cooking technology[10], the level of female education[11], the level of outdoor air pollution and the average minimum yearly temperature can also be important determinants of the choice of cooking fuel. Finally, unobserved attributes such as maternal initiative and determination can also play a role in this decision.

Maximizing household welfare subject to financial and time constraints implies that the health of children and the choice of cooking fuel will also depend on the household income level. Unfortunately, household income is not directly observed in my data. Instead I control for household wealth (W_t^i) (wealth provides a plausible proxy for economic wellbeing and has the additional advantage of not being simultaneously determined with health status or choice of cooking fuels). I also control for an indicator of household income shocks. The survey has a wealth indicator based on a series of household characteristics (flooring, walls and ceiling materials, ownership of goods, type of cooking fuel, toilet facilities and so forth). I create my own wealth score summarizing household characteristics using a principal component analysis[12].

3.2 Identification Strategy

I will estimate a relationship of the form:

$$H_t = \Phi\left(IAP_t, W_t^i, X_t^c, X_t^M, X_t^i, X_t^L, \mu_t\right) \tag{1}$$

where H_t is health status of the child. One of the main difficulties in identifying the effect of indoor air pollution on child health outcomes is selection bias or omitted variable bias. Omitted variable bias is an issue because people who have chosen less harmful cooking materials may do so because, for example, they are more educated, or have higher income or wealth (the most harmful materials, such as dung, are also the cheapest), factors which in turn directly affect health. Hence it is important to control for as many confounding factors as possible (Smith 2000). To address this concern I include a range of time-variant covariates as controls: child characteristics (age, nutritional status, health compared to other children of the same age group), maternal characteristics (education and a dummy if the mother smokes), household characteristics (number of children under five years of age[13], availability of drinking water, crowding, wall and roof permeability[14], interaction of wall and roof permeability with choice of cooking fuel, household size, income shocks[15] and wealth score), community characteristics (level of cooking technology, level of female education, availability of feeding programs as well as child growth, tuberculosis control and immunization programs, population size, a dummy for belonging to the highlands, a dummy for being in an urban area, a poverty index, the level of outdoor air pollution and the average minimum yearly temperature). Nonetheless, time invariant characteristics that are not observed and that cannot directly be controlled for remain a concern. For example, parents who know their children are more vulnerable to health risks, could take measures to improve indoor air quality. Since we have repeated observations by household we can include household fixed effects, which control for all time-invariant household unobserved variables.

3.2.1 Impact of indoor air pollution on intestinal symptoms: the placebo test

Following Pitt, Rosenzweig and Hassan (2005) I test if the relationship between the choice of cooking fuel and child respiratory health is spurious. If this is the case then indoor air pollution should directly impact the probability of suffering health ailments that are completely unrelated to exposure to smoke, but that are highly correlated to other risk factors. A clear example is intestinal symptoms such as diarrhea. There are no studies linking IAP to diarrheal episodes. IAP has been potentially linked only to acute lower respiratory infections, upper respiratory infection, otitis media, chronic obstructive pulmonary disease, asthma, lung cancer, nasopharyngeal and laryngeal cancer, pulmonary tuberculosis, low birth weight, infant mortality and cataracts (Bruce, Perez-Padilla and Albalak 2002). The main paths through which children acquire diarrheal diseases are through infected drinking water and fecal-oral transmission of enteric pathogens (Saidi et al. 1997). There is a positive relationship between respiratory infections and diarrhea but most certainly not between IAP and diarrhea. Children that suffer from diarrhea have weaker immune systems and are therefore more prone to all kind of infections such as respiratory infections and vice versa. However diarrhea does not cause respiratory infections and respiratory infections do not cause diarrhea.

Table 1 presents estimates of the effect of indoor air pollution on the probability of suffering a serious episode of diarrhea using a first-difference model. There is no impact of the choice of cooking fuel on this health variable, in either the whole sample or for either gender. This is a reassuring result since it means that our estimates will not be capturing the indirect effect of other time variant socioeconomic risk factors. Water purification methods could be related to IAP (for example boiling water), yet this effect is not strong enough in the data since any statistically significant effect between IAP and diarrhea was found. This is probably because the negative relationship between IAP and diarrhea due to the choice of boiling water is being canceled out by the positive relationship between IAP and diarrhea due to other risk factors. For example people that cook with hazardous cooking materials probably have in general worst hygiene and hence their children are more exposed to bacteria that could cause diarrheal episodes.

3.3 Specification

I estimate a linearized version of equation (1):

$$H_{ijcRt} = \theta_j + \delta_R + \phi_t + \alpha IAP_{ict} + \beta_1 X_{ijct}{}^{c} + \beta_2 X_{ijct}{}^{M} + \beta_3 X_{ict}^{i} + \beta_4 X_{ct}{}^{L} + \mu_{ijct} \qquad (2)$$

where H_{ijt} is the health status of child *j* at time *t* living in household *i*, community *c* and region *R*. θ_j are individual/household fixed effects, δ_R are region fixed effects and ϕ_t are year fixed effects. IAP_{ict} describes the use of hazardous cooking fuels at time *t* in household *i*. Time varying child and maternal characteristics are summarized by X^{c}_{ijct} and X^{M}_{ijct}. Household characteristics are represented by X^{i}_{ict}, while community characteristics are described by X^{L}_{ct}. The wealth index is included with household characteristics. Finally, μ_{ijct} represents the error term. In practice, since the survey has only two rounds, I estimate equation (2) in first-differences. Standard errors are clustered at the community level to account for within–communities correlation of errors.

