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Is health expenditure on immunisation associated with immunisation coverage in sub-Saharan Africa? A multicountry analysis, 2013–2017

Israel Oluwaseyidayo Idris ,[1,2] Luke Ouma ,[3] Janet Tapkigen,[4] Francis Ifeanyi Ayomoh,[5,6] Gabriel Omoniyi Ayeni[1,7]

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For numbered affiliations see end of article.

Correspondence to
Luke Ouma;
ouma.ondijo@gmail.com

ABSTRACT

Objectives The designing of contextually tailored sustainable plans to finance the procurement of vaccines and the running of appropriate immunisation programmes are necessary to address the high burden of vaccine-preventable diseases and low immunisation coverage in sub-Saharan Africa (SSA). We sought to estimate the minimum fraction of a country's health budget that should be invested in national immunisation programmes to achieve national immunisation coverage of 80% or greater depending on the context, with and without donors' support.

Design Multicountry analysis of secondary data using retrieved publicly available data from the WHO, Global Alliance for Vaccines and Immunization (GAVI) and World Bank databases.

Setting Data on 24 SSA countries, between 2013 and 2017.

Methods We model the variations in immunisation coverage across the different SSA countries using a fractional logit model. Three different generalised linear models were fitted to explore how various explanatory variables accounted for the variability in each of the three different vaccines—measles-containing vaccine (MCV)1, diphtheria, pertussis, tetanus (DPT3) and BCG.

Results We observed an association between current health expenditure (as a percentage of gross domestic product) and immunisation coverage for BCG (OR=1.01, 95% CI: 1.01 to 1.04, p=0.008) and DPT3 (OR=1.01, 95% CI: 1.0 to 1.02, p=0.020) vaccines. However, there was no evidence to indicate that health expenditure on immunisation (as a proportion of current health expenditure) could be a strong predictor of immunisation coverage (DPT, OR 0.96 (95% CI 0.78 to 1.19; p=0.702); BCG, OR 0.91 (0.69 to 1.19; p=0.492); MCV, OR 0.91 (0.69 to 1.19; p=0.482)). We demonstrate in selected countries that to achieve the GAVI target of 80% in the countries with low DPT3 coverage, health expenditure would need to be increased by more than 45%.

Conclusions There is a need to facilitate the development of strategies that support African countries to increase domestic financing for national immunisation programmes towards achieving 2030 targets for immunisation coverage.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ We provide a comprehensive longitudinal multi-country analysis of immunisation coverage and immunisation expenditure among countries in sub-Saharan Africa, offering insights into trends and the associations between health expenditure levels and immunisation coverage.
- ⇒ Immunisation coverage predictions are provided under the assumption that the covariates in the model including fertility rates, population and under-5 mortality remained unchanged, which may not hold in practice and may suffer from overadjustment bias.
- ⇒ Our predictions on improving immunisation coverage require much more than increasing current health expenditure; for instance, community mobilisation, increased health personnel and alternative delivery strategies, which are not necessarily reflected in metrics of health expenditure.
- ⇒ For the secondary data used in this analysis (from the Global Alliance for Vaccines and Immunization, WHO and other United Nations agencies), certain estimates such as those of vaccine coverage are often subject to sampling error and information bias, and other differences in data collection methods in surveys across countries.
- ⇒ There is limited availability of further detailed information on vaccine coverage, such as the distribution of vaccines across socioeconomic groups, which limits further exploration on whether immunisation financing is associated with coverage across various population subgroups.

INTRODUCTION

'No child should die or be sickened by vaccine-preventable diseases (VPDs)', a phrase coined and pledged during the first Ministerial Conference on Immunization in Africa, held from 24 to 25 February 2016 in Addis Ababa, Ethiopia,[1] which signalled the increasing efforts by African governments to address the high-burden of VPDs in Africa. At the time, nearly 1 million African children—inclusive of newborns—died before

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their fifth birthday from VPDs annually; and every year, about 30 million children under-5 years suffer from VPDs in Africa.[2,3] While some of the Ministerial Conference commitments included strengthening supply chains and delivery systems, and increasing universal access to vaccines and sustainable immunisation financing, the latter remains the most critical and arduous to achieve.[1] This is because international donors are gradually reducing their funding for immunisation programmes in low-income and middle-income countries (LMICs),[4,5] as other health priorities, such as HIV/AIDS programmes, compete for limited health funding.[6] Additionally, the financial resources needed for the successful implementation of immunisation programmes in LMICs are increasing because of prohibitive costs associated with the provision of the recent WHO-recommended vaccines such as the pneumococcal conjugate vaccine (PCV) and the cost of extending immunisation activities to hard-to-reach areas.[7] Ensuring sustainable funding for immunisation is presumed to be crucial for attaining universal immunisation and the objectives outlined in the Immunization Agenda 2030 initiative. Sustainable financing for immunisation entails allocating and using resources in a manner that promotes the attainment of immunisation goals while considering the broader framework of health financing. It focuses on optimising the effective, efficient and fair utilisation of resources.[8]

While some progress in terms of increased government funding has been recorded in the past two decades,[9] African countries' efforts to finance their national immunisation programmes require more resources amid competing socioeconomic needs, static/steady donor funding, and understanding the trend of immunisation financing in these countries would assist in the development of appropriately tailored country-level financing strategies that would advance sustainable domestic financing for immunisation programmes and support the expansion of these programmes to optimise national immunisation coverage.

This study aimed at critically analysing immunisation financing in sub-Saharan Africa (SSA) countries from 2013 to 2017. Specifically, we characterise the immunisation financing and immunisation coverage landscape in SSA, and estimate the minimum percentage of a country's health budget—with and without donors' support—that must be invested in the national immunisation programmes with the aim to achieve desirable national immunisation coverage levels (at least 80–90%).

