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Socio-economic determinants of infant mortality rate in Nigeria: Evidence from autoregressive distributed lag technique

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Abstract

Background: The high infant mortality rate (IMR) in Nigeria, in comparison to other African countries and the world at large, has been a major public health concern, while considering the fact that the 3rd Sustainable Development Goal (SDG3) aims to ensure healthy lives and promote well-being for all people of all ages by the year 2030. This study examined the socio-economic determinants of IMR in Nigeria in the short and the long-run periods.
Methods: Data, spanning from year 1990 to 2018, was obtained from the World Bank's World Development Indicator (WDI) database. We adapted the theoretical framework of Grossman health production function model for this study. The autoregressive distributed lag (ARDL) technique was used for both the short-and long-run analysis.
Findings: This study revealed that in the long-run, the total fertility rate and carbon IV oxide (CO_2) significantly increased IMR by a factor of 2.4045 and 0.1194, respectively. On the other hand, Gross Domestic Product (GDP) per capita (as a proxy for wealth status or income level), public health expenditure, and primary gross educational enrolment level for females all significantly decreased the IMR by a factor of 0.2949, 0.0233, and 0.0714, respectively.
Conclusion: Public health expenditure, wealth/income level and the formal education of women are all significant socio-economic factors implicated in the much-needed reduction of Nigeria's high IMR. Adequate attention should thus be given by the Government to increasing public health expenditure, reducing poverty, and also, improving the formal educational level of females, working towards the attainment of the SDG3.

Keywords: ARDL, Infant mortality rate, Socio-economic determinants, Grossman's health production function, Nigeria

Introduction

Infant mortality rate (IMR) is the number of infants dying before getting to age one, per 1,000 live births, in a given year and in a given geographical place. [1] It thus shows the vulnerability of this sub-group of the population; that is the infants, to deaths. Despite the fact that this indicator concentrates on a sub-group of the population, it is said to be suitable measure of the health status of a country's population due to the correlation between the determinants of infants death and the factors that are probable to affect the health status of the general population.[2] It therefore follows that, amongst other indicators, the IMR can be used to compare population health, and hence, the socio-economic development together with the effectiveness of the health system and health programmes, within a country/sub-population of a country over time and also between countries/sub-populations of a country at a particular time.[1,2]

Nigeria's present IMR in the year 2021 is 69.80 deaths per 1000 live births.[3] This means that presently in the year 2021, 1 child in approximately 14 live births will die before getting to age 1 in Nigeria. Despite the efforts by the Nigerian Government to address her high IMR through various community, hospital, or health system-based policies and programmes,[4] the present IMR of 69.80 deaths per 1000 live births in the year 2021 is the 8th highest in the world, and also the 7th highest in Africa.[3] Furthermore, the 3rd goal of the 2015 United Nations (UN) Sustainable Development Goals (SDGs) also has a target to reduce the death of children less than 5 years old (under-5 mortality) to at most 25 deaths per 1,000 live births by 2030.[5] However, with an under-5 mortality rate of 117.2 deaths per 1,000 live births in 2019,[1] Nigeria is far from reaching this target. In order to achieve this SDG target, a more than fourfold reduction in the under-5 mortality rate is required, with improving infant survival as an urgent priority.

The common medical causes of child (under-5) deaths; including that of infants, in Nigeria are due to preventable and treatable diseases such as acute respiratory infections, chronic malnutrition, diarrhoea, measles, and malaria, all of which can either occur individually or in combinations.[6] In addition to the above medical causes of infant mortality, there are also the socio-economic determinants of health.[7] These describe the situations in which people are born in, live in, grow in, and also carry out day-to-day socio-economic activities.[7] The socio-economic determinants of health are responsible for the health inequities; whether in the access or in the financing of healthcare, and are formed by the differences in the distribution of money, power, and resources at various levels, either globally, nationally, or locally.[7] They are thus influenced by policy decisions.[7] These health inequities lead to differences in health status, which is reflected in vital statistics across countries, and also across the different regions within a country.[7]

Given the above discussion, the aim of this paper is to empirically investigate the socio-economic determinants of IMR in Nigeria in both the short-and long-run periods, using time series secondary data obtained mainly from World Bank's World Development Indicator (WDI) database[1]. Proper identification of these factors will help in directing/re-directing Government policies which will aid in increasing the possibility of achieving the SDGs. This paper hypothesized in the null form that the socio-economic variables are not significant determinants of IMR. These non-significant effects of the socio-economic variables on IMR are maintained both in the short-and long-run periods.

Other similar studies have been carried out either in Nigeria using time series data or using panel data from various selected African countries.[8–15] In summary, none of the empirical studies reviewed controlled for atmospheric level of Carbon IV Oxide (CO_2) as part of the independent variables with a possible effect on IMR. However, Adeyemi et al.[16] using the ordinary least square technique (OLS) technique with time-series data for Nigeria that spanned from 1988–2001 found out that CO_2 significantly increased the under-5 mortality rate in the long-run. We considered this variable very important in this study given the strong implication of increasing levels of CO_2, a greenhouse gas, in increased global warming, which in turn possibly leads to an increased occurrence of respiratory diseases and malaria.[17–19] It is important to remember that the latter are major medical causes of child mortality, including infants, in Nigeria.[6] Further statistical analysis is thus needed to establish the possible effect of CO_2 on IMR in both the short and long-run periods. In addition, further statistical analysis is also required regarding various variables, which from the empirical literature done above, showed conflicting effects—these include variable such as per capita income, female employment level, and public health expenditure.

