Estimating the Environmental Factors of Gender Disparity in Child Mortality in Nigeria: What Role Does Indoor Air Pollution Play?

Toluwalope Toyin Ogunro[†] & Olorunfemi Yasiru Alimi[§]

Abstract

Indoor air pollution, stemming from traditional and transitional energy sources for cooking and lighting, poses a significant threat in developing countries. Particularly concerning is its impact on child morbidity and mortality, with 1 in 4 deaths of children under five attributed to environmental factors. This study, using the 2013 Demographic and Health Survey in Nigeria, explores the gender-specific environmental effects on child mortality. Contrary to the belief that girls may have higher immunity, the research employs a logit regression estimator and reveals that both male and female children face mortality risks from traditional and transitional cooking methods. Female children, in particular, exhibit higher mortality risks from traditional energy sources, while outcomes for transitional energy are mixed for both genders. Overall, females face a greater risk of mortality due to indoor air pollution from biomass cooking smoke. The multivariable analysis indicates an 81% increased risk of under-5 mortality for girls using traditional fuels, compared to a 62% increased risk for boys. To mitigate these risks, the study recommends adopting modern energy sources, such as liquefied petroleum gas, and raising awareness about the health hazards associated with traditional and transitional energies. Additionally, factors like education, wealth, breastfeeding, and postnatal check-ups are identified as mitigating factors, while a mother's age, employment, and location amplify the risk of child mortality.

Keywords: Indoor air pollution; childhood mortality; income; education; Nigeria
JEL Classification Codes: K32, Q52

[†]Department of Economics, Lead City University, Ibadan, Nigeria, Email:rehobotty@gmail.com
[§]Corresponding Author, Department of Economics, Lead City University, Ibadan, Nigeria, Email:haleemphemy480@gmail.com; alimi.olorunfemi@lcu.edu.ng

1. Introduction

A major source of indoor air pollution in many developing countries is solid biomass burning (such as firewood, charcoal, crop residue, coal, and animal dung). According to the World Health Organization (WHO, 2018a), about 3 billion people use this air polluting method of heating to generate energy for household cooking, steaming, and roasting. In Nigeria, over 70% of households (rural and urban) use biomass for cooking (International Energy Agency, 2013), often due to the availability and affordability of this form of traditional fuel (Heltberg, 2003). Among the various traditional heating methods available to households in the country, firewood is the most commonly used, thereby exposing around 120 million residents to illness and untimely death due to smoke inhalation from cooking (International Centre for Energy Environment and Development, 2019). Apart from the fact that incessant combustion of biomass is linked to energy poverty (WHO, 2014), solid fuel combustion in unvented stoves (e.g., stone stoves) aggravates health outcomes as there is a release of particulate matter higher than 100 times the World Health Organisation quality standard (WHO, 2014), thereby making it an indispensable source of indoor air pollution. So, the traditional heating method remains a major environmental threat to healthy living in emerging nations like Nigeria.

What's more, biomass smoke causing indoor air pollution contains different pollutant compounds, which are carbon monoxide (CO), nitrogen dioxide (NO_2), particulate matter (PM), sulphur dioxide (SO_2), and polycyclic aromatic hydrocarbons (PAHs). Among these compounds, particulate matter is more deadly as it can penetrate the bloodstream due to its small inhalable size. In 2016, deaths from firewood and kerosene were estimated at 3.8 million, which exceeded deaths from aggregates of malaria, tuberculosis, and HIV/AIDS (WHO, 2018b). The Energy Progress Report in 2018[1] showed that the following health challenges linked to the usage of traditional burning fuels are: chronic respiratory disorders, heart disease, cancer, child pneumonia, cataracts, burns, and the high death rate of children less than five years of age. Statistically speaking, 1 in every 4 deaths of children under the age of five is attributed to environmental factors, and these children are mostly at risk because they are fragile, often attached to their mothers, and breathe faster than adults (United Nations Children's Fund, and World Health Organization, 2019). Furthermore, the WHO (2018a) noted that particulate matter inhalation is responsible for approximately half of the child mortality rate, therefore resulting in pneumonia among children under the age of five years. Most notably, indoor air pollution is linked to acute lower respiratory illness in children; approximately 543,000 under-5 mortality was recorded in low- and middle-income countries in the year 2016 (WHO, 2018b).

Concerning the under-5 mortality rate in Nigeria, the country has an estimated record of 117.2 deaths per 1,000 live births in 2019 against 6 in developed countries (United Nations Children's Fund, 2020), which exceeds the Sustainable Development Goals (SDGs) targets of 25 per 1,000 live births. Numerically, out of the global 5.2 million under-5 deaths in 2019, Nigeria has an estimated average of 858,000 against 824,000 records in India (United Nations Children's Fund, 2020). Nigeria took over from India as the world capital for under-5 mortality rates while the two countries account for almost one-third of the world's total deaths of children below 5 years of age.

[1] The report was prepared by the following agencies: the International Energy Agency (IEA), the International Renewable Energy Agency (IRENA), the United Nations Statistics Division (UNSD), the World Bank, and the World Health Organization (WHO).

More so, Nigeria is among the five countries[2] that account for about 49% of all under-5 mortalities in 2019 (United Nations Children's Fund, 2020).