METHODS

We perform a multicountry analysis of secondary data for 23 countries in SSA, between 2013 and 2017. In this section, we provide a description of the data sources, data description and statistical methods for our analysis.

Data description

SSA consists of 23 low-income, 18 lower middle-income and 4 upper middle-income countries according to the 2022 World Bank classification.[10] This paper focuses on 18 low-income countries: Burkina Faso, Burundi, Chad, the Central African Republic (CAR), Ethiopia, Eritrea, the Gambia, Ghana, Guinea, Liberia, Madagascar, Mali, Mozambique, Republic of the Congo, Rwanda, Sierra Leone, Sudan and Togo, and 6 lower middle-income countries: Benin, Côte D'Ivoire, Djibouti, Senegal, Zambia and Zimbabwe. Of the 24 countries in this study, all are in the sub-Saharan region exclusive of the Republic of Sudan (see countries approved for the Global Alliance for Vaccines and Immunization (GAVI) support[11]). The Republic of Sudan was included in this study as it is the only country in Northern Africa supported by the GAVI. Although South Sudan is GAVI supported, there are no published statistics on its immunisation financing. Countries were included in this study if they had complete data available for the entire period of 2013–2017.

Data source

Data were retrieved from WHO Library, GAVI and World Bank databases. Data for vaccine coverage were obtained for BCG, PCV3, measles-containing vaccine (MCV) and diphtheria, pertussis, tetanus 3 (DPT3) from the WHO and UNICEF estimates of vaccine coverage for all the countries for the entire period.[12] Data for fertility rate, under-5 mortality rates, under-5 population and the total population were obtained from the World Bank. We focused on DPT3 in this study in accordance with previous literature that showed DPT3 as a strong marker for immunisation coverage in the community.[13] Immunisation financing sources in SSA include the government sources, private sector and GAVI.[14] For immunisation financing data, countries are required to report their vaccine and immunisation expenditures annually to the Joint Reporting Form of the WHO and UNICEF. These data are used to estimate the Global Vaccine Action Plan (GVAP) indicator of government commitment, which is analysed and compared across countries annually.

Statistical analysis

We performed both descriptive and inferential statistical analyses. Binary data were summarised using frequencies and proportions, and continuous variables using medians (IQR) where appropriate. To model how the immunisation coverage in different countries across SSA relates to various explanatory variables including immunisation financing between 2013 and 2017, we use a fractional logit model.[15] The fractional logit is estimated with a generalised linear model (GLM) in combination with the logit link function, binomial family and robust options in Stata software, since proportions are bound between 0 and 1. Given the balanced panel data, we considered a fixed-effects model by including the time averages of the time-varying covariates in the model.[15] Three different GLMs were fitted, to explore how various explanatory

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variables accounted for the variability in each of the three different vaccines—MCV1, DPT3 and BCG. For each of the different vaccine-specific outcomes, we fitted two models, one with health expenditure with donor support and the other without. Further, we explored the possibility of creating a single model with interaction terms between total health expenditure and percentage of total health spending on immunisation, but those results showed no evidence of an interaction and hence we chose to proceed with two separate models.

The covariates included in the GLM specified above are: immunisation expenditure, current health expenditure (as a percentage of the gross domestic product (GDP)), fertility rate, under-5 mortality rate, under-5 population and the total population. The choice of explanatory variables to include in the model was based on the empirical knowledge of their association with immunisation coverage from the literature. We further performed predictions based on the fitted models. To this end, we computed the marginal effects—statistics calculated from predictions of a previously fit model at fixed values of some covariates and averaging or otherwise integrating over the remaining covariates.

All countries without complete data for the study period were excluded from the analysis. Statistical tests were performed at the 5% level of significance. Statistical analyses were performed in R software V.3.6.3 (R Core Team, Vienna, Austria) and Stata V.15 (StataCorp, College Station, Texas, USA).

Patient and public involvement

None.

RESULTS

Sociodemographic characteristics

We used data from 24 countries with complete data on immunisation coverage and health expenditure on immunisation between 2013 and 2017. Table 1 presents summary statistics for the demographic characteristics of the 24 countries in this study. Of the four vaccines—BCG, MCV1, PCV3 and DPT3—we observed, BCG had the highest coverage across all the years (2013–2017), with a median coverage exceeding 88%. Further, we note that immunisation coverage increased most for PCV3 and MCV1 (6.5% and 7%, respectively) between 2013 and 2017. This is unsurprising because several countries first introduced the vaccine in their immunisation programme within the study period (2013–2017). We see that across countries, vaccine coverage tended to increase over time, in the duration of the study (except in the Republic of the Congo from 2014), and well above 70–80% (except in some countries such as Guinea, Ethiopia and the CAR).

Table 1 Summary of demographic characteristics of the 24 sub-Saharan countries (2013–2017)

