ENVIRONMENTAL EXPOSURE AND MATERNAL MORTALITY IN SELECTED AFRICAN COUNTRIES

Risikat Oladoyin S. Dauda[1], Olayinka Aminat Olohunlana[1*] & Oluwaseyi Omowunmi Popogbe [2]

[1]Department of Economics, University of Lagos, Akoka, Lagos, Nigeria
[2]Department of Economics, Crawford University, Ogun State, Nigeria

*Corresponding author's email: eniayewuyinka@yahoo.com

Abstract

Improving maternal health is a top priority amongst other global public health issues, hence leading to the well-established literature on the factors determining maternal mortality. However, empirical evidence on the linkage between maternal mortality and environmental exposure is poorly understood in the literature. Therefore, this study seeks to contribute to the literature on the determining factors of maternal mortality by examining its linkage to environmental exposures in selected African countries. The study covers 25 selected African countries for the period between 2000 and 2016. Using the Panel Corrected Standard Error (PCSE), the study establishes inter alia: first, environmental exposures significantly aggravate maternal mortality in Africa. Second, Adolescent fertility, and access to at least one basic amenity increase mortality rates in the continent where current expenditure per capita reduces the prevalence of maternal deaths. Third, renewable energy and electricity consumption significantly reduces maternal mortality in selected African countries. Fourth, income per capita and inflationary levels are however not significant determinants of maternal mortality. The findings have a strong implication for maternal health policy in Africa. The study recommends that intensive efforts should be directed into the reduction of environmental exposures and also seek actionable ways to discourage early exposure to childbirth.

Keywords: Maternal Mortality, Gender Development, Environmental Exposure, Health Expenditure
JEL Classifications: I12, Q52, Q53.

Article history-Received: March 04, 2022, Revised: June 13, 2022, Accepted: June 15, 2022.

Introduction

Improving maternal health is a top priority among other global public health issues (Nichols & Cohen, 2021; Say et al., 2014). It is even more critical in Africa, where 50 per cent of global maternal deaths occur (Girum & Wasie, 2017). Although there seems to be a drop in the maternal mortality rates (MMR) in Africa between 2010 and 2017, the reduction is infinitesimal compared to other advanced regions. For instance, in Eastern Europe and Central Asia, Maternal Mortality Rate (MMR) reduced from 45 deaths per 1,000 live births in 2000 to 26 deaths per 1,000 live births in 2010 and 19 deaths per 1,000 live births in 2017. In South Asia, the MMR reduced drastically from 395 deaths per 1,000 live births in 2000 to 235 deaths per 1,000 live births in 2010 and 163 deaths per 1,000 live births in 2017. In comparison, the average MMR in the African region stood at 871 deaths per 1,000 live births in 2000, 625 deaths per 1,000 live births in 2010, and 530 deaths per 1,000 live births in 2017 (World Health Organisation, 2019).

The high rate of maternal mortality in the continent necessitates the need for development experts and health economists to inquire about the factors determining maternal mortality. Extant studies have continued to investigate the causal factors of maternal mortality globally and in Africa in particular. Many of these studies attribute increasing African maternal deaths to a lack of proper health facilities and skilled healthcare (Girum & Wasie, 2017), poverty (Atake, 2021), increased exposure to heat (Kuehn & McCormick, 2017), ignorance on the part of pregnant women (Sageer et al., 2019), and lack of access to basic amenities (Boyles et al., 2020). However, scarce studies have looked into the link between environmental exposure and maternal mortality.

Environmental exposure refers to direct or indirect contact with physical, biological, solid and liquid chemical substances that is capable of endangering human health (Kim, 2016; Maji et al., 2018). It could manifest as a process of inhalation of harmful substances like nitrogen, methane, particulate matter and carbon. Carbon emissions have been noted to be the leading contributor to environmental exposure, thus inhaling carbon emitted impairs the atmospheric balance of oxygen and leads to difficulty in breathing (Adeneye et al., 2021; Armah et al., 2015; Hanif, 2018). Consequently, exposure to harmful environmental substances has been affirmed to increase cardiovascular disease, cataracts, tuberculosis and other respiratory illnesses (Oladeji, 2015; Smith, 2006; World Health Organisation, 2014). Proximately, environmental exposures may therefore endanger maternal health and aggravates complications during prenatal and postnatal stages of maternal life (Boyles et al., 2020).

Despite the implication of environmental exposure on human health and its probable influence on maternal mortality, African policy experts are not proactive in curbing the worsening effects of environmental exposures in the continent (Nathaniel & Iheonu, 2019; Shobande, 2020). This has been attributed to the possible absence of valid and reliable data that promotes air quality monitoring (Jackson, 2021). To improve the availability and reliability of data on air quality monitoring, the World Bank launched the Clean Air Initiative in Sub-Saharan Africa (CAI-SSA), while the Stockholm Environment Institute launched Air Pollution Information Network for Africa (Amegah & Agyei-Mensah, 2017). However, a direct linkage between health and environmental exposures is yet to be established.

Moreover, there is a dearth of empirical literature on the implications of environmental exposure on maternal health in Africa. The focus on environmental exposures is important because of the higher exposure of the African region to unclean fuel sources, overpopulation, and rising industrialization (Ngbeme et al, 2016). This poses a greater threat to maternal health because the pregnancy period in women is characterized by changes in the body, increased body mass index and reduced capacity to thermoregulate. This may further lead to miscarriages, preterm or stillbirths (Roos et al, 2021). The current study thus seeks to empirically examine the effect of environmental exposures on maternal mortality in Africa. Examining the empirical linkages between environmental exposures and maternal mortality helps in providing policy recommendations that will actualize the sustainable development goals of reducing maternal mortality and combating climate change.

The remaining sections of the paper are as follows: section two presents the review of related literature. The third section describes the methods of data collection and estimation techniques. Section four offers empirical discussions of the findings. The preview of the findings is as follows: the study affirms that carbon emission, a leading cause of environmental exposure, aggravates maternal mortality. Second, the other confounding variables, such as current health expenditure, reduce maternal mortality. Third, early exposure to childbirth through adolescent fertility rates increases pregnancy-induced complications and thus leads to an increasing rate of maternal deaths. Fourth, the study further confirms that lack of access to at least a basic amenity increases risks associated with maternal mortality. Arising from these findings, salient policy recommendations and conclusions were offered in section five.