In the extant literature, there is an increasing recognition of the negative effect of indoor air pollution from traditional energy use on the health of users, mostly mothers and children who stay in enclosed burning energy areas. As a result, health status is a function of the level of pollution, whether equipment used for cooking is vented or unvented, ventilation around the cooking area, and the duration of time vulnerable people stay around toxic pollutants released during cooking (Patel *et al*., 2013). Other factors recognised in past studies that influence child mortality are education, socioeconomic status, and household energy, among others (Riojas-Rodriguez *et al*., 2001; Monden and Smits, 2013; Adegoro and Amoo, 2014; Anyamele *et al*., 2015; Morakinyo and Fagbamigbe, 2107; Yaya *et al*., 2017; Van Malderen *et al*., 2019; Wegbon *et al*., 2019). For instance, Monden and Smits (2013), Adegoro and Amoo (2014), and Anyamele *et al*. (2015) identified the education of mothers as a modifier of child mortality. The findings of Monden and Smits (2013) found that having an educated mother benefits female children both in absolute and relative terms.

Additionally, gender (boys and girls) differences in under-5 mortality had been an issue debated for some time in the body of literature. For instance, Waldron (1998) attributes the high mortality among boys relative to girls to a variation in sex hormones, which could have different effects on the boy and girl children. While the girl child has a combination of *XX* chromosomes and the boy child has a combination of *XY* chromosomes, this represents variation in their biological make-up that protects the girl child from diseases compared to the boy child. According to Waldron (1998), he believed that differences in genetic makeup could justify the variation in human mortality. Some studies also attributed the causes of gender disparity in child mortality to social and medical technology (Waldron, 1998; Drevenstedt *et al*., 2008). Meanwhile, statistics have shown that some regions have a high ratio of girls' mortality to boys' mortality (United Nations Secretariat, 1998; Fikree and Pasha, 2004; Million Death Study Collaborators, 2010). The cause of the higher rate of girls' mortality over boys is attributed to external circumstances that are detrimental to female children, which make their biological and epidemiological merits fully superseded (Monden and Smits, 2013).

For the time being, there are few existing studies linking environmental factors of indoor air pollution with gender-based child mortality in developing countries (see Ahonsi, 1995; Bassani *et al*., 2010; Adepoju, Akanni, and Falusi, 2012; Ezeh *et al*., 2014; Yaya *et al*., 2017). According to Bassani *et al*. (2010), studies on the association between indoor air pollution and gender-based mortality are limited. For children under 5 years old in India, Bassani *et al*. (2010) found that higher mortality among girls is related to household biomass burning. To address the lacuna in the extant literature, this study investigates the gender-based child mortality effects of indoor air pollution in Nigeria using the 2013 Demographic Health Survey data. This is performed by examining the effects of biomass smoke causing indoor air pollution rather than the differences in sex hormones on variations in gender-based mortality in Nigeria. Also, the current statistics depicting that there could be other factors (apart from sex bias) responsible for variations in gender-based child mortality necessitate the need for this study. Specifically, the United Nations

[2]The other four countries are India, Pakistan, Ethiopia, and the Democratic Republic of the Congo.

Children's Fund (2019) statistics show that 221 boys died in the year 1990, compared with 200 deaths among girls in the same period. In 2000, there was a reduction in child mortality (193 deaths of children under five years among boys compared to 175 for girls), and the 2018 data also showed a decline in boy child mortality estimated at 126 deaths against girls at 112. The 2019 statistics reported 123.6 deaths per 1,000 live births for boys, compared to 110.4 among girls (United Nations Children's Fund, 2020). Consequently, available data showing child mortality in boys and girls in Nigeria depicts an imbalance, with mortality among boys exceeding deaths reported among girls.

The current study extends the frontier of knowledge in understanding the effects of indoor air pollution on children's sex mortality in developing countries in the following ways: First, it extends empirical evidence by analysing the interactions between indoor air pollution and gender differences in under-5 mortality in Nigeria using information gathered from 2013 Demographic and Health Surveys on 15,571 lost children under the age of five years in Nigeria. Second, unlike past studies that considered only the overall child mortality (Gayawan and Turra, 2015; Yaya *et al*., 2017), this study takes into consideration the gender differences in child mortality in order to give room for more policy options. Third, contrary to panel studies (see Tella and Alimi, 2016; Ajide and Alimi, 2020; Alimi and Ajide, 2021; Alimi, Ajide, and Ayadi, 2022, etc.) that are characterised by broad policy implications in environment-health studies, it becomes imperative to base inquiries on country-specific studies with extensive sets of cross-sections for more decisive and tailor-made policy recommendations. Fourth, the study arguments the empirical model with salient demographic factors from mother and child characteristics. These features are presented in a single empirical model with the purpose of estimating their impacts on a child's sex mortality. As a final point, this research outcome would inform government policies towards achieving the first,[3] third,[4] and fourth[5] agendas of the Sustainable Development Goals (SDGs) in the case of Nigeria.

Aside from the introductory section, this research paper divides the remaining parts into three. We present methods and data in the second section, while the discussion of results and findings is undertaken in the third section. The last segment of this research paper concludes and offers policy implications.

2. Methods

2.1 Data Source and Extraction

The data was sourced from the Nigeria Demographic and Health Surveys in 2013 (DHS, 2013). The survey exercise is the fifth comprehensive DHS programme conducted across the six geopolitical zones, which are made up of the federal capital territory and thirty-six states in Nigeria. Regarding the sample frame, it was drawn from a list of enumeration areas, which represents the division of regions according to the 2006 population census implementation in Nigeria. A 3-stage stratified random sampling technique was employed in the 2013 Nigeria

[3] Goal 1 of the SDGs focuses on the eradication of extreme poverty by 2030 by ensuring the availability of resources for every person in the world, especially the poor and vulnerable.

