Nutritional status and access to clean fuels: Evidence from South Asia

Priya Bhagowalia* and Parul Gupta

Affiliations:
TERI University, New Delhi, India
*Corresponding author: bhagowalia@alumni.purdue.edu

Selected Paper prepared for presentation at the Agricultural & Applied Economics Association's 2011 AAEA & NAREA Joint Annual Meeting, Pittsburgh, Pennsylvania, July 24-26, 2011

Abstract

Indoor air pollution due to solid fuels is among the ten most important risk factors in global burden of disease leading to respiratory diseases, anaemia, blindness and other disorders. This study examines the correlations between fuel choice and the nutritional status of children. We also explore if factors such as income, kitchen location and education play any role in conditioning fuel choice. Our results suggest that the choice and use of fuel has long lasting effects on the growth and health of children. It is also associated with a higher frequency of respiratory disorders. We find that agricultural households predominantly use unclean fuels.

Keywords: malnutrition, stunting**,** indoor air pollution, fuel choice

I. Introduction

Does the lack of access to clean fuels affect the nutritional status and health of children? What socio-economic factors are correlated with the choice and use of fuel? Do factors such as wealth, housing types, general awareness and education play any role in conditioning fuel choice? We attempt to answer these questions using nationally representative data sets from South Asia.

A large proportion of the agrarian population in South Asia relies on biomass fuels for cooking and heating requirements (Duflo et al., 2008a). These fuels include wood, crop and agricultural residue, animal dung and straw, which are easily accessible from inexpensive farm and forest resources (Holdren and Smith, 2000). According to the WHO, indoor air pollution (IAP) due to solid fuels is among the ten most important risk factors in global burden of disease, and the second most important environmental risk factor (after water and sanitation) (WHO,2002). The risk of IAP arises due to incomplete combustion of biomass fuels in inefficient stoves, located in poorly ventilated areas leading to emission of smoke, particulate matter and polluting gases (such as carbon monoxide and oxides of nitrogen and sulphur). Exposure to such fumes and residue poses a great health risk in the form of respiratory diseases, anaemia, blindness and other disorders, especially for women and children, who spend most of the time indoors and in the vicinity of cooking areas (Mishra, Retherford and Smith, 2002).

The situation is particularly grave in the rural and/or hilly regions of developing countries such as India, Bangladesh and Nepal. In Nepal, 81% of the households use solid (biomass) fuels, and hence are at risk of IAP, while the corresponding figure for Bangladesh stands at 89%. Evidence from India suggests that biomass-fuel using rural homes have daily particulate matter concentrations of 4000–21000 mg/m^3 . Women in such households daily face around two–five hours of exposures to concentrations of 3600–6800 mg/m^3 during cooking (Smith et al, 2000). The United States Environmental Protection Agency (EPA) standard for an acceptable annual 24-hour average of PM_{10} (particulate matter with a diameter of less than or equal to 10μm) is 150$\mu g/m^3$—this is much lower than the 24-hour PM_{10} concentration of more than 2000$\mu g/m^3$ in biomass-fuel-using households in India, reported by some studies (Smith, 2000).