Literature Review

Theoretically, Grossman, (1972) proposed the health production function to explain the relationship between health outcomes and their inputs. The theory stipulates that the wellness of an individual is influenced by factors such as the economic, social, and environmental circumstances surrounding the individual. Extant studies on health outcomes have employed the theory to explain the implications of economic, social and environmental factors influencing their well-being (Alimi et al., 2020; Danovi et al., 2021; Guzel et al., 2021; Hartwig & Sturm, 2018; Rahman et al., 2021). For instance, Rahman (2021) validated the theory through his opinion on the detrimental implications of industrial pollution on public health outcomes in the twenty most industrialized economies in the world. Also, Danovi et al. (2021) found a positive and linear correlation between living with disability and healthcare sustainability in the five largest countries with emerging healthcare systems. However, Hartwig & Sturm (2018) fail to ascertain the theory's validity in their study on the determinants of health spending in Organisation for Economic Cooperation and Development (OECD) countries. This study also seeks to interrogate the validity of the Grossman health production theory in examining the implications of environmental exposure on maternal mortality in Africa.

Empirically, studies on the determinants of maternal mortality have been well established in the literature. Most of these studies are predominant on the economic, health and social-cultural factors that might influence maternal mortality, while scarce studies are documented on the determinants of maternal mortality through the lens of environmental exposures. For instance, Girum & Wasie (2017) investigated the determinants of maternal mortality in 82 developing countries between 2008-2016. Through multiple regression analyses, the study found that adolescent fertility, lack of healthcare access, and socio-economic issues aggravate maternal mortality. On the other hand, having access to skilled birth attendants, improved water sources, and regular sanitation reduces the rate of deaths amongst pregnant women in the selected countries during the period under review.

Say et al. (2014), in their study on the global causes of maternal death, opined that complications in delivery and obstructed labour procedures are among the direct causes of global maternal deaths. The study further noted that other underlying ailment such as Human Immunodeficiency **V**irus infection and **A**cquired Immunodeficiency Syndrome (HIV/AIDS), and other medical anomalies indirectly aggravates maternal mortality. By inference, environmental exposures may also indirectly contribute to global maternal mortality.

Other scholars further examined the determinants of maternal mortalities from the lens of socio-cultural and demographic factors. For instance, Tian and Pan, (2021) examined the implications of socio-economic inequalities in accessing facility bed spaces on maternal mortality in China. The study, which spans through 2004 and 2016, reveals that bed distribution inequalities are significant determinants of maternal deaths in China. Similarly, Atake (2021), in his study on the socio-economic implications of maternal health care in Togo, reveals that regular antenatal visits and hospital-based deliveries are critical in determining maternal health, thus reducing maternal mortality in Togo. Ariyo et al (2021) further investigate the relationship between socio-demographic factors and maternal mortality in Nigeria. The study found a positive and high correlation between maternal deaths, religious beliefs, age, and region of residence.

Also, another strand of studies engaged the literature on the implications of economic conditions in addressing maternal mortality across the globe and in Africa (Banchani & Swiss, 2019; Iheonu et al., 2019). For instance, Banchani and Swiss, (2019) conducted extensive research on the effects of aid to health on maternal mortality in 130 low- and middle-income countries. The study, which spans from 1996 through 2015, found that the overall impact of aid that flows into the health sector was insignificant. However, aid specific to the reproductive and health sector reduces maternal mortality. Iheonu et al., (2019) also enquired about the implications of governance quality on female and maternal mortality in Sub-Saharan Africa (SSA) between 2002 and 2015. The study, which adopts the Driscoll and Kraay fixed effect estimator, found that overall institutional quality and corruption control decreases maternal mortality in SSA.

A succinct scan of the literature suggests that there appear to be limited empirical insights on the exact implication of environmental exposure on maternal mortality, although evidence abounds on its impact on other health outcome indicators. For instance, Mcormick (2017) adopted a systematic literature review approach to examine the link between exposure to heat and fetal health. The study found that a significant number of studies documented that increased exposure to heat pollutants contributes to maternal stress and indirectly influences fetal growth and development.

Related evidence was shown in the works of Gardner et al (2013), who examined the impact of poor environmental conditions on fetal development in Rural Bangladesh within the period 2001 and 2009. The findings reveal that poor environmental condition adversely affects birth weights and stunts the growth of children under five. Similarly, Perlroth & Branco (2017) also affirmed that exposure to environmental and chemical substances during pregnancy has a long-term detrimental impact on child development. Lu et al (2017) also corroborated the findings of Kuehn and McCormick (2017) by noting that a long and negative relationship exists between environmental exposures and public health.

Similarly, Armah et al (2015) found that smoke as a source of environmental exposure contributes to deteriorating health quality, thereby inhibiting the overall health and well-being of persons in Ghana. Cheng et al (2012) examined the impact of environmental pollution on infant and maternal health in 193 countries across all continents. The study revealed that water pollution and inappropriate sanitation aggravate infant mortality through the deteriorating health conditions of their mothers.

However, these studies could not confirm the direct impact of environmental exposures on maternal death. The rare empirical evidence on the implications of environmental exposure on health outcomes was found in the works of Boyles et al (2020), who inquired about environmental factors contributing to maternal mortality and morbidity. The study found that exposure to air pollution, carbon and other harmful substances increases fertility risk and consequently aggravates maternal mortality. Given the paucity of literature on the direct impact of environmental exposures on maternal mortality, this study extends the body of literature by examining the implications of environmental exposures on maternal mortality in Africa. Africa was chosen because it has the highest records of maternal mortality and also has recorded slow growth in the reduction of the menace. It is, however, unclear whether environmental exposures to harmful substances like carbon emission aggravates maternal deaths in the continent. To the best of the researchers' knowledge, little or nothing is known about the relationship. Hence, this study fills the identified knowledge gap in the literature.

