

Effects of Household Use of Biomass Fuel and Kerosene on Birth Weight of Babies in the Philippines

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Birth weight is an important indicator of a child's health status. It is a significant factor of mortality and morbidity. Infants with low birth weight are 40 times more likely to die within the first 28 days of birth than infants with normal birth weight. Moreover, low birth weight infants exhibit a much higher incidence of neurological impairment, gross and fine motor dysfunction and developmental delay. Instead of going down to reduce the incidence of child mortality (which is one of the Millennium Development Goals), the incidence of low birth weight in the Philippines has gone the opposite direction: rising from 20.3% in 2003 to 21.2% in 2008. This paper tackles the very serious issue of birth weight using data from the 2008 National Demographic and Health Survey (NDHS), and focuses on one important risk factor: type of cooking fuel used in the household. Using ordinal logistic regression model, the study establishes that the use of dirty cooking fuel (biomass fuel or kerosene) for daily use of cooking and heating is a significant environmental risk factor of low birth weight. Moreover, the results also show that maternal smoking is significantly associated with the size of the child at birth. Other demographic factors that may be associated with low birth weight are examined as well. Information about the effect cooking fuel on birth weight should lead the government and policymakers to make clean cooking fuel available to Philippine households at a cheap cost.

Keywords: *low birth weight, biomass fuel, maternal smoking, ordinal logistic regression*

1. Introduction

Birth weight is an important indicator of a newborn's health status. There is overwhelming evidence that babies born with low birth weight (babies weighing less than 2500g) face greater risks of mortality and morbidity. For example,

low birth weight infants are 40 times more likely to die within the first 28 days than normal birth infants (Kotagal, 1993). Even if they do survive during this period, low birth weight infants exhibit a much higher incidence of neurological impairment, gross and fine motor dysfunction, and developmental delay (Paneth, 1995). A baby with low birth weight may be at increased risk for complications. Lucile Packard Children's Hospital (henceforth referred to as LPCH) explains that the baby's tiny body is not as strong and, as a result of this, he/she may have a harder time eating, gaining weight, and fighting infection. Complications resulting from this condition account for 24% of neonatal deaths. Moreover, because they have so little body fat, low birth weight babies often have difficulty staying warm in normal temperatures.

The primary cause of low birth weight is premature birth (being born before 37 weeks gestation). Since much of a baby's weight is gained during the latter part of pregnancy, being born early means that a baby has less time in the mother's uterus to grow and gain weight. Another cause of low birth weight is intrauterine growth restriction (IUGR). This occurs when a baby does not grow well in the mother's womb, which can be caused by certain health problems in the mother.

The following common problems of low birth weight babies are summarized by LPCH (2013).

- Low oxygen levels at birth
- Inability to maintain body temperature
- Difficulty feeding and gaining weight
- Infection
- Breathing problems such as respiratory distress syndrome
- Neurologic problems such as intraventricular hemorrhage
- Gastrointestinal problems such as necrotizing enterocolitis
- Sudden infant death syndrome

This study examines the effects of two factors on birth weight: type of cooking fuel and maternal smoking. Maternal smoking in pregnancy is associated with many adverse pregnancy outcomes, low birth weight being one, but also including an increased risk for pre-term birth and complications that increase the risk of growth retardation and may cause fetal death and neonatal death. This issue strikes a chord with the Philippines, where, according to the 2009 Global Adult Tobacco Survey (GATS), the prevalence of tobacco use among adults is 28.3% (17.3 million Filipinos aged 15 years old and over). On the other hand, in the developed countries, Windham, et al. (1999) and the US Department of Health and Human Services report that maternal smoking and exposure to environmental tobacco smoke are the leading causes of low birth weight.

Type of cooking fuel used in the household is the second factor which the authors wish to study. High-pollution fuels (such as biomass, coal and kerosene)

used in the household exposes the family to the ill-effects of indoor-air pollution. Although the chief concern of this study is the effect of indoor-air pollution on birth weight, indoor-air pollution is also associated with stillbirths, heart diseases, tuberculosis, cataract, blindness and asthma (Krishnapriya, 2013), not to mention that poor health outcomes due to indoor air pollution can lead to a fall in labor productivity which in turn results in deterioration of the household's economic status. In the Philippines, the incidence of low birth weight has gone the wrong direction: rising from 20.3% in 2003 to 21.2% in 2008. So far, no study, to the best of the author's knowledge, has tried to clearly examine the link between type of cooking fuel and birth weight of babies in the Philippines.

