

## EXPOSURE TO BIOMASS FUEL SMOKE AND RISK OF CHILD MORBIDITY: AN ANALYSIS ON SOUTH AND SOUTH-EAST ASIAN COUNTRIES

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**Abstract:** *Around 03 billion people still cook using biomass fuels, these cooking practices are hazardous and produce a wide range of health-damaging pollutants causing high level household air pollution. Most of these people using solid fuels belong to lower wealth quintile household and resides in low and middle-income countries. The women and young children who spend most of their time near the domestic hearth are comparatively more exposed to toxic amount of household air pollutants every day. The current study compares the scenario of child respiratory health; assessing the occurrence of ARI and cough among children aged under five in South and Southeast Asian countries. The current study is comprised of analysis of Demographic Health Survey data for Afghanistan, India, Nepal, Cambodia, Bangladesh and Philippines. A comparative study was conducted between the selected countries. The differences in categorical variables were tested using Pearson's  $\chi^2$  Statistics, since both treatment and outcome variable in the study are binomial, a simultaneous equation was used (probit regression model). The results indicated that there is an increased likelihood of occurrence of ARI and cough among children aged under five belonging to the households using solid fuel in the selected South and Southeast Asian countries.*

**Keywords:** Asia, ARI, Child Morbidity, Cough, DHS Data, Indoor Air Pollution, Smoke

## **Introduction**

Household air pollution (HAP) is usually measured indoors and arises from domestic activities of cooking, heating, and lighting. Around 2.6 billion people still cook using biomass fuels (such as firewood, agricultural wastes, charcoal, coal and cow dung) and kerosene is usually the most common fuel for inefficient stoves (1). Most of these people using solid fuels are from lower wealth quintiles and resides in low and middle-income countries (2). These cooking practices are hazardous and produce a wide range of health-damaging pollutants causing high level household air pollution; some small soot particles are produced that penetrate deep into the lungs (3). Indoor smoke can be 100 times higher than acceptable levels for fine particles in poorly ventilated dwellings (4). The women and young children who spend most of their time near the domestic hearth are comparatively more exposed to a toxic amount of HAP every day (5)(6). Household air pollution (HAP) is a severe health risk factor which is intrinsically linked to poverty (7). The Global Burden of Disease Study indicated that household air pollution attributed almost 3.5 million deaths worldwide in 2010 (8). The number further increased to 3.8 million caused by the inefficient use of solid fuels and kerosene for cooking in 2015 (9).

Solid fuel can have serious adverse consequences on health as well as on the environment, and also on economic development (10)(11). Around 2.8 million children face death prematurely each year because of exposure to indoor air pollution from solid fuel concerning health (12). These fuels produce smoke, often used in an inefficient stove or open fire with incomplete combustion, and results in a huge amount of indoor air pollution when smoke is poorly vented (13). Biomass fuels (derived from plant sources) or coal combustion results in the release of products of incomplete combustion such as particulate matter (PM) and carbon monoxide (14). Furthermore, solid fuel is commonly used in homes with poor or absent chimney ventilation of smoke. An estimate given by the International Energy Agency (IEA 2006) indicates that the lack of new policies will increase this figure to 2.7 in 2030 due to population growth (15).

## **DATA AND METHODOLOGY**

### **Data Sources**

The data source used was the Demographic and Health Survey (DHS). Recent available Standard DHS-VIII data of selected eight countries of South and Southeast Asia region have been taken. DHS are nationally-representative household surveys that provide data for a wide range of monitoring and impact evaluation indicators in the areas of population, health, and nutrition.

### **Sample Size**

The present study considers information from currently married women aged 15-49 years of selected South and Southeast Asian countries using recent DHS data of the respective countries. The Afghanistan data set comprises 1, 25,715 women, Bangladesh 43,772 women, India 13,15,617 women Cambodia 33,290 women, Myanmar 22,989 women; Nepal 26,028 women and Philippines 1,51,703 women.

### **Child Morbidity**

With reference to available data from different countries the occurrence of diseases, four categories, i.e., fever, cough, acute respiratory infections (ARI) and diarrhea were taken into consideration to compute child morbidity.

### **Data Analysis**

Differences in categorical variables were tested using Pearson's  $\chi^2$  (chi-square) statistic, i.e., to understand the association between indoor air Pollution and morbidities among children. Since both treatment and outcome variable in this case are binomial, a simultaneous equation has been used, i.e., probit regression model in order to consider the effect of Indoor air Pollution along with other variables. In the binary probit model the event of occurrence of the diseases i. e. fever, diarrhea, ARI and cough, has been taken as 01, and non-occurrence of the event has been taken as 0.

The relationship between specific variables and the outcome probability is interpreted by the means of marginal effect, which accounts for the partial change in the probability. The marginal effect associated with continuous explanatory variables (x) on the probability P ( $Y_i = 1 | X$ ), holding the other variables constant. The marginal effect provides insight into how the explanatory variables shift the probability of risk of the morbidities. Using the command “*margins*” in Stata 16.0 software marginal effects has been calculated for each variable holding other variables constant at their sample mean values.

## RESULTS

### Prevalence of Disease among the Children in the Selected Countries

Table 1 shows the prevalence of childhood morbidity in selected countries. Three major patterns of childhood morbidity that were experienced in the two weeks preceding the survey were examined: diarrhea, fever, ARI and cough. These four diseases have been identified as main morbidities among children under the age of five.

#### Fever

In Nepal, 4.22 percent of the fever cases in children are from the households which are dependent on solid fuels. The scenario of Afghanistan depicts a similar picture where children from 7.59 percent of household using solid fuel suffered from fever. Total prevalence of fever is 6.88 percent among children in Bangladesh. In Cambodia, 6.15 percent of children suffered from fever in the solid fuel using households. Percentage of children suffering from fever among the solid fuel using households in Myanmar, Philippines, and India are 3.55 percent, 4.30 percent, 3.37 percent, and 2.65 percent respectively.