Variable	2013	2014	2015	2016	2017
	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)
DPT3 coverage	86.0 (73.0–92.0)	86.0 (74.0–91.0)	85.0 (76.0–93.0)	84.0 (76.0–92.0)	85.5 (73.5–92.0)
BCG coverage	92.0 (75.0–95.0)	88.0 (80.0–94.0)	93.0 (82.0–97.0)	90.0 (83.0–96.0)	92.0 (80.0–96.0)
MCV1 coverage	80.0 (61.0–90.0)	80.0 (67.0–89.0)	85.0 (68.0–93.0)	87.0 (70.0–90.0)	80.0 (66.5–90.0)
PCV3 coverage	79.5 (63.0–93.5)	81.5 (71.0–90.0)	83.5 (77.0–93.0)	86.0 (78.0–91.5)	82.5 (74.0–91.5)
Domestic general government health expenditure (% of current health expenditure)	26.7 (19.6–29.0)	27.6 (19.9–35.1)	25.3 (20.4–35.1)	25.0 (20.1–38.3)	25.4 (20.0–35.1)
Proportion of health budget on immunisation (with donor support)	0.1 (0.1–0.15)	0.092 (0.1–0.2)	0.1 (0.1–0.2)	0.1 (0.1–0.2)	0.1 (0.1–0.2)
Proportion of health budget on immunisation (no donor support)	0.5 (0.2–0.8)	0.5 (0.2–0.9)	0.6 (0.3–0.9)	0.6 (0.4–1.0)	0.6 (0.2–0.9)
Fertility rate	4.8 (4.4–5.2)	4.7 (4.3–5.1)	4.6 (4.2–5.0)	4.5 (4.2–5.0)	4.7 (4.3–5.1)
Under-5 mortality rates (per 1000 live births)	69.6 (59.8–96.9)	69.8 (59.8–101.8)	67.2 (57.9–99.6)	64.1 (56 - 97)	69 (57.6–98.5)
Under-5 population (millions)	2.0 (0.9–3.3)	2.1 (0.9–3.4)	2.1 (0.9–3.5)	2.1 (0.9–3.6)	2.1 (0.9–3.4)

DPT, diphtheria, pertussis, tetanus; MCV, measles-containing vaccine; PCV, pneumococcal conjugate vaccine.

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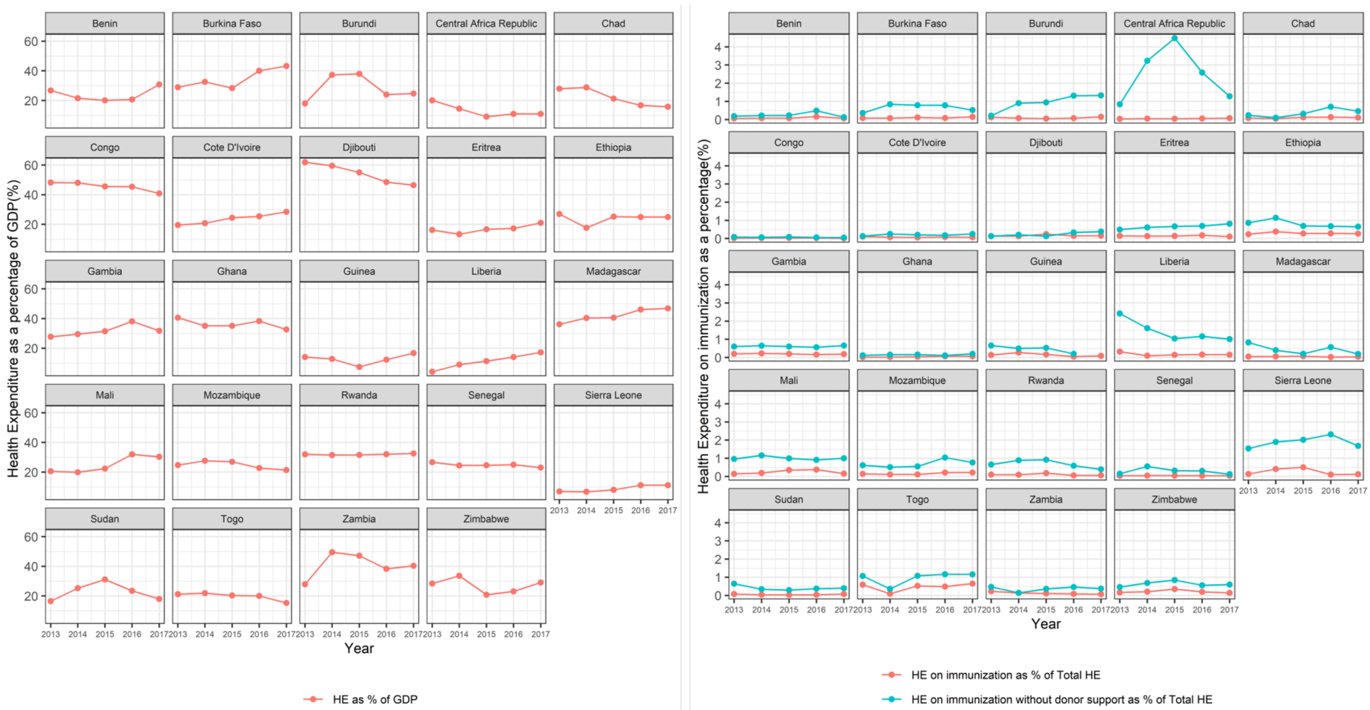

Figure 1 Health expenditure (HE) on immunisation as a percentage of the GDP (left panel) and HE on immunisation as a percentage of the current HE for the 24 sub-Saharan African countries (2013–2017; right panel). GDP, gross domestic product.

The highest health expenditure (as a percentage of the GDP) was in 2014 (28%) and lowest in 2016 (25%). Health budget on immunisation with donor support remained constant at 0.1% across 2013–2017, and between 0.6 and 0.5 without donor support across 2013–2017. Notably, there was important variation across countries; whereas countries such as Ethiopia, Togo, Sierra Leone, Liberia and the CAR spent on average 20% or less of their GDP on health, we see in Zambia, Djibouti and Madagascar expenditure of up to and beyond 50%. The median fertility rates were highest in 2013 (4.8) and lowest in 2016 (4.5). There was an increase in the under-5 population from 2013 to 2016 and then a decrease in 2017 (2.07 million). Overall, there was evidence of decline in mortality rates and fertility rates between 2013 and 2017, while the population of under-5 years increased in the same period.