[4] Goal 3 aimed to end child and maternal mortality as well as the eradication of various disease epidemics like malaria, tuberculosis, HIV/AIDS, respiratory disorders, and other water-borne diseases.

[5] Goal 4 focuses on improving education quality by ensuring affordable, quality, and equal education to every child (both boys and girls) from nursery to tertiary education.

Demographic and Health Surveys. The first stage involves the stratification of each state into urban and rural areas, which leads to the creation of locality lists. As regards the second stage, in every selected list of localities, one enumeration area is randomly selected, and this produces a list of households for selection in the final stage. In the third phase of the clustered urban and rural areas, a total of 45 households were selected via the systematic sampling technique.

In total, the sample consists of 904 clusters (372 in urban areas and 532 in rural areas). Meanwhile, a sample of 40,680 households was selected for the survey (World Bank, 2014). The focus of the study is on the total number of children under the age of 5 lost by parents. The total number of observations captured for the study was 15,571 (8,227 boys and 7,344 girls) lost children under the age of five years. The 2013 Nigeria DHS collects information on household and child characteristics, which comprise fertility preferences, fertility, responsiveness and application of family planning techniques, nuptiality, sexual activity, feeding methods of babies and children under 5 years, child and mother nutritional status, untimely child mortality, infant health, maternal health and mortality, and knowledge of HIV/AIDS and other sexually transmitted diseases.

2.2 Ethical Authorization

The scheme in charge of the data collection has its own organized ways of protecting the information confidentiality of participants. The respondents read the information consent statement, and their participation in the exercise is voluntary, which can be terminated by them at any stage of the interview process. Likewise, the survey was certified by ICF International, and it complies with the rules of the United States Department of Health and Human Services regarding participants' protection and adherence to the laws and regulations of the nation. Nevertheless, this study received approval from DHS on the data usage for research purposes.

2.3 Model Structure and Estimation Method

Following the utility maximizing framework specified by Reichman *et al.* (2009), parents maximize utility from consumption goods (*C*), child health (H_C), parent's health (H_P), and tastes (*T*). The utility function is depicted as:

$$U = f(C, H_C, H_P, T) \tag{1}$$

Adapting the works of Mosley and Chen (1984) and Abate *et al.* (2020), the study modified and specified child health status (survive or die) as a function of indoor air pollution (*iap*), mother's characteristics (*x*), and child characteristics (*z*). This is stated functionally as:

$$H_C = h(iap, x, z) \tag{2}$$

Thus, child health status (H_C) is expressed as a function of the child's characteristics (*x*), the mother's characteristics (*z*), and indoor air pollution (iap). Indoor air pollution from the use of combustible fuel or biomass burning is the third leading disease burden in developing countries. Indoor air pollution from solid fuel use has an adverse effect on child health. Pneumonia in children caused by solid fuel use leads to 2 million deaths among children in low-income countries (World Health Organization, 2006). Apart from the indoor air pollution, child characteristics and mother's

features (such as age, educational qualification, employment status, location, family size, and whether or not a baby is wanted) constitute factors in child mortality.

These predicting variables relating to child mortality are conceptually depicted in Figure 1. The predicting variables, as earlier noted, are indoor air pollution, child characteristics, and mother characteristics. The chart gives a picture of how indoor air pollution, child characteristics, and mother characteristics relate to child mortality.