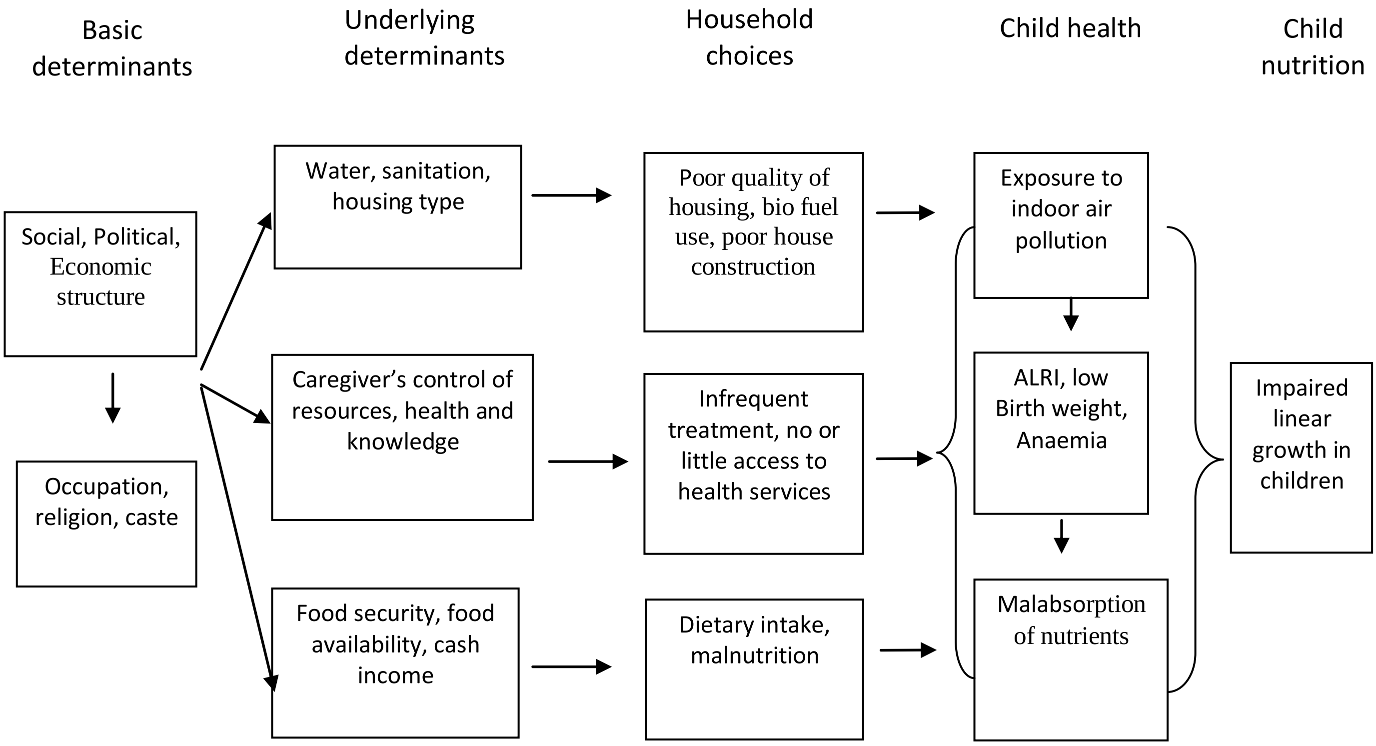
Despite the huge potential impact of IAP on health outcomes there have been very few studies analysing this problem. Epidemiological studies conducted in developing countries have reported on the associations between IAP and adverse health outcomes including anaemia (Mishra and Retherford, 2007), acute respiratory infections in children (Mishra, 2003; Mishra and Retherford, 1997; Smith et al., 2000; Duflo et al., 2008b) and low birth weight (Pope et al., 2010). However factors that are strongly associated with fuel choice and its impact on long term nutrition are relatively unexplored. Our data allows us to examine the impact of fuel choice on health, specifically nutritional status of children in India, and the incidence of respiratory symptoms (cough and breathing problems) using a sample of households from Nepal and Bangladesh. We further explore which socio-economic characteristics of households are closely related to fuel choice. In order to analyze the correlations between fuel choice and child nutrition, we focus on long term growth of children which is captured by the prevalence of stunting.

II. Conceptual framework

We adapt the conceptual framework from the United Nations Children's Fund's framework for the causes of child malnutrition (UNICEF 1990, 1998) and the extended model of care by Engle, Menon, and Haddad (1999) to explore the linkages between IAP and child nutrition. According to this framework the immediate determinants of child nutritional status are dietary intake (energy, protein, fat, and micronutrients) and health status. These are influenced by underlying determinants such as food security, adequate care for mothers and children, and a proper health environment, including access to health services, availability of safe water and sanitation.

We modify this framework to capture the different linkages by which the environment of the house can potentially influence child health.

Figure 1: Conceptual framework



Sources: Authors' adaptation from UNICEF 1990,1998; and Engle, Menon, and Haddad 1999, Mishra and Retherford 2006, Dasgupta et al 2004

The basic determinants in the UNICEF model determine the socio-economic structure of the household which in turn determines social characteristics of caste, religion and occupation which affect incomes. These incomes are translated into food security, access to health services, education for household members and also influence immediate environment of the household such as housing location, construction, access to water and sanitation. At the same time the social environment determines who gets the access within the household—women are primary care givers and their relative status and control over resources, access to health and education are often crucial for child health (see for example Smith and Haddad, 2000; Smith et al, 2003).

We posit that factors underlying nutritional status in children can be observed as household choices manifested in dietary intakes (for food security), treatment for respiratory and other infections, health check-ups during pregnancy, decision making abilities (for caregiver resources) and fuel choice, construction and location of immediate environment of the household. The interaction of all these factors results in indoor air pollution which through its impact on frequency of respiratory infections, asthma, anaemia and low birth weight, impairs the ability of the child to grow and maintain an active and healthy lifestyle. High concentrations of pollutants are known to have damaging effects on human health: particulate matter, oxides of nitrogen and sulphur are associated with bronchitis, tuberculosis, acute respiratory infections (ARI) and reduced lung function in children, while carbon monoxide can lead to low birth weight and neo-natal deaths (Bruce et al., 2000). Moreover, since children's immune system and lungs are not fully developed, exposure at an early age can be particularly damaging (Schwartz, 2004).

III. Data and Methods

III.1 Data

The analysis presented here is based on data on 4798 children under-five years of age included in Bangladesh Demographic and Health Survey (BDHS, 2007) and 4955 children under five years of age included in Nepal Demographic and Health Survey(NDHS, 2006). The datasets include information on demographic, socioeconomic and health variables from a nationally representative probability sample of 5783 Nepalese women (6150 in Bangladesh) aged 15–49 in the sample households.[1]

The 2007 BDHS employs a nationally representative sample that covers the entire population residing in private dwelling units in Bangladesh. The survey used the sampling frame provided by the list of census enumeration areas (EAs) with population and household information from the 2001 Population Census, Bangladesh. The EAs served as the primary sampling units for the survey (PSUs). The survey is based on a two-stage stratified sample of households. At the first stage of sampling, 361 PSUs were selected. The selection of PSUs was done independently for each stratum and with probability proportional to PSU size, in terms of number of households. Because only a small proportion of Bangladesh's population lives in urban areas, urban areas had to be over-sampled to achieve statistical precision comparable to that of rural areas. On average, 30 households were selected from each PSU, using an equal probability systematic sampling technique (NIPORT 2009).

