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Effect of information communication technology and immunization on infant mortality in Nigeria

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Abstract

There is an increasing need to improve health outcomes in developing countries particularly regarding infant mortality. This study examined the effect of information and communication technology (ICT) and child immunization on infant mortality in Nigeria with the view to determine the policy implications. The study utilized time series data covering 2001-2023. The research employs descriptive statistics, unit root test and Auto-Regressive Distributed lag model as its method of data analysis. Access to electricity, rural (percentage of rural population) (AEC), Fixed Broadband Subscriptions (FBS), Mobile Cellular Subscriptions (MCS), and immunization against measles (percentage of children aged 12 to 23 months) (IMM) are all positively correlated with child mortality, while Neonatal death (NND) is negatively correlated with immunization DPT (percentage of children aged 12–23 months) (IMC), Internet usage (percentage of population) (IUI), and people having access to safely managed drinking water services in urban areas (percentage of urban population) (PUSU). The results suggest that both immunization and ICT have a significant impact on child and neonatal mortality rates. The study concludes that to minimize adverse outcomes associated with child and neo-natal mortality, key stakeholders- particularly those in the ICT and health sectors, should leverage immunization and technological solutions to reach as many people as possible. Therefore, the study recommends the adoption of technology to enhance healthcare delivery and encourage the use of digital communication between citizens and medical professionals.

Keywords: Immunization; Mortality rate; Information Communication Technology; Neonatal death; Health sector

1. Introduction

Several initiatives have been aimed at improving healthcare delivery, and Information and Communication Technology (ICT) appears to be one of the most impactful, benefiting patients and strengthening inter-organizational practices particularly in the health sector (William et al., 2019). At the local, regional, and national levels, improvements in healthcare services and health outcomes have driven innovations that integrate mobile phones, internet technology, and other ICT tools. Web-based analytics, microprocessors, wearable technology, telemedicine, and mobile applications are some of these that have led nations to increase their ICT investment in an effort to enhance healthcare outcomes and services (Adeola & Evans, 2018). Furthermore, ICT is now acknowledged as an effective way of healthcare management issues while promoting broader patient participation, through social networking, and other ICT based interactions. Electronic health records, or EHRs, have also become widely used (Marchibroda, 2008).

The use of Information and Communication Technology (ICT), including computers, smartphones, satellites, software, digital platforms, and information systems, to support, enhance, and deliver healthcare services to individuals and

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communities is known as eHealth. It encompasses technologies such as telemedicine, eLearning programs, mobile health (mHealth) applications, and the digital transformation of Health Information Systems (HIS) or Health Management Information Systems (HMIS) (ICT for Health in Africa, 2020). The usage of ICT in a variety of industries, including healthcare, has grown dramatically in recent years due to the expanding availability of mobile phones and internet connectivity (Rana et al., 2020).

Digital technologies support socioeconomic development through three major ways of inclusion, efficiency, and creativity (World Bank, 2016). The following describes these pathways in depth, reducing the cost of information access, guaranteeing the availability of transparent data, facilitating trade, allowing participation in the technology market, and generating job possibilities are all ways to promote inclusion. Better coordination, task automation, and increased use of resources both human and non-human to promote efficiency. Competition, better welfare, and increased government involvement are what spur innovation. Touray *et al.* (2016) showed how combining mobile phone technology with Geographic Positioning Systems (GPS) improved the Emergency Operations Center's staff management and monitoring as well as the distribution of information, including lab results. Other studies have also demonstrated that the increasing use of ICT has a major positive impact on lowering child mortality.

With 51 deaths per 1,000 live births, the World Health Organization (WHO) reports that the African region has the highest chance of a child dying before becoming one year old. This is more than six times the rate in the WHO European Region, which is 8 deaths per 1,000 live births (WHO, 2020). The highest infant mortality rates in the world are still found in sub-Saharan Africa (SSA), despite notable improvements in infant survival rates since the Millennium Development Goals (MDGs) were implemented in the region (Hug et al., 2017).