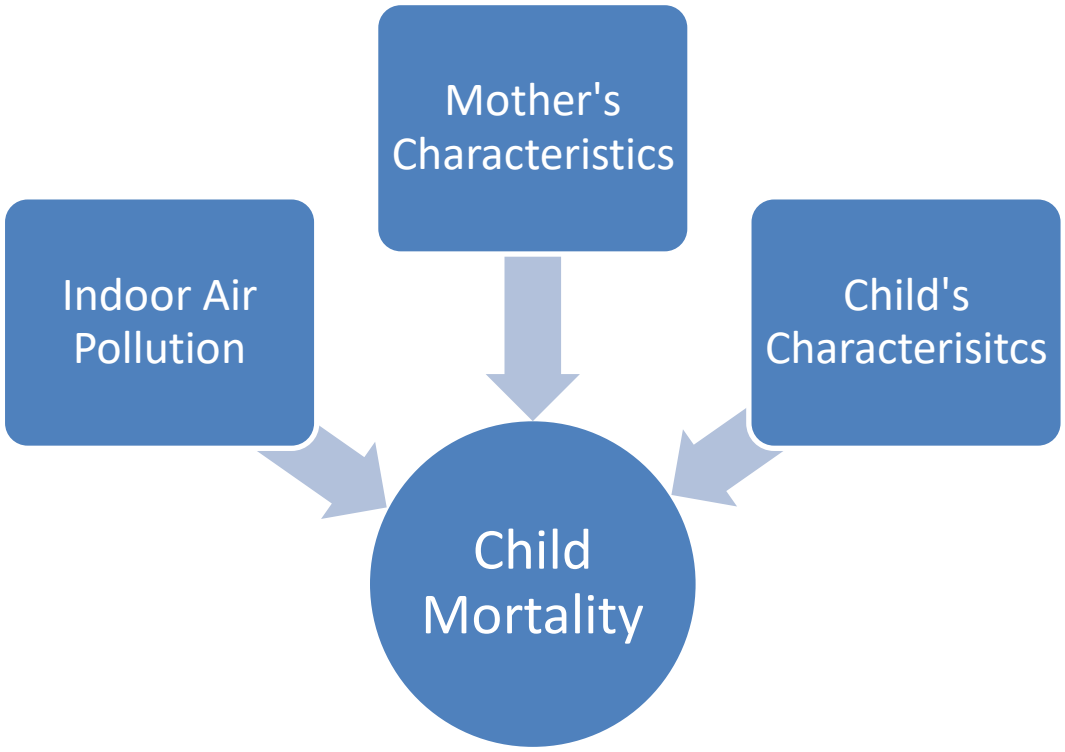

Figure 1: Conceptual links of indoor air pollution and child mortality

Regarding the estimation method, logit regression is adopted to estimate the parameters relating to the relationship between indoor air pollution and children's sex mortality. The logit model is specified as:

$$\log\left[\pi/(1-\pi)\right] = \vartheta_0 + \psi X_i + \mu_i \qquad (3)$$

The probability of behaviour of interviewers is represented by π, while their odds behaviour is denoted by $\pi/(1-\pi)$. As regards X_i, it is a vector of independent variables of various factors influencing child mortality, such as indoor air pollution, child characteristics, and mother characteristics. Concerning the parameters, ϑ_0 denotes constant, ψ represents the vector of parameter estimates for the control variables, and μ_i denotes the disturbance term of the *i*th explanatory variables.

2.4 Variables Description

There are two indices that represent the outcome variable. The first indicator represents the male gender that died before the age of five years (i.e., 1 signifies 'yes' an affirmation of boy child mortality, and '0' indicates no boy child has died). Concerning the second indices, it is measured by the mortality rate of a girl child before the age of five (i.e., 1 signifies 'yes' an affirmation of girl child mortality, and '0' indicates no girl child has died). According to the energy ladder hypothesis, household indoor air pollution is measured by energy use for cooking, categorised based on degree of pollution: traditional energy (animal dung, straw, shrubs, grass, and wood), transitional energy (charcoal and kerosene), and modern energy (biogas, natural gas, LPG, and electricity).

Furthermore, the demographic characteristics relating to mothers in the study include: wealth index (categorised into '1st', '2nd', and '3rd' wealth index), location in rural or urban (0 represents 'urban' and 1 represents 'rural'), age of mother (15–49 years), sex of household head ('male' or 'female'), highest level of education ('no education', 'primary', 'secondary', and 'above'), employment status (currently working or not), mother's expectation to get pregnant ('yes' or 'no'), and family size. As regards the demographic factors relating to the child, the characteristics considered consist of: child use of mosquito nets, postnatal check-ups, child size, and breastfeeding. Specifically, child is breast feeding ('yes' or 'no'), child size ('small', 'average', and 'larger' than average), postnatal check-up ('yes' or 'no'), and child uses mosquito net ('yes' or 'no'). The description of variables used in the study is presented in the appendix (see Appendix 1).

3. Results

3.1 Descriptive Statistics

The descriptive statistics of the gender differences in child mortality are presented in Table 1. The environmental factors influencing child mortality, as reported in Table 1, showed that traditional energy has a strong level of association with a child's sex mortality. The finding revealed that children's sex mortality was high among households using traditional energy and low among those using modern energy. Among households using traditional energy sources, under-5 mortality among girls (90.56%) is higher than child deaths among males (79.57%). However, with the use of modern and transitional energy, the deaths of boys (0.67% and 10.15%) are higher than the mortality rates reported for girls (0.5% and 8.95%), respectively. The chi-square test results (638.15) showed that there is a statistical difference between indoor air pollution and gender disparity in child mortality in Nigeria. Regarding other demographic factors like education and wealth, the results showed that the deaths of boys and girls decreased with advancement in education and a higher wealth index. Likewise, the chi-square test confirmed that differences in a child's sex mortality with respect to education and wealth are statistically significant at 5% level.

Table 1: Descriptive statistics of IAP and child based mortality in Nigeria

Variables	Boys (n = 8,227)	χ^2 Test	P-Value	Girls (n = 7,344)	χ^2 Test	P-Value
Energy						
Modern	0.67	638.15	0.00	0.5	718.82	0.00
Transitional	10.15			8.95		
Traditional	79.57			90.56		
Education level						
non	61.87	68.13	0.00	63.79	78.19	0.00
primary	21.10			20.22		
secondary+	17.03			15.99		
Employment status						
No	29.11	15.48	0.00	27.16	60.43	0.00
Yes	70.89			72.84		
Location						
urban area	22.51	540.72	0.00	21.87	524.47	0.00
rural area	77.49			78.13		
Wealth index						
1st	61.03	70.01	0.00	63.07	90.12	0.00
2nd	31.46			30.11		
3rd	7.51			6.82		
Sex of household head						
Male	91.43	38.64	0.00	92.05	60.05	0.00
Female	8.57			7.95		
Child is breastfeeding						
No	5.16	267.91	0.00	4.93	190.00	0.00
Yes	94.84			95.07		
Child size						
Small	17.16	49.14	0.00	17.88	68.19	0.00
Average	41.03			40.35		
Larger than average	41.82			41.77		
Pregnancy expected						
No	7.3	33.10	0.00	7.04	40.62	0.00
Yes	92.67			92.96		
Postnatal check						
No	79.78	219.69	0.00	79.76	185.89	0.00
Yes	20.22			20.24		
Child uses mosquito net						
No	84.87	19.41	0.00	84.59	11.41	0.00
Yes	15.13			15.41		

Source: Authors' computation (2021) based on Nigeria DHS (2013).