[1] Outliers and missing observations were dropped before the analysis. Hence the effective sample size is 4798 for Bangladesh and 4955 for Nepal.

The NDHS (2006) used the sampling frame provided by the list of census enumeration areas with population and household information from the 2001 Population Census. Each of the 75 districts in Nepal is subdivided into Village Development Committees (VDCs), and each VDC into wards. The primary sampling unit (PSU) for the 2006 NDHS is a ward, subward, or group of wards in rural areas, and subwards in urban areas. The sample for the survey is based on a two-stage, stratified, nationally representative sample of households. At the first stage of sampling, 260 PSUs (82 in urban areas and 178 in rural areas) were selected using systematic sampling with probability proportional to size. A complete household listing operation was then carried out in all the selected PSUs to provide a sampling frame for the second stage selection of households. At the second stage of sampling, systematic samples of about 30 households per PSU on average in urban areas and about 36 households per PSU on average in rural areas were selected in all the regions (MOHP, Nepal 2007).

The India Human Development Survey 2005 (IHDS) is a nationally representative, multi-topic survey administered in 1503 villages and 971 urban neighbourhoods across India. The survey questioned 215,754 individuals from 41,554 households located across all states and union territories of India (except Andaman and Nicobar Islands and Lakshadweep). Our sample included anthropometric measurements of 19,000 children.

In the IHDS, villages and urban blocks (formed the primary sampling unit (PSU) from which the households were selected. In order to draw a random sample of urban households, all urban areas in a state were listed in the order of their size with number of blocks drawn from each urban area allocated based on probability proportional to size. Following this, the enumeration blocks were determined (using information from the Census) and a household sample of 15 households was selected from each block. The rural sample contains half the households that were interviewed initially by NCAER in 1993-94 in a survey titled Human Development Profile of India (HDPI) and the other half of the samples drawn from both districts surveyed in HDPI as well as from the districts located in the states and union territories not covered in HDPI. An overall response rate of 92% was recorded for the survey (Desai et al, 2009)

III.2 Estimation strategy

We use a reduced form equation to estimate the association between fuel choice and nutritional outcomes.

$$Y = \beta_0 + \beta_1 \boldsymbol{H} + \beta_2 \boldsymbol{C} + \beta_3 \boldsymbol{M} + \beta_3 \boldsymbol{F} + \beta_4 \boldsymbol{T} + \beta_3 \boldsymbol{K} + e \qquad (1)$$

Y is the nutritional outcome denoted by stunting or height-for-age z-score (HAZ). A child is considered stunted if his/her height-for-age z-score is two standard deviations below the median of the reference population. The z-scores are calculated relative to the WHO reference population (WHO, 2006) using igrowup package. **H** is a vector of household characteristics such as location, household size, economic status and **C** is a vector of child characteristics such as age, and sex. **M** denotes maternal characteristics such as maternal education, decision making power, and age. **F** represents the categories of fuel—classified as unclean, clean and a combination of both. **T** indicates access to health services in terms of antenatal check-ups and treatment for short term morbidity and **K** represents housing type captured by floor, roof wall materials and kitchen location. A set of regional dummies is also included. The construction of each of these variables in explained below. We use OLS and logit models to estimate the correlations between fuel choice and nutrition.

Indoor air pollution is indirectly determined by the type of fuel used for cooking, lighting or heating. The IHDS (2005) classifies fuel into firewood, dung, crop residues, kerosene, LPG and coal or charcoal. For the India sample, households were classified into three categories based on their fuel use—unclean fuels (firewood, dung, crop residues), clean fuels (LPG, coal/charcoal) and a third category that comprised of a combination of clean and unclean fuels or kerosene. For Nepal and Bangladesh, biogas, charcoal, LPG and electricity have been classified as "clean" fuels. Agricultural residue, animal dung, straw, wood and kerosene are considered "unclean" fuels.

Household characteristics such as economic status were measured by income quintiles and occupation of the head of the household. Households were categorized as agricultural, non agricultural labor, business/petty traders, salaried and other based on the main income source of income. In addition, religion dummies were computed taking on a value of 1 for Hindu, 2 for Muslim and 3 for all other religions. A caste dummy denoting a high caste or a low caste was also constructed.

Characteristics of children included age categories (1-2 years and 2-3 years) and child sex. Child characteristics were also reflected in access to health services denoting treatment for fever, cough and diarrhoea. Maternal characteristics included mother's age, dummies for primary and secondary education and decision making power as a measure of gender inequality. The decision making power index denotes the number of decisions taken independently by women. (who cooks, family planning, purchases, medical help for children).