Considering the distinct features of the nation's parent demographics, the Nigerian government has implemented a number of measures to lower child mortality. The routine house-to-house vaccination program for youngsters is one noteworthy initiative. The death rate is still much higher than in other emerging nations nevertheless (Adeagbo, 2022). In addition, lengthy time of patients awaiting medical attention are a familiar sight in Nigerian public hospitals. Despite consistent improvements over time in the quantity and caliber of healthcare facilities and medical professionals, this still exists (Adeagbo, 2022). Given the country's ongoing health issues, which include high rates of child mortality, restricted access to medical treatment, and unequal resource distribution, it is critical to understand how ICT and immunization influence health indicators. When developing plans to improve healthcare delivery, politicians, healthcare professionals, and development partners can use the evidence-based insights this study offers. This study seeks to promote a just and effective healthcare system, thus enhancing the attainment of Sustainable Development Goals (SDGs). The results of the study will highlight the impact of immunization programs and information and communication technology (ICT) on child mortality rate in Nigeria. The specific objectives of the study are to examine the effect of information communication technology and immunization on infant mortality in Nigeria, as well as examine their effect on neo-natal mortality rate in Nigeria.

2. Methodology

2.1. Types and Sources of Data

The study utilized time series secondary data. The data were majorly sourced from the World Development Indicator. The study covers 2001–2023. The availability of data for the period informed the choice of the period under study.

2.2. Method of Data Analysis

The research utilized Econometrics E-View 10 statistical software to analyse the data for the study. Autoregressive Distributed Lag (ARDL) and Dickey-Fuller model were the major analytical tools used. It is believed that this estimation method is appropriate to achieve the study objectives.

2.3. Unit Root Test

A unit root test was used to detect the presence of stationarity or otherwise. The use of Dickey-Fuller to carry out the unit root test is considered necessary to avoid the problem of spurious results (Gujarati & Porter, 2009).

2.4. Autoregressive Distributed Lag (ARDL) Model

The Autoregressive Distributed Lag (ARDL) Bound Test of co-integration is considered the most suitable test of co-integration given the results of the unit root tests, which indicate that all the variables are not stationary at level but rather a combination of I (1) and I (0) series.

2.5. Model Specification

The Autoregressive Distributed Lag (ARDL) Model Specification was used in this study. The variables of interest are: Electricity availability, rural (percentage of rural population) (AEC), infant mortality rate (per 1,000 live births) (MRI), Internet users (percentage of population) (IUI), fixed broadband subscriptions (FBS), mobile cellular subscriptions (MCS), and people using safely managed drinking water services, urban (percentage of urban population) (PUSU), measles vaccination (percentage of children aged 12–23 months) (IMM), Immunization, DPT (percentage of children aged 12–23 months) (IMC), and Neonatal deaths (NND) for the year.

2.6. Autoregressive Distributed Lag (ARDL) Model Specification

The ARDL model captures both the short-run dynamics and long-run relationships among variables. It can be expressed as follows.

2.6.1. Determinants of infant mortality rate in Nigeria

$$\Delta MRI_t = a_0 + \sum_{i=1}^{p} \beta_i \Delta MRI_{t-i} + \sum_{i=0}^{q1} \gamma_1,\ _i\Delta AEC_{t-i} + \sum_{i=0}^{q2} \gamma_2,\ _i\Delta FBS_{t-i} + \sum_{i=0}^{q3} \gamma_3,\ _i\Delta IMC_{t-i} + \sum_{i=0}^{q4} \gamma_4,\ _i\Delta I + MM_{t-i} + \sum_{i=0}^{q5} \gamma_5,\ _i\Delta IUI_{t-i} + \sum_{i=0}^{q6} \gamma_6,\ _i\Delta MCS_{t-i} + \sum_{i=0}^{q7} \gamma_7,\ _i\Delta PUSU_{t-i} + \lambda_1 \Delta MRI_{t-i} + \lambda_2 AEC_{t-i} + \lambda_3 FBS_{t-i} + \lambda_4 IMC_{t-i} + \lambda_5 IMM_{t-i} + \lambda_6 IUI_{t-i} + \lambda_7 MCS_{t-i} + \lambda_8 PUSU_{t-i} + \varepsilon_t$$