Data and Methodology

Data

The dataset employed in examining the effects of environmental exposures on maternal mortality is obtained from the World Bank Development Indicator (WDI) database. The data consists of indicators for maternal mortality, environmental exposures, and other control variables.

Table 1: Variable description, measurements, and A-priori expectations

Variable	Model code	Definition/ measurement	Expectations
Maternal Mortality rate (%)	*martmort*	Maternal deaths per 1000 live births	n/a
Carbon emission per capita (metric tons)	*carem*	Carbon metric tons emitted per capita	positive
Adolescent fertility rate %	*adfer*	Number of births per 1,000 women ages 15-19	positive
Health expenditure per capita	*hexp*	Annual estimated current health expenditures divided by the total population in the country	negative
Urban Population (%)	*urban*	percentage of urban population to the total population	positive
Access to Basic sanitation (%)	*basan*	percentage of the total population having access to at least basic sanitation services	negative
Inflation (%)	*infl*	Inflation, consumer prices (annual %)	positive
GDP per capita (constant 2010 US $)	*gpdppc*	GDP per capita is gross domestic product divided by midyear population	negative
Renewable electricity output (%)	*relec*	percentage of renewable electricity to total output	negative
Renewable energy consumption	*rener*	percentage of renewable energy consumed to total final energy consumption)	negative

Source: Authors' Compilations, 2021

The choice of these controlled variables is based on their established relevance as key maternal mortality determinants. Table 1 presents the description of the variables employed in this study. Based on the availability of data for the key variable of interest, the observation period shall be from the year 2000 to 2016 for 25 countries highly prevalent in maternal mortality.

The names of the sampled countries are Benin, Burundi, Cameroon, Central African Republic, Chad, Congo Democratic Republic, Cote d'Ivoire, Eritrea, Ethiopia, Estiwani, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Mauritania, Niger, Nigeria, Sierra Leone, Tanzania, Togo, and Zimbabwe. The incidence of missing data points is observed in the dataset. To address this issue, the study follows Banchani & Swiss (2019) approach to handling the missing data points by replacing the missing points with the average of the last four most recent years in the dataset. Thus, making the panel dataset strongly balanced.

Table 2: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Matmort	425	747.37	302.38	314.00	2480.00
Carem	425	0.34	0.30	0.02	1.40
Adfer	425	116.39	35.14	54.11	217.16
Hexp	425	45.00	50.56	0.00	380.86
Urban	425	35.64	12.97	8.25	66.00
Basan	425	23.24	13.93	3.40	58.37
Infl	425	7.95	30.75	-9.62	513.91
Gdppc	425	1031.86	854.19	194.87	4650.14
Relec	425	46.77	38.24	0.00	100.00
Rener	425	76.10	15.94	31.84	98.34

*****Variable codes are as described in Table 1, "Obs", "Mean", "Std. Dev", "Min" and "Max" are indicators for the number of observations; averages, standard deviations, minimum and maximum observations of the variables employed in the study.*

Source: Authors' compilation from STATA 13.0 Output, 2021

Table 2 presents the descriptive statistics of the variables employed in this study. It reveals that the selected countries in Africa have an average of about 747 maternal deaths per 1000 live births within the period under study. Also, environmental exposures, proxy with carbon emission per capita, has about 0.34 tons of carbon emission per person within the sampled countries. More importantly, Table 3 presents the interrelatedness of the variables. The findings presented in Table 3 show that all the regressors have coefficients below the threshold of 70 per cent. It also reveals that the majority of the regressors are significantly correlated with the regressands.

Table 3: Correlation matrix

Variables		(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(x)
matmort	(i)	1									
carem	(ii)	-0.3142*	1								
adfer	(iii)	0.4984*	-0.3694*	1							
hexp	(iv)	-0.2295*	0.5930*	-0.2147*	1						
urban	(v)	-0.1035*	0.0902*	-0.0588	-0.0103	1					
basan	(vi)	-0.1975*	0.4693*	-0.3368*	0.4726*	0.0221	1				
infl	(vii)	-0.0278	-0.0691	-0.0182	-0.0351	-0.023	-0.0034	1			
relec	(viii)	-0.2173*	0.0195	-0.2658*	-0.0259	-0.1865*	0.1004*	0.1412*	1		
rener	(ix)	0.3413*	-0.6169*	0.3874*	-0.3054*	-0.4117*	-0.2274*	0.1033*	0.1837*	1	
gdppc	(x)	-0.2691*	0.6955*	-0.1936*	0.7549*	0.2627*	0.4520*	-0.0569	-0.0513	-0.4952*	1

*****Variable codes are as described in Table 1,* denotes a 5 per cent level of significance*

Source: Authors' compilation from STATA 13.0 Output, 2021

However, due to the complexity of a panel dataset, the a-priori expectation of spatial and temporal effects is envisaged. These may lead to the presence of heteroscedasticity, panel autocorrelation and cross-sectional dependence (contemporaneous correlation). Cross-sectional dependence may be envisaged due to the increasing globalization of economies where the effects of economic, trade and financial integration of the sampled countries may impact the outcome of the regression outcome. Therefore, this may lead to biased standard errors and inefficient estimation. More so, the presence of autocorrelation and heteroscedasticity may arbitrarily inflate the coefficient of determination beyond their actual values. Thus, it appears unsafe to ignore the effect of these complexities in the model, especially when they are not controlled.