In addition, from our empirical literature review, it was found out that other variables, such as female education level and total fertility rate (TFR), have not been extensively empirically researched in both the short and long-run periods, especially within the Nigerian context. From the empirical literature review, female educational level was only controlled for by the panel data study by Abbuy[9] using data from 6 countries that constitute the West African Economic Monetary Union (WAEMU), which does not include Nigeria. Caldwell's[20] theorem identified female education as a strong possible factor for reducing IMR. Furthermore, from the empirical studies reviewed, only Osawe[8] and Abbuy[9] controlled for fertility rate in their separate panel data analysis on the determinants of IMR. Both studies found out that TFR increased IMR, but the effect was only statistically significant in the study by Osawe[8]. Nigeria has had a persistently high TFR of more than 5 live births per woman,[1] which increases the risk of infants and mothers to birth complications, and hence possible death, due to the high parity and the associating reduced birth spacing.[21] Further statistical analysis on the socio-economic determinants of IMR in both the short-and long-run periods is thus generally required.

Methods

Theoretical Framework

This paper is based theoretically on the Grossman[22] health production function model, hereafter just called the Grossman model. From the application of this model, Sede and Izilien[23] estimated the 'Grossman death model' which this study also draws from. The Grossman [22] model starts with the assumption that people derive utility at time, t, from two goods: health (H_t) and a composite good (Z_t), which can be seen as 'all other goods'. This is represented in equation (1):

$$U = U(HS_t, Z_t) \quad (1)$$

Where: 'HS_t' is the total health stock at time t;

'Z_t' represents other goods or services consumed at time t from which utility is also derived.

From the Grossman[22] model, the following important points are noted:

In addition to been used as a consumption good, HS_t; just like any other capital good, can be increased through investments and decreased due to depreciation. For instance, habits such as excessive smoking and alcohol drinking will increase the depreciation rate, and thus, rapidly decrease health stock. While activities such as exercising, the use of medical care services for prevention or treatment of diseases, and also socio-economic factors such as improved educational level and increase in income will all increase the investment into the health stock. According to the Grossman[22] model, net investment in health stock is equal to gross investment minus depreciation. This is represented by equation (2):

$$HS_{t+1} - HS_t = I_t - \delta_t HS_t \quad (2)$$

Where: 'HS_t'= Health stock at a particular time t;

'HS_{t+1}' = Health stock in the future period (t+1)

'δ_t'=depreciation in health stock at time t;

'I_t'= Gross investment in health stock at time t.

From point (1) above, investment into health is thus a function of several medical and socio-economic factors. This is shown in equation (3):

$$I_t = I(M_t, E_t, Y_t) \quad (3)$$

Where: 'M_t' = Medical care services accessed at time t;

'E_t' = Educational level at time t;

'Y_t' = Income level at time t;

This means that equation (2) can thus be rewritten as: $HS_{t+1} - HS_t =$

$$(M_t + E_t + Y_t) - \delta_t HS_t \quad (4)$$

There is a lifetime time path that ranges from 0; when an individual is born, to T; the time of death. This is shown in equation (5):

$$t(0 \to T) \quad (5)$$

Furthermore, at the time of death (T), HS_{t+1} and δ_t from equation (2) each becomes zero. These are shown in equations (6) and (7):

$$\lim_{t \to T} \delta \to 0 \quad (6)$$

$$\lim_{t \to T} HS_{t+1} \to 0 \quad (7)$$

For survival to occur, a minimum level of health (H_{min}) is required. Such that at the time HS_t is less than H_{min}, death occurs. This is shown in equation (8), remembering that from equation (5) death occurs at time T.

$$HS_t < H_{min} = T \quad (8)$$

From all of the above information given, it therefore follows that the Grossman death model can be derived by applying the information given in equations (6), (7) and (8) into equation (4), resulting in equation (9) as shown:

$$HS_t < H_{min} = T = -(M_t + Y_t + E_t) \quad (9)$$

Equation (9) above can be written in a linear form as an econometric model; which is the theoretical model for this study, as shown in equation (10):

$$T = a - (\beta_1 M_t + \beta_2 Y_t + \beta_3 E_t) + e \quad (10)$$

Where: 'T' represents death, which in the case of this study is infant mortality;

'a' represents intercept;

'β_1 to β_3' represent the different coefficients for the various independent variables;

'M_t' represents medical care services either for treatment or prevention of diseases;

'Y_t' represents income level of the household;

'E_t' represents education; in the case of this study, this is the educational level of the mother;

'e' represents the error term.

From equation (10), which is the theoretical model of this study, it can be deduced that the incomes of households, access to medical care services and educational level of the women all have an inverse relationship with infant mortality.