IV. Data

My main data sets used in this study are the 1st and 2nd rounds of the Young Lives International Study of Childhood Poverty survey. The first round included data on children ages 6 months to 17 months collected in 2002. The second round took place between late 2006 and early 2007.

4.1 Key Variables

The health status of the child is measured by the incidence of a life threatening illness that could be the consequence of exposure to indoor air pollution (the illnesses included in this definition are high fever, pneumonia, severe cough, asthma and acute respiratory problems). The occurrence of these episodes is measured from birth (for the first round) and from the time when the 1st interview took place (for the second round)[16]. Using acute health conditions instead of minor episodes allows me to avoid capturing seasonal health problems.

The independent variable of interest in this study is the presence of indoor air pollution in the household. I classify a household as suffering from indoor air pollution if it uses any cooking fuel other than electricity, gas or kerosene. Since I use a first difference approach to obtain identification, the variation in the choice of cooking method is coming from the households that switched fuels from one round to the other. Over 12% of households (240) switched their cooking fuel (either by changing from a contaminating to a non-contaminating fuel (7.5%) or vice-versa (4.7%)). It should be noted that this switch in fuel choice is not capturing fuel mixing.

The survey specifically asked for the main type of fuel used most frequently and hence does not capture transitory fuel changes. Furthermore, according to the Peruvian Continuous Demographic and Health Survey for 2006 (Rustein and Klescovich 2009) most households (78%) use only one type of fuel for cooking. Of the remaining 22% that use more than one type they do not necessarily mix between pollutant and non pollutant fuels, they just swap a type of hazardous cooking fuel for another (for example wood instead of cow dung).

4.2 Descriptive Statistics

Table 2 presents descriptive statistics for the households that changed their cooking fuel in the second round as well as for both survey rounds. In addition, this table shows how figures are modified when I separate households that use a hazardous cooking fuel from households that do not. In the first round 54% of households used contaminating cooking materials while 51% did so in the second round. The composition of this group varies significantly between rounds since, as mentioned previously 12% of households switched fuels. Panel A shows household characteristics. The probability of suffering a serious respiratory-related illness decreased between rounds (14% vs. 10% which amounts to 289 vs. 186 children) with over 19% of the children (371) changing their health status (this percentage includes the children that became seriously ill in the following round after being healthy in the previous one, as well as the children that did suffer a serious respiratory-related illness in the first round, but did not in the second round). This result is to be expected since according to the medical literature the incidence of acute respiratory illnesses decreases with age (Tucher, Coulter and Downes, 1952). During the first round the probability of suffering a serious respiratory-related illness is very similar between homes with and without indoor air pollution (14%) yet in the second round it is larger for more polluted homes (11% vs. 8%). Diarrhea is also more common in homes using hazardous cooking materials as is lower birth weight. The most salient difference in child characteristics relates to the nutritional level of the child. Children living in households with indoor air pollution are more than three times as likely to be malnourished than their counterparts in households with better air. The nutritional status of the children also worsens as they age (malnourishment increases from 18% to 32% between rounds). The most notable socioeconomic divergences are related to maternal education (almost double the level in less-contaminated households in contrast to more polluted ones), the presence of other women in the household (slightly higher in homes that do not use hazardous cooking fuels), wall and roof permeability (with more permeability in homes that cook with contaminating materials), the probability of suffering an income shock (higher in houses with indoor air pollution and in the first round) and wealth. There are drastic differences in household wealth between homes that use hazardous cooking materials and those that do not. Homes with cleaner air are much better off financially. Panel B presents community characteristics. During the first round 66% of the sample lived in urban areas, compared to 69% during the second round. Most of the homes that use a non-hazardous cooking fuel are in urban areas. Both the probability of living in the highlands and the size of the population differ greatly by the choice of cooking fuel. Over 67% of households that suffer indoor air pollution live in the mountains. On the contrary, households that do not cook with hazardous fuels live in much more densely inhabited localities. Access to immunization programs was higher for less polluted homes during the first round. In the second round almost universal access eliminates these differences. Households that use hazardous cooking fuels are geographically clustered together. This is a persistent trend. The average level of female education is much higher in communities where less-contaminated households are located and it increases over time. The level of outdoor air pollution also varies substantially between rounds and choice of fuel. It is always higher where less polluted homes are located and it increases across time. Finally, average minimum temperature is persistently lower in areas where households that use more hazardous cooking fuels locate.