Access to health services is quantified by care during pregnancy (antenatal check-ups for at least one pregnancy) and treatment taken for cough, fever and diarrhoea. The same variables are also used to denote the availability of health services when we examine the factors determining fuel choice.

Housing construction was valued by the construction materials (*pucca* or not *pucca*) denoting if the roof, wall and floor are made of proper bricks, stone and concrete or not. In addition we also consider kitchen location indicating an outdoor kitchen, separate kitchen and kitchen in living area.

IV. Results

IV. 1 Results from Nepal and Bangladesh

We first present descriptive results for Nepal and Bangladesh and then the descriptive and regression results for India. Socio-demographic characteristics of children in Nepal and Bangladesh are summarized in Table 1a and Table 1b respectively. All children are classified into two groups based on the fuel type used in their households: clean and unclean (biomass). The proportion of households using unclean fuels is much greater in rural areas. 65% of the households in Nepal and 95% in Bangladesh using clean fuels are from urban region, while more than 80% (Nepal) and 71% (Bangladesh) users of unclean fuels are rural residents. In Nepal, unclean fuels are used only by households in the lower income quintiles; in Bangladesh 91% of the households in the richest quintile use clean fuels. For the Nepal sample, there appears to be a subtle association between mother's education and fuel choice: of all users of clean fuels, almost 19% women had completed at least secondary and 18% had higher than secondary education; among users of unclean fuels, more than 65% had received no formal education. The results for Bangladesh are similar with 29% of the households having higher than secondary education use clean fuels.

Tables 2a and 2b show the incidence of respiratory symptoms in children. In the sample from Nepal 48% of the children in households using unclean fuels complained of chest pain or shortness of breath in the two week preceding the survey. 37.74% of Bangladeshi children in polluting-fuel-using households suffer from shortness of breath. In Nepal, around 36% of the children in households using clean fuels are anaemic while the corresponding figure for unclean fuels is almost 49% (Table 2c).

Apart from respiratory symptoms and anaemia, the possible associations between anthropometric indicators of children and fuel usage were also assessed. The indicators analysed were height, weight and size at birth[2]. Indicators for wasting, stunting and underweight were also examined, according to WHO definitions[3].

Table 3a tabulates the average of height and weight for children from Nepal by fuel type. The average height and weight for children in households using cleaner fuels are higher than those who live in households using unclean fuels. All differences are significant at the 5% level of significance. Incidence of wasting, underweight and stunting is higher for children in households using unclean fuels, for both samples. Results are shown in Tables 3c-d.

IV.2 Results from India

Table 4 shows the distribution of children by fuel type and other socio-economic characteristics across rural and urban areas. In rural areas, 83% of the children live in households using only unclean fuels for cooking, lighting and heating, while 15% live in households that use a combination of both. This number changes dramatically for urban areas where 35% of the children live in households using unclean fuels only, while 28% live in those that use clean fuels only. In contrast, only 0.57% of children live in rural households that use clean fuels exclusively. The age and sex distribution of children is more uniform across rural and urban areas. As expected, household size tends to be larger in rural areas than in urban.

[2] Size at birth was only analysed for Nepal, since data on this variable was not available in the Bangladesh sample.

[3] Underweight: weight-for-age z-score<-2; Stunting: height-for-age z-score<-2; Wasting: weight-for-height<-2

Mothers of rural children tend to be educated to a lesser degree than mothers in urban areas. Around 15% of the rural women have received primary education and 27% have received secondary education. Corresponding figures for urban areas are 13% for primary and 58% for secondary education. Gender equality is similar in urban and rural areas, with women making around 75% of the decisions either alone or jointly with a spouse.

In rural areas, 32% of the children live in households that have an outdoor kitchen, 44% have a separate kitchen while 23 % have a kitchen in the living area. The existence of a separate kitchen in the household in urban areas is much more at 60%.

Access to health services differs greatly across urban and rural areas. While 31% of the women in rural areas did not have any health check-ups during pregnancy, 68% of them actually had at least one antenatal check-up. Urban mothers have much better access with 89% having had antenatal check-ups. Treatment for fever, cough and diarrhoea is similar across rural and urban areas. Around 83% of the rural household are predominantly Hindu while 12% are Muslim in the sample. About 21% households belong to higher castes.

Table 5 shows the prevalence of stunting among children aged 0-5 years. Overall, 48% of the children in our sample are stunted and live in household that use unclean fuels only, whereas 32% live in households using clean fuels only. Stunting is higher among children whose mothers have only primary education as compared to those who have secondary education. Stunting is also higher among children who live in households having a kitchen within the living area.

Prevalence of stunting is higher among children whose mothers did not receive any antenatal check-ups and children who did not receive treatment for short-term morbidity. Children of Muslim households and low caste households are likely to be more stunted as well.