Empirical Model

Based on the information obtained from the empirical literature reviewed and the theoretical model, this study adopts a 7-variable model, including IMR as the dependent variable. The general form of the empirical model is represented in equation (11):

$$IMR = f(PHEXP, GDPPC, LFPRF, PGERF, TFR, CO_2) \quad (11)$$

Where: 'PHEXP' is Public Health Expenditure, 'GDPPC' is Gross Domestic Products Per Capita, 'LFPRF' is Labour Force Participation Rate for Females, 'PGERF' is the Primary Gross Enrolment Rate for Females, 'TFR' is Total Fertility Rate and 'CO_2'represents Carbon IV Oxide.

The short-run model is represented by equation (12):

$$\begin{aligned}\Delta(\mathrm{IMR})_t = a_0 + b_1\Delta\ln(\mathrm{PHEXP})_t &+ b_2\Delta\ln(\mathrm{GDPPC})_t \\ &+ b_3\Delta\ln(\mathrm{LFPRF})_t \\ &+ b_4\Delta\ln(\mathrm{PGERF})_t \\ &+ b_5\Delta\ln(\mathrm{TFR})_t \\ &+ b_6\Delta\ln(\mathrm{CO_2})_t + \theta\varepsilon_{t-1} \\ &+ \mu_t \qquad (12)\end{aligned}$$

Note that, following Sede and Ohemeng[27], the log values of the variables were taken, so that the regression coefficients of the independent variables can also be interpreted as elasticity. Where 'a_0' is the intercept, 'b_1 to b_6' are the short-run coefficients for the variables: PHEXP, GDPPC, LFPRF, PGERF, TFR and CO_2 respectively. The variables are the same as represented in equation (11) above. 'θ' is the coefficient of the error correction term (ECT) which is lagged by one year period and represented as 'ε_{t-1}' in equation 12 above, 'Δ' represents the difference identity, and 'μ_t' is the residual term.

On the other hand, the long-run model is represented by equation (13):

$$\ln(\mathrm{IMR})_t = a_0 + \alpha_1\ln(\mathrm{PHEXP})_t + \alpha_2\ln(\mathrm{GDPPC})_t + \alpha_3\ln(\mathrm{LFPRF})_t + \alpha_4\ln(\mathrm{PGERF})_t + \alpha_5\ln(\mathrm{TFR})_t + \alpha_6\ln(\mathrm{CO_2})_t + \mu_t \qquad (13)$$

'a_0' is the intercept, 'μ_t' is the residual term, 'α_1 to α_6' are the long-run coefficients for the variables: PHEXP, GDPPC, LFPRF, GERF, TFR and CO_2 respectively. Our a priori expectations for both the short and long-run analysis were: b_1, α_1, b_2, α_2, b_3, α_3, b_4, α_4 and θ, all< 0; while b_5, α_5, b_6 and α_6, all>0.

Variables Description

The complete list of variables used in this study, their definition and sources are presented in table 1.

Data analysis

Secondary data for Nigeria spanning from 1990 to 2018 (time series data) was used in order to provide answers to the research aim stated above. This time range was chosen as it allowed for the collection of complete data for all the chosen variables. E views version 9.0 was used for all the statistical analyses, and the statistical significance level was set at 0.05(5%) for all of the statistical analyses. First, descriptive statistical analysis was done for all the variables so as to summarise them, including showing the frequency distribution of the variables. The chosen summary measures used were mean, standard deviation, minimum and maximum values, skewness, and kurtosis. Then, a unit root test was done for all the variables. Usually, in economic analysis, researchers are often faced with the problem of deriving stationarity in the time series variables incorporated in the study of interest.[23,27] Poor data could be injurious to policy. To avoid spurious results, the data is usually subjected to preliminary testing.[23,27] Thus, this prompts the relevance of conducting the unit root test to realize the stochastic process in the time series analysis.[23,27] Sede and Ohemeng[27] alluded to the fact that securing stationarity in contemporary studies involves the use of the Augmented Dickey-Fuller test (ADF) test.

The stationarity levels and the order of integration of the variables determines the econometric technique to be employed.[15] If all the variables are stationary at level 1(0), then OLS can be used for the estimation of the econometric model.[15] However, if all the variables are stationary at first difference 1(1), then the error correction model (ECM) will be used for the short-run analysis, and also for the long-run analysis if there is the presence of co-integration which can be confirmed through the Johansen technique.[15] On the other hand, if the variables are stationary at a mixture of 1(0) and 1(1), Autoregressive Distributed Lag (ARDL) technique will be used.[15] Also, according to David[15], ARDL, together with the bound test technique, can also be used irrespective of the sample size or the order of integration. That is, either all the variables are stationary at one level; level 1(0) or 1(1), or a mixture of both.