V. Results

5.1 The impact of indoor air pollution on child health

Results are shown in **Table 3**. The dependent variable in **Table 3** is the occurrence of a life threatening respiratory-related illness and the independent variable of interest is the use of a hazardous cooking fuel. The first column shows results for pooled data, while column two provides panel estimations. All specifications include child, regional and time fixed effects as well as time variant child characteristics, maternal characteristics, household characteristics and community characteristics[17]. The standard errors are clustered at the community level. According to the pooled data estimation, indoor air pollution has a positive but not statistically significant effect on the probability of a child suffering from a life-threatening respiratory-related illness. When the impact is estimated using a logistic regression instead of an OLS regression the odd ratio obtained (OR: 2.14) is right in the range obtained by the epidemiological literature (Mishra 2003; Fuentes-Leonarte et al. 2009). Children exposed to IAP are more than twice as likely to have experienced a life-threatening respiratory- related illness as children in households that choose non –hazardous cooking fuels. The panel estimation also shows a positive effect, but this time the coefficient is significant and much larger. This change in the coefficient could indicate the presence of unobserved heterogeneity that if not accounted for could bias the results downwards. For example if the child's frailty is negatively correlated with his/her health outcome but it is positively correlated with the level of IAP in the household the coefficient will be underestimated by not controlling directly for this time invariant unobserved characteristic. The switch to a hazardous cooking fuel increases the probability of suffering a life-threatening respiratory-related illness by over 16 percentage points. This implies that a child's probability of suffering a serious respiratory-related episode increases from 14.1 to 16.4 percent if a harmful cooking fuel is chosen by the household. In addition ventilation appears not to be of any consequence for the dispersion of indoor air pollution. None of the interaction terms of construction permeability and cooking fuel choice has a statistically significant impact on the probability of a poor health outcome for the panel estimation. Only in the pool estimation the interaction term of roof permeability and cooking fuel choice is significant. Yet the sign is negative, indicating that less permeability will decrease the probability of having a serious respiratory-related illness given the use of a hazardous cooking fuel. A less permeable roof is associated with a less precarious home and higher income levels and hence better chances of leading a healthier life despite being exposed to higher levels of indoor air pollution. Hence the pure effect of permeability cannot be distinguished with these data.

5.2 Impact of other women in the household on child health outcomes

The presence of other women in the household such as grandmothers or aunts could reduce the impact of indoor air pollution on child health. The hypothesis that other women in the household could affect the child's level of exposure to IAP is based on a model presented in a paper by Pitt, Rosenzweig and Hassan (2005). This model assumes individuals in the households are aware of the health consequences of being exposed to pollutants and want to optimize household utility by allocating unhealthy tasks to less productive women. Yet this model also takes into account that very young children (0-4 years of age) are the most vulnerable to respiratory symptoms due to their physiology and the fact they stay very close to their mothers during the cooking process. Hence, the authors argue that households could behave in such a way as to minimize the damage cause by IAP by reallocating exposure times across women such that women with very young children have less exposure to pollution. I test this premise by including in my basic panel estimation a control for the presence of grandmothers or aunts, as well as an interaction term between the presence of other female family members and the choice of a hazardous cooking fuel. This last term will allow me to calculate any differential effect of the presence of other grown women on pollution exposure. These results are presented in column 3 of **Table 3.** The effect of the use of a hazardous cooking fuel on the probability of suffering a serious respiratory-related illness barely decreases and the significance level of the coefficient is kept constant. Neither the interaction term that's included nor the coefficient for the presence of grandmothers or aunts is statistically significant. This last coefficient is positive, indicating a probable competition for resources in a household with additional potential mothers more concerned with the health of their own offspring. Hence, ignoring the presence of these other women appears not to bias the results.

5.3 The impact of indoor air pollution according to gender

Gender can be a major epidemiological element for several health conditions. In the case of acute respiratory infections sex can be a determining factor in their incidence and severity. These illnesses are more severe and frequent in younger males as a consequence of their narrower peripheral airways (Dezateux and Stocks 1997; Falagas, Mourtzoukou and Vardakas 2007). Furthermore, differences in the levels of polio-virus specific antibodies in the immunoglobulin serum between girls and boys and the presence of heterozygosity in the X chromosomes could explain the superior capability of girls to resist infection (Glezen et al. 1971). Furthermore, the epidemiology literature has found that the negative effect of cooking smoke on ARI is higher among boys than among girls (Mishra et al. 2005). However, these differences could be arguably due to a differential treatment and care of young boys and girls in developing countries.

I test this theory by estimating separate production functions for the respiratory health status of boys and girls (see **Table 4**). Indoor air pollution has a positive and highly statistically significant impact on the respiratory health exclusively of boys but not of girls[18]. This effect is much larger than for the total sample. The presence of indoor air pollution increases the occurrence of a serious illness in boys by 35 percentage points. This increase will raise the probability that a boy will suffer from a life-threatening respiratory-related condition from 15.1 percent to 20.4 percent. Yet these results could be due to the existence, in some cultures, of a preferential treatment shown to boys because they are considered a better investment. Boys could be diagnosed much more often than girls if they were taken to health professionals more frequently. However the sample shows that this is not the case. Looking at conditional treatment rates by gender I find the same percentage (99%) of boys and girls that suffered a serious respiratory-related episode were taken to a health facility. Hence it is not the case that under diagnosis is driving the lack of results for girls. It could also be argued that these results are due to higher levels of exposure for boys. According to Mishra et al. 2005 young Indian boys suffer from higher levels of IAP exposure since mothers keep them closer to them while cooking due to the discriminatory behavior against girls. The sample consists of 50% girls and 50% boys. The percentage of children suffering from a serious respiratory-related condition by gender is very similar (49% girls and 51% boys). Moreover, the percentage of boys in houses that use hazardous cooking fuels is very close to the percentage of girls (49% vs. 51%). Again, these percentages mimic the sample distribution, indicating no bias in terms of exposure.

Yet some could state that mothers could be more inclined to take a respiratory condition more seriously if it is the boy who is suffering from it. A priori I cannot discard this hypothesis. However the data shows no systematic difference in terms of illness recount by gender. Furthermore, the mothers in the sample do not appear to have a strong male preference when it comes to investments in child health. When vaccination rates are examined the percentage of girls vs. boys that get vaccinated is very similar to the sample gender breakdown[19].

