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Effects of Immunisation on Child Mortality in West Africa

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Abstract*— This study investigates the effect of immunisation coverage on child mortality in 15 West African countries and panel data was sourced from the World Development Indicators for period 2000-2019, with a particular interest in the Global Vaccine Action Plan (GVAP) initiative. The fixed effects and random effects analysis was used for estimation. The results show that immunisation coverage for Hepatitis B did not significantly impact child mortality before the GVAP initiative, but was significant during the post-GVAP era in reducing child mortality; maternal literacy and improved water source are significant factors in reducing child mortality. The results suggest that improvements in immunisation coverage have not translated to significant reductions in child mortality in West Africa. This could be due to the inefficient impact of the GVAP initiative in West Africa. The study recommends that governments in West Africa could focus on strengthening the impact of the GVAP initiative by ensuring an enabling environment for the initiative through its African Regional Immunisation Strategic Plan to carry out its objectives and programmes that promote awareness for mothers could be implemented by governments within this region with the aim of achieving a reduction in under-five deaths.

Keywords*— child mortality, global vaccine action plan, component, immunisation, Vaccine-Preventable Disease, formatting

I. INTRODUCTION

Child mortality captures the probability of children under the age of five years dying from diseases which could be prevented by immunisation, despite the significant global decline in the deaths of children under the age of five from 12.6 million in 1990 to 5.0 million in 2020 [1],[2], [3], [4] and [5]. There are still over 13,000 under-five deaths per day from preventable causes, with about 26% occurring in Nigeria and India [6]. In recent years, the African continent has experienced some levels of variations as regards coverage of immunisation and child mortality [7]. Coverage for Hepatitis B vaccination in parts of Africa rose from almost zero per cent in 2000 to above 50% in 2011 except for countries like Liberia, Gabon and Chad.

The GVAP initiative was introduced to ensure the protection of all people from Vaccine-Preventable Diseases (VPDs) as a result of improving coverage for immunisation by 80% in every district and 90% in every country; have control over VPD; encouraging the government's continued support for protecting their citizens from VPDs; exceed the target of reducing child mortality among others [8].

In West Africa, research on the relationship between health investments and child mortality is recently evolving. For example, [9] researched health expenditure and child health outcomes in West Africa from 1991-2015, using panel fully modified ordinary least square technique and concluded that public health expenditure, immunisation, and maternal literacy are important drivers to reduce child mortality. Similarly, [10] carried out another study with a focus on 46 sub-Saharan African countries from 2000 -2015 using descriptive and analytical methods, it was concluded that increases in health expenditure were significant in reducing child mortality. However, no econometric estimation technique was employed.

This study intends to focus on the effectiveness of the GVAP on immunisation coverage in West Africa. Consequently, more empirical studies must be carried out on the effects of immunisation on under-five mortality in the West African region considering the high mortality rate from preventable causes within the region. Also, the literature to date does not include any study examining the research question regarding the GVAP effectiveness for the West African region. A question that comes to the fore is- has the GVAP initiative lived up to expectations in terms of helping to improve immunisation coverage for Hepatitis B, thus reducing child mortality in West Africa.

The major concern is the extent to which the GVAP initiative has contributed to increasing the level of immunisation coverage in West Africa thereby impacting child mortality. The study is organized as follows: next is the literature review, thereafter, the model specification, and then the empirical findings. The last section contains the conclusion.

II. Literature Review

Many studies have been carried out in investigating different aspects of investments or expenditures as it relates to child health, both economically and medically. This review involves previous studies that generally analysed the effect of health investments on child health, and in particular under-five mortality. Reference [11] examined the impact of private, public and external healthcare expenditure on infant mortality in sub-Saharan Africa. The result showed an inverse significant relationship between public and external health care expenditure and infant and neonatal mortality, and an insignificant relationship between private health spending and infant and neonatal mortality. However, this research was not specifically about the West African region.

Furthermore, [10] investigated health expenditure impacts on health outcomes in sub-Saharan Africa. Although no econometric analysis was used, the result showed that increases in health expenditures were significant in reducing child and maternal mortality, as well as improving life expectancy. However, [12] examined the impact of spending on public health on the mortality of under-five infants in 10 selected sub-Saharan African countries. The result showed that there exists a positive effect of public health expenditure on infant and child mortality, and a negative significant effect of per capita GDP, immunisation, and health assistance, on child mortality. This result may not be generally applicable to West African countries.

In the findings of [13], upon studying healthcare expenditures, and their impact on economic growth and infant mortality with evidence from 93 developed and developing countries, the author concluded that there was a positive effect of health expenditure on reducing child mortality only for upper-middle-income and high-income countries, with no significant impact on low-income and lower-middle-income countries. Also, public health expenditure had a greater impact on mortality rates than private investment at lower development levels, while at high development levels; private health spending had a positive impact on child mortality.