Furthermore, the frequency distribution of a child's sex mortality is greater for households with employment status than those without employment. Rural male child mortalities (77.49%) are marginally minimal when compared to rural girl child mortalities (78.13%), but absolutely not in urban areas. According to Table 1, the household head classification of gender stratification of

child mortality revealed that male-headed families experienced a higher percentage of under-5 child mortality than families headed by the opposite sex.

This is not surprising because many African families are headed by men. More so, about 95.07% of female deaths under the age of 5 years are still breastfeeding, compared to 94.84% of male child mortality who are also breastfeeding. Concerning the demographic factor of child size, the report from the study revealed that about 80% of both sexual categories are above the average size. In addition, lots of households that do not go for postnatal check-ups were reported to have experienced under-5 mortality, but the death rate is higher in boys. The report further showed that a uniform spread (about 84%) of children's sex mortality was recorded across the use of mosquito nets in households.

3.2 Logistic Regression Results

The logit regression result of indoor air pollution and children's sex mortality is presented in Table 2. In the table, two different models were presented for each sexual category, i.e., boy child mortality (unadjusted and adjusted models) and girl child mortality (unadjusted and adjusted models). The empirical results showed that the odds of child mortality for both sexes experienced by households using traditional energy sources were higher than those using transitional and modern fuels, respectively. A comparative analysis between the two sex categories showed that the odds of girl child mortality were 81% greater than those of other energy sources, while the odds of boy child mortality were only 62%. The estimates are statistically significant at the conventional level. Similarly, in the unadjusted models, both child sex mortalities are significant statistically at 1% level with traditional and transitional energies. This implies that girls in households using traditional sources of fuel are at a higher risk of under-5 child deaths compared to the opposite sex (boys under 5) whose households also use solid fuels. Statistically speaking, the difference was significant at 1% level.

Table 2: Logit regression analyses of factors affecting gender mortality in Nigeria

Variables	Model 1 (Boys)		Model 2 (Girls)	
	Unadjusted Coefficient	**Adjusted Coefficient**	**Unadjusted Coefficient**	**Adjusted Coefficient**
Energy choice				
Modern	Ref.	Ref.	Ref.	Ref.
Transitional	0.32**(2.16)	0.54** (2.27)	0.51*** (2.86)	0.51 (1.88)
Traditional	1.25***(8.68)	0.62** (2.55)	1.57*** (9.07)	0.81*** (2.93)
Wealth index				
1st	Ref.	Ref.	Ref.	Ref.
2nd	-0.66*** (23.25)	-0.40*** (-8.20)	-0.73***(24.80)	-0.45*** (-8.85)
3rd	-1.31***(-28.13)	-0.67*** (-6.64)	-1.42***(-28.22)	-0.72*** (-6.61)
Education				
Non	Ref.	Ref.	Ref.	Ref.
Primary	-0.34***(-10.17)	-0.32*** (-6.19)	-0.42***(-12.21)	-0.38***(-6.99)
Secondary+	-1.19***(-35.47)	-0.82*** (-13.08)	-1.27***(-35.54)	-0.85***(-12.94)
Employment	0.11*** (3.93)	0.07 (1.72)	0.23***(7.76)	0.18*** (4.02)
Location in rural	0.68***(23.01)	0.23*** (4.38)	0.71 (22.62)	0.13*** (2.45)
Sex of household head	-0.28***(-6.20)	-0.92 (0.17)	-0.37 (-7.71)	-0.15** (-2.10)
Child size				
Small	Ref.	Ref.	Ref.	Ref.
Average	-0.20***(-5.29)	-0.53 (-0.95)	-0.27 (-6.95)	-0.11 (-1.92)
Large	-0.27***(26.06)	-0.47 (0.39)	-0.31 (-28.47)	-0.07 (-1.14)
Age	0.81*** (42.2)	0.09*** (33.59)	0.08** (42.12)	1.10*** (32.84)
Family size	-0.001 (-0.14)	0.007 (1.21)	0.003 (0.31)	0.0006 (0.11)
Pregnancy expected	0.27***(0.00)	-0.01 (-0.19)	0.32 (6.3)	0.03 (0.69)
Breastfeeding	-1.12*** (-15.6)	-1.41*** (-9.51)	-0.96***(-13.21)	-1.30*** (-8.62)
Mosquito net	-1.60*** (4.40)	-0.00 (0.98)	-0.13***(-3.39)	0.008 (0.14)
Postnatal check	-0.59***(-14.69)	-0.11** (-2.23)	-0.57***(-13.61)	-0.08 (-1.61)

Note: Coefficients in parenthesis represent the t-statistics; *** & ** significance at 1% and 5% respectively.
Source: Author's computation (2021) based on Nigeria DHS (2013).