The bounds test technique is a co-integration test done in order to determine the presence of a long-run equilibrium relationship between the time series variables that are not stationary.[28] This is important as the presence of variables in a model that does not converge in the long-run could, again, be injurious to policy.[27] However, the measurement of bounds on ARDL is said to be sensitive to the selection of optimal or maximum lag length.[28] Therefore, the wrong choice of an optimal lag length can lead to the generation of a biased result.[28]

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Table 1: Details and source of the variables used for the analysis

Variables	Description	Sources
Infant Mortality Rate (IMR)	Infant mortality rate (IMR) is the number of infants dying before getting to age one, per 1,000 live births, in a given year and in a given geographical place. [1] This is the dependent variable.	World Bank's WDI[1]
Primary Gross Enrolment Rate for Females (PGERF) expressed as a %	PGERF is the ratio of total enrollment of females in primary school; regardless of their ages, to the population of the official age group in primary school. It is expressed as a percentage. This is an independent variable representing the female educational level.	Indexmundi[24]
Labour Force Participation Rate for Females (LFPRF) expressed as a %	This is the proportion of females in a country's population that are economically active. It is expressed as a percentage. The working-age population consists of ages 15 years and older. This is also an independent variable.	World Bank's WDI[1]
Gross Domestic Product Per Capita (GDPPC) in constant 2017 international $	This gives the value of goods and services produced within a country per person. It is used here as a proxy for wealth status or income level, which in turn proxies access to medical care services. This is also an independent variable.	World Bank's WDI[1]
Public Health Expenditure (PHEXP) as a % of Government expenditure	This shows the level of Nigerian government spending on health, expressed as a percentage of her total government expenditure. This is also an independent variable.	Imuoghele and Ismaila[25]; World Bank's WDI[1]
Carbon IV oxide (CO_2) emission measured in million tonnes	CO_2 emissions are those released from the production of cement and the burning of fossil fuels. They include CO_2 produced during consumption of liquid, solid, gas fuels and gas flaring. It is measure of environmental cleanliness. This is also an independent variable	Knoema[26]
Total Fertility Rate (TFR)	This represents the total number of live births per woman assuming she lives to the end of her reproductive years and also has children according to the age specific fertility rates of that particular year. This is also an independent variable.	World Bank's WDI[1]

Therefore, the wrong choice of an optimal lag length can lead to the generation of a biased result.[28] Furthermore, obtaining the correct optimal lag length choice for each variable in the ARDL model is important so as to avoid the autocorrelation, non-normality, and heteroscedasticity of the error terms.[28] The optimal number of lags in each of the variables for a long-run relationship can be determined using the Akaike information criterion (AIC), the Schwarz information criterion (SC), and the Hannan-Quinn information criterion (HQ).[27,28] Diagnostic testing was then finally done in order to determine if the estimated model was correctly specified together with its usefulness in terms of forecasting. Tests for normality of errors, serial correlation, and heteroscedasticity were all done.

Results

Descriptive statistics

Table 2 shows that the average value (mean) of IMR was approximately 100.2 deaths per 1,000 live births, ranging from a minimum of 75.7 deaths per 1,000 live births to a maximum of 125.1 deaths per 1,000 live births. The probabilities of the Jarque-Bera statistics were all greater than 5%, except that of labour force participation rate for females (LFPRF). This means that that the null hypothesis of a normal distribution cannot be rejected for all of the variables, except LFPRF.

Table 2: Results from the descriptive statistics for all the study variables.

Variables	IMR	LFPRF	PHEXP	PGERF	CO_2	TFR	GDPPC
Mean	100.24	53.81	3.34	84.49	94.32	5.99	4004.47
Maximum	125.10	55.31	7.28	94.29	110.70	6.49	5516.39
Minimum	75.70	48.11	0.90	72.48	74.70	5.39	2901.77
Std. Dev.	18.11	2.65	1.77	5.68	9.38	0.30	971.77
Skewness	0.104	-1.43	0.51	-0.15	-0.28	-0.26	0.28
Kurtosis	1.44	3.21	2.34	2.22	2.23	2.31	1.46
Jarque-Bera	2.999	9.93	1.76	0.84	1.09	0.90	3.25
Probability	0.22	0.007	0.41	0.66	0.58	0.64	0.20

Source: Authors' computation using Eviews 9.0. 'Std. Dev'=Standard Deviation.

Unit root tests analysis

The ADF test statistics were not included within the respective 95% critical value range at first differencing for all variables used in the analysis (Table 3). The result shows that the null hypothesis which says that the time series variables are not stationary at first difference cannot be accepted, meaning that the series is stationary at their first differences. That is, they are integrated of the order one, or I (1).

Thus, a choice of ARDL statistical technique for this study was made. According to David[15], the ARDL technique uses various optimal lags together with a single reduced equation that estimates the short and long-run parameters simultaneously, which fits the aim of this paper. This is not so with the other conventional methods.[15] Therefore, the bound test was conducted in order to determine the presence of a long-run relationship among the variables.

Table 3: Summary of unit root tests

Variables	ADF Test Statistics	95% Critical Value of ADF	Order of Integration	Status
D(IMR)	-3.8686	-3.0049	I(1)	Stationary
D(CO_2)	-5.3384	-2.9763	I(1)	Stationary
D(TFR)	-3.4678	-2.9862	I(1)	Stationary
D(GDPPC)	-2.1496	-1.9539	I(1)	Stationary
D(LFPRF)	-2.4105	-1.9539	I(1)	Stationary
D(PGERF)	-3.9954	-2.9919	I(1)	Stationary
D(PHEXP)	-5.5364	-2.9763	I(1)	Stationary

Source: Authors' computation using Eviews 9.0.