The effects of fuel type and other confounding factors on the height-for-age z-scores are shown in Table 6. The effect of unclean fuels or a combination of unclean and clean fuels is to lower the HAZ. This effect is robust to the inclusion of other regressors. HAZ is lower among children in households using only unclean fuels relative to those using a combination or only cleaner fuels. Other factors that influence the HAZ are child age, lower income, and secondary education of mothers. Lack of access to health services as measured by “no treatment” lowers the HAZ while antenatal check-ups tend to increase the HAZ. The location of the kitchen has a significant effect. Relative to the omitted category of "separate kitchen", a kitchen in the living area significantly lowers the HAZ.

The results from the logit regressions of stunting show a similar trend (Table 7). Relative to using clean fuels only, the use of unclean fuels only increases the odds of stunting as does a combination of clean and unclean fuels. Other factors that increase the odds of stunting are household size, poor economic status, and the presence of kitchen on the living area. As expected, higher education of mothers and antenatal check-ups lower the odds of stunting. These results suggest that stunting and lower HAZ among children may be attributed in part to their exposure to smoke from unclean fuels.

Table 8 presents the odds ratio for fuel choice on household characteristics. We find that the choice of fuel (clean or unclean) is significantly conditioned by economic status. Households in the lower income quintiles have higher odds of using unclean fuels only. Location of the house in an urban area increases the odds of using clean fuels. The main income source for the household—denoted by occupation—also affects fuel choice: agricultural households are more likely to use unclean fuels than salaried or business households possibly because of the easy availability of fuels such as dung and crop residues.

As expected, mother's education lowers the odds of choosing unclean fuels; however, decision making power surprisingly increases the odds. The choice of fuels is, to some extent correlated with region—households in the central region of India tend to use more of unclean fuels. Access to health services lowers the odds of choosing unclean fuels possibly because of awareness or information on their negative impacts. Finally, relative to a separate kitchen, kitchen in the living area increases the odds of choosing unclean fuels. It is unclear, whether this effect is reflective of household status or is capturing another unobserved correlate.

V. Conclusions

Our study indicates that fuel choice and use is associated with higher incidence of respiratory infections and stunting among children aged 0-5 years in South Asia The results are robust to the inclusion of other confounding factors for instance household economic status, women's education, access to health services and location of kitchen. The associations we see here suggest the existence of some association between fuel usage and health outcomes for children below five years of age in all three samples. Although some unexpected associations were found between incidence of cough and use of unclean fuels in the Nepal sample, the associations between all symptoms and unclean fuels were consistent with theoretical expectations in Bangladesh. In addition, evidence from the data seems to show that better air quality (and use of cleaner fuels) positively impacts anthropometric indicators of children especially in India. Use of unclean fuels also seems to be adversely related with anaemia and size at birth of children in the Nepalese sample and with stunting among children in India.

We do not claim to establish a causal relationship since our data are cross sectional in nature. A detailed exposure assessment would require monitoring of air quality and modelling its impact on nutrition. Our use of variables such as fuel usage as a proxy for exposure to biomass fuel smoke could very well mask the complex nature of the relationship between health and smoke. This approach is undoubtedly a simplification of the scale of exposure that women and children are subject to. Neither do these associations capture the full gamut of health impacts that exposure to indoor air pollution entails. Although we have not focused explicitly on time use, stove type, ventilation, or prices of cleaner fuels, we believe these results justify the need to direct attention to short term measures that could mitigate the negative impacts of biomass fuels on nutrition. To the extent that biomass fuel smoke exposure has a continued and cumulative effect on the health of children, it is likely that our coefficients underestimate the extent of damage.

We also acknowledge limitations related to the use of variables that are found to be highly correlated to child nutrition – gender inequality, iron supplementation, dietary diversity, access to community or self help groups, and health services. Wherever possible we have used indices that denote some degree to access to health, and gender inequality at the household level. We also control for several socio-economic characteristics that are correlated with access to food, health or participation in help groups or nutrient supplementation programs.

Despite these limitations, this study brings to light some of the urgent though somewhat neglected issues in the context of child and women nutrition. Nutritional and health interventions traditionally focus on supplying nutrients to women and children, subsidizing food or providing natal and neo-natal care. There is an evident relation between poverty and use of unclean fuels: households at lower levels of income tend to rely more on locally available, but inefficient fuels. This association is described as the "energy ladder" (Holdren and Smith, 2000). But, the movement up the "ladder" is unclear: the World Bank reports that the use of biomass for all energy sources has remained constant since 1975. This reiterates the inequalities present across the world in terms of access to basic needs such as clean and efficient fuel. As our study shows, the home environment also in which women and young children spend the maximum time also has a strong impact on their general health and nutrition.

Our analysis lends greater support for real time monitoring and tracking daily and seasonal variations in pollutant concentrations and strengthening approaches to tackle malnutrition. While we have not formally tested for all of these, some measures could include increasing awareness of mothers and pregnant women, adoption of simple ventilation practices, use of permeable materials (thatch/tin) in construction and/or improved stoves.

References

Bruce N, Perez-Padilla R and Albalak R 2000, 'Indoor air pollution in developing countries: a major environmental and public health challenge', Bulletin of the World Health Organization, vol. 78, no. 9, pp 1078-92.