This study also controls for the effects of three additional factors: type of place of residence, intake of iron tablets during pregnancy, and educational attainment of the mother. The data come from the National Demographic and Health Survey (NDHS) 2008, conducted by the National Statistics Office (NSO). Gamma measures of association between birth weight and each of the factors are computed to establish association. Ordinal logistic regression is then used to determine which factors have a significant effect on birth weight.

2. Review of Related Literature

Many studies, some of which we now present, establish maternal smoking as a strong dose-dependent factor affecting a baby's birth weight. One particularly interesting study is that of Bernstein et al. (2005) which, after doing a prospective study on 160 pregnant smoking women, concludes that for each additional cigarette per day that a participant smoked in the third trimester, there is an estimated 27g reduction in the child's birth weight. Simpson and Smith (1986) relate the incidence of low birth weight to smoking in each social group using published data for 1984. Their result concludes that assuming 12.5% of cigarette smokers stopped during pregnancy, 18.1% of all low birth weights were caused by maternal smoking in 1984. Simpson and Smith further remark that the relative risk of producing a low birth weight baby has been shown in several studies to be approximately 2.0 for mothers who smoke. The risk is independent of the other known risk associations, including previous pregnancy history, parity, maternal height and weight, social class, and race. Intervention trials aimed at reducing maternal smoking in pregnancy and retrospective analyses examining the relationship of maternal smoking to birth weight suggest that reductions or complete cessation of maternal smoking during the course of gestation is associated with improved birth weights (Dollan-Mullen, 1994; England, 2001).

The other factor causing low birth weight that the authors wish to study is the type of cooking fuel. The 2007 report on indoor air pollution from solid fuels of the World Health Organization (WHO) observes that around half of the world's population still relies on solid fuels for everyday needs: 2.4 billion on biomass

and 0.6 billion on coal, and that the impact of solid fuel smoke exposure on both low birth weight and stillbirth is consistent. In the Philippines, the percentage of households using solid fuel (which includes charcoal, wood and agricultural crops) is 65.6%, nearly one-third of all Filipino households.

One study similar to this paper was done by Epstein et al. (2013). Epstein's paper examines the impact of maternal use of different household cooking fuels in India on birthweight. Taking socioeconomic and child-specific factors into account, his paper runs a logistic regression to examine the impact of fuel use on fetal and infant health. The results indicate that household use of high-pollution fuels is significantly associated with increased odds of low birth weight and neonatal death. Another similar study by Siddiqui, et al. (2007) examines the factors affecting birth weight in Southern Pakistan, and estimates that the odds of a woman's delivering a low birth weight baby is 77% greater if she lives in a household which uses wood fuel, instead of natural gas. That of Mishra et al. (2007) concludes that women who cooked only with wood, dung, or crop residues were significantly more likely to have experienced a stillbirth than those who cooked with electricity, LPG, biogas, or kerosene. Dutta (2012), using the National Family and Health Survey in India, observes that women exposed to household pollution are almost one and a half times at risk of delivering low birth weight babies. The studies of Epstein, Mishra and Dutta were done for India, Siddiqui's was for Pakistan, and this study attempts to blaze a trail for the Philippines.

The WHO report describes that the cooking fuels are typically used indoors or in partly enclosed cooking areas, thus leading to very high levels of exposure to smoke which contains products of incomplete combustion. The most heavily exposed people are the women of childbearing age and young children. Since these women continue with their domestic role of cooking throughout pregnancy, the developing foetus in their womb is also exposed. Risk of low birth weight is not, in fact, the only danger that comes with biomass fuel. Exposure to indoor smoke is also linked to asthma, cataracts, tuberculosis, and adverse pregnancy outcomes like ischaemic heart disease, interstitial lung disease, and laryngeal cancer. Rehfuess (2006), in the important publication of the WHO, entitled *Fuel for Life: Household Energy and Health* makes a description which deserves to be quoted in full:

“Opening the door to their homes makes for a hazy welcome: thick grey smoke fills the air, making breathing unbearable and bringing tears to the eyes. The inefficient burning of solid fuels on an open fire or traditional stove indoors creates a dangerous cocktail of hundreds of pollutants, primarily carbon monoxide and small particles, but also nitrogen oxides, benzene, butadiene, formaldehyde, polyaromatic hydrocarbons, and many other health-damaging chemicals. Day in and day out, and for hours at a time, women and their children breathe in amounts of smoke equivalent to consuming two packs of cigarettes per day. Where coal is

used, additional contaminants such as sulfur, arsenic and fluorine may also be present in the air.”