Bounds test for co-integration in the Long-run

In Table 4, the Bounds test revealed that there is long-run relationship among the variables since the F – statistic of approximately 5.76 is greater than the I0 and I1 values, even at 1% significance level. The null hypothesis of no long-run relationship was thus rejected.

Vector Auto Regression (VAR) Lag Selection Criteria

The lag length result of Akaike information criterion (AIC), Schwarz, Hannan-Quinn information criteria is shown in Table 5. The estimation of a VAR-model requires the use of optimum lag-length in the equation of the model. The Akaike information criterion (AIC) was used to determine the lag length of the VAR-model and minimized for order 2.

Table 4: Bounds test analysis

Critical value	Lower bound value(I0)	Upper bound value(I1)
1%	3.15	4.43
2.50%	2.75	3.99
5%	2.45	3.61
10%	2.12	3.23

Key: F statistics = 5.763596

Table 5: VAR Lag selection criteria

Lag	Log L	LR	FPE	AIC	SC	HQ
0	284.0409	Na	2.89e-18	-20.52155	-20.18559	-20.42165
1	567.0106	398.2536	9.75e-26	-37.85264	-35.16498	-37.05346
2	694.2357	113.0890*	7.04e-28*	-43.64709*	-38.60772*	-42.14862*

Where '' indicates the Lag order selected by the criterion. LR=sequential modified likelihood Ratio (LR) test statistic (each test at 5% level); FPE=final prediction error; AIC= Akaike information criterion; SC=Schwarz information criterion; HQ= Hannan-Quinn information criterion.*

Short and Long-run Regression

In Table 6, we present both the short-run and long-run relationship between socio-economic determinants of infant mortality rate. The ECT is negative and statistically significant and hence conformed to economic theory.[23] IMR converged to its equilibrium in the long-run, and there was no divergence between the variables employed. In other words, the ECT indicated the existence of a stable and converging long-run relationship between IMR and all the exogenous variables used in the study. Also, the speed of adjustment reflected by the convergence coefficient was estimated to be slow. The speed of adjustment of IMR to long-run equilibrium aftershocks in the short-run was estimated to be 31.27%. Thus, it will take a longer time for the variables to bring IMR back to the steady-state path should shock from the exogenous variables disrupt the initial equilibrium.

In the short-run, IMR was significantly influenced at the 5% level by the one-time lagged value of public health expenditure, GDP per capita, labour force participation rate for females, primary gross enrolment ratio for females, and the TFR. From all of these mentioned variables, only public health expenditure and labour force participation rate for females had a positive effect, the others had negative effects. The estimated results showed that a 1% increase in one time-lagged value of public health expenditure significantly increased the IMR by a factor of 0.0079. This effect, however, did not follow the a priori expectation. The result further showed that a 1% increase in GDP per capita significantly decreased the IMR by a factor of 0.0922. This effect followed the a priori expectation. Also, a one-unit increase in the labour force participation rate for females significantly increased the IMR by a factor of 0.1645. This effect, however, did not follow the a priori expectation. Furthermore, a unit increase in primary gross enrolment ratio for females significantly decreased the IMR by a factor of 0.0559. This effect followed the a priori expectation. A unit increase in TFR significantly decreased the IMR by a factor of 3.0962. This effect, however, did not follow the a priori expectation.

In addition, from the results obtained in the short-run, one–time-lagged value of IMR increased the current IMR by a factor of 0.5487. This effect, however, had a borderline significance level (0.0506). That is, this effect was statistically significant at the 10% level. On the other hand, a unit increase in public health expenditure increased the IMR by a factor of 0.0017. This effect was, however, not statistically significant, even at the 10% level. This effect did not follow the a priori expectation. The one–time-lagged value of labour force participation rate for females decreased the IMR by a factor of 0.0853. This effect was, however, not statistically significant, even at the 10% level. Also, from the short-run results, a unit increase in CO_2 increased the IMR by a factor of 0.0011. Although this effect followed the a priori expectations, it was, however, not statistically significant, even at the 10% level. In summary, it, therefore, follows that in the short-run, TFR resulted in the greatest significant reduction in IMR, while the one-time lagged value of IMR resulted in the greatest significant increase in IMR.

From the long-run results, it was found out that the following variables: GDP per capita, TFR, and CO_2, all had significant effects on

IMR. However, only the effect of GDP per capita decreased the IMR, the others increased it. All of these effects, therefore, followed the a priori expectations. It was estimated that a one-unit increase in GDP per capita significantly decreased the IMR by a factor of 0.2949. It was also estimated that a one-unit increase in TFR significantly increased the IMR by a factor of 2.4045. In addition, a one-unit increase in CO_2 significantly increased the IMR by a factor of 0.1194. Furthermore, two of the variables: public health expenditure and primary gross enrolment ratio for females had a statistically significant effect on IMR at the 10% level. The finding reveals that public health expenditure and primary gross enrolment ratio for females decreased the IMR by factors of 0.0233 and 0.0714, respectively. Both of these effects followed a priori expectations. On the other hand, the labour force participation rate for females increased the IMR. In detail, it was found out that a unit increase in labour force participation rate for females increased the IMR by a factor of 0.1643. This effect was, however, not statistically significant. This effect also went against a priori expectations. It, therefore, follows that in the long-run, TFR resulted in the greatest significant increase in IMR, while the GDP per capita resulted in the greatest significant decrease in IMR.