Health expenditure and immunisation expenditure

Figure 1 (left panel) shows the health expenditure (as a percentage of the GDP) and the health expenditure on immunisation (as a percentage of the current health expenditure) for 24 African countries. The World Bank 2019 data on the health expenditure (as a percentage of the GDP) show that there is variation in this expenditure. Liberia showed a sharp increase in the health expenditure as a percentage of GDP. Other countries with a sharp increase are Sierra Leone, Madagascar and Cote d'Ivoire. Djibouti had a sharp decline in health expenditure over the 5 years, although it had the highest health expenditure with 61% in 2017 compared with Liberia which had the lowest health expenditure at 4%. Rwanda generally faced a flat trend.

Immunisation financing

Figure 1 (right panel) reports the expenditure on vaccines for routine immunisation (as a percentage of current health expenditure) with and without donor support. The health expenditure on immunisation (as a percentage of current health expenditure) for all the countries showed a constant trend of below 1%. Evidently, donor support in financing the cost of vaccines accounted for a larger proportion relative to government contribution. There was limited variability in health expenditure on immunisation with the majority evidenced by the marginal increase and declines over the 5-year period, except for a few countries like the CAR, Sierra Leone and Liberia. For Burkina Faso (0.14%), Burundi (0.14%), Côte D'Ivoire (0.07%), Djibouti (0.15%), Eritrea (0.11%), Ethiopia (0.27%), the Gambia (0.19%), Ghana (0.07%), Madagascar (0.04%), Mozambique (0.22%), Rwanda (0.06%), Sierra Leone (0.12%), Sudan (0.08%), Zambia (0.07%), Zimbabwe (0.14%), Togo (0.65%), Senegal (0.04%), Guinea (0.09%), Liberia (0.15%), the CAR (0.07%), Chad (0.11%), the Republic of the Congo (0.01%) and Benin (0.06%), co-finance routine vaccines are supported by the GAVI. Co-finance means that apart from GAVI financing the vaccines, the countries also contribute to the cost of GAVI-supported vaccines.[16]

Additionally, figure 1 (right panel) reports how much countries would need to finance vaccines without the GAVI's support. Sierra Leone would need to contribute

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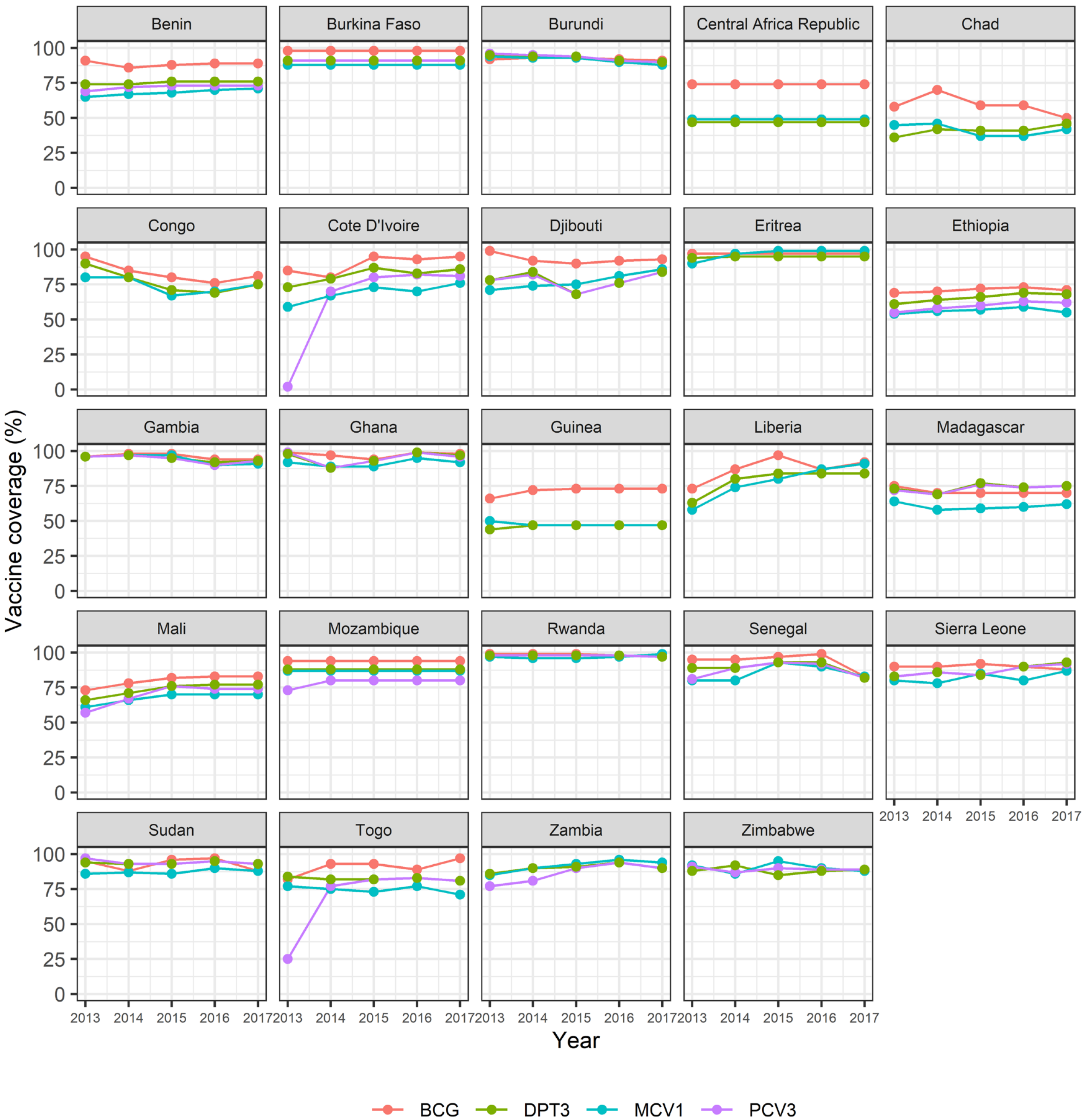

Figure 2 Vaccine coverage for BCG, DPT, MCV1 and PCV3 between 2013 and 2017 for the 24 sub-Saharan African countries. DPT, diphtheria, pertussis, tetanus; MCV, measles-containing vaccine; PCV, pneumococcal conjugate vaccine.