Finally, it could be stated that the estimates presented are being driven by a bias in initial conditions. According to Bruce, Perez-Padilla and Albalak (2000), children with low birth weights are the most vulnerable to acute lower respiratory infections. Nonetheless, the percentage of children belonging to the lowest birth weight by gender is very similar (53% girls and 47% boys). If anything, girls are being overrepresented in the low birth weight group. Hence the results are not capturing worst initial conditions for boys. These differential impacts are very hard to attribute to any other socioeconomics risk factor and hence reinforce previous medical evidence related to the frailty of younger boys' respiratory physiology.

As in the estimations for the total sample, wall ventilation does not facilitate the dispersion of indoor air pollution. Yet the interaction term of roof permeability and cooking fuel choice has a negative and statistically significant impact on the probability of boys suffering a life-threatening respiratory-related episode. If a hazardous cooking material is used, less ventilation will decrease a boy's probability of suffering from a serious respiratory condition. This result once more indicates that a sturdier building material is a proxy for socioeconomic level. Yet the coefficient for wall permeability for the subsample of girls is significant and positive. In contrast with previous estimations, these results could suggest more permeability decreases the probability of suffering from a serious respiratory-related episode. Nevertheless this is just a correlation since due the structure of the data the effect of permeability cannot be clearly distinguished.

VI. Discussion

This paper offers new evidence of the impact of indoor air pollution on child health outcomes. It also analyzes the validity of various mitigation strategies discussed in the literature. In contrast to previous work it uses longitudinal micro data and exploits a rich set of controls. Using this data, I find a positive, statistically significant and considerable impact of indoor air pollution on a child's respiratory health. The presence of other adult women in the household does not generate a differential impact on child health for households that use hazardous cooking fuels. If anything their presence could generate a negative impact on health outcomes probably due to a more intense competition for resources. Similarly, construction materials permeability appears not to attenuate the impact of indoor air pollution on child health outcomes. On the contrary, sturdier construction materials are a proxy for higher socioeconomic status. Less permeability when a hazardous cooking fuel is used is correlated with better outcomes. This result indicates that the pure effect of permeability cannot be distinguished with these data. Hence I am unable to correctly assess the validity of Dasgupta et al. (2004a, b) hypothesis of the benefits of more ventilation in the house.

The results found in this paper have to take into account the Peruvian context. Children in Peruvian households using hazardous cooking fuels are exposed to levels of pollution much higher than the ones established by international standards. Furthermore, ventilation is really inadequate in these homes, with mostly no chimneys or few windows. In addition, households using hazardous cooking materials more often are characterized by less educated women who have fewer incentives/knowledge to take preventive measures to reduce their children's exposure to smoke.

A shortcoming of this study is its inability to control for the pollutant mix, particle composition, exposure patterns and exposure levels. Since it does not provide a continuous measure of pollution or exposure it is unable to quantify the relationship between exposure level and risk. However, this does not disqualify the results found. At most the impacts shown in this study are slight higher bounds. According to Ezzati and Kammen (2001b) models that are unable to measure the dose of pollution and hence do not take into account its spatial distribution, activity patterns, as well as the existence of concentrated emission periods underestimate exposure. This is particularly important for women who cook for whom exposure could be up to 71% underestimated. Yet according to this study for children 0-5 years of age exposure is underestimated by a mere 3%. On the other hand, Ezzati and Kammen (2001a) show that the exposure-response relationship between daily exposure to PM_{10} and acute respiratory infections is an increasing and concave function. Specifically for children younger than five acute respiratory infections rates rise faster for exposures < 2000 ug/m^3. Hence it is possible that the estimates presented in this study are overestimates for children that are exposed to low concentration levels of particulate matters. Yet according to the environmental country analysis carried out for Peru by the World Bank in 2007, indoor concentration of particles (PM_4 (ug/m^3)) exceed 500 mg/m^3 in 40% of the households monitored. This means the average child in Peru living in a home that uses hazardous cooking materials is exposed to extremely high levels of pollutants. Consequently the estimates found are still relevant for policy analysis.

It should be noted that with very high probability children from less well-off households are being under diagnosed. Mothers who do not have their children diagnosed with respiratory-related illnesses are probably poorer and have less access to transport and higher quality health services. Both rural and mountainous areas in Peru are characterized by lack of access to goods and services as well as with much higher usage of smoky fuels. Hence, children who are probably underdiagnosed live in areas with higher usage of smoky fuels. This relationship could bias the results downwards. Considering both the overestimation due to the lack of a dose-response relationship and the underestimation due to underdiagnoses, the results found in this study could be quite close to the actual relationship between indoor air pollution and child health. In addition this paper tests claims investigated in the epidemiological literature that indicate acute respiratory infections are more severe and frequent for boys. Groups with different innate characteristics could be more vulnerable to indoor air pollution. This will lead to heterogeneous treatment effects and to an underestimation of the actual impact of hazardous cooking materials on those who are more intensely affected. I provide evidence that indicates indoor air pollution is a much more severe problem among young boys than girls. These findings are consistent with previous studies that indicate a delayed lung development among boys younger than six years old (Glezen et al. 1971; Dezateux and Stocks 1997; Falagas, Mourtzoukou and Vardakas 2007). A limitation of this paper is the lack of a source of exogenous variation. However the robustness checks performed to test if the type of cooking material was indirectly channeling other socioeconomics risk factors provides evidence for the premise that the results found are causal and not merely descriptive. Future research should focus on analyzing possible mitigation strategies and on identifying more general sources of exogenous variation that could allow causal relationships to be unequivocally established.