#### Diarrhea

1.49 percent of children from the solid fuel using household in Nepal suffered from Diarrhea; in Afghanistan, it is 7.40 percent. In Bangladesh, it is 1.0 percent who belonged to the household using solid fuel for cooking. Cambodia showed 2.84 percent of diarrhea cases. In Myanmar, the calculated percentage of diarrhea suffering children from solid fuel using houses were 2.42 percent. Philippines and India also showed a very high prevalence of diarrhea among children in the solid fuel using households.

#### Acute Respiratory Infections (ARI)

Indoor air pollution has a significant effect on ARIs; the evidence was found in Nepal where 0.59 percent of children having ARIs were from solid fuel using households. 3.66 percent of children born in the households using solid-fuel suffered ARI in Afghanistan. For Bangladesh the percentage is 1.01 percent. 1.21 percent children in Cambodia suffered ARI in the solid-fuel using households. In Myanmar, Philippines and India the percentage of children suffering from ARI are 0.71 percent, 0.42 percent and 0.58 percent, respectively.

#### Cough

The highest prevalence of cough in the solid fuel using households was found in Afghanistan which is around 6 percent while minimum prevalence is seen in India with 2.13 percent. 4.25 percent of children in Nepal from the households using solid fuel had cough. In Afghanistan, 6.32 percent of children suffered ARI who belonged to the households using solid-fuel. In Bangladesh and Cambodia also the percentages were high i.e., 5.98 percent and 4.75 percent respectively. The percentage of children suffering from cough in Myanmar, Philippines and India were 3.40 percent, 5.27 percent and 2.24 percent respectively.

### Results of Marginal Effect from Probit Regression Analysis:

#### Fever

Table 2 shows the result of marginal probabilities from the probit regression analysis of fever with respect to its related covariates. Since the Coefficients of a probit regression model is not directly interpretable, the marginal probabilities are calculated to see the effect of various categories of independent variables on the outcome variable. When we see the probabilities across different countries, a clear picture of variations can be seen. For the type of fuel used for cooking in the household, among 7 selected countries, Afghanistan showed the highest probability of occurrence of fever among solid fuel user with a probability value of 0.065 and least probability of occurrence was seen in India (0.024). Among solid-fuel using households'

highest probability of occurrence of fever was seen in Afghanistan (0.067) and India occupied the extreme bottom with a probability of 0.026. Even after consuming safe drinking water probability of occurrence of fever was seen to be highest in Afghanistan and Bangladesh with a probability 0.66. In unsafe drinking water, the probability was highest in Bangladesh (0.075), and least probability was seen in India (0.023). Where there were no toilet facilities, highest probability of occurrence of fever was seen in Afghanistan (0.079). In all the three categories (no toilet, flush toilet, and pit & others) India occupied the bottom with probabilities of occurrence 0.027, 0.024 and 0.024 respectively. The results remain unchanged when interaction effect of fuel used for cooking and source of drinking water was seen for Afghanistan. Nepal occupied the top position in terms of probabilities of occurrence of fever, and lowest probability was seen in India.

### **Diarrhea**

In table 3 Afghanistan showed the highest probability of occurrence of Diarrhea i.e., 0.071 percent whereas Nepal shows the lowest probability (0.012). Now, when we see the scenario for solid fuel usage, Afghanistan again occupied the top position on the list with a probability of 0.072 whereas Bangladesh shows the least (0.008). The Scenario for the people who use safe drinking water, Afghanistan topped the list with the highest probability of getting diarrhea as compared to other counterparts, whereas Bangladesh is at the bottom. For, unsafe use of drinking water, again Afghanistan is at the top of the list with a probability of 0.072 whereas Nepal stands at the bottom. It can clearly see that the probabilities for all the countries came out to be highly significant. People who cook food outside the home, Afghanistan, and Bangladesh shows the highest probabilities i.e., 0.065 and 0.007 respectively. For the Education levels of the mother, in all four sub-categories of education (Illiterate, primary, secondary and higher education) Afghanistan shows the highest probability of occurrence of diarrhea followed by Myanmar whereas Bangladesh shows the least probabilities of occurrence of diarrhea among all the countries selected for the study. For poor, middle and rich wealth quintile of the population, Afghanistan shows the highest probabilities i.e., 6.7 percent, 7.6 percent and 7.5 percent respectively in all the three categories. For the categories of parity and birth interval, the overall scenario does not change at all when we try to see the interaction effect of “fuel” and “water source used” on diarrhea. In these study for the selected countries, we can clearly put forward our conclusion that Afghanistan has the highest chance of getting diarrhea followed by Myanmar, and Bangladesh occupies the bottom indicating a better health scenario as compared to all other countries.

### **ARI (Acute Respiratory Infections)**

Table 4 shows the result of marginal probabilities from the probit regression model of the binary outcome variable ARI (Acute Respiratory Infections) with respect to different covariates. From the different types of fuel used for cooking in the household, solid fuel using households in Afghanistan shows 0.03 probability, followed by Cambodia & Myanmar. When we see in terms of education of the mother, children born to illiterate mothers of Afghanistan have the highest probabilities of suffering from ARI. For, the interaction effect of fuel used for cooking and sources of drinking water, the probability of occurrence of ARI for the children of Afghanistan is the highest in all the four categories.

### **Cough**

In table 5 result of marginal effect of probit regression model for occurrence of cough are presented, it was observed from the analysis that the children of Nepal have the highest probability of suffering cough in both non-solid and solid fuel using households with probabilities 0.049 and 0.058 respectively. When interaction effect of fuel used for cooking and source of drinking water was seen the interaction effect of both “safe” and “unsafe” drinking with solid fuel showed the highest probability of occurrence of Cough in Nepal and least probability was seen in India. The effect of fuel used for cooking and source of drinking water also shows the similar results.