1.54% in 2013, 1.90% in 2014, 2.02% in 2015, 2.32% in 2016 and 1.68% more in 2017. Similarly, the CAR, which had the biggest difference, would need 0.84% in 2013, 3.24% in 2014, 4.48% in 2015, 2.59% in 2016 and 1.28% in 2017 more to self-finance vaccines. On the other hand, the Republic of the Congo, Ghana, Djibouti and Benin showed they were at a steady pace at self-financing vaccines.

Immunisation coverage trends

Figure 2 shows the coverage of BCG, MCV1, DPT3 and PCV3 vaccines in 24 countries from 2013 to 2017. Zambia and Zimbabwe had missing data on BCG coverage, while Guinea, Liberia, the Republic of the Congo, Eritrea, the CAR and Chad had missing data on PCV3 coverage.

Most countries had relatively consistent immunisation performance as measured by the DPT3 coverage. Countries that achieved the GAVI goal of 90% coverage by 2015 included Burkina Faso (91%), the Gambia (97%), Ghana (98%), Burundi (93%), Rwanda (98%), Zambia (90%), Eritrea (95%) and Sudan (93%), while Côte D'Ivoire, Mozambique, Senegal, Sierra Leone, Togo and Zimbabwe had above 80% DPT3 coverage between 2013 and 2017.

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In contrast, Benin, Liberia, Madagascar, Mali, the CAR, the Republic of the Congo, Chad, Djibouti and Guinea were below the GVAP target percentage of greater than 80% DPT3 coverage. In Benin, Liberia, Madagascar and Mali, the coverage was above 75%. Guinea did not acquire a 50% DPT3 coverage by the end of 2017, while coverage for MCV1 also lagged. The Republic of the Congo saw huge drops between 2013 and 2016 and an increase in 2017. The CAR and Guinea have struggled to bring its coverage above 50% throughout the 5 years. Chad has shown low coverage with the highest of 42% and lowest of 39%. Chad and the CAR had the lowest DPT3 coverage by 2017. Although Ethiopia's coverage showed lower immunisation coverage (below 75%), there is a significant increase in the coverage over the 5 years with the lowest of 59% and highest of 69%.

Figure 2 shows PCV coverage. Among the 24 GAVI-eligible countries, 18 of them had adopted the PCV vaccine. These include Benin, Burkina Faso, Burundi, Côte D'Ivoire, Djibouti, Ethiopia, the Gambia, Ghana, Madagascar, Mali, Mozambique, Rwanda, Senegal, Sierra Leone, Sudan, Togo, Zambia and Zimbabwe. The other countries, the CAR, Chad, the Republic of the Congo, Eritrea, Guinea and Liberia, had lagged behind in the introduction of the PCV by the year 2017.

Predicting immunisation coverage

Table 2 shows that health expenditure on immunisation (as a proportion of current health expenditure) is not a significant predictor of immunisation coverage. To clarify, the predictions are calculated from the fitted model at fixed values of some of the covariates, and that health expenditure covariates varied, while fertility rates, population and under-5 mortality remained unchanged. Also, the predictions are based on the model assuming immunisation financing with donor support.

Contrary to expectation, the relationship is negative (even though this has been seen in some studies[17]). Further, it is surprising that certain countries with low expenditure on immunisation had high coverage (>80%); for example, the Republic of the Congo had 90% DPT3 coverage in 2014 with a health expenditure on immunisation (as a proportion of current health expenditure) of 0.03%, while Sierra Leone had 83% DPT3 coverage and a health expenditure on immunisation (as a percentage of current health expenditure) of 0.4% in the same year. On the other hand, other countries with similar expenditure on immunisation in 2017 showed different immunisation coverage. For example, we observed that Chad and Eritrea had a 41% and 95% DPT3 coverage, yet they had similar health expenditure on immunisation (as a proportion of current health expenditure) of 0.10% in 2017. This similar observation was made for the second model with the variable immunisation without donor support. The inverse relationship observed for certain countries is a major contributor to the negative association observed in our model. However, we observe that the association between current health expenditure as a percentage of GDP and immunisation coverage showed a stronger link with BCG (p=0.008) and DPT3 (p=0.020) vaccines. Therefore, health expenditure as a percentage of GDP is an important predictor of immunisation coverage. Under-5 mortality was shown to be associated with DPT3 coverage.

We sampled countries with the lowest percentage of DPT3 and BCG coverage to predict immunisation coverage as we vary current health expenditure (as a percentage of the GDP). The results are visualised in figure 3 and online supplemental figure 1. Figure 3 shows immunisation coverage for countries with less than desired level of DPT3 coverage (below 80%) to visualise how much expenditure on health as a percentage of GDP would result in an increase in DPT3 coverage with all other variables unchanged. These countries include Benin, the CAR, Chad and Guinea. We used the health expenditure (as a percentage of the GDP) variable to perform the prediction as it was the most important variable of interest associated with immunisation coverage.

On average, we observe a steady increase in the predicted immunisation coverage for the four countries as health expenditure (as a percentage of the GDP) increases. For Benin and Guinea, to realise a desired level of DPT3 coverage of at least 80%, we notice that the 2017 current health expenditure should be increased to about 45% of the total GDP. In Chad and the CAR, a 45% increase in health expenditure (as a percentage of GDP) would result in 60% DPT3 coverage.