Also, Table 2 presents the empirical findings of other significant factors that affected gender differences in under-5 child deaths in Nigeria. Compared with the reference category of wealth index, children in wealthier households had a significantly lesser risk of child mortality. Thus, wealthier households are likely to have lower cases of children's sex mortality, as the coefficients of the wealth index are negative and significant at 1% in both unadjusted and adjusted models. In magnitude terms, the odds of girl child mortality occurring in wealthy household of the 2nd and 3rd categories were 72% and 45%, respectively, against 67% and 40% incidence in a male child living in affluent homes (see the adjusted coefficients in Table 2). It means that girls in wealthier family are at a lesser risk of child mortality than boys under the age of 5 living in rich households. Similarly, education is negatively and significantly associated with both boy and girl child mortality. Specifically, households with primary and secondary education have higher chances of experiencing lower cases of child mortality compared to non-educated families. Just like the estimates of the wealth index, the odds of girl child mortality happening in educated homes were 38% and 85% less for households with primary and secondary education, compared to 32% and

82% less prevalence in boy child mortality, respectively. The implication of the result is that households with a higher level of education are likely to have lower cases of girl child mortality compared to the opposite sex (boys) born into educated homes. Pictorial evidence that wealth and education are associated with lower children's sex mortality is depicted, respectively, in Figures 2 and 3.

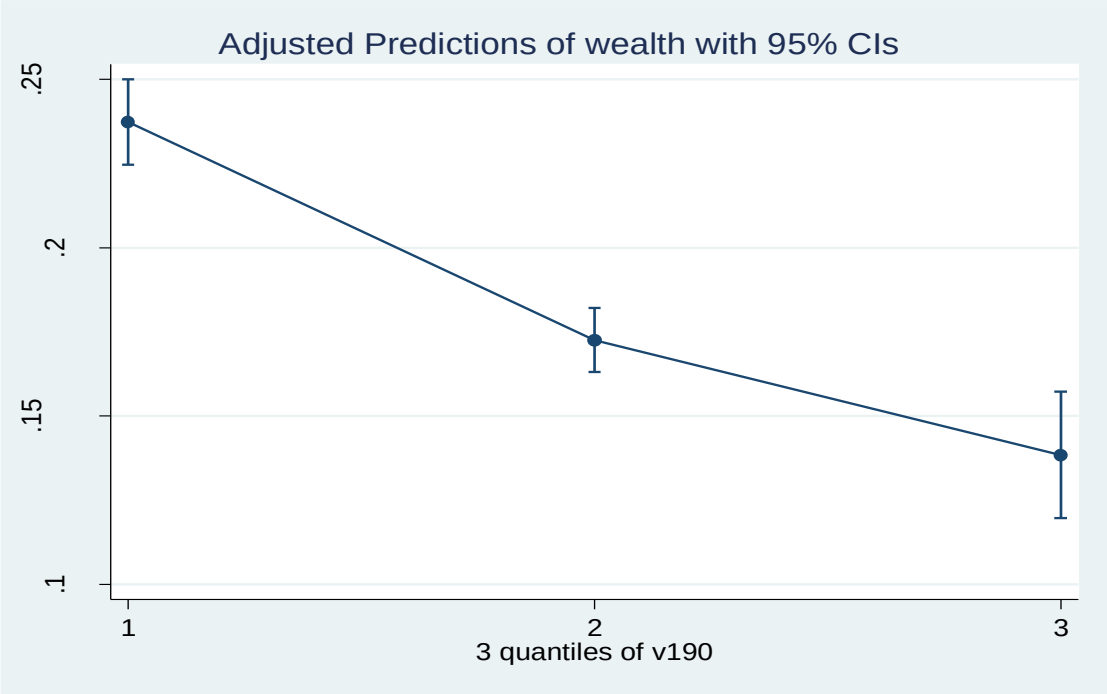

Figure 2: Graphical representation of child mortality and wealth index.
Note: The figure shows a decreasing trend in boy child mortality with higher level of wealth.

Apart from education and wealth factors, Table 2 reveals other significant factors that affect under-5 child deaths. The result showed a significantly greater risk of under-5 deaths for children born into a household residing in rural areas than for those residing in urban areas. The estimated parameters showed that a rural girl child (with an odd of 13%) is at a lesser risk of dying at ages 0–4 years compared to a male child (with an odd of 23%) residing in the rural area. Similarly, the study reported that a mother's age and employment have a direct and significant relationship with child mortality, while the girl child is at higher risk than the boy child. On the contrary, the study showed that there is a greater chance of child mortality for boys and girls under the age of five who are not breastfed, but the odds are higher for females than males. The finding is similar for children that were not taken for a postnatal check-up. Summarily, breastfeeding and postnatal check-ups reduce the risk of a child's sex mortality at 1% significance level. Concerning the use of mosquito nets, their usage significantly reduces the risk of boy child mortality but is statistically insignificant for girl child mortality. As regards factors like child size, sex of household head, family size, and pregnancy expectancy, they have no significant effect on a child's sex mortality in Nigeria.