3. Methodology

3.1 Cumulative logits model

The response variable, birth weight, is categorized into three levels: very low (less than 1500g), low (at least 1500g but less than 2500g), and standard (at least 2500g). Since the categories of the response are ordered, the model to be used should take this ordering into account. The study uses the cumulative logit model for ordinal response. Following the discussion of Agresti (2007), which we outline, Y represents the response variable, $j = 1, 2, 3$ represents the categories of birth weight, and π_j the probability that the birth weight is in category j . For category j , the cumulative probability for Y is:

$$P(Y \leq j) = \pi_1 + \dots + \pi_j, \quad j = 1, 2, 3 \quad (1)$$

The cumulative logits are defined as

$$\text{logit}[P(Y \leq j)] = \log \left[\frac{P(Y \leq j)}{1 - P(Y \leq j)} \right] = \log \left[\frac{\pi_1 + \dots + \pi_j}{\pi_{j+1} + \dots + \pi_J} \right], \quad j = 1, \dots, J-1 \quad (2)$$

As Agresti (2007) describes it, a model for cumulative logit j is similar to a binary logistic regression model in which the categories from 1 to j combine to form a single category, while categories $(j + 1)$ to J form a second category. For an explanatory variable, the model

$$\text{logit}[P(Y \leq j)] = \alpha_j + \beta x, \quad j = 1, \dots, J-1 \quad (3)$$

has parameter β describing the effect of x on the logarithm of the odds of response in category j or below. Since the parameter β does not have a j subscript, the model is identical for all the $(J - 1)$ cumulative logits, enabling us to have a single parameter, instead of $(J - 1)$, that describes the effect of x .

Consider two values a and b of x , an odds ratio comparing the cumulative probabilities is

$$\frac{P(Y \leq j | X = b) / P(Y > j | X = b)}{P(Y \leq j | X = a) / P(Y > j | X = a)} \quad (4)$$

Taking the logarithm of the expression in (4) gives the difference between the cumulative logits at the two values a and b of x , and, using equation (3), can be shown to be equal to $\beta(b-a)$, which is proportional to the distance between a and b . Since this study will be dealing with dummy variables as predictors, the

difference $(b-a) = 1$ so that the ratio in (4) is equal to e^β . Thus, for every unit increase in x , the odds of response below any given category multiplies by e^β .

The assumption that we are working on here is that the same proportionality constant (β) applies for each cumulative probability. This property is called the *proportional odds assumption*, an assumption that in this study was verified before proceeding with the model. Lastly, the maximum likelihood fitting process uses an iterative algorithm simultaneously for all j .

3.2 Gamma statistic

The gamma statistic G is a measure describing the relation between two ordinally scaled variables. Suppose A and B are two variables measured in the ordinal level, where A_1, A_2, \dots, A_k are the possible values of A while B_1, B_2, \dots, B_r are the possible values of B . Furthermore, we assume the following ordering for the levels of A and B : $A_1 < A_2 < \dots < A_k$ and $B_1 < B_2 < \dots < B_r$. Siegel and Castellan (1988) give the following formula for the parameter γ :

$$\begin{aligned} \gamma &= \frac{P[A \& B \text{ agree in order}] - P[A \& B \text{ disagree in order}]}{1 - P[A \& B \text{ are tied}]} \\ &= \frac{P[A \& B \text{ agree in order}] - P[A \& B \text{ disagree in order}]}{P[A \& B \text{ agree in order}] + P[A \& B \text{ disagree in order}]} \end{aligned} \quad (5)$$

The gamma statistic G , used to estimate γ is then defined as

$$G = \frac{\# \text{agreements} - \# \text{disagreements}}{\# \text{agreements} + \# \text{disagreements}} \quad (6)$$

The value of G is a number between -1 and $+1$. If there are no disagreements in the ordering, $G = 1$. Similarly, if there are no agreements in the orderings, then $G = -1$. Moreover, the quantity

$$z = (G - \gamma) \sqrt{\frac{\# \text{agreements} - \# \text{disagreements}}{N(1 - G^2)}} \quad (7)$$

is approximately normally distributed with mean 0 and variance 1. The test of significance by using the distribution in (7) is conservative since the variance of G , shown in (8), is an upper limit (Siegel and Castellan, 1988):

$$\text{Var}(G) \leq \frac{N(1 - G^2)}{\# \text{agreements} - \# \text{disagreements}} \quad (8)$$

4. Variables Used in the Study

The data used for this study come from the National Demographic and Health Survey (NDHS) for the year 2008. This survey is designed to assess the demographic and health situation in the country. The 2008 NDHS covers a national sample of approximately 13,000 households and 14,000 women aged 15 to 49 years.