Countries that achieved 90% DPT3 coverage such as Burkina Faso, the Gambia and Sudan spent about 43%, 23% and 46%, respectively, on health expenditure (as a percentage of GDP). For countries that achieved 80% DPT3 coverage such as Liberia, Mozambique and Togo, the health expenditure as a percentage of GDP was 17%, 21% and 15%, respectively.

Online supplemental figure 1 shows immunisation coverage for countries with less than desired level of BCG coverage (below 80%). These countries include Ethiopia, the CAR, Mali and Guinea. We predict that increasing the 2017 health expenditure (as a percentage of GDP) by 25% to 35% would result in 80% coverage in BCG in these countries.

DISCUSSION

In this study, we examined the association between immunisation expenditure and health expenditure (as a percentage of the GDP) has on immunisation coverage between 2013 and 2017. Our study findings showed that over the 5-year period, immunisation coverage for DPT3, BCG and PCV3 was satisfactory overall (>80% median coverage), a reflection of progress towards increasing access to immunisation and a signal for a decrease in under-5 mortality from VPDs in SSA. Nonetheless, the GVAP target of 90% coverage was not attained, with many countries recording suboptimal national and subnational immunisation coverage amid struggle to increase immunisation financing and vaccine accessibility. The marginal

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Table 2 Regression model results

Variable	DPT coverage		BCG coverage		MCV coverage	
	OR (95% CI)	**P value**	**OR (95% CI)**	**P value**	**OR (95% CI)**	**P value**
Health expenditure as a percentage of GDP	1.01 (1.0 to 1.02)	0.020	1.02 (1.01 to 1.04)	0.008	1.01 (0.99 to 1.03)	0.234
Health expenditure on immunisation	0.65 (0.31 to 1.39)	0.270	0.68 (0.28 to 1.68)	0.405	0.76 (0.44 to 1.32)	0.334
Fertility rate	0.17 (0.02 to 1.39)	0.098	0.31 (0.02 to 5.95)	0.440	0.93 (0.11 to 7.82)	0.944
Mortality rate among under-5 years old	0.97 (0.96 to 0.99)	0.003	0.99 (0.99 to 1.0)	0.236	0.99 (0.99 to 1.0)	0.434
Under-5 population	1.01 (0.99 to 1.03)	0.126	0.99 (0.99 to 1.0)	0.185	0.99 (0.99 to 1.0)	0.481
Population	0.99 (0.97 to 1.0)	0.120	0.99 (0.99 to 1.0)	0.149	0.99 (0.99 to 1.0)	0.292
Model with expenditure on health immunisation without donor support						
Health expenditure as a percentage of GDP	1.02 (1.01 to 1.03)	0.003	1.02 (1.01 to 1.04)	0.005	1.01 (1 to 1.03)	0.168
Health expenditure on immunisation	0.96 (0.78 to 1.19)	0.702	0.91 (0.69 to 1.19)	0.492	0.91 (0.69 to 1.19)	0.482
Fertility rate	0.13 (0.01 to 1.16)	0.067	0.24 (0.01 to 5.25)	0.367	0.68 (0.07 to 6.33)	0.739
Mortality rate among under-5 years old	0.97 (0.96 to 0.99)	0.002	0.99 (0.99 to 1.0)	0.326	0.99 (0.99 to 1.0)	0.544
Under-5 population	1.01 (0.99 to 1.03)	0.144	0.99 (0.99 to 1.0)	0.203	0.99 (0.99 to 1.0)	0.438
Population	0.99 (0.97 to 1.0)	0.094	0.99 (0.99 to 1.0)	0.141	0.99 (0.99 to 1.0)	0.190

DPT, diphtheria, pertussis, tetanus; GDP, gross domestic product; MCV, measles-containing vaccine.

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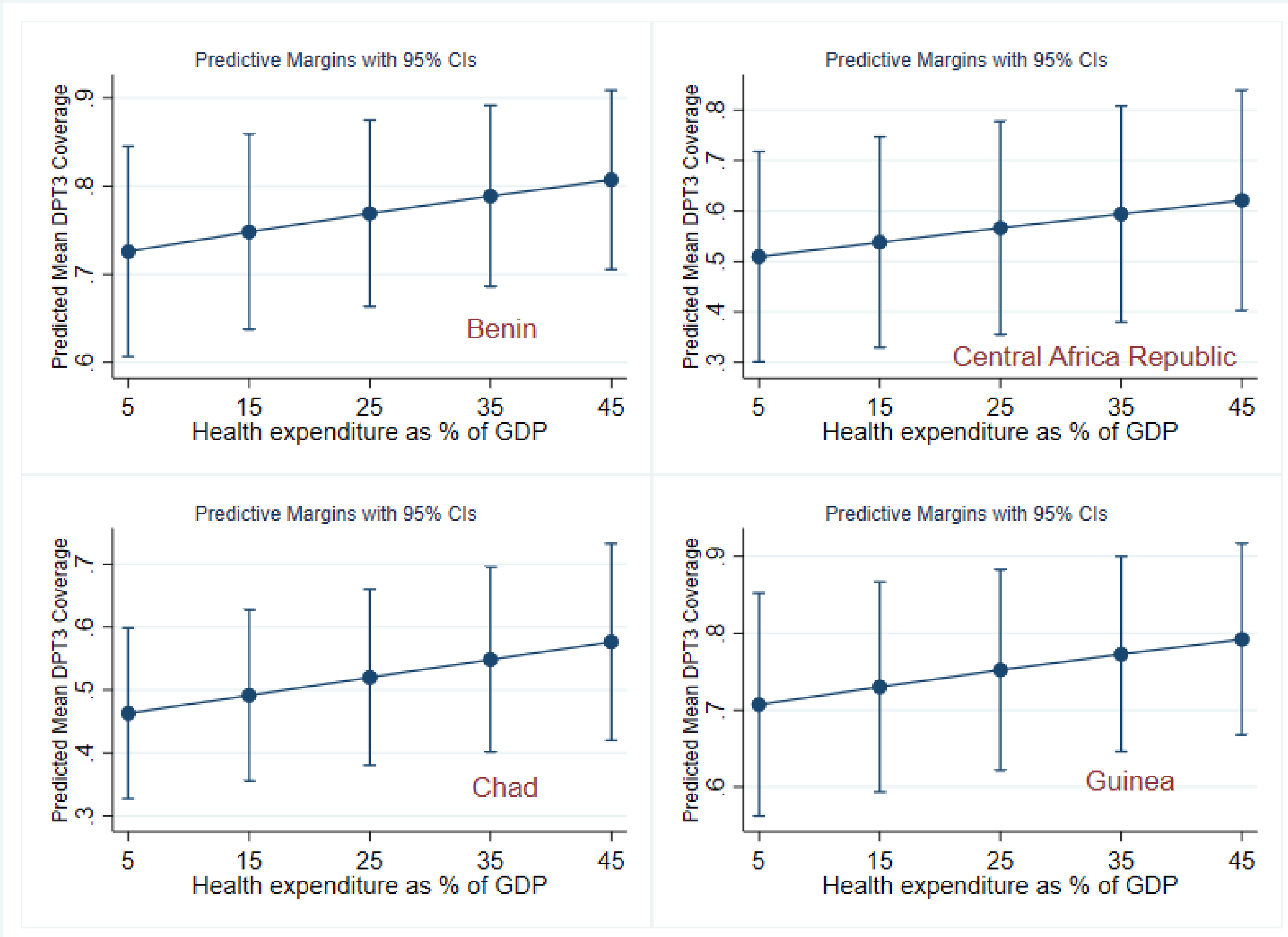