In light of this, the fixed and random estimators may appear inefficient, thus producing spurious results. Two alternative efficient estimators have been suggested by Baloch et al (2019) and Marques and Fuinhas, (2012) to handle the panel heteroscedasticity, autocorrelation, and cross-sectional dependence. The first estimator, the Feasible Generalised Least square (FGLS), appears to produce robust estimations, but it is adequate mainly for infinite samples (Driscoll & Kraay, 1998). It is also applicable when the number of periods is greater or equal to its cross-sections (T≥N) (Lu, 2017). However, for panel datasets whose composition does not meet up with the conditions of the FGLS, the panel corrected standard error (PCSE) estimator is considered suitable to produce robust outcomes (Hoechle, 2007). It performs better in a situation where the number of periods is lesser than the number of cross-sections (T≤N) (Marques & Fuinhas, 2012). In relating this to the panel dataset of this study, it appears that the PSCE is preferred for its analysis because it has 25 countries across 17 year-time- period. However, as suggested by (Marques & Fuinhas, 2012) and Moutinho et al (2020), pre-estimation analysis is conducted to affirm the suitability of the estimation technique for this study. The following section provides a detailed explanation of the pre-estimation analysis.

PCSE pre-estimation conditions.

Following the suggestions of Marques and Fuinhas (2012) and Moutinho *et al.* (2020), the study follows the highlighted pathway to test for the presence of heteroskedasticity, autocorrelation and cross-sectional dependence in the panel dataset. First, the mean of the variance inflation factor is estimated to ascertain that there is no existence of multicollinearity amongst the datasets. Table 4 shows that the mean VIF of the panel dataset is 1.98.

Table 4: Multicollinearity test outcome

Variables	VIF	1/VIF
Gdppc	3.76	0.266311
Hexp	2.89	0.346171
Carem	2.29	0.436213
Basan	1.47	0.681251
Adfer	1.24	0.80377
Urban	1.24	0.809326
Infl	1.01	0.992913
Mean VIF	1.98	

Source: Authors' compilation from STATA 13.0 Output, 2021

This submits that the variables are not suffering from multicollinearity, hence casting out doubt on the possibility of collinearity amongst the variables employed in this study. Second, the presence of serial autocorrelation is also tested using the Wooldridge test for autocorrelation.

Table 5: Pre-estimation tests for PSCE

	Fixed Effects	Random Effects	Pooled
Frees' test	6.084*	6.278	-
Pesaran's test	-1.106*	-1.346*	-
Wooldridge test F (N (0, 1))	129.586***	-	-
Panel Heteroscedasticity	-	-	416.58***
Modified Wald test (x^2)	-	-	2896.74***

Notes: all the tests were conducted using Stata 15.0. The command *xtcds* was used for frees and Pesarans's tests for cross-sectional dependence, while *xtserial* is used for the Wooldridge autocorrelation test. The test is normally distributed N (0, 1) and tests the null hypothesis of no serial correlation. *lrtest* is used for panel heteroscedasticity. The modified Wald test distribution. *,***, **, * denote significant at 1,5 and 10 per cent respectively*

Source: Authors' compilation from STATA 13.0 Output, 2021

Table 5 column 1 presents the result of the analysis. The results confirmed the rejection of the null hypothesis, hence suggesting the presence of first-order autocorrelation. Third, the modified Wald-test was used to check for group-wise heteroscedasticity in the fixed effect estimation residuals. The findings in Table 5 column 2 reveals that the errors are heteroscedastic, therefore making the rejection of the null hypothesis mandatory. Lastly, the assumption of cross-sectional dependence was confirmed by performing Pesaran and Friedman's test for either the fixed or the random effect estimation. The results, as presented in Column 2 and 3 of Table 5, reveals that the null hypothesis is rejected in the two estimators.

Model specification

Owing to the presence of autocorrelation, GroupWise panel heteroskedasticity and contemporaneous correlation in the panel dataset, this study adopts the panel corrected the standard error as its choice of estimation technique. Asides from the complexities associated with the panel dataset, the choice of PCSE is further corroborated by the length of timeframe and the number of cross-sections employed in this study.

The timeframe is lesser (17 years) than the number of sampled countries (25 countries). Hence, this estimation technique appears appropriate for estimating the effects of environmental exposures on maternal mortality in Africa. Following Wang *et al. (*2019) who examined the link between maternal health and clean energy adoption, this study adopts the model thus

$$Matmort_{cp} = \partial_0 + \partial_1\, Carem_{cp} + \partial_2\, adfer_{cp} + \partial_3\, hexp_{cp} + \partial_4\, urban_{cp} + \partial_5\, infl_{cp} + \partial_6\, gdppc_{cp} + \varepsilon_{cp} \qquad (1)$$

With c equal the sampled countries from 1 ……. N and p equal the annual sampled period from 1…… P. ∂_{1-6} are the coefficients of the constant term, the variable of interest and other controlling variables. Matmort is the ratio of maternal deaths per 100,000 live births; $Carem$ is the metric tons of carbon emitted per capita, a proxy for environmental exposure. Other confounding variables are $Adfer$ indicating the number of births per 1000 women within the adolescent ages of 15 and 19. Hex indicates the annual estimated current health expenditure per person in each country. $Urban$ is the percentage of the populace living in the urban communities to the total population, while $infl\ and\ gdppc$ are the levels of inflation and gross domestic product per person in each sampled country respectively ε_{cp}, which represents the error term equal to the $\varepsilon_{cp-1} + \mu_{cp}$. μ_{cp} is serially uncorrelated but correlated over countries.

Discussion of Empirical Findings

This section presents the baseline regression results of the empirical investigation on the link between environmental exposure and maternal mortality in selected African countries between the years 2000 and 2016. Using the fixed effect, random effect and pooled OLS estimation techniques, Table 6 presents the summary of the findings. Columns 1, 3, and 7 of the table revealed that carbon emission, a measure of environmental exposure has a positive impact on maternal mortality. The findings from the three models are similar in terms of the direction of the relationship. However, the strength of the relationship and the coefficient differ. The findings show an insignificant and irregular degree of relationship between carbon emissions and maternal mortality.

In the same manner, Table 6, Column 2, 5 and 8 shows that renewable energy has a negative implication on maternal mortality. The findings from the fixed and random effect were insignificant while the pooled OLS revealed a 10 per cent level of significance, a result that should be interpreted cautiously. Lastly, renewable electricity also exerts a negative but weak influence on maternal mortality in the selected countries during the period under review.