2.6.2. Determinants of neonatal deaths in Nigeria

$$\Delta NND_t = a_0 + \sum_{i=1}^{p} \beta_i \Delta NND_{t-i} + \sum_{i=0}^{q1} \gamma_1,\ _i\Delta AEC_{t-i} + \sum_{i=0}^{q2} \gamma_2,\ _i\Delta FBS_{t-i} + \sum_{i=0}^{q3} \gamma_3,\ _i\Delta IMC_{t-i} + \sum_{i=0}^{q4} \gamma_4,\ _i\Delta IMM_{t-i} + \sum_{i=0}^{q5} \gamma_5,\ _i\Delta IUI_{t-i} + \sum_{i=0}^{q6} \gamma_6,\ _i\Delta MCS_{t-i} + \sum_{i=0}^{q7} \gamma_7,\ _i\Delta PUSU_{t-i} + \lambda_1 \Delta NND_{t-i} + \lambda_2 AEC_{t-i} + \lambda_3 FBS_{t-i} + \lambda_4 IMC_{t-i} + \lambda_5 IMM_{t-i} + \lambda_6 IUI_{t-i} + \lambda_7 MCS_{t-i} + \lambda_8 PUSU_{t-i} + \varepsilon_t$$

- **Dependent Variable:** ΔMRI_t and ΔNND_t represents the first-differenced Mortality rate, infant (per 1,000 live births) and Number of neonatal deaths respectively capturing short-term changes.
- **Independent Variables:** ΔAEC_{t-i}, ΔFBS_{t-i}, ΔIMC_{t-i}, etc., represent the first-differenced values of the independent variables (short-run dynamics) at different lags, p and q_i represent the lags for the dependent and independent variables, respectively.
- **Long-Run Equation:** The coefficients λ1,λ2,…,λ9 represent the long-run relationships between the dependent variable (infant mortality rate and neo-natal death) and the independent variables (health expenditure, GDP per capita, etc.).
- **Error Term:** ε_t is an error term.

3. Results and discussion

3.1. Stationary Test

3.1.1. Unit Root Test was

To check the stationary of the data, Augmented Dickey Fuller (ADF) unit root test was utilized in this study.

Table 1 Result of the Unit Root Test

Variables	ADF test statistics	Critical Value of 5%	Prob. Value	Order of Integration
AEC	-5.032379	-3.004861	0.0006	I(0)
FBS	-14.89888	-4.450425	0.0001	I(0)
IMC	-3.319471	-3.012363	0.0269	I(1)
IMM	-3.469966	-3.012363	0.0197	I(1)
IUI	-7.980913	-3.690814	0.0000	I(0)
MCS	-6.407180	-3.673616	0.0003	I(0)
MRI	-5.178642	-3.673616	0.0029	I(0)
NND	-3.304588	-3.040391	0.0301	I(1)

PUSU	-7.232217	-3.012363	0.0000	I(0)

Source: Researchers Computations, 2024 Using E-views 10

According to the results of the Augmented Dickey Fuller unit root test, the ADF unit root test was conducted for the model variables both at level and first difference. For all the variables at levels, the null hypothesis indicating unit root test cannot be rejected since the ADF statistics are below the critical value at 5% significance level. Table 1 result revealed that all the variables became stationary after taking first difference. The 5% significance level was used to define the stationarity in the study.