Dasgupta S, Huq M, Khaliquzzaman M, Pandey K and Wheeler D 2004, 'Indoor air quality for poor families: new evidence from Bangladesh', *Policy Research Working Paper Series 3393,* The World Bank.

Dasgupta S, Wheeler D, Huq M and Khaliquzzaman M 2009, 'Improving indoor air quality for poor families: a controlled experiment in Bangladesh', *Indoor Air,* vol. 19, no. 1, pp. 22-32

Desai, Sonalde, Reeve Vanneman, and National Council of Applied Economic Research, New Delhi. (2005)India Human Development Survey (IHDS), 2005 [Computer file]. ICPSR22626-v8. Ann Arbor, MI:
Inter-university Consortium for Political and Social Research

Desai, S., A. Dubey, B.L. Joshi, M. Sen, A. Shariff, and R. Vanneman. 2009. "India Human Development Survey: Design and Data Quality." IHDS Technical Paper No. 1. University of Maryland, College Park,MD.

Duflo E, Greenstone M and Hanna R 2008a, 'Indoor air pollution, health and economic well-being', *Surveys and Perspectives Integrating Environment & Society,* vol. 1, no. 1, pp 1-9.

Duflo E, Greenstone M, and Hanna R 2008b, 'Cooking stoves, indoor air pollution and respiratory health in rural Orissa', *Economic & Political Weekly,* vol. 43, no. 32, pp. 71-76.

Engle PL, Menon P and Haddad L 1999, 'Care and nutrition: concepts and measurement', *World Development,* vol. 27, no. 8, pp. 1309-1337.

Holdren JP and Smith KR 2000, 'Energy, the environment, and health', in Goldemberg J (ed.), *The World Energy Assessment: Energy and the Challenge of Sustainability,* UN Development Programme, New York.

Khalequzzaman M, Kamijima M, Sakai K, Chowdhury NA, Hamajima N and Nakajima T 2007, 'Indoor air pollution and its impact on children under five years old in Bangladesh', *Indoor Air*, vol. 17, no. 4, pp 297-304.

Mishra V 2003, 'Indoor air pollution from biomass combustion and acute respiratory illness in preschool age children in Zimbabwe', *International Journal of Epidemiology*, no. 32, pp 847–53.

Mishra V and Retherford RD 1997, 'Cooking smoke increase the risk of acute respiratory infections in children', *National Family Health Survey Bulletin*, no. 8, pp 1–4.

Mishra V and Retherford RD 2007, 'Does biofuel smoke contribute to anaemia and stunting in early childhood?', *International Journal of Epidemiology*, no. 36, pp 117–129.

Mishra V, Retherford RD, and Smith KR 2002, 'Indoor air pollution: the quiet killer', *Asia Pacific Issues*, no. 63, pp. 1-8.

Ministry of Health and Population (MOHP) Nepal, New ERA, and Macro International Inc. 2007, 'Nepal Demographic and Health Survey 2006', Kathmandu, Nepal: Ministry of Health and Population, New ERA, and Macro International Inc.

National Institute of Population Research and Training (NIPORT), Mitra and Associates, and Macro International. 2009, 'Bangladesh Demographic and Health Survey 2007'. Dhaka, Bangladesh and Calverton, Maryland, USA: National Institute of Population Research and Training, Mitra and Associates, and Macro International.

Pope DP, Mishra V, Thompson L, Siddiqui AR, Rehfuess EA, Weber M and Bruce NG 2010, 'Risk of low birth weight and stillbirth associated with indoor air pollution from solid fuel use in developing countries', *Epidemiologic Reviews*, vol. 32, no. 1, pp 70-81.

Rinne ST, Rodas EJ, Rinne ML, Simpson JM and Glickman LT 2007, 'Use of biomass fuel is associated with infant mortality and child health in trend analysis', *American Journal of Tropical Medicine and Hygiene*, vol. 76, no. 3, pp 585-591.

Schwartz J 2004, 'Air pollution and children's health', *Pediatrics*, vol. 113, pp 1037-1043.

Smith L, and Haddad L 2000, *Explaining malnutrition in developing countries: A cross country analysis*. Washington D.C: International Food Policy Research Institute.

Smith, L. C., U. Ramakrishnan,, A. Ndiaye, L. Haddad, L., and R. Martorell. 2003. *The Importance of Women's Status for Child Nutrition in Developing Countries*. Washington D.C: International Food Policy Research Institute.

Smith KR 2000, 'National burden of disease in India from indoor air pollution', Proceedings of the *National Academy of Sciences of the United States of America*, vol. 97, no. 24, pp 13286-13293.

Smith KR, Samet JM, Romieu I and Bruce N 2000, 'Indoor air pollution in developing countries and acute lower respiratory infections in children', *Thorax*, vol. 55, no. 6, pp 518-532.

Stata Corporation 2009. Stata/SE 11 for Windows.

Tole L 1998, 'Sources of deforestation in tropical developing countries', *Environmental Management,* vol. 22, no. 1, pp. 19-33.

UNICEF 1990, 'The State of the World's Children',Oxford, Oxford University Press.