In terms of the confounding variables, adult female fertility, inflation, and income per capita depicts an aggravating impact on maternal mortality but with varying level of significance. On the other hand, the level of government expenditure on health and the level of urbanisation has a strong and significant influence on reducing maternal mortality in Africa. Whereas access to at least one basic sanitation amenity is negative but has a conflicting level of influence on maternal mortality.

The findings emanating from the three baseline estimation techniques suggest the presence of heteroskedasticity and cross-sectional dependence as earlier discovered in the preliminary analysis. As a robustness check and a means to correct the identified violations of the ordinary least square regression, the panel corrected standard error shall be used to redress the anomaly.

Table 6: Baseline regression results using the fixed effects, random effects, and pooled Regression estimators.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Fixed	Fixed	Fixed	Random	Random	Random	Pooled	Pooled	Pooled
Lmarmort	0.9942	0.9570*	-0.9420	0.8760	0.7350	-0.6741	0.9439**	0.9441*	-0.9418**
	(410.41)	(348.60)	(-259.18)	(432.68)	(358.95)	(-237.78)	(212.41)	(209.50)	(-207.18)
Carem	44.0322	-	-	33.5173	-	-	22.8856	-	-
	(0.69)	-	-	(0.53)	-	-	(3.96)	-	-
rener	-	-0.0613	-	-	-0.4224	-	-	-0.2648**	-
	-	(-0.05)	-	-	(0.36)	-	-	(-2.76)	-
relec	-	-	-1.6611*	-	-	-1.6397*	-	-	-0.0555*
	-	-	(-3.95)	-	-	(-3.97)	-	-	(-1.67)
adfer	11.0986***	11.1302***	10.4500***	10.1702***	10.0931***	9.647***	0.2362***	0.2319***	0.1864***
	(15.46)	(15.30)	(14.44)	(16.27)	(15.84)	(15.28)	(5.82)	(5.57)	(4.57)
hexp	-0.8478***	-0.8677***	-0.7363***	-0.8542***	-0.8882***	-0.7585***	-0.08609**	-0.0781*	-0.0801**
	(-3.88)	(-3.95)	(-3.43)	(-3.89)	(-4.01)	(-4.70)	(-2.27)	(-1.86)	(-2.08)
urban	-9.1796**	-8.7582***	-11.0833***	-9.6142***	-9.1820***	-11.219***	0.0427	-0.1029	-0.044
	(-3.06)	(-2.89)	(-3.78)	(-4.01)	(-3.75)	(-4.70)	(0.25)	(-0.98)	(-0.98)
basan	-2.0166	-1.8337	-1.4890	-1.3722	-1.1174	-1.0375	0.2220**	0.2918***	0.2885***
	(-1.42)	(-1.31)	(-1.09)	(-1.03)	(-0.86)	(-0.82)	(2.19)	(2.88)	(2.82)
infl	0.3386**	0.34188**	0.31455**	0.3159**	0.3152**	0.2995**	-0.2255	-0.0185	-0.2247
	(2.28)	(2.30)	(2.15)	(2.09)	(2.30)	(2.03)	(0.37)	(0.30)	(-0.36)
gdppc	0.1815***	0.1870***	0.1486***	0.1451***	0.1870***	0.1197***	0.00071	0.0032	0.0051**
	(4.91)	(5.17)	(4.05)	(4.14)	(5.17)	(3.49)	(0.28)	(1.31)	(2.15)
constant	-337.1211**	-345.4105**	-84.4232	-186.99*	-345.4105**	33.263	-16.1033**	-11.6771	-2.3292
	(-2.05)	(-1.79)	(-0.49)	(-1.29)	(-1.79)	(0.21)	(-2.34)	(-1.19)	(-0.31)
Time dummy	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
No. of Obs.	425	425	425	425	425	425	400	400	400
R-squared	0.6602	0.6598	0.6727	0.6588	0.6598	0.6718	0.9737	0.9839	0.9663
F-Statistics	109.06***	108.86***	115.40***	-	-	-	7934.9	7776.21***	7776.21***
Wald Stat	-	-	-	703.14***	705.14***	749.65***	-	-	-

Source: Authors computation from STATA 2021
*P-Value<0.01
**P-value<0.05
***P-value<0.1

Table 7 reveals the empirical findings on the relationship between environmental exposures and maternal mortality in selected African countries between the years 2000 and 2016. The result presented lays credence to the suitability of the PCSE because it presents a more robust and revealing linkage between environmental exposures and maternal deaths in the continent. It reveals that environmental exposures significantly increase maternal deaths in Africa.

Table 7: The Panel Corrected Standard Error Results

Dep. variable: Maternal Mortality	(1)	(2)	(3)
	PSCE	PSCE	PSCE
	H-corr. coef. /t-stats.	H-corr. coef. /t-stats.	H-corr. coef. /t-stats.
L.marmort	0.9302***	0.9429***	0.9439***
	(145.95)	(144.50)	(212.41)
Carem	0.228856***	-	-
	(5.35)	-	-
Rener	-	-0.2517***	-
	-	(-3.37)	-
Relec	-	-	-0.0578***
	-	-	(-1.69)
Adfer	0.2362***	0.2339***	0.1897***
	(5.48)	(5.44)	(4.40)
exp	-0.08609**	-0.0509	-0.0561
	(-2.20)	(-1.26)	(-1.38)
Urban	0.222	-0.0748	-0.0157
	(0.28)	(-0.74)	(-0.17)
Basan	0.2220***	0.2885***	0.2867***
	(2.78)	(3.60)	(3.60)
Infl	-0.2254	-0.0391	-0.4350
	(0.68)	(-1.33)	(-1.46)
Gdppc	0.0007	0.0022	0.0037
	(0.27)	(0.89)	(1.55)
Constant	-16.1033**	12.3183*	-0.7554
	(-2.42)	(-1.47)	(-0.09)
time dummy	Yes	Yes	Yes
No. of Obs.	400	400	400
r-squared	0.9939	0.9942	0.9942
F-Statistics	-	-	-
Wald Statistic	39084.12***	39420.10***	39823.92***

*****Variable codes are as described in Table 1,*, ** and *** denotes 10%, 5% and 1% level of significance respectively*

Source: Authors' compilation from STATA 13.0 Output, 2021

This indicated that a one-point increase in environmental exposures through the inhalation of carbon emission could lead to an increase of about 22.88 per cent increase in maternal deaths in Africa. This finding aligns with Boyles *et al.* (2020), Kuehn and McCormick (2017) and Shobande (2020). For instance, Boyles *et al.* (2020) affirm that inhaling harmful chemicals and other pollutants increases metabolic disorders infertility and thereby leading to maternal deaths in both the short and long run. Closely linked to this finding are the submissions in the works of Kuehn and McCormick (2017). The study corroborates the earlier findings by admitting that heat exposures deteriorate fetal development and maternal health. More so, Shobande (2020) also submits that increased energy usage increases mortality rates in Africa, particularly amongst children and infants.