Figure 3 Predicted (DPT3) immunisation coverage with varying health expenditures on immunisation as a percentage of GDP. DPT, diphtheria, pertussis, tetanus; GDP, gross domestic product.

increase in coverage between 2013 and 2017 (6–7%) may be attributed to the early operational and programmatic readiness at national and subnational levels, with high-level political interest at the global and national level.[18] However, majority of SSA health systems are still weak and plagued with low capacity of healthcare workers, poor vaccine management, lack of commitment, inadequate quality social mobilisation and community engagements, and poor coordination at management level.[18]

Unusually, low vaccine coverage levels (<50%) in countries like Benin, the CAR, Chad and Guinea have also been reported elsewhere (Mosser *et al*[19] and Ikilezi *et al*[20]) and partly attributed to low maternal education attainment.[21] While low investment in health expenditure (as a percentage of the GDP) in these countries may be flagged as a potential contributor, countries like Sierra Leone, with one of the lowest allocations of health expenditure (as a percentage of the GDP), attained higher DPT3 coverage, suggesting the role of other contributors such as conflict,[22] vaccine shortages[23] and inadequate knowledge on vaccination by health workers.[23]

Most countries in SSA are still and perhaps more heavily reliant on the GAVI and other external support to finance more than half of their vaccination programmes. Our findings (>87% of SSA countries financing less than half of their vaccines programme), while similar to previous studies,[24 25] demonstrate that it is imperative that SSA countries should explore innovative health financing options and contextually appropriate domestic resource mobilisation strategies that will foster a significant and sustained increase in the domestic funding for immunisation programmes. Arguably, increased domestic funding of immunisation programmes in SSA is important to prevent the funding gap that may result as development assistance for dwindling health and some countries transitioning away from donor funding.

The finding that health expenditure on immunisation (as a percentage of current health expenditure) is not associated with immunisation coverage could be attributed to several factors. First, it is likely that internal security challenges in countries like Chad[23] significantly compromise the systems for cold chain, vaccine storage and delivery and scared mothers from taking their children for immunisation. As such, immunisation coverage levels of 41% are unsurprising. On the other hand, certain countries with low expenditure on immunisation had

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high immunisation coverage (>80%), the Republic of the Congo and Sierra Leone being classic examples. This low expenditure on immunisation may be the result of a low fiscal space for health, low prioritisation of immunisation by the government and a possible substitution effect—with government reallocating resources for immunisation to other priorities because of the availability of external funding for healthcare from organisations like the GAVI and UNICEF. The low fiscal space for health is linked to the macroeconomic realities in these countries as countries would likely spend more on health if they had higher GDP, provided health remained a key priority for the government. Third, expenditure on supplementary immunisation activities (SIAs), though significant, is often not accounted for as a direct immunisation cost. Such reason could explain the absence of a positive association between health expenditure on immunisation and immunisation coverage when all countries' data are pooled.

Elsewhere, we noted an important association between DPT3 coverage and under-5 years mortality. There is a possibility that increases in health expenditure may be linked to the observed decline in under-5 mortality.[26] Onishchenko *et al* suggested that increases in national immunisation expenditure correlated with reduced infant mortality and increased life expectancy.[5] It is globally presumed that decline in under-5 years mortality trend is one of the major expected outcomes of health spending on immunisation. Thus, we hypothesise that expenditure on some subsectors of national health programmes (such as vertical community-based management of acute malnutrition, integrated management of neonatal and childhood illness, integrated community case management) implemented in integration with immunisation could have contributed to the reduced mortality rate observed. In that context, the positive association between health expenditure and under-5 years mortality in our study should not be interpreted as an inevitable outcome regardless of how the money is spent. Previous studies have suggested that the quality of national institutions (degree of public sector accountability, stability of the political system, workforce productivity and so forth) is associated with effectiveness of public spending.