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APPENDIX

A.1 Identification Strategy

A.1.1 Simultaneity bias

There are two main challenges to identifying the effect of pollution on health: simultaneity and selection bias. This study offers evidence that selection bias has been dealt with appropriately. Differences between households that change over time such as income shocks and child health changes are both accounted for. Specifically controls for maternal education, the nutritional status of the child, as well as his/her health compared to other children of the same age group are included. In addition, a dummy equal to one for households that suffer the loss of a job, income source or family enterprise in added. Nevertheless, the choice of cooking fuel could be, in addition, determined simultaneously with the respiratory health of the child. The conceptual framework states there are several variables that could affect both of these outcomes simultaneously. Authors such as Owusu-Boadi and Kuitunen (2006) identify female education in the community as a determinant of choice of cooking method. Yet, this variable can also affect the information available about health promoting behaviors. Similarly, the level of community cooking technology is relevant for both, the choice of cooking fuel and the health status of the child. It represents what is technologically available and socially acceptable in the locality. Even if the household uses clean fuels for cooking if all the neighbors and relatives cook with smoky fuels the health of the child will be compromised. Another factor influencing both choices is the average minimum temperature. Households living in colder areas will choose to cook with smoky fuels since they also provide warmth. This is especially true in the Peruvian context where almost no additional heating devices are recorded. In the Young Lives study survey less than 4% of the households confirmed having a heating device. Lower temperatures have also been associated with higher incidence of respiratory problems, since people tend to congregate indoors. This study in contrast to previous work is able to control for all these variables. Yet, both choices could also be affected by unobserved common shocks. I address this issue by regressing indoor air pollution on the respiratory health of the child plus a wide set of explanatory variables that could mediate their relationship[20]. As shown in the last column of **Table A1**, the occurrence of a serious respiratory-related illness does not have a statistically significant impact on the choice of cooking fuel. Hence, I believe that simultaneity is not a paramount concern.

A.1.2 Correlates of the choice of cooking fuel

As depicted by the descriptive statistics (**Table 2**), the choice of cooking fuel is highly correlated to socioeconomic characteristics as well as community level variables. Columns 1 and 2 of **Table A1** present results for these relationships using pooled and panel data. With the exception of the variable that identifies a household as urban or rural, introducing household fixed effects eliminates or at least reduces the significance of several time-varying covariates. For example: the impact of maternal education, roof permeability, community cooking technology level, supply of firewood and the probability of living in the highlands. In other cases, it at least reduces the magnitude of the effect of the covariates, as for the impact of household wealth and community female education level. These results suggest that introducing household fixed effects in addition to directly controlling for socioeconomic and community levels variables, is a good identification strategy.

A.2 Data attrition

A.2.1 Data Sets

I use three main sources of data. Young Lives International Study of Childhood Poverty tracks 2,052 Peruvian children born in the year 2000/1 for 15 years (the sampling strategy selected approximately 100 children in 20 different geographical sites)[21]. The first round collected data of children ages 6 months to 17 months in 2002. The second round took place between late 2006 and early 2007. This survey includes information about the child, the household and the social, economic and environmental context of the community where the child resides. This data allows me to control for different aspects in the child's life that could affect his/her health status, such as the child's nutritional level and age. I match these data with statistics at the regional level by using the 2002 and 2006 National Household Surveys (ENAHO). These are yearly surveys conducted nationally to measure living conditions, poverty levels and the impact of social programs. Finally, I merge in information about annual average minimum temperatures for each locality from the Peruvian National Meteorological and Hydrological Service (SENAMHI) database.

A.2.2 Data Attrition

The Young Lives study has a modest attrition rate. The survey team made sure to track migrating children between survey rounds. The non-response rate was 4.39%. The children that are missing (90) are not necessarily dead they just could not be found or refused to participate in Round 2. Nowhere in the 'Young Lives' country report for Peru is it mentioned that children died during the two surveys. Tests for selection bias due to this attrition reveal almost no statistically significant differences between the sample of children who dropped out of the study during the second round and the children who continued in the sample as shown in the **Table A2** (this table contains mean difference tests for a wide range of child, household and community characteristics). The only significant differences of means (at a 5% level) are for the probability of having an immunization program in the child's community and for the average minimum local temperature. Given the minimum differences no selection bias correction was applied.

A.3 Robustness checks

A.3.1 Impact of moving on child health outcomes

I use a first difference approach to obtain identification, which means that the variation in the choice of cooking method is coming from the households that changed their cooking fuel from one round of the survey to the other. Hence it is important to discard the hypothesis that the variation in cooking method is due to people relocating and having to change fuel sources. Looking at the households that moved (16% of the sample) I find only 20% switched cooking fuels. This number is not that much bigger to the percentage of people who switch despite not moving (11%). Yet, it is possible that people move due to employment or other types of shocks that might otherwise generate a spurious correlation between health outcomes and cooking method.

In order to assess this hypothesis, I ran a panel estimation that includes, in addition, a dummy variable that indicates that a person moved from his or her previous address. As before, the estimation includes individual, regional and time-fixed effects and all previous controls. The standard errors are clustered at the community level. The results are presented in **Table A3**. The coefficient associated with the use of a hazardous cooking fuel has increased slightly. The level of statistical significance is kept constant. This result could indicate that not controlling for the households that moved could, if anything, bias the results downwards.

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[1] What makes these materials especially harmful is the way they are used. They are usually burned in simple stoves that do not achieve complete combustion and hence release very harmful chemicals into the air.