As a check on whether renewable energy and electricity impact maternal mortality in the continent, Column 2 of Table 7 reveals that the estimated outcomes of the link between renewable energy and maternal mortality are adverse and significant. The results point out that a percentage increase in the ratio of renewable energy to total energy consumption implies a reduction in maternal deaths by more than 25 per cent within the period under review. In a similar situation, Column 3 of Table 5 shows that the usage of renewable electricity statistically reduces maternal mortality in Africa. In magnitude, the result indicated that a point increase in renewable electricity decreases maternal deaths by 6 per cent. This finding corroborates the recommendations of Shobande (2020) on the need to intensify the use of renewable energy and electricity in Africa for the achievement of a significant reduction in mortality rates in Africa. This is because the use of clean and renewable energy can cushion the deteriorating effects of carbon emission (environmental exposure) on maternal mortality in Africa.

On the impact of other factors that could influence maternal mortality, adolescent fertility significantly intensifies the rate of maternal mortality on the continent. The findings support other extant studies (Banchani & Swiss, 2019; Wang et al, 2019) that early exposure to childbirth for women between the ages of 15 and 19 aggravates maternal deaths in Africa. For instance, Banchani and Swiss (2019) found that adolescent fertility increases maternal mortality in low- and middle-income countries. Subsequently, accessing at least one basic amenity such as safe drinking water by the Africans is expected to reduce the prevalence of maternal deaths on the continent. However, the findings in all the models indicated otherwise. This indicated that there exists a positive and significant influence on maternal mortality. Invariably, the non-conformity to the a-prior expectation may be attributed to the unavailability or inadequacy in the maintenance of the existing basic amenity. Thus, having a reverse implication on maternal health. This finding, however, conforms with Cheng *et al.* (2012) but contradicts Shobande (2020), who submits that access to improved sanitation and water resources reduces mortality rates in Africa.

Another confounding variable that appears to have a significant reductive effect on maternal mortality is the current rate of healthcare expenditure per capita of persons in the sampled African countries. Illustratively, a point percentage increase in healthcare expenditure per capita reduces the rate of maternal deaths by 8 per cent. The outcome of the analysis complements the study by Owusu et al (2021). The study affirmed that investments in healthcare through increasing health expenditure have a deteriorating impact on mortality. This, however, contradicts the findings in the study of Shobande (2020), which documented an insignificant influence of health expenditure on health outcomes in Africa. On the contrary, the level of income per capita appears not significantly linked to maternal mortality. This outcome contradicts the works of Banchani and Swiss (2019), which posit that the level of economic development as measured by GDP per capita has a reductive effect on maternal mortality in Africa. The contradiction may be a result of the non-linearity nature of the indicator measured in the study.

Conclusion

This study contributed to the literature on maternal mortality by escalating its causal factors through the lens of environmental exposures. The relevance of the study to the Sustainable Development Goals (SDGs) is also noteworthy. The linkage between maternal mortality and environmental degradation provided an insight into the achievement of goals 3, 7 and 13, which are respectively good health and well-being, affordable and clean energy, and climate action. The provision of affordable and eco-friendly energy will enhance the good health and well-being of pregnant women. This implies the birth of healthy children, being nursed by healthy mothers in a healthy society.

Carbon emission per capita, which appears to be the leading contributor to environmental exposures and degradation, was examined on the rate of maternal mortality in Africa. The culture of the previous studies in the literature has mainly focused on foreign aid, health expenditure, heat exposure, water, sanitation, use of contraceptives and other socio-cultural factors (Ariyo et al., 2021; Banchani & Swiss, 2019; Cheng et al., 2012; Kuehn & McCormick, 2017). However, the impact of environmental exposures appears to be lacking attention in the stream of extant studies on maternal mortality. This led to the examination of the impact of environmental exposures on maternal mortality in 25 African countries between the period 2000 and 2016.

Using the panel corrected standard error (PCSE) regression estimation technique to correct for the incidences of heteroscedasticity, serial autocorrelation and contemporaneous correlation, the following outcomes were established. (i) Environmental exposures have a significant adverse effect on maternal health, thus aggravating the incidences of maternal mortality in Africa. (ii) renewable energy and electricity have proven to contribute to the reduction of maternal mortality in Africa. (iii) early exposure to childbirth through adolescent fertility poses significant risks to maternal health and thereby increases mortality amongst pregnant women. (iv) funds committed to health expenditure contributes significantly to the reduction of maternal mortality in the continent. (v) access to a least one basic sanitation aggravates maternal mortality.

Arising from the outcome of this study, the policy implications are as follows. First, particular attention should be given to the reduction of environmental exposures in curbing the menace of maternal mortality in Africa. This becomes imperative as exposure to harmful substances such as carbon emissions tends to increase the prevalence of maternal deaths in the continent. This may often be likened to the fact that most of the direct environmental exposures are through the use of traditional cooking and electricity-generating methods. Some of the methods are the use of firewood, coal, fuel-consuming generators and vehicles. These methods have been proven to increase the direct emission and inhalation of carbon and other harmful substances. Thus, this study exposes the need to intensify the campaign on the use of renewable energy and electricity because it may likely reduce environmental exposures and reduce maternal mortality in the continent as buttressed by the reductive impact of renewable electricity and energy on maternal mortality.