### **Discussion**

Under five mortality and morbidities are dependent on many factors including various maternal and socioeconomic factors (16) (17). The outcome of this study shows that the use of biomass fuel for cooking has a significant effect on occurrence of diseases among the under five

children. Studies on indoor air pollution typically focus on the specific pollutants like PM (particulate matter) and CO (carbon monoxide) which can cause morphologic and biochemical changes after penetrating deep into the lungs. In the biomass fuel using households the mean 24 hour PM level is 300–3,000  $\mu\text{g}/\text{m}^3$ , but can reach up to 30,000  $\mu\text{g}/\text{m}^3$ , which is much higher than the acceptable range of PM level in the air (18). CO when inhaled can cause systemic effect on one's biology by binding with the hemoglobin and produces carboxyhemoglobin, which can reduce the oxygen delivery to the vital tissues (19). This can be a reason to cause illnesses among the children where CO is ambient in the air produced while burning any solid fuel. Another study in India found that there is a significant association between solid biomass fuel use in the households and respiratory symptoms and severity of the disease among the children from those households (20). A study in Nairobi also found the increased risk of Asthma when the study population was exposed to wood smoke (21). Another study showed that there was a significant trend of higher infant mortality among the households that uses solid biomass fuel in greater proportions (22). These studies contribute to the base of effect of household air pollution caused by burning biomass-fuel on child health. But these results might not be adequate to assess any unique relationship. A review of published evidence revealed that there is an increased risk of lower respiratory infection in children with the use of biomass fuel (23). Another study found that among the households using solid fuel there is a significantly increased risk of cough and earache (22). One more study had reported that burning biomass fuel in developing countries is linked to respiratory symptoms and chronic respiratory diseases in children (18). The major limitation of this study is its cross-sectional design, which does not account for past exposure to biomass fuel smoke also the duration of exposure. Since the data were collected retrospectively there is potential risk of recall bias influencing the results. Strength of this study was the diversity of data. The analysis was made for six South and Southeast Asian countries. In Conclusion, the result of this study suggests that exposure to biomass fuel smoke is associated with increased risk of morbidity among children. The findings have important policy implications which includes the need for a public information campaign to increase awareness about the risks of biomass fuel smoke exposure.

It was observed from the analysis that there is a significant effect of household air pollution caused by solid fuel use on occurrence of certain diseases among the children under the age of five. Biomass fuel smoke has significant effect on the occurrence of all the four categories of the diseases in the study i.e. fever, cough, acute respiratory infections and diarrhea. Interaction

**Table 01: Percentages of selected morbidities among under-five children by type of fuel use in selected South and Southeast Asian Countries**

Morbidities	Nepal		Afghanistan		Bangladesh		Cambodia		Myanmar		Philippines		India	
	%	P-value	%	P-value	%	P-value	%	P-value	%	P-value	%	P-value	%	P-value
<b>Fever</b>														
Non-solid Fuel	4.47	0.00	7.64	0.00	6.73	0.00	7.08	0.00	2.75	0.00	3.00	0.00	2.17	0.00
Solid Fuel	4.22		7.59		6.88		6.15		3.55		4.30		2.65	
<b>Total</b>	<b>4.28</b>		<b>7.61</b>		<b>6.85</b>		<b>6.29</b>		<b>3.40</b>		<b>3.73</b>		<b>2.47</b>	
<b>Diarrhoea</b>														
Non-solid Fuel	1.35	0.00	8.05	0.00	1.31	0.00	2.99	0.00	1.28	0.00	0.98	0.00	1.46	0.00
Solid Fuel	1.49		7.40		1		2.84		2.42		1.66		1.91	
<b>Total</b>	<b>1.45</b>		<b>7.60</b>		<b>1.04</b>		<b>2.86</b>		<b>2.22</b>		<b>1.36</b>		<b>1.74</b>	
<b>ARI</b>														
Non-solid Fuel	0.28	0.00	2.60	0.00	0.8	0.00	1.42	0.00	0.54	0.00	0.24	0.00	0.43	0.00
Solid Fuel	0.59		3.66		1.01		1.21		0.71		0.42		0.58	
<b>Total</b>	<b>0.51</b>		<b>3.34</b>		<b>0.98</b>		<b>1.24</b>		<b>0.68</b>		<b>0.34</b>		<b>0.52</b>	
<b>Cough</b>														
Non-solid Fuel	4.25	0.00	5.92	0.00	5.86	0.00	5.71	0.00	3.66	0.00	3.76	0.00	1.94	0.00
Solid Fuel	4.25		6.32		5.98		4.75		3.40		5.27		2.24	
<b>Total</b>	<b>4.30</b>		<b>6.20</b>		<b>5.97</b>		<b>4.89</b>		<b>3.45</b>		<b>4.61</b>		<b>2.13</b>	

**Table 02: Marginal effect of Selected Variables on Fever among under-Five Children in South and South-east Asian Countries**