Reference [9] examined the long-run relationship between government health spending and child mortality in 15 countries in West Africa from 1991 to 2015. It was concluded that immunisation, maternal literacy, and the quality of institutions were important determinants of child mortality reduction. HIV prevalence which reflects maternal morbidity was omitted from the model. The findings of [14] from their study on the effects of public health expenditures on child mortality in 11 countries reveal that expenditures on health have a significant effect on reducing child mortality. In contrast, [15] revealed a positive significant relationship between public health expenditure and child mortality in Nigeria.

III. Model Specification

Panel data was sourced from the World Development Indicators for the period 2000-2019. Drawing from previous studies such as [12] and [16], the adopted health production function is explicitly stated as:

$$\begin{aligned} lnCM_{it} = \alpha_0 &+ \alpha_1 DGVAP_{it} + \alpha_2 lnIM_{it} \\ &+ \alpha_3 DGVAP_{it} * lnLM_{it} \\ &+ \alpha_4 lnLEB_{it} + \alpha_5 lnPU_{it} \\ &+ \alpha_6 lnML_{it} + \alpha_7 lnMH_{it} \\ &+ \alpha_8 lnGDP_{it} + \alpha_9 lnISF_{it} \\ &+ \alpha_{10} lnIWS_{it} + V_i + \mu_t + \varepsilon_{it} \end{aligned}$$

where CM_{it} is child mortality rate; $DGVAP_{it}$ =dummy variable (GVAP) initiative; IM_{it} = childhood immunization coverage for HepB3; $DGVAP_{it} * ln\,I\,M_{it}$ = interaction term between dummy variable (GVAP) and immunisation; $lnLEB_{it}$ =life expectancy at birth; $lnPU_{it}$ = prevalence of undernourishment in children below the age of 5; $lnML_{it}$= maternal literacy; $lnMH_{it}$= maternal health as an indicator of the prevalence of HIV in women aged 15-49; $lnGDP_{it}$ = per capita gross domestic product in constant US dollars; $lnISF_{it}$ = improved sanitary facilities; $lnIWS_{it}$ = improved water source; V_i = unobserved country-specific effect, μ_t= unobserved time-specific effect, and ε_{it} = zero mean constant variance random disturbance term.

Child mortality rate is the dependent variable. The GVAP dummy variable captures the effect of GVAP on child health when immunisation coverage is zero and it is expected that a negative relationship will exist as the target of GVAP is reducing child mortality. The GVAP dummy variable is represented as 0 for pre-GVAP (2009-2010) and 1 for post-GVAP (2011-2019). Immunisation coverage is the percentage of children between the ages of 12 and 23 months who have been vaccinated against hepatitis B3. Immunisation is a preventive health care intervention measure in children so it is expected that there will be an inverse relationship with child health. This variable explains its effect on child health when the GVAP is zero. The interaction term between the dummy variable (GVAP) and immunisation explains its effect on child mortality rate when the GVAP is in place. It is expected that the GVAP will improve immunisation coverage thereby reducing child mortality.

Life expectancy at birth represents the initial health stock of children and it is expected that healthier children at birth are more likely to live past their fifth birthday. Prevalence of undernourishment is expected to have a positive effect on child mortality being that children will not have enough immunity to combat diseases. Maternal literacy captures the literacy level of mothers as it is believed that female literacy enhances a mother's knowledge about children's health outcomes, as they become more conscious of nutrition and health needs which are necessary for child survival. A negative relationship is expected. Maternal health represents maternal morbidity of women living with HIV and it is expected that it will have a positive effect on child mortality, being that HIV is somewhat transmittable. Per

capita, Gross Domestic Product is included so as to control for parental income levels, which is a necessary determinant for children accessing health care or not and how much can be invested. A negative relationship is expected. Improved sanitary facilities and improved water sources as captured by the percentage of people with improved access. These variables are necessary to know the environmental condition in which people reside, seeing that children and people live in a location which affects their health status. It is expected to have an inverse effect on child mortality rate.

The fixed effects and random effects methods of estimation are the techniques to be used for this study. The fixed effects allow for correlation between the random variables and the independent variables in an unobserved effects model while the random effect is preferred when the assumption of uncorrelation between the unobserved effect and all explanatory variables is upheld. The Hausman specification test will be used to assess the consistency of an estimator in comparison with an alternative estimator, which may be less efficient.

IV. Empirical Results

A. Descriptive statistics

The descriptive statistics of the variables used are presented in Table 1. This table suggests that there are no outliers that may affect the empirical analysis negatively as indicated by the minimum and maximum values. For skewness, the negative value of child mortality shows that more West African countries have more than the average value of mortality. The same interpretation also applies to skewness for immunisation. Per capita, gross domestic product has a positive value showing that more West African countries have less than the average per capita GDP.