Second, the reductive impact of current health expenditure on maternal mortality implies that increasing expenditure on healthcare facilities has a significant impact on improving the quality of life of pregnant women. Given this, the African government should seek ways to improve the funds allocated to healthcare services, thus increasing access to affordable healthcare services for pregnant women in the continent. Also, a monitoring mechanism needs to be put in place to ensure that funds are not diverted to other use. This will ensure optimal usage of funds allocated for healthcare. Third, early exposure to childbirth through adolescent fertility should be put in check as it aggravates the incidence of maternal mortality in Africa. Indeed, early teenage pregnancy is an issue of concern in Africa and given the multiplying effect of this on maternal mortality, constant awareness and orientation should be given to girl child education. Also, child spacing and the use of contraceptives should be embarked upon to reduce early exposure to childbirth.

Lastly, access to basic sanitation behaves in a contradictory manner. The findings suggest that access to at least one basic sanitation amenity aggravates maternal mortality. This may perhaps be attributed to the quality of maintenance of the sanitation amenities. Thus, health policy authorities should seek ways to improve and increase access to sanitation facilities. This will not just significantly reduce the incidence of maternal mortality but also the general well-being of citizens in the continent.

In light of these policy recommendations, future studies should focus on decoupling environmental exposures to identify which of the chemical substances has the most significant weight in aggravating maternal mortality. Also, a consideration of the role of governance quality in moderating the effect of environmental exposure on maternal mortality would be worthwhile.

References

Adeneye, Y. B., Jaaffar, A. H., Ooi, C. A., & Ooi, S. K. (2021). Nexus between carbon emissions, energy consumption, urbanization and economic growth in Asia: Evidence from common correlated effects mean group estimator (CCEMG). *Frontiers in Energy Research*, *8*, 1–15. https://doi.org/10.3389/fenrg.2020.610577

Alimi, O. Y., Ajide, K. B., & Isola, W. A. (2020). Environmental quality and health expenditure in ECOWAS. *Environment, Development and Sustainability*, *22*(6). https://doi.org/10.1007/s10668-019-00416-2

Amegah, A. K., & Agyei-Mensah, S. (2017). Urban air pollution in Sub-Saharan Africa: Time for action. *Environmental Pollution*, *220*. https://doi.org/10.1016/j.envpol.2016.09.042

Ariyo, E., Mortelmans, D., Wouters, E., & Masquillier, C. (2021). Investigating the influence of socio-demographic and family factors on perceptions of safety among conflict displaced children in Nigeria. *Child and Adolescent Social Work Journal*, *38*(1). https://doi.org/10.1007/s10560-020-00669-1

Armah, F. A., Odoi, J. O., & Luginaah, I. (2015). Indoor air pollution and health in Ghana: Self-reported exposure to unprocessed solid fuel smoke. *EcoHealth*, *12*(2). https://doi.org/10.1007/s10393-013-0883-x

Atake, E. (2021). Socio-economic inequality in maternal health care utilization in Sub-Saharan Africa: Evidence from Togo. *The International Journal of Health Planning and Management*, *36*(2). https://doi.org/10.1002/hpm.3083

Baloch, M. A., Zhang, J., Iqbal, K., & Iqbal, Z. (2019). The effect of financial development on the ecological footprint in BRI countries: evidence from panel data estimation. *Environmental Science and Pollution Research*, *26*(6), 6199–6208. https://doi.org/10.1007/s11356-018-3992-9

Banchani, E., & Swiss, L. (2019). *The impact of foreign aid on maternal mortality* (Vol. 2019). UNU-WIDER. https://doi.org/10.35188/UNU-WIDER/2019/645-6

Boyles, A. L., Beverly, B. E., Fenton, S. E., Jackson, C. L., Jukic, A. M. Z., Sutherland, V. L., Baird, D. D., Collman, G. W., Dixon, D., Ferguson, K. K., Hall, J. E., Martin, E. M., Schug, T. T., White, A. J., & Chandler, K. J. (2020). Environmental factors involved in maternal morbidity and mortality. *Journal of Women's Health*, *30*(2). https://doi.org/10.1089/jwh.2020.8855

Cheng, J. J., Schuster-Wallace, C. J., Watt, S., Newbold, B. K., & Mente, A. (2012). An ecological quantification of the relationships between water, sanitation and infant, child, and maternal mortality. *Environmental Health*, *11*(1), 4–18. https://doi.org/10.1186/1476-069X-11-4

Danovi, A., Olgiati, S., & D'Amico, A. (2021). Living longer with disability: Economic implications for healthcare sustainability. *Sustainability*, *13*(8). https://doi.org/10.3390/su13084467

Gardner, R. M., Kippler, M., Tofail, F., Bottai, M., Hamadani, J., Grandér, M., Nermell, B., Palm, B., Rasmussen, K. M., & Vahter, M. (2013). Environmental exposure to metals and children's growth to age 5 years: A prospective cohort study. *American Journal of Epidemiology*, *177*(12). https://doi.org/10.1093/aje/kws437

Girum, T., & Wasie, A. (2017). Correlates of maternal mortality in developing countries: An ecological study in 82 countries. *Maternal Health, Neonatology and Perinatology*, *3*(1), 19–29. https://doi.org/10.1186/s40748-017-0059-8

Grossman, M. (1972). *The Demand for health: A Theoretical and empirical investigation*. Columbia University Press for the National Bureau of Economic Research.

Guzel, A. E., Arslan, U., & Acaravci, A. (2021). The impact of economic, social, and political globalization and democracy on life expectancy in low-income countries: are sustainable development goals contradictory? *Environment, Development and Sustainability*, *23*(9). https://doi.org/10.1007/s10668-021-01225-2

Hanif, I. (2018). Impact of economic growth, nonrenewable and renewable energy consumption, and urbanization on carbon emissions in Sub-Saharan Africa. *Environmental Science and Pollution Research*, *25*(15). https://doi.org/10.1007/s11356-018-1753-4

Hartwig, J., & Sturm, J.-E. (2018). Testing the Grossman model of medical spending determinants with macroeconomic panel data. *The European Journal of Health Economics*, *19*(8). https://doi.org/10.1007/s10198-018-0958-2

Hoechle, D. (2007). Robust standard errors for panel regressions with cross-sectional dependence. In *The Stata Journal* (Vol. 7, Issue 3).