Variables	Nepal	Afghanistan	Bangladesh	Cambodia	Myanmar	Philippines	India
<b>Type of fuel</b>							
Non-solid fuel	0.027***(0.003)	0.065***(0.002)	0.062***(0.006)	0.052***(0.005)	0.04***(0.006)	0.033***(0.003)	0.024***(0.00)
Solid fuel	0.041***(0.002)	0.067***(0.001)	0.067***(0.002)	0.058***(0.002)	0.044***(0.002)	0.044***(0.002)	0.026***(0.00)
<b>Source of water</b>							
Safe	0.038***(0.002)	0.066***(0.001)	0.066***(0.002)		0.044***(0.002)	0.04***(0.001)	0.026***(0.00)
Unsafe	0.03***(0.005)	0.068***(0.001)	0.075***(0.01)		0.042***(0.003)	0.044***(0.002)	0.023***(0.00)
<b>Toilet facility</b>							
No facility	0.061***(0.005)	0.079***(0.003)	0.073***(0.009)	0.065***(0.003)	0.051***(0.005)	0.053***(0.005)	0.027***(0.00)
Flush	0.034***(0.002)	0.063***(0.003)	0.064***(0.005)	0.049***(0.003)	0.035***(0.007)	0.039***(0.001)	0.024***(0.00)
Pit and Others	0.034***(0.003)	0.065***(0.001)	0.066***(0.002)	0.049***(0.009)	0.042***(0.002)	0.04***(0.003)	0.024***(0.00)
<b>Place to cook</b>							
Outside house	0.039***(0.003)	0.056***(0.001)	0.063***(0.002)	0.045***(0.002)	0.036***(0.003)	0.034***(0.002)	0.025***(0.00)
Inside house	0.037***(0.002)	0.073***(0.001)	0.081***(0.005)	0.071***(0.003)	0.047***(0.002)	0.043***(0.001)	0.026***(0.00)
<b>Wall material</b>							
Kachcha	0.039***(0.006)	0.061***(0.005)	0.053***(0.004)	0.118***(0.033)	0.041*(0.022)	0.039***(0.002)	0.022***(0.00)
Semi Pucca	0.037***(0.002)	0.063***(0.001)	0.072***(0.005)	0.058***(0.003)	0.042***(0.002)	0.042***(0.002)	0.028***(0.00)
Pucca	0.038***(0.004)	0.063***(0.003)	0.067***(0.002)	0.056***(0.002)	0.052***(0.005)		0.025***(0.00)
<b>Floor material</b>							
Kachcha	0.053***(0.007)	0.093***(0.005)			0.211*(0.121)		0.03***(0.001)
Pucca	0.031***(0.004)	0.063***(0.001)	0.067***(0.002)	0.057***(0.005)	0.044***(0.007)	0.038***(0.002)	0.024***(0.00)
Semi Pucca	0.039***(0.002)	0.07***(0.001)	0.064***(0.005)	0.056***(0.002)	0.043***(0.002)	0.044***(0.002)	0.026***(0.00)
<b>Roof material</b>							
Kachcha	0.035***(0.004)	0.075***(0.002)	0.074***(0.013)	0.066***(0.007)	0.039***(0.003)	0.045***(0.004)	0.026***(0.001)
Semi Pucca	0.047***(0.005)	0.064***(0.001)	0.054***(0.005)	0.042***(0.003)	0.045***(0.011)	0.049***(0.008)	0.028***(0.00)
Pucca	0.035***(0.002)	0.076***(0.007)	0.068***(0.002)	0.062***(0.002)	0.046***(0.002)	0.04***(0.001)	0.021***(0.00)
<b>Educational attainment of the mother</b>							
Illiterate	0.025***(0.002)	0.065***(0.001)	0.039***(0.002)	0.044***(0.003)	0.035***(0.003)	0.019***(0.004)	0.018***(0.00)
Primary	0.056***(0.005)	0.093***(0.004)	0.065***(0.003)	0.061***(0.002)	0.042***(0.002)	0.031***(0.002)	0.028***(0.00)
Secondary	0.06***(0.006)	0.077***(0.005)	0.106***(0.004)	0.062***(0.004)	0.059***(0.005)	0.048***(0.002)	0.036***(0.00)
Higher	0.067***(0.011)	0.044***(0.007)	0.075***(0.009)		0.037***(0.011)	0.044***(0.003)	0.037***(0.001)
<b>Wealth</b>							
Poor	0.04***(0.003)	0.063***(0.001)	0.084***(0.004)	0.058***(0.003)	0.065***(0.004)	0.047***(0.002)	0.032***(0.00)
Middle	0.036***(0.003)	0.068***(0.002)	0.066***(0.004)	0.06***(0.004)	0.025***(0.003)	0.037***(0.003)	0.026***(0.00)
Rich	0.035***(0.004)	0.07***(0.002)	0.049***(0.003)	0.054***(0.004)	0.025***(0.003)	0.028***(0.003)	0.017***(0.00)
<b>Maternal age at birth</b>							
20 years and below	0.025***(0.003)	0.034***(0.002)	0.036***(0.002)	0.038***(0.005)	0.02***(0.005)	0.027***(0.003)	0.01***(0.00)
21-30 years	0.035***(0.002)	0.065***(0.001)	0.068***(0.002)	0.051***(0.002)	0.033***(0.002)	0.035***(0.001)	0.026***(0.00)
30 years & above	0.064***(0.006)	0.089***(0.002)	0.112***(0.006)	0.075***(0.004)	0.064***(0.004)	0.054***(0.002)	0.04***(0.001)
<b>Parity</b>							
Two and below	0.087***(0.006)	0.254***(0.008)	0.148***(0.006)	0.138***(0.006)	0.095***(0.007)	0.097***(0.005)	0.053***(0.001)
Third and above	0.026***(0.001)	0.06***(0.001)	0.047***(0.001)	0.041***(0.002)	0.035***(0.002)	0.032***(0.001)	0.019***(0.00)
<b>Birth interval</b>							
One year	0.028***(0.003)	0.056***(0.001)	0.054***(0.003)	0.038***(0.003)	0.036***(0.003)	0.031***(0.002)	0.024***(0.00)
Two to Three Years	0.033***(0.003)	0.066***(0.001)	0.053***(0.003)	0.049***(0.003)	0.034***(0.003)	0.039***(0.002)	0.025***(0.00)
Four and above Years	0.047***(0.003)	0.088***(0.002)	0.074***(0.002)	0.07***(0.003)	0.05***(0.003)	0.05***(0.002)	0.028***(0.00)
<b>Interaction of fuel with water source</b>							
Non-solid fuel with Safe	0.028***(0.003)	0.066***(0.002)	0.062***(0.006)		0.041***(0.008)	0.034***(0.004)	0.024***(0.00)
Non-solid fuel with Unsafe	0.014***(0.007)	0.063***(0.003)	0.064 (0.041)		0.038***(0.007)	0.032***(0.003)	0.023***(0.001)
Solid fuel with Safe	0.042***(0.002)	0.065***(0.001)	0.066***(0.002)		0.044***(0.002)	0.042***(0.002)	0.027***(0.00)
Solid fuel with Unsafe	0.035***(0.006)	0.069***(0.002)	0.076***(0.009)		0.043***(0.003)	0.048***(0.003)	0.024***(0.001)