Table 1: Descriptive statistics of variables for the model

Variable	Mean	S.D.	Min.	Max.	Skew
LNCM	4.586	0.505	2.701	5.416	-1.387
LNIMH	4.343	0.276	2.708	4.595	-2.698
LNLEB	4.044	0.105	3.675	4.290	-0.165
LNPU	2.644	0.583	1.548	3.926	0.222
LNML	4.144	0.312	3.073	4.579	-0.907
LNMH	4.065	0.091	3.811	4.209	-0.851
LNGDPC	6.771	0.542	5.897	8.155	0.800
LNIWS	4.128	0.190	3.607	4.480	-0.403
LNISF	3.036	0.637	1.648	4.350	0.155

Source: Authors' calculations using STATA software

B. Correlation Analysis

The signs conform to *a priori* expectations except for the prevalence of undernourishment which has a negative sign as opposed to a positive sign. The independent variables do not have high correlations with themselves as they have values less than 0.8. Thus, the fear of multicollinearity is allayed.

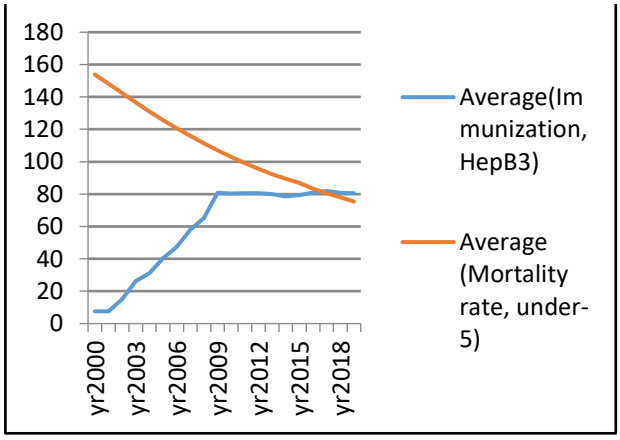
Table 2: Correlation statistic for Immunisation Coverage of Hepatitis B3

Variable	LNCM								
LNCM	1.00	LNIMH							
LNIMH	-0.36	1.00	LNLEB						
LNLEB	-0.94	0.49	1.00	LNML					
LNPU	-0.72	0.23	0.65	1.00	LNMH				
LNML	0.42	0.02	-0.42	-0.17	1.000	LNGDPC			
LNGDPC	-0.70	-0.05	0.55	0.53	-0.40	1.00	LNIWS		
LNIWS	-0.76	0.39	0.71	0.43	-0.09	0.49	1.00	LNISF	
LNISF	-0.57	0.13	0.49	0.31	-0.59	0.45	0.57	1.00	LNPU
LNPU	-0.18	0.05	0.15	0.12	-0.08	0.10	0.13	0.187	1.00

C. Trend Analysis

Figure 1 shows the trend in immunisation coverage for Hepatitis B3 and child mortality in West Africa. From the data gathered, Hepatitis B3 coverage for some countries in West Africa between 2000 and 2008 was unavailable; this accounted for the low average recorded, however, between 2009 and 2019, Hep B3 immunisation coverage was relatively constant and the child mortality rate declined.

Figure 1: Trend in Hepatitis B3 Immunisation Coverage and Child Mortality in West African Countries



D. Regression results

From the Hausman specification test in Table 3, the fixed effect estimation method is adopted and will be used for the interpretation of the results. The result of the fixed-effects estimation for immunisation coverage on child mortality is shown in Table 4.

Table 3: Hausman Test

CHI^2	35.39
$PROB>CHI^2$	0.0001

The F-statistic is significant for the model and the robust standard errors are consistent in the presence of any pattern of heteroskedasticity within panels.

Immunisation coverage although had a positive coefficient was not statistically not significant. The statistical insignificance of this variable shows that immunisation coverage before the GVAP initiative has no significant impact on child mortality in

West Africa. This is however a surprising result and thus does not follows the a priori expectation. The insignificant impact of immunisation coverage in the absence of the GVAP suggests that there is a need for intense efforts in West Africa to drive child mortality to the least minimum. This is especially important given the year 2030 target of the Sustainable Development Goals (which is to reduce child mortality to as low as 25 per 1000 live births).

The negative sign of the coefficient of interaction term meets the a priori expectation, specifically meaning immunisation coverage when the GVAP initiative had been put in place. This is the independent variable of interest. The coefficient of the interactive term is inelastic. For every 1% increase in immunisation coverage, the average effect is a 0.15% decrease in child mortality rate. One of the objectives of the African Regional Immunisation Strategic Plan for the GVAP is to improve immunisation coverage (HepB3 inclusive). This implies that the GVAP initiative has helped in improving immunisation coverage and is significant in reducing child mortality in West Africa. This means that the level of GVAP in West Africa is significant in child mortality reduction.