Diagnostic Tests

Post-estimation diagnosis was carried out to check for normality, serial correlation and heteroscedasticity of the residuals. The result is presented in Table 7.

Discussion

In both the short and long-run, an increase in the present level of GDP per capita significantly reduced the IMR. This long-run effect is similar to the findings by Osawe[8] and Abbuy[9]. GDP per capita can be used as a measure of per capita income as seen in the studies by Abbuy[9] and Edeme et al.[10], and hence also an indication of the poverty level or wealth status as reported by Sede and Ohemeng[27]. Poverty level/wealth status will definitely negatively affect access to health care services when needed, and even if received, it will also negatively affect how quickly these services are accessed. This is of particular importance in Nigeria where more than 90% of people are involved in out-of-pocket (OOP) payments for health care services.[29] This is further complicated by the fact that in 2012 approximately 15% and 4% of Nigerians spent more than 10% and more than 25% of their income or household consumption on OOP health care expenditure, respectively.[1] These are different thresholds for measuring catastrophic health spending.[30]

It is important to note that health care costs also include; from the consumers/patients perspective, direct non-medical costs such as accommodation, transportation to the hospital; which is especially important for poor families staying in rural areas with no nearby health facility, and indirect costs such as the cost of a parent or relative giving up a source of paid employment so as to stay with a sick child in the hospital.[31] High dependence on OOP payments will thus increase the probability of poor people not using the modern and more effective health care services at all or using them at a minimal level.[32] These poor families thus instead have an increased probability of utilizing the less effective, but, affordable, traditional health care services.[32] There could also be an increased rate of discontinuation of modern medical treatment

Table 6: Summary of the short and long-run analysis

Variable	Coefficient	Std. Error	T-Statistics	Probability
Short-run Equation				
D(LNIMR(-1))	0.5487	0.2501	2.1937	0.0506*
D(LNPHEXP)	0.0017	0.0023	0.7735	0.4555
D(LNPHEXP(-1))	0.0079	0.0019	4.2393	0.0014***
D(LNGDPPC)	-0.0922	0.0281	-3.2869	0.0072***
D(LNLFPRF)	0.1645	0.0617	2.6653	0.0220**
D(LNLFPRF(-1))	-0.0853	0.0600	-1.4207	0.1831
D(LNPGERF)	-0.0559	0.0011	-4.9793	0.0004***
D(LNTFR)	-3.0962	1.1369	-2.7234	0.0198**
D(LNCO2)	0.0011	0.0073	1.4575	0.1729
ECT(-1)	-0.3127	0.0822	-3.8031	0.0029***
Long-Run Equation				
LNPHEXP	-0.0233	0.0114	-2.0365	0.0665*
LNGDPPC	-0.2949	0.0222	-13.2691	0.0000***
LNLFPRF	0.1643	0.2369	0.6939	0.5022
LNPGERF	-0.0714	0.0357	-2.001	0.0706*
LNTFR	2.4045	0.1680	14.3130	0.0000***
LNCO2	0.1194	0.0227	5.2688	0.0003***
C	1.7838	1.006	1.7732	0.1039

*Where '***', '**' and '*' indicate significance at 1%, 5% and 10% levels, respectively, while 'Std. Error'=standard error*

Table 7: Post-estimation diagnosis of the variables

Name of test	Purpose of test	P value	Decision
Jarque-Bera test	Normality of residuals	0.4668	Residuals are normally distributed
Breusch-Godfrey test	Serial correlation of residuals	0.6666	Residuals are not serially correlated
Breusch-Pagan-Godfrey test	Heteroscedasticity in the residual	0.4787	There is no heteroscedasticity in the residual

with possibly worsening of the complications of diseases, with increased risk of the death of infants occurring.[33] All of these will further increase health care costs.[32]

It therefore also follows that high OOP payments, especially at the catastrophic level, will possibly push families into poverty, and push those ones who were already poor further down into poverty due to the detrimental effect of the illnesses on their earnings.[33] For instance, in 2012, approximately 4% of Nigerians were pushed below the $1.90 poverty line measured at the 2011 Purchasing Power Parity (PPP) due to OOP health care expenditure.[1] This will create further difficulty in utilizing modern health care services. There is thus a vicious cycle between poverty, high OOP payments; especially at the catastrophic level, and increasing difficulty in utilizing health care services, with an associating increased risk of death, including that of infants, occurring. In addition, poverty has been associated with poor environmental conditions such as poor sanitary facilities, difficulty in accessing clean water, and the pollution of air, water, and land. [34] These poor environmental conditions have been associated with diseases such as diarrhoea and malaria, while remembering that these are the major causes of child mortality (under-5) mortality, including infant mortality, in Nigeria.[6,34] From the foregoing discussion, poverty is thus a very important socioeconomic factor linked with increasing infant mortality.