We further note that a higher expenditure on immunisation in some countries such as Mali, Togo, Zimbabwe and Sierra Leone may indicate that immunisation was prioritised in these countries, with increased funding from domestic and external sources. Immunisation is primarily financed through government expenditure such as government revenue (tax), borrowing and grants. Government revenues increase as the economy of the country grows. Therefore, economic downturn leads to low expenditure requiring governments to prioritise budget allocations between competing sectors. The Sabin Programme rolled out in Mali and Sierra Leone may be linked to higher immunisation coverage as it focused on linking the agenda of the Ministry of Health, Ministry of Finance and the parliament, supporting collective actions and resulting in a government-owned sustainable immunisation programme. In addition, the programme helped these countries compare plans for developing national immunisation trust funds such as decentralisation, legislation and budget reforms resulting in improved budget allocation.[27]

It is likely that the predominance of donor funding for immunisation in most of the countries may account for the near-constant level of funding on immunisation as support for immunisation from donors is more predictable unlike domestic funding from government, which may be subject to change from one budget cycle to another. Health expenditure (as a percentage of the GDP) could have been reduced because of a shift in the government's priorities with resources that should have otherwise been spent on the health sector being allocated to other sectors. Furthermore, our results project that a >45% increase in health expenditure as a percentage of GDP would be needed to meet the GAVI target of 80% in the countries with the least DPT3 coverage. This suggests a dire need for SSA governments to review their health policies and adopt legislation that targets equitable protection of health of all its citizens, such as in the case of Burkina Faso.[28] The involvement of the communities and civil societies in immunisation programmes could also drive success in these countries.[25]

Overall, SSA governments need to improve their health system policies and adopt legislation that targets equitable protection of the health of all citizens, as witnessed in Burkina Faso.[28] Countries are advised to sustain and increase their spending on health. Elsewhere, Moreno-Serra and Smith offer hard evidence that investing in broader health coverage can generate significant gains in terms of population health.[29] Furthermore, the effective implementation of integrated primary healthcare has also been reported to have contributed to improved health coverage including immunisation coverage. The association between spending and other components of the primary healthcare such as nutrition may indirectly contribute toward better immunisation outcomes. In another study on health spending and vaccination coverage in low-income countries (LICs), the authors found that the high vaccination coverage rates in certain LICs could not be attributed to factors such as economic development, total health spending or aggregated development assistance for health.[30] However, they observed that in a broader group of LICs, the success of vaccination coverage was linked to an increase in government health spending, especially in the context of routine immunisation vaccines. In another study by Jowett *et al* that examined public health spending in relation to certain universal health coverage indicators, one of the findings showed that in half of countries within each of the spending quintiles (upper, middle and lower spenders), DPT3 coverage rates are above 80% and even above 70% for the lowest spenders.[31]

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CONCLUSION

We recommend that countries with the least DPT3 and BCG coverage rates should increase their health expenditure, achieving at least DPT3 and BCG coverage of 80%. Second, prioritising expenditure on health as a percentage of GDP should be a concern of the government due to its potential association with population health. Also, while sustained support from donors remains vital, governments across these countries should prioritise spending on health in their fiscal planning and implementation, including resource mobilisation. Government and non-governmental bodies need to ramp up resources to meet the immunisation gaps, by exploring evidence-based strategies and best practices in financing national health programmes. Besides, promoting and/or strengthening implementation of integrated healthcare delivery could enhance efficiency and effectiveness. Also, countries may from time to time conduct cost-effectiveness analysis of their intervention strategies related to health, especially for immunisation.

Furthermore, countries should continue to explore immunisation investment alternatives and balance competing objectives to derive maximum benefits. Furthermore, we recommend that other metrics should be in place in addition to coverage to track the success of health expenditure on immunisation, considering the externalities that are associated with better outcomes. This aligns with what is proposed in the Immunization Agenda 2030 relating to immunisation coverage target and data management.

We also recommend that countries in conflict adopt strategies that would guarantee health access to all parties in conflict as this will optimise vaccine access and/or availability. Immunisation interventions and spending should be tailored in the direction that accommodates local context, with relative guarantee for good outcomes. Finally, we recommend that countries should continue to generate and keep detailed immunisation data outcomes of immunisation interventions such as SIAs at national and subnational levels including data on investments, outcomes and challenges to guide and improve intervention by the government and its partners.

Further study to understand the immunisation systems and financing mechanisms of countries with low spending and high coverage to explore opportunities for efficiency is recommended.

Author affiliations
[1]Immunization Analysis & Insights Unit, NAIJAHEALTH Initiative, Lagos, Nigeria
[2]Health Emergencies Programme (WHE), WHO, Geneva, Switzerland
[3]Population Health Sciences Institute, Newcastle University, Newcastle upon Tyne, UK
[4]Department of Health Sciences, University of Tampere, Tampere, Finland
[5]Health Policy, Federal Ministry of Health, Abuja, Federal Capital Territory, Nigeria
[6]Nuffield Department of Primary Care Health Sciences, University of Oxford, Oxford, UK
[7]Health Emergencies Programme (WHE), WHO Regional Office for Africa, Daresalam, Tanzania

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Contributors All authors equally contributed to the writing of the manuscript. IOI conceptualised this study, conducted the data collection and management, planned the methodology and contributed to the data analysis. JT participated in the conceptualisation of the study, and contributed to data collection, management and data analysis. LO participated in the conceptualisation of the study and the data management, planned the methodology and solely conducted the data analysis. FIA contributed to the manuscript writing and revision. GOA contributed to the manuscript writing and revision. All authors read and approved the final manuscript.

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ORCID iDs
Israel Oluwaseyidayo Idris http://orcid.org/0000-0003-0920-0490
Luke Ouma http://orcid.org/0000-0001-9145-8719

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