Note: For the countries where data was not available for the variable under study was left empty. Significance level \*p < 0.1. \*\*p < 0.05. \*\*\*p < 0.01

**Table 03: Marginal effect of Selected Variables on Occurrence of Diarrhea Among Under-Five Children in South and South-east Asian Countries**

Variables	Nepal	Afghanistan	Bangladesh	Cambodia	Myanmar	Philippines	India
<b>Type of fuel</b>							
Non-solid fuel	0.012***(0.002)	0.071***(0.002)		0.023***(0.003)	0.022***(0.005)	0.016***(0.002)	0.017***(0.00)
Solid fuel	0.014***(0.001)	0.072***(0.001)	0.008***(0.001)	0.026***(0.001)	0.029***(0.002)	0.016***(0.001)	0.018***(0.00)
<b>Source of water</b>							
Safe	0.014***(0.001)	0.071***(0.001)	0.008***(0.001)		0.028***(0.002)	0.015***(0.001)	0.018***(0.00)
Unsafe	0.01***(0.003)	0.072***(0.001)			0.028***(0.003)	0.017***(0.001)	0.016***(0.00)
<b>Toilet facility</b>							
No facility	0.026***(0.004)	0.088***(0.003)	0.012***(0.004)	0.031***(0.002)	0.028***(0.004)	0.02***(0.003)	0.02***(0.00)
Flush	0.011***(0.001)	0.063***(0.003)	0.009***(0.002)	0.021***(0.002)	0.021***(0.006)	0.015***(0.001)	0.016***(0.00)
Pit and Others	0.013***(0.002)	0.07***(0.001)	0.008***(0.001)	0.024***(0.007)	0.028***(0.002)	0.016***(0.002)	0.016***(0.00)
<b>Place to cook</b>							
Outside house	0.012***(0.001)	0.065***(0.001)	0.007***(0.001)	0.021***(0.001)	0.022***(0.002)	0.015***(0.001)	0.017***(0.00)
Inside house	0.015***(0.001)	0.076***(0.001)	0.014***(0.002)	0.031***(0.002)	0.031***(0.002)	0.016***(0.001)	0.018***(0.00)
<b>Wall material</b>							
Kachcha	0.015***(0.004)	0.069***(0.005)	0.004***(0.001)	0.056***(0.024)	0.061***(0.028)		0.016***(0.00)
Semi Pucca	0.014***(0.001)	0.072***(0.001)	0.011***(0.002)	0.023***(0.002)	0.026***(0.001)	0.015***(0.001)	0.02***(0.00)
Pucca	0.012***(0.003)	0.073***(0.003)	0.008***(0.001)	0.027***(0.001)	0.039***(0.005)	0.016***(0.001)	0.017***(0.00)
<b>Floor material</b>							
Kachcha	0.015***(0.004)	0.087***(0.004)					0.022***(0.001)
Pucca	0.011***(0.002)	0.072***(0.001)	0.008***(0.001)	0.026***(0.004)	0.029***(0.006)	0.015***(0.001)	0.017***(0.00)
Semi Pucca	0.014***(0.001)	0.07***(0.001)	0.01***(0.003)	0.026***(0.001)	0.028***(0.001)	0.016***(0.001)	0.018***(0.00)
<b>Roof material</b>							
Kachcha	0.009***(0.002)	0.086***(0.002)	0.01***(0.004)	0.031***(0.005)	0.023***(0.002)	0.018***(0.002)	0.02***(0.001)
Semi Pucca	0.016***(0.003)	0.068***(0.001)	0.009***(0.002)	0.019***(0.002)	0.028***(0.01)	0.023***(0.005)	0.02***(0.00)
Pucca	0.014***(0.001)	0.055***(0.006)	0.008***(0.001)	0.028***(0.001)	0.031***(0.002)	0.015***(0.001)	0.014***(0.00)
<b>Educational attainment of the mother</b>							
Illiterate	0.011***(0.001)	0.07***(0.001)	0.005***(0.001)	0.022***(0.002)	0.022***(0.003)	0.006***(0.002)	0.013***(0.00)
Primary	0.019***(0.003)	0.104***(0.005)	0.009***(0.001)	0.026***(0.002)	0.026***(0.002)	0.015***(0.001)	0.021***(0.00)
Secondary	0.019***(0.003)	0.087***(0.005)	0.012***(0.002)	0.029***(0.003)	0.04***(0.004)	0.017***(0.001)	0.024***(0.00)
Higher	0.015***(0.005)	0.06***(0.008)	0.014***(0.004)		0.026***(0.01)	0.016***(0.002)	0.025***(0.001)
<b>Wealth</b>							
Poor	0.013***(0.002)	0.067***(0.001)	0.014***(0.002)	0.03***(0.002)	0.044***(0.003)	0.019***(0.001)	0.023***(0.00)
Middle	0.015***(0.002)	0.076***(0.002)	0.008***(0.002)	0.02***(0.003)	0.021***(0.003)	0.013***(0.002)	0.017***(0.00)
Rich	0.014***(0.003)	0.075***(0.002)	0.005***(0.001)	0.022***(0.002)	0.012***(0.002)	0.009***(0.001)	0.012***(0.00)
<b>Maternal age at birth</b>							
20 years and below	0.012***(0.002)	0.039***(0.002)	0.005***(0.001)	0.022***(0.004)	0.016***(0.005)	0.013***(0.002)	0.007***(0.00)
21-30 years	0.012***(0.001)	0.071***(0.001)	0.009***(0.001)	0.023***(0.001)	0.022***(0.002)	0.013***(0.001)	0.018***(0.00)
30 years & above	0.025***(0.004)	0.092***(0.002)	0.01***(0.002)	0.033***(0.003)	0.039***(0.003)	0.021***(0.002)	0.026***(0.001)
<b>Parity</b>							
Two and below	0.031***(0.004)	0.27***(0.008)	0.018***(0.002)	0.071***(0.005)	0.069***(0.006)	0.04***(0.003)	0.041***(0.001)
Third and above	0.01***(0.001)	0.065***(0.001)	0.006***(0.001)	0.017***(0.001)	0.022***(0.001)	0.012***(0.001)	0.013***(0.00)
<b>Birth interval</b>							
One year	0.01***(0.002)	0.061***(0.001)	0.006***(0.001)	0.019***(0.002)	0.024***(0.003)	0.013***(0.001)	0.017***(0.00)
Two to Three Years	0.013***(0.002)	0.071***(0.001)	0.008***(0.001)	0.023***(0.002)	0.023***(0.003)	0.014***(0.001)	0.018***(0.00)
Four and above Years	0.016***(0.002)	0.094***(0.002)	0.01***(0.001)	0.031***(0.002)	0.031***(0.002)	0.019***(0.001)	0.018***(0.00)
<b>Interaction of fuel with water source</b>							
Non-solid fuel with Safe	0.013***(0.003)	0.072***(0.002)	0.008***(0.002)		0.028***(0.007)	0.016***(0.003)	0.017***(0.00)
Non-solid fuel with Unsafe	0.008(0.006)	0.068***(0.004)			0.01***(0.004)	0.015***(0.002)	0.016***(0.001)
Solid fuel with Safe	0.014***(0.001)	0.071***(0.001)	0.008***(0.001)		0.028***(0.002)	0.015***(0.001)	0.019***(0.00)
Solid fuel with Unsafe	0.011***(0.004)	0.073***(0.002)	0.013***(0.004)		0.03***(0.003)	0.018***(0.002)	0.016***(0.00)