[2] The specific mechanisms by which contaminants found in biomass smoke affect health outcomes are specific to each type of pollutant. Particles, especially those with diameters below 2.5 microns ($PM_{2.5}$), which can penetrate very deep into the lungs, generate acute bronchial irritation and increased reactivity. Acute exposure to either nitrogen dioxide or sulphur dioxide, also increase bronchial reactivity. In addition, longer term exposure to nitrous

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oxides increments susceptibility to bacterial and viral lung infections (Bruce, Perez-Padilla and Albalak 2000). Finally, carbon monoxide binds with hemoglobin which decreases the amount of oxygen delivered to key organs.

[3] These diseases deplete vital nutrients and complicate the child's recovery by decreasing food consumption and absorption. The consequent nutritional deficiencies will weaken the immune system, rendering the child more vulnerable to other diseases.

[4] 'During the first 2 years the brain develops rapidly through neurogenesis, axonal and dendritic growth, synaptogenesis, cell death, synaptic pruning, myelination, and gliogenesis' (Grantham-McGregor et al. 2007).

[5] Given the small size of particulates generated from firewood combustion, the difference between PM4 and PM2.5 particulate matters is little in this case.

[6] Even in the next wealth quintile barely, 3% of households cook with hazardous materials.

[7] This is a function of the type of fuel used.

[8] I use the price of gas, the most popular cooking fuel in Peru. It was used by 49% of the population according to the Environmental Health Module of the Peruvian Continuous Demographic and Health Survey for 2006.

[9] I use the supply of firewood the most popular choice of hazardous cooking fuel.

[10] I define community cooking technology as the percentage of households in the community (excluding the child's household) that uses hazardous cooking materials.

[11] Following Owusu-Boadi and Kuitunen (2006) I included female education as a determinant of choice of cooking method. This variable is measured as the average level of years of education for women at the community excluding the child's mother.

[12] This wealth score is created using housing quality characteristics, consumption of durables and access to utility services. The index includes the following variables: rooms per person, quality of floor, roof and wall, dummies for the possession of durables by the household and finally dummy variables indicating access to drinking water, electricity, a toilet and fuel.

[13] This variable represents a time constraint for the mother since additional younger children will demand part of her time.

[14] As the value of either of these variables increase, permeability decreases.

[15] This is a dummy equal to one for households that suffer the loss of a job, income source or family enterprise.

[16] The survey asks the following: 'In the last four years has NAME had one or more serious illness or injuries when you really thought s/he might die?'

[17] Individual time invariant variables such as birth weight, ethnicity, gender, maternal height and maternal age at birth where excluded from the estimation, since individual fixed effects are included.

[18] The difference between coefficients is statistically significantly different from zero only at a 10% level.

[19] The most common vaccines administered in the sample where the measles vaccine, the HIB vaccine and the vaccine against tuberculosis. 49% of girls vs. 51% of boys received the first one, while 50% of girls vs. 50% of boys received both the HIB and the tuberculosis vaccines.

[20] They include regional fixed effects, individual fixed effects and time fixed effects. Other controls: child nutritional level, maternal education level, household size, crowding, availability of drinking water, wall permeability, roof permeability, household wealth score, negative income shock, community cooking technology, community female education level, population size, dummies for belonging to the highlands and an urban area, a poverty index, the level of outdoor air pollution and the average minimum yearly temperature.

[21] This survey oversampled individuals in poor areas and by design excluded the wealthiest 5% of the sample in order to focus more on poorer groups and ethnic minorities. Hence it is not a nationally representative sample, although it is representative of the Peruvian population in a broad array of socio-economic indicators (Escobal et. al 2008).

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Table 1 - Panel data estimation of the impact of indoor air pollution on a child's probability of getting diarrhea

Dependent variable:	Life threatening episode of diarrhea		
	Total	Gender	
		Female	Male
Hazardous cooking fuel	0.048	0.023	0.087
	(0.071)	(0.159)	(0.071)
Other Controls	YES	YES	YES
Observations	1874	926	948
R^2	0.035	0.071	0.051

Source: Young Lives Study Round 1 and 2, ENAHO 2002, 2006 and SENAHMI.
Note: Robust standard errors clustered by community in parentheses, * significant at 10%; ** significant at 5%; *** significant at 1%. They include regional fixed effects, individual fixed effects and time fixed effects. Other controls: child's age, nutritional level and relative health status, maternal education, a dummy if the mother smokes, number of children under 5 years of age, availability of drinking water, crowding, negative income shock, household size, wealth score, availability of feeding programs as well as preventive and curative health public programs, female education level and cooking technology in the community, population size, a dummy for belonging to the highlands, a dummy for living in an urban area, a poverty index, the level of outdoor air pollution and the average minimum yearly temperature.. The independent variable is the choice of a hazardous cooking fuel