Concerning the effect of females being economically active, we found that in the short-run, the current labour force participation rate for females significantly increased the IMR. In the long-run, an increase in the labour force participation rate for females increased the IMR, but this effect was not statistically significant. This long-run effect of female labour force participation rate on IMR observed in this study was similar to the effect found out by Osawe[8], but, opposite the effect by Raji[11]. This thus shows a possible less success on the part of women in combining work, especially that outside of the home, together with infant care, while considering the fact that women bear the major burden of the latter, especially in developing countries.[35] This effect may be due to less time available to the mothers to care for themselves, especially during pregnancy, and also care for their infants due to their employment status.[35]

However, it was found out that in the short-run, a one-time lag in the female labour force participation rate decreased the IMR, but this effect was not statistically significant. The possible reduction effect on IMR by female labour force participation could possibly be due to the fact that employment for females, especially when they are employed for cash and have control over their earnings, have been shown to significantly increase their autonomy regarding household decisions; including decisions regarding their own and their children's health care.[36] Women are thus able to make quick decisions about seeking modern health care, and to a reasonable extent, have the resources to do so. This is particularly important in Nigeria for two reasons. Firstly, due to her patriarchal setting which makes women's participation in decision making in both formal and informal settings of low importance.[37] Secondly, as previously mentioned, the large dependence of her citizens on OOP increases costs of accessing health in Nigeria, which may get to a catastrophic level. [29,30]

In this study, the short-run, a one-time lag in the public health expenditure and current public health expenditure both increased the IMR, but only the effect of the one-time lag variable was statistically significant. This is opposite the finding by David[15] This may be due to Nigeria's public health expenditure that has been persistently less than 15% of the government expenditure.[1] This margin or cut-off is known as 'the Abuja declaration in which different African countries pledged at least 15% of government expenditure to be allocated to the health sector for its improvement.[38] in addition, Nigeria's health care system has been described as being in a deplorable state, especially the government or public hospitals or health centres, with the associating presence of obsolete, inadequate medical equipment.[39] Improved health infrastructure implies an increase in the number of health facilities, especially in rural areas, increased availability of health resources; including medical personnel, drug, bed spaces, and others, and equity in distribution and access of health care resources.[12] Improved health infrastructure also involves better organization, execution, and evaluation of public health practices.[12] This will lead to improvement in the quality of life of people, reduction in the prevalence of diseases and death rate.[16] Considering all of this, it is therefore not surprising that from this study, in the long-run, public health expenditure decreased IMR, with a statistical significance level at 10%.

Regarding education, in the short-run, an increase in the enrolment of females in primary school significantly reduced IMR. In the long-run, the same effect was noticed, but, the effect was statistically significant at 10% level. The long-run finding is similar to that by Abbuy[9] using the female literacy rate. The effect of primary education followed Caldwell's[20] theorem on the prime importance of female education in reducing infant mortality. According to the Caldwell[20] theorem, educated mothers are more likely to break away from traditions about illnesses, life, and death, and thus accept the available modern therapies. Education will thus make mothers have increased demands relating to modern child health care and treatment, leading to an increase in procedures such as child immunization and also improved feeding practices.[20] Education also makes women know where the right health facilities are, and then access them.[20] Furthermore, within the health facilities, the educated mother is more likely to demand attention from medical personnel even when they are reluctant to do so.[20] Education will also help to modify the intra-familial relationship between husbands and wives, especially within a patriarchal setting which has the husband as the main decision-maker, towards a more balanced environment where women are also active participants in household decision making, including that pertaining to health care.[20, 36]

Furthermore, this study showed that increase in CO_2 level increased IMR in both the short and long-run. However, only the effect in the long-run was statistically significant. The long-run effect was similar to that found by Adeyemi et al.[16] Looking at the data from several sources; World Bank's WDI[1] and Kneoma[26], the atmospheric CO_2 in Nigeria has increased steadily across the years. The increase in CO_2 over the years in Nigeria has been attributed to increasing population together with the accompanying increase in human activities; such as increased urbanization, increased waste generation, increased waste disposal and increased deforestation, and also increased industrialization and economic growth.[40] The increasing population is due to Nigeria's persistently high TFR of at least 5.0 live births per woman.[1,40] The increasing economic growth has been attributed to the need for diversification of the economy, with a corresponding expansion of the industrial, agricultural, financial, tourist, and manufacturing sectors.[40] These sectors rely on fossil fuel for energy generation, which thus increases CO_2 emissions.[40]

Increasing levels of atmospheric CO_2 has been shown to be a threat to human respiratory health, through the promotion and worsening of respiratory disease such as asthma, Respiratory Tract Infections (RTI).[18] This is important considering the fact that acute respiratory infections are implicated as a major cause of child mortality, including that of infants, in Nigeria.[6] In addition, increasing levels of CO_2, which is a greenhouse gas, have been implicated in global warming.[17] Warmer average temperatures, within the survival capability of mosquitoes, have been associated with the increase in reproduction and maturity of mosquitoes.[19] This will possibly increase the transmission of malaria, which has also been identified as a main cause of child mortality, including infants, in Nigeria.[6]