Note: For the countries where data was not available for the variable under study was left empty.  
Significance level \*p < 0.1. \*\*p < 0.05. \*\*\*p < 0.01

**Table 04: Marginal effect of selected variables on occurrence of ARI among Under-Five Children in South and South-east Asian Countries**

Variables	Nepal	Afghanistan	Bangladesh	Cambodia	Myanmar	Philippines	India
<b>Type of fuel</b>							
Non-solid fuel		0.024***(0.001)		0.015***(0.003)	0.015***(0.004)	0.003***(0.001)	0.005***(0.00)
Solid fuel	0.005***(0.001)	0.03***(0.001)	0.009***(0.001)	0.012***(0.001)	0.012***(0.001)	0.004***(0.00)	0.006***(0.00)
<b>Source of water</b>							
Safe	0.005***(0.001)	0.027***(0.001)	0.009***(0.001)		0.013***(0.001)	0.004***(0.00)	0.006***(0.00)
Unsafe		0.032***(0.001)			0.012***(0.002)	0.004***(0.001)	0.005***(0.00)
<b>Toilet facility</b>							
No facility	0.005***(0.002)	0.035***(0.002)	0.017***(0.004)	0.014***(0.001)	0.012***(0.003)	0.008***(0.002)	0.006***(0.00)
Flush	0.004***(0.001)	0.028***(0.002)	0.008***(0.002)	0.011***(0.001)	0.01***(0.004)	0.003***(0.00)	0.005***(0.00)
Pit and Others	0.006***(0.001)	0.028***(0.001)	0.009***(0.001)	0.007***(0.003)	0.013***(0.001)	0.005***(0.001)	0.006***(0.00)
<b>Place to cook</b>							
Outside house	0.006***(0.001)	0.025***(0.001)	0.008***(0.001)	0.01****(0.001)	0.009***(0.001)	0.004***(0.001)	0.005***(0.00)
Inside house	0.004***(0.001)	0.031***(0.001)	0.015***(0.002)	0.014***(0.001)	0.015***(0.001)	0.004***(0.00)	0.006***(0.00)
<b>Wall material</b>							
Kachcha	0.005***(0.002)	0.03****(0.003)	0.009****(0.002)	0.013(0.013)			0.005****(0.00)
Semi Pucca	0.005****(0.001)	0.029****(0.001)	0.008****(0.002)	0.015****(0.002)	0.012****(0.001)	0.004****(0.001)	0.006****(0.00)
Pucca	0.006****(0.002)	0.026****(0.002)	0.009****(0.001)	0.011****(0.001)	0.017****(0.003)	0.004****(0.001)	0.005****(0.00)
<b>Floor material</b>							
Kachcha	0.007***(0.003)	0.034****(0.003)					0.007****(0.00)
Pucca	0.003****(0.001)	0.026****(0.001)	0.008****(0.001)	0.01****(0.002)	0.008****(0.003)	0.004****(0.001)	0.005****(0.00)
Semi Pucca	0.005****(0.001)	0.033****(0.001)	0.012****(0.003)	0.013****(0.001)	0.013****(0.001)	0.004****(0.001)	0.006****(0.00)
<b>Roof material</b>							
Kachcha	0.003****(0.001)	0.028****(0.001)	0.014***(0.006)	0.023****(0.004)	0.01****(0.001)	0.006****(0.001)	0.006****(0.00)
Semi Pucca	0.01****(0.003)	0.029****(0.001)	0.007****(0.002)	0.01****(0.001)	0.009*(0.005)	0.006***(0.003)	0.006****(0.00)
Pucca	0.004****(0.001)	0.034****(0.005)	0.009****(0.001)	0.012****(0.001)	0.015****(0.001)	0.004****(0.00)	0.004****(0.00)
<b>Educational attainment of the mother</b>							
Illiterate	0.003****(0.001)	0.028****(0.001)	0.005****(0.001)	0.008****(0.001)	0.009****(0.002)	0.004****(0.001)	0.004****(0.00)