Table 2 - Descriptive statistics for both rounds

Panel A: Child/household characteristics

Child/household characteristics	Round 1			Round 2			ΔIAP	
	Mean	IAP=0	IAP= 1	Mean	IAP=0	IAP= 1	Δ<0	Δ>0
Prob. of serious respiratory-related illness	14%	14%	14%	10%	8%	11%	10%	8%
Prob. of diarrhea	7%	6%	7%	4%	3%	5%	1%	2%
Prob. of being malnourished	18%	8%	26%	32%	14%	49%	25%	25%
Prob. of lowest birth weight quarter	22%	21%	24%				22%	19%
Prob. of a boy	50%	52%	49%				47%	52%
Maternal education level	1.79	2.46	1.23	2.02	2.66	1.43	2.11	2.10
(Standard deviation)	(1.19)	(1.22)	(0.83)	(1.28)	(1.30)	(0.92)	(1.00)	(1.05)
Number of grandmas/aunts at home	0.61	0.66	0.56	0.38	0.41	0.36	0.42	0.58
(Standard deviation)	(1.05)	(1.05)	(1.05)	(0.83)	(0.87)	(0.78)	(1.01)	(0.88)
Wall permeability	2.63	2.77	2.52	2.72	2.80	2.65	2.62	2.72
(Standard deviation)	(0.69)	(0.60)	(0.74)	(0.68)	(0.59)	(0.75)	(0.78)	(0.68)
Roof permeability	2.07	2.32	1.86	2.14	2.39	1.91	2.14	2.05
(Standard deviation)	(0.60)	(0.68)	(0.42)	(0.57)	(0.60)	(0.41)	(0.56)	(0.56)
Prob. of income shock	15%	16%	13%	3%	4%	2%	3%	1%
Household Wealth score	0.00	2.09	-1.74	0.00	2.18	-2.03	1.06	-0.42
(Standard deviation)	(2.48)	(1.81)	(1.37)	(2.56)	(1.58)	(1.34)	(1.54)	(1.53)
Number of observations	2025	934	1116	1962	946	1016	147	93

Panel B: Community characteristics in urban areas

Community characteristics	Round 1			Round 2			ΔIAP	
	Mean	IAP=0	IAP= 1	Mean	IAP=0	IAP= 1	Δ<0	Δ>0
Urban	66%	98%	39%	69%	98%	43%	92%	80%
Highlands	50%	31%	67%	49%	28%	68%	37%	47%
#of people living in the locality	4802	6631	3264	15270	27628	3763	11631	14227
(Standard deviation)	(4118)	(3993)	(3554)	(22184)	(25352)	(8804)	(18474)	(17343)
Immunization program in locality	85%	93%	78%	98%	100%	98%	98%	99%
Community cooking technology[1]	54%	19%	83%	53%	21%	82%	46%	41%
Community female education level[2]	3.93	4.31	3.61	4.18	4.59	3.81	4.29	4.11
(Standard deviation)	(0.66)	(0.72)	(0.39)	(0.71)	(0.72)	(0.43)	(0.68)	(0.60)
Outdoor air pollution	0.61	0.86	0.40	0.91	0.96	0.86	0.90	0.91
(Standard deviation)	(0.64)	(0.54)	(0.64)	(0.54)	(0.58)	(0.50)	(0.53)	(0.66)
Average minimum temperature (C°)	12.33	13.51	11.33	13.09	14.90	11.41	14.18	12.43
(Standard deviation)	(7.66)	(7.86)	(7.36)	(7.20)	(6.63)	(7.31)	(7.10)	(7.87)

[1] Percentage of households in the community (excluding the child's household) that uses hazardous cooking materials

[2] It is not measure in the same units as maternal education level

Source: Young Lives Study Round 1 and 2. Note: IAP: Indoor air pollution = Cooking with a hazardous fuel.

Table 3 - Impact of indoor air pollution on a child's respiratory health

Dependent variable:	Serious Respiratory-related Illness		
	Pooled[1]	Panel	
	(1)	(2)	(3)
Hazardous cooking fuel	0.089	0.163	0.161
	(0.056)	(0.046)***	(0.047)***
Wall permeability	-0.008	0.032	0.033
	(0.005)	(0.025)	(0.025)
Roof permeability	0.003	-0.003	-0.003
	(0.014)	(0.021)	(0.021)
Fuel x wall permeability	-0.007	-0.035	-0.036
	(0.015)	(0.026)	(0.026)
Fuel x roof permeability	-0.034	-0.026	-0.027
	(0.018)*	(0.025)	(0.025)
Women at home			0.007
			(0.012)
Fuel x women at home			0.014
			(0.022)
Other controls	YES	YES	YES
Observations	3833	1874	1874
R^2	0.035	0.032	0.033

[1] A very similar result is obtained when running a Probit regression instead of an OLS regression. When running a logistic regression the odd ration is equal to 2.14.

Source: Young Lives Study Round 1 and 2, ENAHO 2002, 2006 and SENAHMI.

Note: Robust standard errors clustered by community in parentheses, * significant at 10%; ** significant at 5%; *** significant at 1%. They include regional fixed effects, individual fixed effects and time fixed effects. Other controls: child's age, nutritional level and relative health status, maternal education, a dummy if the mother smokes, number of children under 5 years of age, availability of drinking water, crowding, negative income shock, household size, wealth score, availability of feeding programs as well as preventive and curative health public programs, female education level and cooking technology in the community, population size, a dummy for belonging to the highlands, a dummy for living in an urban area, a poverty index, the level of outdoor air pollution and the average minimum yearly temperature. Covariates that should be taken care by the fixed effect (sex, maternal age at birth, maternal height, birth weight and ethnicity) were not included. The independent variable is the choice of a hazardous cooking fuel.