3.1.2. Co-Integration

Table 2a ARDL Long run Bound Test

Test Statistics				
F-Statistics	242.9984			
Critical Value Bounds				
Significance	10%	5%	2.5%	1%
I(0)	1.92	2.17	2.43	2.73
I(1)	2.89	3.21	3.51	3.9

Source: Researchers Computations, 2024 Using E-views 10

After investigating the stationary of the data, the time series data was examined for Co-integration.

Autoregressive Distributed Lag (ARDL) Bound Test of co-integration was considered the most suitable test of co-integration given the results of the unit root tests. In this study, this is used for the model. When the test's F-statistic exceeds the Critical Value of Upper Bound at a selected level of significance, in this case 5%, the null hypothesis is rejected. Conversely, if the F-statistic is less than the Critical Value of the Lower Bound, the null hypothesis is accepted. The test is regarded as inconclusive when the F-statistics fall between the upper and lower bounds.

Nonetheless, the aforementioned test's test shows that the variables' F-statistics are 242.9984, with 5% Critical Values for the Upper Bound being 2.17 and the Lower Bound being 3.21. This indicates that both the lower and upper bounds' critical values are less than the F-statistic, 242.9984. While the alternative hypothesis is accepted, this suggests the rejection hypothesis. As a consequence, the test indicates that the variables under examination have a co-integration (long-term link). The outcome is in line with research by Dutta Gupta and Sengupta (2019), which demonstrates the existence of a long-term association between ICT and health outcomes.

Table 2b ARDL Long run Bound Test

Test Statistics				
F-Statistics	22.70740			
Critical Value Bounds				
Significance	10%	5%	2.5%	1%
I(0)	1.92	2.17	2.43	2.73
I(1)	2.89	3.21	3.51	3.9

Source: Researchers Computations, 2024 Using E-views 10

The Autoregressive Distributed Lag (ARDL) Bound Test of co-integration is the most suitable test of co-integration given the results of the unit root tests, which indicate that all the variables are not stationary at level but rather a combination of I (1) and I (0) series. In this study, this is used for the model. Dependent and independent variables do not have a long-term relationship, according to the null hypothesis. When the test's F-statistic exceeds the Critical Value of Upper Bound at a selected level of significance, in this case 5%, the null hypothesis is rejected. Conversely, if the F-statistic is less than the Critical Value of the Lower Bound, the null hypothesis is accepted. The test is regarded as inconclusive when the F-statistics fall between the upper and lower bounds.

Nonetheless, the aforementioned test's result shows that the variables' F-statistics are 22.70740, with 5% Critical Values for the Upper Bound being 2.17 and the Lower Bound being 3.21. According to this, the F-statistic (22.70740) is higher than the Critical Values of the model's bottom and upper bounds. While the alternative hypothesis is accepted, this suggests the rejection hypothesis. As a result, the test indicates that the variables under investigation have a co-integration (long-term relationship).

3.2. Estimated Regression Result

Table 3a Result of the Estimation for the long run and short run effects of information communication technology and immunization on infant mortality in Nigeria

Short run relationship				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.***
C	-0.805661	0.139384	-5.780138	0.0007
MRI(-1)*	0.279132	0.065819	4.240888	0.0038
AEC**	0.009630	0.006179	1.558531	0.1631
FBS**	0.000409	0.000771	0.530765	0.6120
IMC**	-0.053703	0.022647	-2.371277	0.0495
IMM**	0.049189	0.022682	2.168598	0.0668
IUI**	0.012093	0.007975	1.516294	0.1732
MCS**	0.008562	0.007038	1.216469	0.2632
PUSU**	0.113976	0.040000	2.849383	0.0247
Long run relationship				
AEC	-0.034500	0.020632	-1.672138	0.1384
FBS	-0.001466	0.002742	-0.534728	0.6094
IMC	0.192393	0.061693	3.118564	0.0169
IMM	-0.176220	0.060540	-2.910830	0.0226
IUI	-0.043324	0.019149	-2.262467	0.0581
MCS	-0.030674	0.024196	-1.267707	0.2454
PUSU	-0.408322	0.196525	-2.077714	0.0763
C	2.886311	0.209007	13.80964	0.0000
R^2 = 0.999819 ADJUSTED R^2 = 0.999613 F-statistic = 4841.659 Prob(F-statistic) = 0.000000 Durbin-Watson stat = 1.536068				