4.1 Dependent variable

Birth weight

As already mentioned, the dependent variable used in this study is the baby's birth weight, categorized into three groups: very low (less than 1500g), low (at least 1500g but less than 2500g) and standard (2500g or greater). Ordinal logistic regression is run with the three categories as the levels of the response variable. There is one limitation, however: a large proportion of births occurred at home, and therefore birth weight was not reported for these cases. This led to missing observations for more than one in four births (28 percent). By NSO's own testimony, "Babies are more likely to be weighed at birth if they are born to women aged 20 to 34, they are first births, the mother lives in an urban area, the mother is better educated, and the mother is in the highest wealth quintile. For example, while 89 percent of births to women with college or higher education were weighed at birth, the corresponding percentage of births to women with no education is only 15 percent." Since education will turn out to be associated with birth weight, there is clearly some bias when only few birth weights are recorded among women with no education. For this reason, the study also uses an alternative dependent variable, size of child at birth, described next.

Size of child at birth

Mothers were asked about their perception of the child's size at birth, whether the child was very small, small, average size, large, or very large at birth. The size of child at birth is a reasonable alternative for actual birth weight, as the NSO affirms: "Although subjective, the mother's judgment has been shown to correlate well with the actual birth weight. The 2008 NDHS results indicate that mortality levels for children perceived by their mother to have been small or very small at birth are higher than those of other children. The neonatal mortality rate for infants reported by their mother to be small or very small at birth is, for example, more than twice that of infants reported to be average or larger at birth."

4.2 Independent variables

Type of cooking fuel

The main factor affecting birth weight which this paper tries to study is type of cooking fuel. This variable has been categorized into clean fuel (electricity, LPG,

natural gas, or biogas), and dirty fuel (traditional biomass fuel and kerosene). The terms “clean” and “dirty” are used only for this study’s purposes. The second category, dirty fuel, includes coal, lignite, charcoal, wood, straw/shrubs/grass, agricultural crop, and animal dung. Although not a biomass fuel, kerosene was lumped in this category because it produces soot and other particulates when burned and is therefore not considered clean.

Maternal smoking

The second independent variable is a dichotomous variable for maternal smoking. It takes on only two possible values: whether the mother smokes anything or not.

Type of place of residence

This study controls for the effect of type of place of residence, also a dichotomous variable. It also has two possible values: living in urban area or rural area.

Given or bought iron tablets during pregnancy

Because pregnant women are prone to developing anemia and their daily iron requirements may be difficult to meet with their regular diets, they are encouraged to take iron supplements. The authors are also interested in the effect of taking iron tablets on the birth weight of babies. This variable is also dichotomous: whether the mother was given or bought iron tablets during pregnancy or not.

Dummy variables for level of education

The study also controls for the effect of education on birth weight. For the logistic regression run, the educational attainment variable has been categorized into four: (1) no education or incomplete primary, (2) completed primary education, (3) completed at most secondary education, (4) completed at least higher education. Category (1) is used as base category in the regression runs.

5. Results

Table 1 shows the distributions of birth weight for each level of the explanatory variables, while Table 2 shows the distributions of size of child at birth for each level of the explanatory variables. Some summary statistics follow, and then the graphs depicting the associations between birth weight and the other variables are shown. Lastly, the gamma measures of association between birth weight and the explanatory variables, as well as the gamma measures for size of child at birth and the explanatory variables are presented.

Some summary statistics of birth weight are shown in Table 3. Only the levels of type of cooking fuel and mother’s educational attainment appear to have a substantial difference in mean birth weight. In particular, households with clean cooking fuel have higher mean birth weight levels than households using dirty cooking fuel. Furthermore, higher levels of education of the mother correspond

Table 1. Distribution of Birth Weight for the Different Levels of the Factors

		Birth Weight		
		Very Low	Low	Standard
Type of Cooking Fuel	Clean	44	152	1121
	Dirty	158	561	2567
Maternal Smoking	Smokes	10	42	170
	Does not smoke	192	671	3518
Type of Places of Residence	Urban	98	328	1863
	Rural	104	385	1825
Intake of Iron Tablets	Took Fe tablets	133	442	2404
	Did not take Fe tablets	21	71	323
Mother's educational attainment	No education or Incomplete primary	18	87	264
	Complete primary	30	85	402
	Incomplete secondary	39	121	631
	Complete secondary	62	222	1188
	Higher	53	198	1203