Regarding TFR, in the short-run, an increase in the present value of TFR significantly reduced the IMR. However, in the long-run, an increase in TFR significantly increased the IMR. This long-run effect is similar to the finding by Adeyemi et al.[16] Nigeria's TFR has been consistently high with a value of approximately 6.0 to 7.0 live births per woman from 1960 to 2016.[1] It only slightly reduced to approximately 5.3 live births per woman in 2019.[1] High TFR increase the prevalence of infant mortality through a reduction in birth spacing to less than 2 years and an increase in the parity level to more than four, both of which increase the risk of complications, to both mother and child, such as haemorrhage, increasing incidence of premature birth and low birth weight.[21] There is also increased rivalry, due to the short birth interval, among siblings for nutritional resources, which may be scarce.[21] This will also affect how long breastfeeding can occur for each child, with an associating increase in the risk of malnutrition of infants.[21] All of the above factors will increase the risk of infant mortality occurring.[6,21]

An increase in fertility rate also increases the economic burden of households, which is further worsened by a reduction in the ability of these women to be economically active since they have the huge recurrent burden of pregnancy, childbirth, and child-rearing.[21] This means that households cannot commit a great number of resources to adequately provide good housing with good sanitation, clothes, adequate food, education, and access to modern health services for their children.[21] All of these will increase the risk of diseases such as diarrhoea, malnutrition, and malaria occurring due to poor environmental conditions.[34] In addition, all of these diseases are known medical causes of child, including infant, mortality in Nigeria.[6]

Recommendations

It is recommended that a holistic approach is needed to reduce IMR—which combines addressing socio-economic, environmental, and medical factors that affect infant mortality. These are: 1) Emphases should be placed on educating females, and also advancing this educational level beyond the primary level to secondary and beyond. This will help improve the chances of getting a paid job and advancing career-wise, with an associated increase in income. This will also help women in increasing their autonomy in relation to household decision-making, including health care decisions, and also be able to pay for medical services at the time of usage. Furthermore, regarding the significant increasing effect of female employment on IMR, in the home front, especially in the cases where both partners work outside of the homes, there should be a re-negotiation, and hence a more equitable distribution, of child care role. This will thus redistribute the load of child care, which is traditionally placed mainly on women, so that children can still get adequate care when mothers work outside of the homes.

2) Given the significant decreasing effect of GDP per capita, used as a proxy for wealth status, on IMR in both the short and long-run, poverty reduction schemes should be a major focus area for the Nigerian Government.

3) There should also be an increase in the expenditure on health by Government so as to achieve the stated Abuja target regarding the public health expenditure. In addition, as part of the Government's increased spending on health, there should be measures put in place by the Nigerian Government to increase the National health insurance coverage so as to reduce the large dependence on OOP payments. This will help to increase access and utilization of modern medical care services, which in turn will reduce infant mortality.

4) Relating to environmental factors, such as the increasing level of atmospheric CO_2, technologies, such as renewable energy, which reduce the emission of CO_2 without any need to slow down the increasing economic activities associated with the increasing population should be encouraged. This will thus help to ensure sustained economic growth.

5) Measures should also be put in place to address Nigeria's persistently high TFR. This includes increasing the demand for family planning through various community awareness campaigns, and subsequently meeting this demand with the use of more effective modern contraceptives, in comparison with the traditional family planning methods. Government should also ensure that family planning centres should be readily accessible in various communities, with various modern contraceptive methods consistently and readily available. This will reduce the problem of stock-out and also enable women to choose a preferred method of choice from a wide collection of more effective modern contraceptives. This will enable the women to be able to stick to their chosen modern contraceptive method, thus reducing the discontinuation rate of modern contraceptives.

Strengths and Limitations of the study

This study provided a more comprehensive view of the effect of socio-economic variables on infant mortality rates. Also, the use of time-series data allowed for the examination of a possible cause-effect relationship. However, because of the absence of complete data, some variables such as basic or improved sanitation, use of clean water, and the use of health insurance scheme were not included in the model. The use of aggregate data did not also allow for differential analysis across the different geopolitical zones in Nigeria.

Conclusion

IMR is high in Nigeria, as clearly noticed when compared to that of other countries in

Africa and in the world in general. GDP per capita (used as a proxy for wealth status), primary education for females, and public health expenditure were each shown to significantly reduce IMR in the long-run, while increases in fertility rate and CO_2 were each shown to significantly increase the IMR in the long-run. These socio-economic determinants of IMR need to be adequately addressed by Government in order to achieve a significant reduction in IMR, while holding out hope for Nigeria regarding the achievement of the 3rd goal of the SDGs.

Authors' Contributions

EO conceived the idea of the study, drafted the initial manuscript, including the methodology, and was also responsible for the data collection. CAI was responsible for the statistical analysis and for the interpretation of results. EO was responsible for writing the discussion of the paper. The final manuscript was reviewed and concluded on by both EO and CAI.

Conflict of Interest

None declared.

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