Source: Researchers Computations, 2024 Using E-views 10

From the Table 3a, the dependent variable is the infant mortality rate (IMR), while the independent variables are the follows: mobile cellular subscriptions (MCS), people using safely managed drinking water services, urban (% of urban population) (PUSU), access to electricity, rural (% of rural population) (AEC), fixed broadband subscriptions (FBS), immunization, DPT (% of children ages 12-23 months) (IMC), immunization, measles (% of children ages 12-23 months) (IMM), and individuals using the Internet (percentage of population) (IUI).

The result shows when all independent variables are held constant, the dependent variable's coefficient is -0.805661 in the short term and 2.886311 in the long term, according to the results. This suggests that there is a negative relationship between the intercept ($\beta 0$) and infant mortality rate (IMR) in the short term and a positive relationship in the long term. The regression equation's intercept is -0.805661. When all of the independent variables are equal to zero, the infant mortality rate (IMR) is displayed. It is negative, meaning that when all independent variables are equal to zero, the infant mortality rate (IMR) is negative. The model is statistically significant at 1% level of significance.

The regression coefficient of Immunization, DPT (% of children ages 12-23 months) (IMC) is -0.053703. This shows that if Immunization, DPT (% of children ages 12-23 months) (IMC) increases by 1, the number of infant mortality rate (IMR) decreases by -0.053703; this is negative indicating that there is a negative relationship between number of infant mortality rate (IMR) and Immunization, DPT (% of children ages 12-23 months) (IMC). The relationship is statistically significant at 5% level of significance. This result is consistent with results of a previous study on the role of immunization in reducing infant mortality by protecting infants from vaccine-preventable diseases. Immunization have led to significant decline in both the incidence and mortality rates of such diseases. For instance, a study by Sandra *et al.*, (2007) reported a greater than 92% decline in cases and a 99% or greater decline in deaths due to diseases prevented by vaccines recommended before 1980. Additionally, the Centers for Disease Control and Prevention (CDC) notes that immunizations, when administered according to guidelines, can reduce the risk of sudden infant death syndrome (SIDS) by 50%. More evidence support that immunization significantly contributes to reducing infant mortality by preventing infectious diseases and associated complications. The World Health Organization (WHO) and Lawrence & Frenkel (2021) estimates that vaccination prevents 3.5–5 million deaths per year, with up to 1.5 million children dying each year from diseases that could have been prevented by vaccination.

The regression coefficient of immunization, measles (% of children ages 12-23 months) (IMM) is 0.049189. This shows that if immunization, measles (% of children ages 12-23 months) (IMM) increases by 1, number of infant mortality rate (IMR) increases by 0.049189; this is positive indicating that there is a positive relationship between number of infant mortality rate (IMR) and immunization, measles (% of children ages 12-23 months) (IMM). It is statistically significant only at 10 percent level of significance. This result is inconsistent with results of World Health Organization (WHO) estimates that immunization prevents 3.5–5 million deaths per year, with up to 1.5 million children dying each year from diseases that could have been prevented by vaccination.