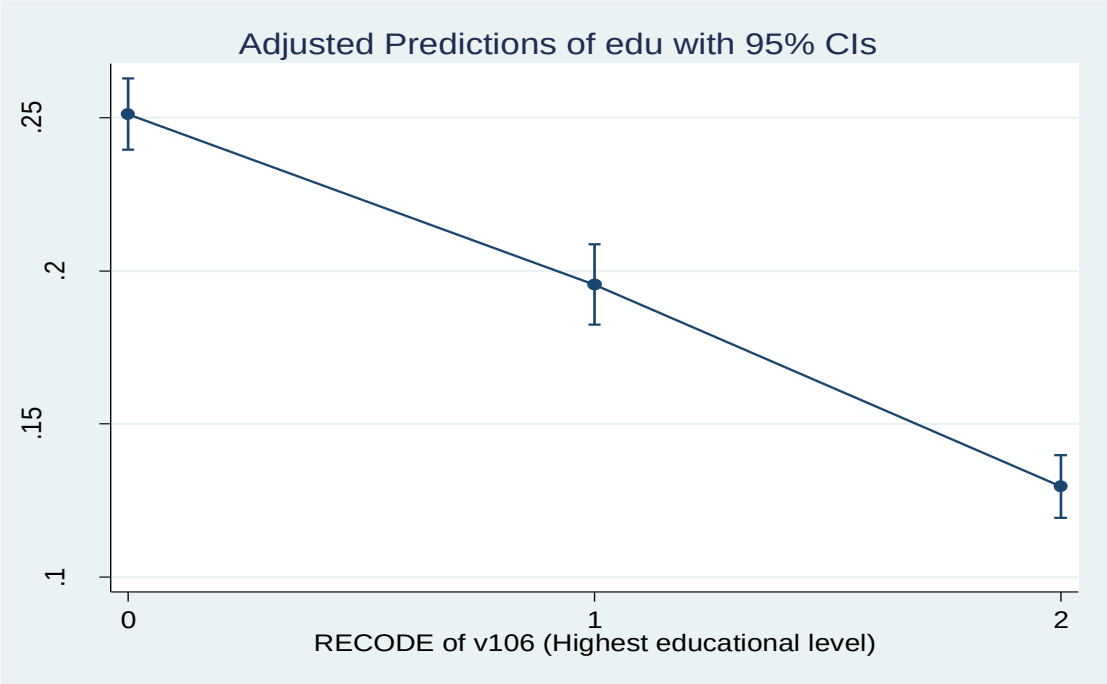

Figure 3: Graphical representation of boy child mortality and education.
Note: The figure shows a declining trend in child mortality with higher level of education.

3.3 Discussion of Findings

The study found that indoor air pollution is significantly associated with an increasing risk of child mortality in boys and girls after controlling for possible co-founding factors like wealth, education, employment status, location, child size, age, family size, postnatal check-up, breastfeeding, pregnancy expectation, and use of mosquito nets. Exclusively, we found that households' use of biomass fuels is statistically related to child mortality. In specific terms, the findings from this study revealed that both sexes are at risk of mortality from traditional and transitional energy use in cooking, while the girl child is prone to a higher risk of mortality from transitional energy than the boy child. This is in line with the study conducted by Bassani *et al.* (2010) that found more girls than boys died from biomass burning, but we disagree with Abate *et al.* (2020) that male children are more at risk of death compared to female infants. The study noted that the use of traditional or biomass fuels increased the risk of under-5 mortality in girls by 81%, compared to a 62% increased risk for boys under age 5. Also, Ajide, Dauda and Alimi (2023) discovered that poor electricity access increases infant mortality rates. Furthermore, the empirical results are consistent with the findings of past studies in Nigeria, such as those by Ezeh *et al*. (2014), Anyamele *et al*. (2015) and Morakinyo and Fagbamigbe (2017). It complements the results of Morakinyo and Fagbamigbe (2017) that household use of clean cooking fuel is negatively associated with infant mortality. Likewise, Ezeh*et al*. (2014) found that household burning of biomass is associated with a risk of child mortality among children aged 12-59 months. This contradicts the results of Epsteinm *et al*. (2013), who found that household use of solid fuels is not statistically associated with neonatal mortality in India. As well, Ezeh *et al*. (2014) found an insignificant relationship between solid fuels and neonatal deaths in Nigeria. This study supports the submission of Ezeh *et al*. (2014) that traditional energy sources begin to significantly affect a child's health during postnatal periods. The authors attribute their submission to the fact that

children in their early lives are usually in the company of their mothers while cooking, thereby increasing the risk of mortality because of their exposure to high concentrations of pollutants.

The prevalence rate of child mortality is lower among wealthy families. This conforms with the findings of Argeseanu (2004), El Awour, Abed, and Ashour (2012), and Yaya *et al*. (2017) that child mortality is significantly lower in households with rich status. In the same way, education reduces the risk of boy and girl child mortality, and this is also buttressed in past studies like Fayehun (2010), Adedini (2014), Wegbom *et al*. (2019), and Abate *et al*. (2020). The two socio-economic factors favour girl children over boys. Again, demographic factors like breastfeeding and postnatal check-ups are found to be negatively related to child mortality among boys and girls. The two co-founding factors are more favourable for boys. Thus, the study found education, wealth, breastfeeding, and postnatal checks as mechanisms that are responsible for the observed gender disparity in under-5 mortality. Wealth and education are in favour of girls, while breastfeeding and postnatal check-ups favour boys. This aligns with the mixed empirical evidence in many sub-Saharan Africa studies (see Klasen, 1996; Svedberg, 1996; Monden and Smits, 2013).

Meanwhile, the study found other socioeconomic factors, like a mother's age, employment, and location, to be risk factors for child mortality. This is in line with the results of Adegoro and Amoo (2014), who found that the age of the mother, location in rural areas, and employment in some sectors are positively related to child mortality in Nigeria. Regarding a mother's age, it is a risk factor for child mortality, as older mothers have higher chances of experiencing boy and girl child mortality. This supports the work of Samuel and Amoo (2014), who found that children born to women in their late reproductive years are more likely to experience child mortality. Yaya *et al*. (2017) reported a similar finding: older women have higher chances of child mortality. This is against the submission of Wegbom (2020) that mothers below 25 years have more reported cases of child mortality. The direct relationship between a mother's employment and child mortality aligns with Adedini's (2014) finding that children of mothers in formal employment died before age 5.