Table 2. Distribution of Size of Child at Birth for the Different Levels of the Factors

		Size of Child at Birth				
		Very Large	Larger than Average	Average	Smaller than Average	Very Small
Type of Cooking Fuel	Clean	58	357	828	177	59
	Dirty	149	1092	2713	865	242
Maternal Smoking	Smokes	10	61	191	59	24
	Does not smoke	197	1388	3350	983	277
Type of Places of Residence	Urban	97	670	1483	397	132
	Rural	110	779	2058	645	169
Intake of Iron Tablets	Took Fe tablets	124	887	2045	573	175
	Did not take Fe tablets	23	175	477	168	45
Mother's educational attainment	No education or Incomplete primary	29	164	451	197	56
	Complete primary	23	190	512	157	46
	Incomplete secondary	42	259	608	207	46
	Complete secondary	57	421	1032	295	90
	Higher	56	415	938	186	63

to higher mean birth weights. Surprisingly, the mean birth weight among mothers with incomplete secondary level of education is higher than the mean birth weight among mothers with complete secondary and even higher education. The succeeding analyses will reveal, however, that the different levels of education show substantially different distributions of birth weight, and there is a strictly decreasing relationship between a mother's level of education, and the percentage of babies suffering from low or very low birth weight.

Table 3. Summary Statistics of Birth Weight (in grams) for each of the Explanatory Variables

		Mean	Minimum	Maximum	Standard Deviation
Type of Cooking Fuel	Clean	3050	771	6758	652.8
	Dirty	2960	226	5669	719.4
Maternal Smoking	Smokes	2952	907	4989	683.4
	Does not smoke	2988	226	6758	703.1
Type of Places of Residence	Urban	2990	226	6758	675.3
	Rural	2982	453	5669	727.9
Intake of Iron Tablets	Took Fe tablets	2992	226	6758	699.4
	Did not take Fe tablets	2950	907	5125	735.2
Mother's educational attainment	No education or Incomplete primary	2902	453	5669	765.6
	Complete primary	2956	907	5443	760.5
	Incomplete secondary	3021	861	6758	736.0
	Complete secondary	2987	544	5397	675.8
	Higher	2997	226	5851	660.2

Figure 1 gives the percentage distribution by birth weight for each type of cooking fuel. It is easily noticeable from the subdivided bar chart that there is higher percentage of low and very low birth weight babies among those households which use dirty cooking fuel. It follows of course that those households using clean cooking fuel have a higher percentage of standard birth weight babies. The gamma statistic measuring the association between type of cooking fuel and birth weight is shown in Table 4, and it says that the association is significant.

The percentage distribution of birth weight for each status of maternal smoking is shown in Figure 2, where we can see that the incidence of standard birth weights is greater among babies whose mothers do not smoke. On the other hand, low birth weight and very low birth weight babies have a higher percentage of total births among households where the mother smokes, although the difference seems smaller than the comparison seen for type of cooking fuel.