The regression coefficient of people using safely managed drinking water services, urban (% of urban population) (PUSU) is 0.113976. It shows that if people using safely managed drinking water services, urban (% of urban population) (PUSU) increases by 1, number of infant mortality rate (IMR) increases by 0.113976; this is positive indicating that there is a positive relationship between number of infant mortality rate (IMR) and people using safely managed drinking water services, urban (% of urban population) (PUSU). It is statistically significant at 5% and 10% level of significance. This result is inconsistent with a report of UNICEF (2009) that access to safe water is crucial for reducing infant mortality, as it helps prevent waterborne diseases and supports overall child health. Since their immune, respiratory, and digestive systems are still developing, children are particularly susceptible to the health risks associated with inadequate water supply and sanitation, according to Fayehun (2010). Contaminated water sources can also result in infectious diseases like diarrhea, which are a contributing factor to infant deaths.

The Long-run relationship result revealed that the intercept of the regression equation is 2.886311. In the long term, it displays the infant mortality rate (IMR) when all independent variables are equal to zero. It is positive, meaning that when all independent variables are equal to zero, the infant mortality rate (IMR) is positive. At the 1%, 5%, and 10% significance levels, it is statistically significant.

Immunization, DPT (percentage of children aged 12–23 months) (IMC) has a regression coefficient of 0.192393. There is a positive correlation between the number of infant mortality rates (IMR) and immunization, DPT (% of children ages 12-23 months) (IMC), as evidenced by the fact that if immunization, DPT (% of children ages 12-23 months) (IMC) increases by 1, the number of infant mortality rates (IMR) increases by 0.192393. At the 1%, 5%, and 10% significance levels, this relationship is statistically insignificant. This outcome contradicts Sandra et al.'s (2007) findings, which showed a larger drop in cases and a noteworthy drop in mortality from diseases that vaccinations avoided. Furthermore, vaccinations can lower the incidence of SIDS by 50% when given in accordance with recommended protocols, according to the Centers for Disease Control and Prevention (CDC). Immunization against measles (percentage of children aged 12–23 months) (IMM) has a regression coefficient of -0.176220. It demonstrates that if immunization, measles (% of children ages 12-23 months) (IMM) is increased by 1, the number of infant mortality rates (IMR) is decreased by -0.176220; this is negative, suggesting that there is a negative relationship between the two variables. At the five percent significance levels, this relationship is statistically significant. The World Health Organization (WHO) estimates that immunization prevents 3.5 to 5 million deaths annually, with up to 1.5 million children dying from diseases that could have been avoided by vaccination. This result is in line with such projections.

Internet users as a percentage of the population (IUI) has a regression coefficient of -0.043324. This indicates that there is a negative correlation between the number of infant mortality rates (IMR) and the number of internet users (percentage of the population) (IUI). For example, if the number of Internet users (IUI) is one, the number of infant mortality rates (IMR) is -0.043324. At the 10 percent significance level, this association is statistically significant. This finding is in line with that of Khelfaoui et al., (2022), who found that greater internet access significantly decreased newborn mortality rates after analyzing data from 27 low-income countries between 2000 and 2017. The researchers concluded that mobile cellular subscriptions and internet access, to a lesser extent, contributed to lower newborn mortality rates in these nations. In order to enhance health outcomes, they advised governments and policymakers in low-income nations to think about extending internet-related ICT developments.

The regression coefficient of People using safely managed drinking water services, urban (% of urban population) (PUSU) is -0.408322. It demonstrates that if the number of people using safely managed drinking water services, urban (as a percentage of the urban population) (PUSU) is increased by 1, the number of infant mortality rates (IMR) is decreased by -0.408322. This indicates a negative correlation between the two variables. At the ten percent significance level, this association is statistically significant. This outcome is in line with findings of Yulong (2024) and Lin et al., (2023), who found that having piped water considerably lowers infant mortality—a 10% increase in piped water coverage lowers infant mortality by 15%.