UNICEF 1998, 'The State of the World's Children', Oxford, Oxford University Press.

World Health Organization (WHO) 2006, Multicentre Growth Reference Study Group. WHO Child Growth Standards based on length/height, weight and age. Acta Paediatr*ica* Suppl*ementum* 2006; 450: 77–86.

World Health Organization (WHO) 2002, World Health Report, WHO, Geneva.

WHO 2004, *Country profiles of Environmental Burden of Disease (Nepal)*, viewed June 10, 2010, http://www.who.int/quantifying_ehimpacts/national/countryprofile/nepal.pdf

WHO 2004, *Country profiles of Environmental Burden of Disease (Bangladesh)*, viewed June 10, 2010,
http://www.who.int/entity/quantifying_ehimpacts/national/countryprofile/bangladesh.pdf

Tables

Table 1a: Sample description by fuel type and socio-economic indicators (Nepal)

Factor	Fuel types	
	Clean (n=357)	Polluting (n=4598)
Location %		
Urban	64.71	18.75
Rural	35.29	81
Wealth %		
Poorest	0	32
Poorer	0	23
Middle	0	18.88
Richer	12.32	18.01
Richest	87.68	8.18
Education (mother) %		
No education	12.04	65.33
Incomplete primary	6.72	13.27
Complete primary	5.32	4.89
Incomplete secondary	38.38	12.68
Complete secondary	19.05	2.68
Higher	18.49	1.15

Figures may not add to 100 vertically due to rounding

Table 1b: Sample description by fuel type and socio-economic indicators (Bangladesh)

Factor	Fuel types	
	Clean (n=498)	Polluting (n=4300)
Location %		
Urban	94.78	28.12
Rural	5.22	71.88
Wealth %		
Poorest	0.40	23
Poorer	1.61	23.19
Middle	0.6	20.35
Richer	5.42	19.07
Richest	91.97	13.77
Education (mother) %		
No Education	11.24	30.51
Incomplete Primary	14.86	22.81
Complete primary	7.03	9.91
Incomplete secondary	25.90	25.70
Complete secondary	11.45	6.07
Higher	29.52	5

Figures may not add to 100 vertically due to rounding

Table 2a: Prevalence of respiratory symptoms in Nepalese children

Symptoms in last two weeks	Fuel types	
	Clean	Polluting
Cough %	27.45	17.73
Shortness of breath %	37.36	48.71
Chest pain/Running nose %		
Chest only	29.73	45.59
Nose only	43.24	30.23
Both	0	23.17

Table 2b: Prevalence of respiratory symptoms in Bangladeshi children

Symptoms in last two weeks	Fuel types	
	Clean	Polluting
Cough %	29.52	37.28
Shortness of breath %	31.97	37.74
Chest pain/Running nose %		
Chest only	25.53	27.11
Nose only	61.70	62.31
Both	10.64	10.08

Table 2c: Prevalence of anaemia in Nepalese children

Anaemia status	Fuel types	
	Clean (n=297)	Polluting (n=4122)
Severe	0	1
Moderate	15	22
Mild	21	26
Not anaemic	64	51

Table 3a: Anthropometric indicators (Nepal)

Variable (mean)	Fuel types	
	Clean	Polluting
Height (cm)	86.03	81.85
Weight (kg)	11.45	10.21

Table 3b: Anthropometric indicators (Bangladesh)

Variable (mean)	Fuel types	
	Clean	Polluting
Height (cm)	84.95	82.29
Weight (kg)	11.20	10.12

Table 3c: Wasting/Underweight/Stunting (Nepal)

	Fuel types	
	Clean	Polluting
Wasting %	6	94
Underweight %	3	97
Stunting %	3	97

Table 3d: Wasting/Underweight/Stunting (Bangladesh)

	Fuel types	
	Clean	Polluting
Wasting %	7	93
Underweight %	6	94
Stunting %	7	93

Table 4: Fuel type and other socioeconomic characteristics across rural and urban areas (IHDS, 2005)

Characteristics	Rural	Urban
Biomass fuel smoke		
high	83.70	35.21
combination	15.73	36.20
low	0.57	28.60
Child Sex		
female	48.47	47.52
male	51.53	52.48
Child age (years)	2.64	2.61
household size	7.27	6.18
Women's education		
Primary	15.07	13.50
Secondary	27.22	58.18
Women's decision making power	3.24	3.35
Mother's age	27.55	27.26
Kitchen type		
Outdoor kitchen	32.51	16.36
Separate kitchen	44.28	60.05
Living area	23.21	23.59
Region		
Central	9.24	8.01
East	29.83	13.79
North	28.72	23.57
Northeast	2.30	1.52
South	12.31	23.48
West	17.60	29.63
Health services		
No ante-natal checks	31.45	10.08
Antenatal check-ups	68.55	89.92
No short term morbidity	68.31	68.60
No treatment for fever, cough or diarrhoea	1.54	1.11
Treatment for fever, cough, diarrhoea	30.137	30.28
Religion		
Hindu	83.29	73.71
Muslim	12.26	21.03
Other	4.45	5.26
Caste		
high caste	21.38	36.35
low caste	78.62	63.65