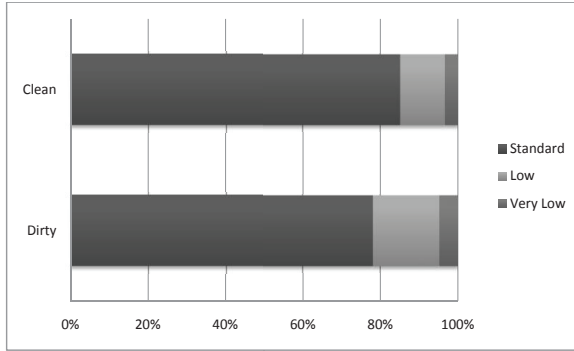


Figure 1. Percentage Distribution of Birth Weight by Type of Cooking Fuel

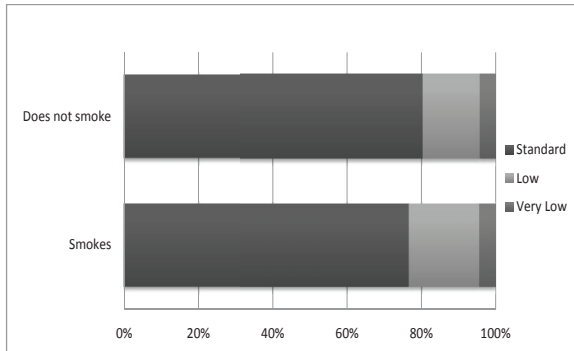


Figure 2. Percentage Distribution of Birth Weight by Maternal Smoking

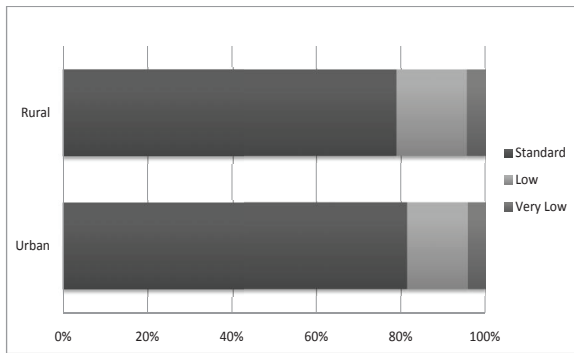


Figure 3. Percentage Distribution of Birth Weight by Type of Residence

The association between percent distribution by birth weight and type of place of residence is presented in Figure 3. We see that standard birth weights have a higher percentage to total births in the urban areas, though, again, the difference is only slight. Nonetheless, Table 4 reports a significant association between birth weight and type of place of residence.

Whether or not a mother takes iron tablets during pregnancy, it does not appear to affect birth weight largely, as Figure 4 shows. There is greater incidence of low birth and very low birth weights among babies whose mothers did not take iron supplements during pregnancy, but the association presented in Table 4 is not significant.

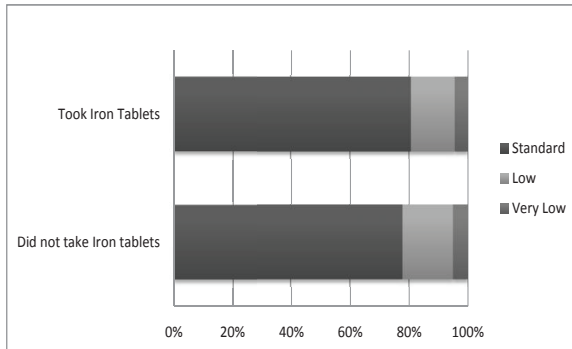


Figure 4. Percentage Distribution of Birth Weight by Intake of Iron Tablets

Lastly, the percent distribution of birth weight by educational attainment is another variable that this study looks into. Figure 5 shows an unquestionable association between educational attainment of the mother and birth weight. We can see that the percentage of children having low or very low birth weight decreases as the level of education of the mother gets higher. Nearly 25% of births among mothers with incomplete primary education (or no education) result in low birth weight or very low birth weight babies. Conversely, as the educational attainment gets higher, the percentage standard birth weights increases.

The gamma coefficients (which measure the association between birth weight and each of the independent variables) are summarized in Table 4. The z-values that are computed are conservative values, and thus the true p-values could be smaller than what is reported. The advantage of the gamma measure of association over the chi-square is that it captures the ordinal nature of the variables used in this study. The chi-square test for independence does not take into account the inherent order present in variables measured in the ordinal level (birth weight and educational attainment).

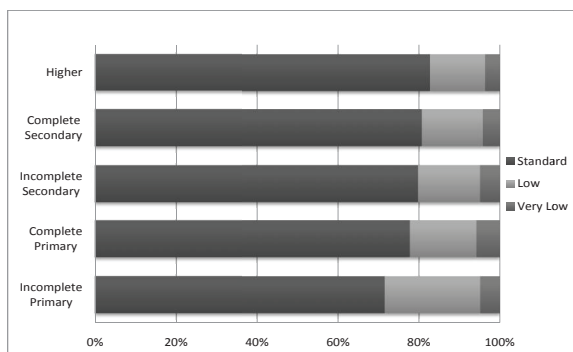


Figure 5. Percentage Distribution of Birth Weight by Mother's Education

Table 4. Gamma Measures of Association between Birth Weight and the Explanatory Variables

Variable	Gamma statistic	Asymptotic Std. Error	z-value	p-value
Type of Cooking Fuel	0.2226	0.0407	5.57	<0.001
Maternal Smoking	0.1012	0.0768	1.32	0.187
Type of Place of Residence	-0.0738	0.0354	-2.08	0.038
Given or bought Fe tablets during pregnancy	0.0806	0.0601	1.34	0.180
Educational attainment	-0.1009	0.0146	4.37	<0.001

The results based on the gamma measures of association, given in Table 4, show that type of cooking fuel, type of place of residence, and mother's educational attainment are associated with a child's birth weight. We see that the strongest association (in terms of the value of the gamma statistic) is with type of cooking fuel. Moreover, maternal smoking and intake of iron tablets appear to have no association with birth weight. It must be remembered, however, that 28% of the observations here are missing due to unreported weights at birth. We have already argued that the missing cases are likely to have high incidence of low birth weight. Thus, in measuring the associations, it is well worth computing for the gamma statistics using size of child at birth (which is highly correlated with birth weight) and each of the explanatory variables. The results are given in Table 5.