Table 3b The table above shows the result for the long run and short run effects of the relationship between information communication technology and immunization on neo-natal mortality in Nigeria

Short run relationship				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.***
C	-1.314577	0.588229	-2.234806	0.0605
NND(-1)*	0.227565	0.111212	2.046216	0.0800
AEC**	0.004738	0.006953	0.681458	0.5175
FBS**	0.003029	0.001106	2.737977	0.0290
IMC**	-0.029490	0.023622	-1.248432	0.2520
IMM**	0.018792	0.021781	0.862777	0.4168
IUI**	-0.025935	0.005815	-4.460069	0.0029
MCS**	0.019088	0.009847	1.938453	0.0937
PUSU**	-0.025406	0.057810	-0.439477	0.6736
Long run relationship				
AEC	-0.020822	0.030960	-0.672544	0.5228
FBS	-0.013310	0.005527	-2.408039	0.0469
IMC	0.129590	0.090603	1.430315	0.1957
IMM	-0.082578	0.086326	-0.956576	0.3706
IUI	0.113968	0.036324	3.137573	0.0164
MCS	-0.083878	0.039112	-2.144566	0.0692
PUSU	0.111644	0.224386	0.497556	0.6340
C	5.776723	0.274516	21.04331	0.0000
R^2 = 0.998755 ADJUSTED R^2 = 0.997332 F-statistic = 701.9716 Prob (F-statistic) = 0.000000 Durbin-Watson stat = 3.302442				

Source: Researchers Computations, 2024 Using E-views 10

From the summary of the estimated results above, Neo-natal death (NND) is the dependent variable, while Access to electricity, rural (% of rural population) (AEC), Fixed broadband subscriptions (FBS), Immunization, DPT (% of children ages 12-23 months) (IMC), Immunization, measles (% of children ages 12-23 months) (IMM), Individuals using the Internet (% of population) (IUI), Mobile cellular subscriptions (MCS) and People using safely managed drinking water services, urban (% of urban population) (PUSU) are the independent variables. When all independent variables are held constant, the dependent variable's coefficient is -1.314577 in the short term and 5.776723 in the long term. This suggests that there is a negative correlation between the intercept (β0) and neonatal death (NND) in the short term and a positive correlation in the long term.

The short-term analysis's outcome indicates that the regression equation's intercept is -1.314577. When all of the independent variables are equal to zero, it displays the number of neonatal deaths (NND). When all of the independent variables are equal to zero, it is negative, meaning that neonatal death (NND) is negative. The model is statistically significant.

Fixed broadband subscriptions (FBS) have a regression coefficient of 0.003029. There is a positive correlation between the number of neonatal deaths (NND) and fixed broadband subscribers (FBS), as evidenced by the fact that if FBS increases by 1, the number of NND increases by 0.003029. Mobile cellular subscriptions (MCS) have a regression coefficient of 0.019088. There is a significant correlation between the number of neonatal deaths (NND) and mobile cellular subscriptions (MCS), as evidenced by the fact that if MCS grows by 1, NND increases by 0.019088.

Internet users as a percentage of the population (IUI) has a regression coefficient of -0.025935. It demonstrates that the number of neonatal deaths (NND) falls by -0.025935 if the number of Internet users (percentage of the population) (IUI) rises by 1; this is negative, suggesting that there is a negative relationship between the two variables. At the 1% significance level, this relationship is statistically significant. This finding aligns with the findings of Nyamawe & Seif (2014), who concluded that increased mobile phone usage and wider network coverage offer potential opportunities to improve the quality of MNCH services. Fixed broadband subscriptions (FBS) have a regression coefficient of 0.003029. There is a significant relationship between the number of neonatal deaths (NND) and fixed broadband subscribers (FBS), as evidenced by the fact that if FBS increases by 1, the number of NNDs increases by 0.003029. At the 5% significance level, it is statistically significant. This result contradicts the findings of Nyamawe & Seif (2014), who found that ICT has been shown to be useful in lowering the rates of maternal and neonatal death. The study's findings indicate that ICT can improve the provision of high-quality healthcare services. The study claims that several initiatives are taking advantage of mobile phones' benefits in providing information on maternal and neonatal mortality rates.