Primary	0.009****(0.002)	0.042****(0.003)	0.011****(0.001)	0.015****(0.001)	0.01****(0.001)	0.004****(0.001)	0.007****(0.00)
Secondary	0.007****(0.002)	0.034****(0.003)	0.013****(0.002)	0.011****(0.002)	0.025****(0.003)	0.003****(0.001)	0.008****(0.00)
Higher	0.006*(0.003)	0.016****(0.004)	0.008****(0.003)	0.01*(0.006)	0.016***(0.008)		0.009****(0.001)
<b>Wealth</b>							
Poor	0.007****(0.002)	0.029****(0.001)	0.014****(0.002)	0.013****(0.001)	0.023****(0.003)	0.004****(0.001)	0.007****(0.00)
Middle	0.005****(0.001)	0.027****(0.001)	0.008****(0.002)	0.013****(0.002)	0.006****(0.002)	0.003****(0.001)	0.006****(0.00)
Rich	0.003***(0.001)	0.031****(0.001)	0.005****(0.001)	0.011****(0.002)	0.005****(0.001)	0.004****(0.001)	0.004****(0.00)
<b>Maternal age at</b>							
20 years and below	0.002***(0.001)	0.015****(0.001)	0.005****(0.001)	0.008****(0.003)	0.007***(0.003)	0.003***(0.001)	0.003****(0.00)
21-30 years	0.005****(0.001)	0.028****(0.001)	0.008****(0.001)	0.01****(0.001)	0.008****(0.001)	0.003****(0.00)	0.005****(0.00)
30 years & above	0.008****(0.002)	0.039****(0.001)	0.019****(0.003)	0.018****(0.002)	0.02****(0.002)	0.006****(0.001)	0.009****(0.00)
<b>Parity</b>							
Two and below	0.01****(0.002)	0.105****(0.006)	0.021****(0.002)	0.033****(0.003)	0.018****(0.003)	0.01****(0.002)	0.012****(0.00)
Third and above	0.004****(0.001)	0.026****(0.001)	0.006****(0.001)	0.008****(0.001)	0.012****(0.001)	0.003****(0.00)	0.004****(0.00)
<b>Birth interval</b>							
One year	0.004****(0.001)	0.024****(0.001)	0.007****(0.001)	0.007****(0.001)	0.011****(0.002)	0.003****(0.001)	0.005****(0.00)
Two to Three Years	0.003****(0.001)	0.029****(0.001)	0.007****(0.001)	0.012****(0.001)	0.011****(0.002)	0.005****(0.001)	0.006****(0.00)
Four and above	0.006****(0.001)	0.038****(0.001)	0.01****(0.001)	0.015****(0.001)	0.014****(0.001)	0.004****(0.001)	0.006****(0.00)
<b>Interaction of fuel with water source</b>							
Non-solid fuel with Safe	0.004****(0.001)	0.023****(0.001)	0.007****(0.002)		0.018****(0.006)	0.003****(0.001)	0.005****(0.00)
Non-solid fuel with Unsafe		0.024****(0.002)			0.01***(0.004)	0.003****(0.001)	0.005****(0.001)
Solid fuel with Safe	0.005****(0.001)	0.028****(0.001)	0.009****(0.001)		0.012****(0.001)	0.005****(0.001)	0.006****(0.00)
Solid fuel with Unsafe	0.007***(0.003)	0.034****(0.001)	0.009****(0.003)		0.013****(0.002)	0.004****(0.001)	0.005****(0.00)

Note: For the countries where data was not available for the variable under study was left empty. Significance level \*p < 0.1. \*\*p < 0.05. \*\*\*p < 0.01



**Table 05: Marginal Effect of Selected Variables on Cough among Under-Five Children in South and South-east Asian Countries**