The coefficient of maternal literacy is correctly signed (negative) as expected and statistically significant. The more informed mothers are, the more likely they are to visit hospitals for antennal and post-natal sessions, access and improve hygiene. Child mortality will drop by 0.19% with a 1% increase in maternal literacy. The statistical significance of maternal literacy implies that the more increasingly aware mothers become the lower the chances of experiencing child deaths. Maternal health has a negative sign and is statistically significant, implying that as maternal morbidity increases, child mortality decreases, this is against the expectation, and it is in line with the empirical study of [16]. The expectation is that as maternal health worsens as a result of HIV prevalence in women, under-five mortality will also increase, being that HIV is somewhat transferable. A possible explanation for this negative coefficient could be the improvements in technology which prevent HIV-infected mothers from transmitting the virus to their unborn children, thus giving birth to HIV-free children.

The prevalence of undernourishment in West Africa does not have a contributing influence on the mortality of children under the age of five as it was insignificant. Life expectancy at birth was also statistical insignificance. It was expected that the healthier children are at birth, the less likely they were to die before the age of five. This could probably be a result of inaccessibility to quality primary healthcare facilities, pandemic or exposure to life-threatening circumstances.

Table 4: Empirical result for Hepatitis B3 immunisation coverage on child mortality

Variables	**Coefficient**
Dgvap	0.040 (0.465)
dgvap_lnimmh	-0.154(0.097)*
lnimmh	0.012 (0.753)
Lnleb	0.918 (0.607)
Dlnpu	0.112 (0.083)
Lnml	-0.186 (0.095)
Lnmh	-1.121 (0.401)**
lngdpc	0.084 (0.140)**
Lniws	-0.335 (0.103)***
Lnisf	0.002 (0.082)
Constant	7.010 (2.051)
R-squared	0.42
F-stat	794.77
F-stat (p-value)	0.000
Corr(u_i)	-0.524
Time dummy	Yes
No. of observation	111

Note: ***, **, * are statistically significant at 1%, 5% and 10% significance levels respectively. Standard errors are in parentheses.

The coefficient of improved water source is negative and significant, suggesting that child mortality will fall by 0.34% with a 1% increase in an improved water source. Improved water source is a contributing determinant to the reduction of child mortality in West Africa. This implies that as there are increased accesses to improved water sources, infections and disease spread can be curtailed which directly or otherwise reduces the deaths of children less than five years of age.

The GDP per capita coefficient is positive and significant at the 5% level of significance. This indicates that increases of 1% in GDP will increase child mortality by 0.08%, this is not in line with the *a priori* expectation. A possible explanation may be that allocations for health care are not effectively and efficiently utilised by some West African countries, probably caused by corruption [12]

Improved sanitation facilities have a positive and insignificant effect on child mortality, implying that the healthier the environment with access to improved sanitation facilities, the more likely children below five years will die. This is not according to *a priori* expectations.

The time and country dummies capture shocks or events that may be peculiar to a specific year or country.

V. CONCLUSION

The study shows that immunisation coverage did not significantly help to reduce child mortality, before the GVAP era, in West Africa. However, in the post-GVAP era which is denoted by the interaction of immunisation and GVAP, immunisation coverage helped reduce child mortality. Variables such as maternal literacy and improved water source are significant to the reductions in child mortality. Policy implications from the findings of this research for West African countries are:

The finding that maternal literacy explains the reduction in child mortality in West African countries implies that governments can count on this variable to significantly impact child mortality. Programmes that create and promote awareness for mothers could be implemented by governments within this region with the aim of achieving a reduction in under-five deaths.

Policies should also focus on ensuring the availability and accessibility of clean and safe water within their environs, as the economic expectation of improved water sources can be relied on to reduce child mortality in West Africa. Comparing the results for immunisation coverage, before and after the GVAP initiative, there seems to be not much difference; governments in West Africa could strengthen the impact of GVAP by ensuring an enabling environment for the initiative through its African Regional Immunisation Strategic Plan to carry out its objectives, resulting in the protection of their citizens from VPDs, thereby reducing child mortality within the region.

The study was limited in accessing recent data which captured immunisation coverage during the Covid-19 pandemic, due to unavailability; hence the study could not go beyond the year 2019 at the time the empirical analysis was conducted. Upon recent data availability, further empirical studies could be conducted to assess whether there has been a significant change in immunisation coverage and how it has impacted child mortality in West Africa. The study recommends that West African governments can focus on programmes that create and promote awareness for mothers with the aim of achieving a reduction in under-five deaths. Also, the availability and accessibility of clean and safe water within this region could help combat child mortality

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