In Table 5, the results show that size of child at birth has a significant association with all of the explanatory variables. The strongest associations, having gamma values of 0.1162 and 0.1112 are with type of cooking fuel and maternal smoking, respectively. These are the two main explanatory variables of interest in this study.

Table 5. Gamma Measures of Association between Size of Child at Birth and the Explanatory Variables

Variable	Gamma statistic	Asymptotic Std. Error	z-value	p-value
Type of Cooking Fuel	-0.1162	0.0243	-4.78	<0.001
Maternal Smoking	-0.1112	0.0457	-2.43	0.015
Type of Place of Residence	0.0784	0.0208	3.77	<0.001
Given or bought Fe tablets during pregnancy	-0.1082	0.0306	-3.54	<0.001
Educational attainment	-0.1009	0.0146	-6.91	<0.001

The results of the ordinal logistic regression with the categories of birth weight as dependent variable are presented in Table 6. The table shows that type of cooking fuel is strongly significant in predicting whether a child's birth weight is very low, low or standard. Moreover, the dummy variables representing the education of the mother are also significant indicating that they affect the probability of a baby's weight's being very low, low or standard. The negative sign attached to the estimate of the coefficient for type of cooking fuel tells us that if the household uses clean cooking fuel, the probability that a baby's birth weight is in the very low birth weight direction decreases. Similarly, the negative coefficient for higher education indicates that if the mother has finished at least higher education, there is smaller probability that a baby's weight is in the direction of very low birth weight.

Table 6. Logistic Regression Results with Birth Weight as Dependent Variable

Variable	Estimate	Standard Error	Wald Chi-square	p-value
Type of Cooking Fuel*	-0.3637	0.1121	10.5193	0.001
Dummy for Primary Education***	-0.2897	0.1616	3.2146	0.073
Dummy for Secondary Education**	-0.3555	0.1621	4.8121	0.028
Dummy for Higher Education**	-0.3758	0.1689	4.9531	0.026
Maternal Smoking	-0.1100	0.1968	0.3123	0.576
Intake of Iron Tablets	-0.0339	0.109	0.097	0.755
Type of Place of Residence	0.0060	0.094	0.004	0.9490
Intercept 1*	-2.5098	0.2516	99.5195	<0.001
Intercept 2*	-0.8628	0.2424	12.6696	<0.001

*Sig. at 1%; **Sig. at 5%; ***Sig. at 10%

The estimates of the coefficients for maternal smoking, intake of iron tablets and type of place of residence are not significant. It appears that these variables lose their explanatory power once type of cooking fuel and the dummy

variables for education are already included in the model. Except for type of place of residence (which does not affect birth weight significantly) the signs of the coefficients attached to the variables agree with expectations.

The estimates of the odds ratios are given in Table 7. These odds ratios are obtained by exponentiating the estimates of the coefficients in Table 6.

Table 7. Estimated Odds Ratios for each of the Explanatory Variables with Birth Weight as Dependent Variable

Variable	Odds Ratio Estimate
Type of Cooking Fuel	0.695
Dummy for Primary Education	0.748
Dummy for Secondary Education	0.701
Dummy for Higher Education	0.687
Maternal Smoking	0.896
Intake of Iron Tablets	0.967
Type of Place of Residence	1.006

If the household uses clean cooking fuel, the odds that the baby's weight is in the very low birth weight direction rather than the stand birth weight direction is just 70% of the odds if cooking fuel used was dirty, thus a reduction of 30%. Moreover, the odds ratio of 0.687 for higher education indicates that if the mother has finished at least higher education, the odds of having a low birth weight baby rather than a standard birth weight baby is roughly 69% of the odds if the mother had no education at all (since the base category is no grade completed).

The odds ratio for higher education is smallest among the three dummy variables for education. Primary education has the largest among the three. This result is exactly as expected, since the incidence of low birth weight is highest among households where the mother has finished only primary education, and the incidence decreases as the mother moves to higher levels of education, a relationship seen already in Figure 5.