4. Conclusion and Policy Implications

This study investigates the environmental effects of gender differences in child mortality in Nigeria using the 2013 Demographic and Health Survey. The aim was to understand which of the child's sexes is at risk owing to the submission of Waldron (1983) that the girl child has higher immunity from diseases as a result of genetic make-up. Some studies, like Van Malderen *et al*. (2019), submitted that there is a high preference for a gender against the opposite sex that informs care, and there is a greater preference for male children in Africa. The logistic regression estimator is employed to estimate the environmental factors of gender disparity in child mortality in Nigeria, while also controlling for the child's and mother's characteristics. The findings revealed that both boys and girls face mortality risks linked to traditional and transitional energy use in cooking. However, girls show a higher susceptibility to mortality from traditional energy sources, whereas the impact of transitional energy sources presents mixed findings. On average, girls are prone to a higher risk of mortality from indoor air pollution than the boys. This study contributes to the growing body of evidence on the adverse health effects of household air pollution, aligning with previous studies in Nigeria and emphasizing the urgent need for interventions to mitigate indoor air pollution and its impact on child health outcomes.

The policy implications arising from these findings are manifold. Firstly, there is a pressing need for targeted interventions to promote the adoption of clean cooking technologies and reduce reliance on biomass fuels among households in Nigeria. Government initiatives aimed at subsidizing or providing access to clean cooking technologies, such as liquefied petroleum gas (LPG) stoves or improved cookstoves, could significantly reduce indoor air pollution and associated health risks. Additionally, public awareness campaigns highlighting the health hazards of indoor air pollution and the benefits of clean cooking technologies could help drive behavioural change and the adoption of cleaner cooking practices.

Strategies to curtail the risk of child mortality include increasing needs for the adoption of modern energy, most especially liquefied petroleum gas (LPG), which has been a challenge in rural and peri-urban areas as there are no gas infrastructures in place. Also, there are problems with the affordability of gas and stoves in these locations. This is because access to firewood in rural locations is often a motivating factor to continue burning traditional energy. Private investors are not willing to invest in gas infrastructures in the rural areas. Technological progress has improved the manufacturing of small-sized cylinders (3kg and 6kg) recently. However, the government should take further action to ensure that modern energy is accessible and affordable to the poor and vulnerable. Thus, promoting widespread access to liquefied petroleum gas (LPG) in both rural and urban areas is an effective strategy to encourage the adoption of modern energy sources. This would also be a remedy for the ongoing deforestation in the country. Also, there is a need to sensitize households on the health implications of cooking with traditional and transitional energies. The Sustainable Development Goals (SDGs) emphasize the importance of modern energy access across countries that are energy poor. While some nations, particularly in Asia, have shown dedicated efforts towards this goal, it is not as much of a priority in many developing countries like Nigeria. There is a crucial need to promote the adoption of modern energy sources across all socio-economic levels in Nigeria.

Furthermore, addressing the socio-economic determinants of child mortality, such as wealth, education, and access to healthcare, is paramount. The study linked factors such as mothers' age, employment status, and household location to higher child mortality rates among boys and girls. Conversely, education, wealth, breastfeeding, and postnatal check-ups were identified as mitigating factors for under-5 mortality in both genders. Notably, the study revealed that girls benefit more from wealth and education, while boys benefit from breastfeeding and postnatal check-ups. Therefore, education emerges as a crucial determinant in reducing child mortality. The educational attainment of parents positively impact income-generating activities and equip them with the necessary knowledge and skills to mitigate child mortality. Consequently, there is an urgent need to increase the uptake of education in Nigeria. Additionally, enhancing the financial status of households serves as a means to facilitate the adoption of modern energy sources. Policies aimed at improving socio-economic status, enhancing educational opportunities, and increasing access to maternal and child healthcare services will contribute to reducing child mortality rates. Targeted interventions to support vulnerable populations, including rural communities and older mothers, would help address disparities in child health outcomes. Overall, a multi-sectoral approach involving collaboration between government agencies, non-governmental organizations, and communities is essential to effectively address the complex factors contributing to child mortality and improve health outcomes for Nigerian children.

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Conflict of Interest
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this research paper.

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Appendix

Appendix 1: Description of Variables

Variable	Description
Child mortality (boy/girl)	Dummy; 1 represents child is alive and 0 otherwise
Child size	Continuous; 1 represents small child size, 2 represents average and 3 is larger than average
Pregnancy expected	Dummy; equal to 1 if pregnancy is expected and 0 otherwise.
Child is breastfed	Dummy equal to 1 if child is breastfed and 0 otherwise
Postnatal check-up	Dummy equal to 1 where check-up is done for child after birth
Child use of mosquito net	Dummy equal to 1 if child uses mosquito net and 0 otherwise
Energy use	Continuous; 1 represents traditional fuel; 2 is transitional fuel (kerosene and coal) and 3 is modern energy
Wealth index	Nominal variable
Mother's age	Continuous
Family size	Continuous
Employment status	Dummy
Educational level	Continuous
Location	Dummy
Sex of household head	Continuous