Table 4 - Panel data estimation of the impact of indoor air pollution on a child's respiratory health level by gender

Dependent variable:	Serious Respiratory-related Illness	
	Female	Male
Hazardous cooking fuel	-0.037	0.348
	(0.132)	(0.134)**
Wall permeability	0.052	0.017
	(0.022)**	(0.039)
Roof permeability	-0.034	0.019
	(0.026)	(0.036)
Fuel x wall permeability	-0.034	-0.039
	(0.032)	(0.039)
Fuel x roof permeability	0.059	-0.105
	(0.061)	(0.046)**
Other Controls	YES	YES
Observations	926	948
R^2	0.050	0.070

Source: Young Lives Study Round 1 and 2, ENAHO 2002, 2006 and SENAHMI.
Note: Robust standard errors clustered by community in parentheses, * significant at 10%; ** significant at 5%; *** significant at 1%. They include all previous controls. The independent variable is the choice of a hazardous cooking fuel

Appendix Tables

Table A1 – Correlates of the choice of cooking fuel

Dependent variable:	Choice of hazardous cooking fuel		
	Pooled	Panel	
		(1)	(2)
Child nutritional level	0.002	0.005	0.005
	(0.003)	(0.004)	(0.004)
Maternal education level	-0.016	-0.016	-0.016
	(0.004)***	(0.012)	(0.012)
Wall permeability	0.012	0.014	0.013
	(0.013)	(0.018)	(0.018)
Roof permeability	0.045	0.037	0.037
	(0.011)***	(0.017)**	(0.017)**
Household Wealth score	-0.111	-0.099	-0.099
	(0.016)***	(0.017)***	(0.017)***
Community cooking technology	0.336	-0.044	-0.044
	(0.077)***	(0.135)	(0.135)
Community female education level	-0.161	-0.152	-0.152
	(0.093)*	(0.082)*	(0.082)*
Gas price	0.003	0.002	0.002
	(0.004)	(0.003)	(0.003)
Supply of firewood	-0.089	-0.077	-0.076
	(0.046)*	(0.049)	(0.049)
Highlands	-0.167	-0.166	-0.165
	(0.029)***	(0.080)*	(0.080)*
Urban	-0.057	-0.089	-0.089
	(0.033)*	(0.029)***	(0.030)***
Serious Respiratory-related Illness			0.01
			(0.016)
Other controls	YES	YES	YES
Observations	3971	1923	1923
R^2	0.752	0.251	0.251

Source: Young Lives Study Round 1 and 2, ENAHO 2002, 2006 and SENAHMI.
Note: Robust standard errors clustered by community in parentheses, * significant at 10%; ** significant at 5%; *** significant at 1%. They include regional fixed effects, individual fixed effects and time fixed effects. Other controls: household size, crowding, negative income shock, availability of drinking water, population size, a poverty index, the level of outdoor air pollution and the average minimum yearly temperature.

Table A2: Test for mean differences between attrite sample and continuing sample

Variable	Continued		Attrite		T -statistic
	Mean	S.D	Mean	S.D	Ho: diff =
Prob. of serious respiratory-related illness	0.14	0.35	0.20	0.40	-1.65
Prob. of diarrhea	0.07	0.25	0.07	0.25	0.02
Prob. of being malnourished	0.17	0.01	0.24	0.05	-1.54
Birth weight	3201	12	3188	57	0.23
Prob. of a boy	0.50	0.01	0.41	0.05	1.73
Maternal education level	1.80	1.20	1.67	0.10	0.96
Number of grandmas/aunts at home	0.60	1.05	0.67	1.61	-0.57
Wall permeability	2.63	0.69	2.61	0.71	0.27
Roof permeability	2.07	0.59	2.12	0.65	-0.85
Hazardous cooking fuel	0.54	0.50	0.53	0.50	0.22
Prob. of income shock	0.14	0.35	0.21	0.41	-1.78
Household Wealth score	0.01	0.06	-0.21	0.25	0.81
#of people living in the locality (in 1000s)	4.81	0.09	4.68	0.41	0.29
Immunization program in locality	0.85	0.01	0.76	0.05	**2.57**
Community cooking technology	0.54	0.39	0.50	0.40	0.99
Community female education level	3.93	0.66	3.85	0.64	1.22
Outdoor air pollution	0.61	0.64	0.64	0.68	-0.52
Average minimum temperature (C°)	12.46	7.59	9.49	8.72	**3.60**
Highlands	0.50	0.01	0.59	0.05	-1.64
Urban	0.65	0.01	0.72	0.05	-1.37

Source: Young Lives Study Round 1
Note: Attrite sample: 90 children. Continuing children: 1962.

Table A3 - Impact of indoor air pollution on a child's respiratory health controlling for moving

Dependent variable:	Serious Respiratory-related Illness
	Panel
Hazardous cooking fuel	0.168
	(0.050)***
Wall permeability	0.033
	(0.024)
Roof permeability	-0.003
	(0.021)
Fuel x wall permeability	-0.037
	(0.026)
Fuel x roof permeability	-0.026
	(0.025)
Family moved	-0.021
	(0.036)
Other controls	YES
Observations	1874
R^2	0.033

Source: Young Lives Study Round 1 and 2, ENAHO 2002, 2006 and SENAHMI.
Note: Robust standard errors clustered by community in parentheses, * significant at 10%; ** significant at 5%; *** significant at 1%. They include regional fixed effects, individual fixed effects and time fixed effects. Other controls: child's age, nutritional level and relative health status, maternal education, a dummy if the mother smokes, number of children under 5 years of age, availability of drinking water, crowding, negative income shock, household size, wealth score, availability of feeding programs as well as preventive and curative health public programs, female education level and cooking technology in the community, population size, a dummy for belonging to the highlands, a dummy for living in an urban area, a poverty index, the level of outdoor air pollution and the average minimum yearly temperature. The independent variable is the choice of a hazardous cooking fuel.