We now compare the results of Table 6 by running a logistic regression using size of child at birth as dependent variable. The output is shown in Table 8. The regression run in Table 8 is based on a larger, and an arguably unbiased sample. Cooking fuel and education still turn out to be significant predictors of the probability that the size of child at birth is very small, smaller than average, average, large or very large, as recalled by the mother. Intake of iron tablets now figures out to be a significant determinant of the size of the child at birth. Moreover, maternal smoking, although still not quite significant, has a p-value near the borderline, and a high estimated effect at $\hat{\beta} = -0.1970$.

Table 8. Logistic Regression Results with Size of Child at Birth as Dependent Variable

Variable	Estimate	Standard Error	Wald Chi-square	p-value
Type of Cooking Fuel***	-0.1389	0.0741	3.5118	0.061
Dummy for Primary Education***	-0.1727	0.0941	3.3704	0.066
Dummy for Secondary Education***	-0.1851	0.0971	3.6329	0.057
Dummy for Higher Education*	-0.3510	0.1035	11.5031	<0.001
Maternal Smoking	-0.1970	0.1276	2.3856	0.123
Intake of Iron Tablets*	-0.1890	0.0647	8.5452	0.004
Type of Place of Residence	-0.0380	0.0615	0.3763	0.540
Intercept 1*	-2.4364	0.1550	246.9351	<0.001
Intercept 2*	-0.7739	0.1442	28.7947	<0.001
Intercept 3*	1.6602	0.1462	128.9713	<0.001
Intercept 4*	4.0300	0.1657	591.4727	<0.001

*Sig. at 1%; **Sig. at 5%; ***Sig. at 10%

The estimates of the odds ratios corresponding to the logistic regression run in Table 8 are given in Table 9. The odds ratio estimate of 0.870 for type of cooking fuel indicates that if the cooking fuel used is clean, the odds that the baby's size at birth is in the "very small" direction rather than "very large" direction is 87% of the odds when dirty cooking fuel is used. Education once again reduces the odds of low birth weight. If the mother has finished at least higher education, the odds that the size of child at birth is in the very small direction, rather than very large, is 70.4% of the odds when the mother has no education.

Table 9. Estimated Odds Ratios for each of the Explanatory Variables, with Size of Child at Birth as Dependent Variable

Variable	Odds Ratio Estimate
Type of Cooking Fuel	0.870
Dummy for Primary Education	0.841
Dummy for Secondary Education	0.831
Dummy for Higher Education	0.704
Maternal Smoking	0.821
Intake of Iron Tablets	0.828
Type of Place of Residence	0.963

6. Conclusion

The study has investigated the effect of type of cooking fuel on birth weight of babies using the NDHS 2008 data. For the purposes of this research, cooking fuel has been categorized into two types: clean and dirty. Clean cooking

fuel includes electricity, LPG, natural gas, and biogas. On the other hand, dirty cooking fuel includes kerosene, coal, lignite, charcoal, wood, straw, agricultural crop and animal dung. The descriptive analysis has hinted at the relationship between cooking fuel and birth weight, and results based on logistic regression have established that, indeed, use of dirty cooking fuel increases the probability of low birth weight.

The study has also looked at the effect of maternal smoking on the baby's birth weight. The logistic regression run shows that its effect is not significant. However, the researcher should investigate this relationship further, since the estimated effect of maternal smoking is relatively large, and the gamma statistic tells us that it is significantly associated with the size of child at birth.

Other variables that may be associated with type of cooking fuel have been controlled for in this study. These variables are mother's highest level of education, intake of iron tablets during pregnancy, and type of place of residence. Among these three, it is the education of the mother which has a significant effect on the birth weight of the baby, while intake of iron tablets significantly affects the child's size at birth as recalled by the mother.

Perhaps the study's principal conclusion is the result that type of cooking fuel does affect the birth weight of a baby. The reason for such an effect is that cooking fuel contributes to intrauterine growth restriction, causing the baby to have light weight. The descriptive analysis shows that among households which use clean cooking fuel, only 14.9% of births result in low or very low birth weights, while this percentage is 21.9% among households using dirty cooking fuel, providing evidence that use of dirty cooking fuel is a serious threat to a pregnant mother and the fetus in her womb, causing IUGR. This study has shown that the government should make initiatives to make clean cooking fuels accessible at a cheaper cost to households that use biomass fuel or kerosene.

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