Table 5: Prevalence of stunting among children aged 0-5 years by fuel type and other socioeconomic characteristics (IHDS, 2005)

Characteristics	Stunting
Biomass fuel smoke	
high	48.86
combination	38.69
low	32.8
Women's education	
Primary	46.71
Secondary	37.92
Kitchen type	
Outdoor kitchen	46.56
Separate kitchen	42.89
Living area	50.41
Health services	
no ante natal checks	56.48
Antenatal check ups	41.53
No short term morbidity	45.58
no treatment for fever, cough or diarrhoea	50.48
treatment for fever, cough, diarrhoea	45.77
Religion	
Hindu	45.44
Muslim	50.16
Other	37.28
Caste	
high caste	41.58
low caste	47.07

All figures in percentages

Table 6: Effects of fuel type, maternal characteristics and other socio-economic factors on Height-for-age, all India (OLS)

	Model 1	Model 2	Model 3
Biomass fuel smoke			
Unclean	-0.83***	-0.79***	-0.22**
Combination	-0.36***	-0.33***	-0.13
Child characteristics			
Child age 1-2 years		0.87***	0.90***
Child age 2-3 years		-0.17*	-0.16*
Sex		0.07	0.02
Household characteristics			
Household size		-0.01**	-0.02
Economic Status			
Lowest quintile			-0.31*
2nd quintile			-0.40***
3rd quintile			-0.33*
4th quintile			-0.27*
Rural /Urban			0.10
Mother's characteristics			
Primary education			0.17*
secondary education			0.30***
decision making power			-0.03
Mother's age			-0.00
Region			
Central			-0.12
East			0.21
North			0.01
South			0.13
West			0.12
Health services			
No treatment for fever, cough or diarrhoea			-0.15*
Treatment for fever, cough or diarrhoea			-0.27
Antenatal check-ups			0.45***
Kitchen type			
Outdoor Kitchen			-0.02
Living area kitchen			-0.20*
Constant	-0.84***	-1.19***	-1.61***
N	15709	15709	13005
F	56.84	54.68	22.74
R^2	0.01	0.05	0.07

** $p < 0.10$, * $p < 0.05$, *** $p < 0.001$

Table 7: Effects of fuel type, maternal characteristics and other socio-economic factors on Stunting, all India (Odds Ratios)

	Model 1	**Model 2**	**Model 3**
Biomass fuel smoke			
Unclean	1.96***	1.90***	1.25*
Combination	1.29*	1.26*	1.10
Child characteristics			
Child age 1-2 years		0.82***	0.80***
Child age 2-3 years		1.23***	1.23*
Sex		0.90*	0.94
Household characteristics			
Household size		1.02*	1.03*
Economic Status			
Lowest quintile			1.48*
2nd quintile			1.54*
3rd quintile			1.42*
4th quintile			1.31*
Rural /Urban			1.05
Mother's characteristics			
Primary education			0.95
secondary education			0.82*
decision making power			1.02
Mother's age			1.00
Region			
Central			1.06
East			0.80
North			0.99
South			0.89
West			0.78
Health services			
no treatment for fever, cough or diarrhoea			1.07
treatment for fever, cough, diarrhoea			1.17
Antenatal check ups			0.65***
Kitchen type			
Outdoor Kitchen			0.95
Living area kitchen			1.23*
N	15709	15709	13005
Wald Chi^2	98.94	139.50	301.77

** $p < 0.10$, * $p < 0.05$, *** $p < 0.001$

Table 8: Associations of fuel type with household characteristics, all India (Odds Ratios)

	Unclean fuels	Clean fuels
Economic Status		
Lowest quintile	6.29***	0.12***
2nd quintile	4.92***	0.16***
3rd quintile	3.59***	0.32***
4th quintile	2.03***	0.41***
Rural /Urban	0.23***	17.25***
Occupation		
Agriculture	2.82***	0.14***
Non agricultural labour	1.61*	0.70**
Business/petty trade	1.16	0.99
Salaried	0.80	1.32
Household characteristics		
Household size	1.07***	0.74***
Religion		
Hindu	1.69*	0.67*
Muslim	2.10*	0.45*
Low caste	1.52***	0.74*
Mother's characteristics		
Primary education	0.71*	1.25
secondary education	0.31***	2.16***
decision making power	1.15*	1.10**
Mother's age	1.00	1.03***
Region		
Central	1.89*	2.19
East	0.56	0.32*
North	0.52*	2.65*
South	1.15	1.08
West	1.01	1.75
Health services		
treatment for fever, cough, diarrhoea	1.01	0.69***
no treatment for fever, cough or diarrhoea (proxy for health services)	1.90*	0.53
Antenatal check ups	0.44***	1.89*
Kitchen area		
Outdoor Kitchen	3.26***	0.22***
Living area kitchen	1.73***	0.49***
N	15696	15696

Exponentiated coefficients
** $p < 0.10$, * $p < 0.05$, *** $p < 0.001$