Mobile cellular subscriptions (MCS) have a regression coefficient of 0.019088. There is a positive relationship between the number of infant mortality rates (IMR) and mobile cellular subscriptions (MCS), as evidenced by the fact that if MCS is 1, the number of infant mortality rates (IMR) is 0.019088. At the ten percent significance level, this association is statistically significant. This finding contradicts the findings of Nyamawe & Seif (2014), who found that ICT has been shown to be useful in lowering the rates of maternal and neonatal death. Through the use of information and communication technology, expectant and new moms receive SMSs reminding them to visit clinics on a regular basis and providing helpful information about every stage of their pregnancy.

The long-term relationship's outcome indicates that the regression equation's intercept is 5.776723. In the long term, it displays the Neo-natal Mortality Rate (NND) when all independent variables are equal to zero. It is positive, meaning that when all independent variables are equal to zero, the infant mortality rate (IMR) is positive. At the one, five, and ten percent significance levels, it is statistically significant.

The results of the study revealed that Fixed broadband subscriptions (FBS) have a regression coefficient of -0.013310. There is a negative correlation between the number of neonatal deaths (NND) and the number of fixed broadband subscriptions (FBS), as evidenced by the fact that if FBS is increased by 1, the number of NNDs would decrease by -0.013310. At the five percent significance levels, it is statistically significant. This outcome is in line with research from the Pan American Health Organization (2016), which found that ICT use can help achieve universal health coverage, improve treatment quality, increase access, lessen inequities, and lower the number of fetal and neonatal fatalities. The results revealed the regression coefficient of Individuals using the Internet (% of population) (IUI) is 0.113968. It demonstrates that if the percentage of people using the Internet (IUI) rises by 1, the number of neonatal deaths (NND) rises by 0.113968; this is positive, suggesting that there is a positive correlation between the number of NNDs and the percentage of people using the Internet (IUI). According to research by Perrin et al., (2018) and the Pan American Health Organization (2016), the use of ICTs can help achieve universal health coverage, improve the quality of care, promote access, reduce inequities, and lower fetal and neonatal deaths. This relationship is statistically significant at the 5 and 10 percent level of significance.

Mobile cellular subscriptions (MCS) have a regression coefficient of -0.083878. It indicates that there is a negative correlation between the number of infant mortality rates (IMR) and mobile cellular subscriptions (MCS). For example, if MCS is 1, the number of infant mortality rates (IMR) is -0.083878. At the ten percent significance level, this association is statistically significant. This outcome is in line with research by Perrin et al., (2018) and the Pan American Health

Organization (2016), which found that ICT use can help achieve universal health coverage, improve care quality, increase access, lessen inequities, and lower fetal and neonatal mortality.

4. Conclusion

This study examined the effect of Information Communication Technology and immunization on infant mortality from 2001 to 2023. Based on these findings, the study reported that Immunization, DPT (percentage of children aged 12-23 months) (IMC) immunization, measles (percentage of children aged 12-23 months) (IMM), Internet users (percentage of population) (IUI), and people using safely managed drinking water services (PUSU) were the major factors affecting infant mortality in the long run and Immunization, DPT (percentage of children aged 12-23 months) (IMC), Immunization, measles (percentage of children aged 12-23 months) (IMM), and people using safely managed drinking water services (PUSU) in the short run majorly affect infant mortality in Nigeria. Consequently, Fixed Broadband Subscriptions (FBS), Mobile Cellular Subscriptions (MCS), Internet users (percentage of population) (IUI) are the major factors affecting neonatal mortality in the long run and short run. The study concluded that, in order to improve infant mortality and neonatal mortality in Nigeria, information communication technology and immunization programmes need to be scaled up. Therefore, the study recommended that, to minimize adverse outcomes associated to infant and neonatal mortality, relevant particularly those in the ICT and health sectors, should deploy the use of immunization and ICT solutions to reach as many people as possible.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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