Variables	Nepal	Afghanistan	Bangladesh	Cambodia	Myanmar	Philippines	India
<b>Type of fuel</b>							
Non-solid fuel	0.02***(0.002)	0.047***(0.002)	0.049***(0.005)	0.046***(0.005)	0.05***(0.007)	0.041***(0.003)	0.021***(0.00)
Solid fuel	0.042***(0.002)	0.055***(0.001)	0.058***(0.002)	0.042***(0.002)	0.048***(0.002)	0.053***(0.002)	0.023***(0.00)
<b>Source of water</b>							
Safe	0.037***(0.002)	0.052***(0.001)	0.057***(0.001)		0.047***(0.002)	0.047***(0.002)	0.022***(0.00)
Unsafe	0.028***(0.005)	0.054***(0.001)	0.055***(0.008)		0.049***(0.003)	0.053***(0.002)	0.022***(0.00)
<b>Toilet facility</b>							
No facility	0.064***(0.006)	0.069***(0.002)	0.069***(0.009)	0.049***(0.003)	0.053***(0.005)	0.067***(0.005)	0.023***(0.00)
Flush	0.031***(0.002)	0.05***(0.003)	0.061***(0.005)	0.037***(0.002)	0.043***(0.008)	0.049***(0.002)	0.021***(0.00)
Pit and Others	0.032***(0.003)	0.05***(0.001)	0.056***(0.002)	0.038***(0.008)	0.047***(0.002)	0.042***(0.003)	0.023***(0.00)
<b>Place to cook</b>							
Outside house	0.035***(0.002)	0.046***(0.001)	0.054***(0.002)	0.035***(0.002)	0.04***(0.003)	0.043***(0.002)	0.022***(0.00)
Inside house	0.037***(0.002)	0.057***(0.001)	0.072***(0.004)	0.052***(0.002)	0.052***(0.002)	0.052***(0.001)	0.022***(0.00)
<b>Wall material</b>							
Kachcha	0.039***(0.006)	0.053***(0.004)	0.048***(0.004)	0.052***(0.025)	0.03***(0.02)		0.02***(0.00)
Semi Pucca	0.037***(0.002)	0.053***(0.001)	0.061***(0.004)	0.046***(0.003)	0.049***(0.002)	0.051***(0.002)	0.024***(0.00)
Pucca	0.033***(0.004)	0.055***(0.003)	0.057***(0.002)	0.041***(0.002)	0.043***(0.005)	0.048***(0.002)	0.022***(0.00)
<b>Floor material</b>							
Kachcha	0.049***(0.007)	0.061***(0.004)			0.11***(0.1)		0.026***(0.001)
Pucca	0.029***(0.004)	0.049***(0.001)	0.057***(0.002)	0.042***(0.004)	0.043***(0.007)	0.047***(0.002)	0.021***(0.00)
Semi Pucca	0.038***(0.002)	0.057***(0.001)	0.057***(0.005)	0.043***(0.002)	0.048***(0.002)	0.052***(0.002)	0.023***(0.00)
<b>Roof material</b>							
Kachcha	0.031***(0.004)	0.057***(0.002)	0.06***(0.011)	0.06***(0.007)	0.038***(0.003)	0.061***(0.004)	0.024***(0.001)
Semi Pucca	0.048***(0.005)	0.052***(0.001)	0.046***(0.005)	0.031***(0.002)	0.057***(0.013)	0.06***(0.008)	0.024***(0.00)
Pucca	0.033***(0.002)	0.059***(0.007)	0.058***(0.002)	0.046***(0.002)	0.054***(0.003)	0.048***(0.001)	0.02***(0.00)
<b>Educational attainment of the mother</b>							
Illiterate	0.025***(0.002)	0.052***(0.001)	0.035***(0.002)	0.03***(0.003)	0.039***(0.003)	0.031***(0.005)	0.015***(0.00)
Primary	0.047***(0.004)	0.07***(0.004)	0.057***(0.003)	0.045***(0.002)	0.042***(0.002)	0.04***(0.002)	0.026***(0.00)
Secondary	0.059***(0.006)	0.062***(0.004)	0.087***(0.004)	0.05***(0.004)	0.073***(0.005)	0.058***(0.002)	0.033***(0.00)
Higher	0.076***(0.012)	0.033***(0.006)	0.068***(0.008)	0.027***(0.009)	0.057***(0.013)	0.049***(0.003)	0.034***(0.001)
<b>Wealth</b>							
Poor	0.034***(0.003)	0.051***(0.001)	0.073***(0.003)	0.045***(0.003)	0.071***(0.004)	0.056***(0.002)	0.029***(0.00)
Middle	0.033***(0.003)	0.051***(0.002)	0.056***(0.004)	0.049***(0.004)	0.032***(0.003)	0.041***(0.003)	0.022***(0.00)
Rich	0.042***(0.005)	0.057***(0.002)	0.043***(0.003)	0.038***(0.003)	0.029***(0.003)	0.037***(0.003)	0.015***(0.00)
<b>Maternal age at birth</b>							
20 years and below	0.023***(0.003)	0.027***(0.001)	0.035***(0.002)	0.027***(0.005)	0.024***(0.006)	0.031***(0.004)	0.01***(0.00)
21-30 years	0.035***(0.002)	0.052***(0.001)	0.057***(0.002)	0.037***(0.002)	0.034***(0.002)	0.043***(0.001)	0.022***(0.00)
30 years & above	0.056***(0.005)	0.07***(0.002)	0.093***(0.005)	0.059***(0.003)	0.074***(0.004)	0.067***(0.003)	0.036***(0.001)
<b>Parity</b>							
Two and below	0.081***(0.006)	0.194***(0.007)	0.124***(0.005)	0.106***(0.006)	0.1***(0.007)	0.12***(0.006)	0.047***(0.001)
Third and above	0.026***(0.001)	0.048***(0.001)	0.041***(0.001)	0.03***(0.001)	0.039***(0.002)	0.039***(0.001)	0.016***(0.00)
<b>Birth interval</b>							
One year	0.029***(0.003)	0.044***(0.001)	0.044***(0.003)	0.028***(0.002)	0.041***(0.004)	0.041***(0.002)	0.021***(0.00)
Two to Three Years	0.029***(0.002)	0.052***(0.001)	0.046***(0.003)	0.039***(0.003)	0.044***(0.004)	0.049***(0.002)	0.022***(0.00)
Four and above Years	0.046***(0.003)	0.072***(0.002)	0.065***(0.002)	0.051***(0.002)	0.052***(0.003)	0.057***(0.002)	0.024***(0.00)
<b>Interaction of fuel with water source</b>							
Non-solid fuel with Safe	0.021***(0.003)	0.048***(0.002)	0.05***(0.005)		0.05***(0.008)	0.039***(0.004)	0.021***(0.00)
Non-solid fuel with Unsafe	0.013***(0.006)	0.046***(0.003)	0.028(0.026)		0.05***(0.009)	0.044***(0.004)	0.022***(0.001)
Solid fuel with Safe	0.043***(0.002)	0.053***(0.001)	0.058***(0.002)		0.047***(0.002)	0.051***(0.002)	0.023***(0.00)
Solid fuel with Unsafe	0.035***(0.007)	0.057***(0.001)	0.059***(0.009)		0.049***(0.004)	0.056***(0.003)	0.022***(0.001)

Note: For the countries where data was not available for the variable under study was left empty. Significance level \*p < 0.1. \*\*p < 0.05. \*\*\*p < 0.01

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