Iheonu, C. O., Agbutun, S. A., Omenihu, C. M., Ihedimma, G. I., & Osuagwu, V. N. (2019). The impact of governance quality on mortality rates in Sub-Saharan Africa. *African Population Studies*, *33*(1). https://doi.org/10.11564/33-1-1353

Jackson, D. (2021). Air pollution in Sub-Saharan Africa. The Borgen project. https://borgenproject.org/air-pollution-in-sub-saharan-africa/

Kim, E. J. (2016). U.S. global change research program: The impacts of climate change on human health in the United States: A scientific assessment. *Journal of the American Planning Association*, *82*(4). https://doi.org/10.1080/01944363.2016.1218736

Kuehn, L., & McCormick, S. (2017). Heat exposure and maternal health in the face of climate change. *International Journal of Environmental Research and Public Health*, *14*(8), 853–875. https://doi.org/10.3390/ijerph14080853

Lu, Z.-N., Chen, H., Hao, Y., Wang, J., Song, X., & Mok, T. M. (2017). The dynamic relationship between environmental pollution, economic development and public health: Evidence from China. *Journal of Cleaner Production*, *166*. https://doi.org/10.1016/j.jclepro.2017.08.010

Maji, K. J., Dikshit, A. K., Arora, M., & Deshpande, A. (2018). Estimating premature mortality attributable to PM2.5 exposure and benefit of air pollution control policies in China for 2020. *Science of the Total Environment, 612*. https://doi.org/10.1016/j.scitotenv.2017.08.254

Marques, A. C., & Fuinhas, J. A. (2012). Are public policies towards renewables successful? Evidence from European countries. *Renewable Energy*, *44*, 109–118. https://doi.org/10.1016/j.renene.2012.01.007

Mgbemene, C. A., Nnaji, C. C., & Nwozor, C. (2016). Industrialisation and its backlash: Focus on climate change and its consequences. *Journal of Environmental Science and Technology*, *9*, 301-316.

Moutinho, V., Madaleno, M., & Elheddad, M. (2020). Determinants of the environmental Kuznets curve considering economic activity sector diversification in the OPEC countries. *Journal of Cleaner Production*, *271*. https://doi.org/10.1016/j.jclepro.2020.122642

Nathaniel, S. P., & Iheonu, C. O. (2019). Carbon dioxide abatement in Africa: The role of renewable and non-renewable energy consumption. *Science of The Total Environment*, *679*. https://doi.org/10.1016/j.scitotenv.2019.05.011

Nichols, C. R., & Cohen, A. K. (2021). Preventing maternal mortality in the United States: Lessons from California and policy recommendations. *Journal of Public Health Policy*, *42*(1). https://doi.org/10.1057/s41271-020-00264-9

Oladeji, J. T. (2015). Environmental and health implications of processing, harvesting, distribution and using both renewable and nonrenewable energy sources. *Journal of Energy Technologies and Policy*, *5*(7), 40–45.

Owusu, P. A., Sarkodie, S. A., & Pedersen, P. A. (2021). Relationship between mortality and health care expenditure: Sustainable assessment of health care system. *PLoS ONE*, *16*(2 February 2021). https://doi.org/10.1371/journal.pone.0247413

Perlroth, N. H., & Branco, C. W. C. (2017). Current knowledge of environmental exposure in children during sensitive developmental periods. *Jornal de Pediatria (Versão Em Português)*, *93*(1). https://doi.org/10.1016/j.jpedp.2016.11.003

Rahman, M. M., Alam, K., & Velayutham, E. (2021). Is industrial pollution detrimental to public health? Evidence from the world's most industrialised countries. *BMC Public Health*, *21*(1175), 1–11.

Ross, N., Kovats, S., Hajat, S., Filippi, V., Chersich, M., Luchters, S., Scorgie, F., Nakstad, B., Stephansson, O., & Consortium, C. (2021). Maternal and newborn health risks of climate change: A call for awareness and global action. *AOGS Acta Obstetricia et Gynecologica Scandinavica*, *100*, 566-570

Sageer, R., Kongnyuy, E., Adebimpe, W.O., Omosehin, O., Ogunsola, E. A., & Sanni, B. (2019). Causes and contributory factors of maternal mortality: evidence from maternal and perinatal death surveillance and response in Ogun state, Southwest Nigeria. *BMC Pregnancy Childbirth*, *19*(63). https://doi.org/10.1186/s12884-019-2202-1

Say, L., Chou, D., Gemmill, A., Tunçalp, Ö., Moller, A.-B., Daniels, J., Gülmezoglu, A. M., Temmerman, M., & Alkema, L. (2014). Global causes of maternal death: a WHO systematic analysis. *The Lancet Global Health*, *2*(6). https://doi.org/10.1016/S2214-109X(14)70227-X

Shobande, O. A. (2020). The effects of energy use on infant mortality rates in Africa. *Environmental and Sustainability Indicators*, *5*. https://doi.org/10.1016/j.indic.2019.100015

Smith, K. R. (2006). Health impacts of household fuelwood use in developing countries. *Unasylva*, *57*, 41–44.

Tian, F., & Pan, J. (2021). Hospital bed supply and inequality as determinants of maternal mortality in China between 2004 and 2016. *International Journal for Equity in Health*, *20*(1), 51–65. https://doi.org/10.1186/s12939-021-01391-9

Wang, Y., Chen, X., & Ren, S. (2019). Clean energy adoption and maternal health: Evidence from China. *Energy Economics*, *84*. https://doi.org/10.1016/j.eneco.2019.104517

World Health Organisation. (2014). *The burden of disease from Ambient Air Pollution for 2012*.

World Health Organisation. (2019). *Trends in maternal mortality: 2000 to 2017*, WHO, Geneva