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Journal of Vaccines & Vaccination

Research Article

Relationship between Vaccine Stockouts and Vaccination Rate: Examination of Unique Administrative Data from Nigeria

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ABSTRACT

Background: Universal access to vaccines is crucial in protecting the population from deadly diseases. This study presents the prevalence of vaccine stockouts in Nigeria and examines the correlation between the vaccine stockouts and vaccine take-up.

Methods: We use the unique administrative data of monthly vaccine stockouts at each health facility in Nigeria. To evaluate the correlation between the stockouts and the vaccine take-up, the administrative data was merged to Nigeria Demographic and Health Survey conducted in 2013. We used the logistic regression for the correlational study.

Results: The prevalence of vaccine stockouts in Nigeria is high: 82.7 percent between 2012 and 2013. We find the negative correlation between vaccine stockouts and the vaccine take-up. However, we observe the differential correlational pattern depending on the regional vaccine coverage, which we consider as the proxy of the level of demand for vaccines.

Conclusion: We find that, while vaccine stockouts is correlated with the low vaccine take-up on average, the high stockouts is also attributed to the high vaccination coverage in regions with high demand for vaccines. To increase the vaccination rate, it is the most effective to strengthen the health system to reduce vaccine stockouts in regions with the low vaccination coverage.

Keywords: Correlation; Nigeria; Vaccination rate; Vaccine stockouts

INTRODUCTION

Vaccination saves millions of lives. For example, in the USA, many deadly vaccine-preventable diseases reduced its reported cases by more than 90 percent after the introduction of vaccines [1]. In developing countries, vaccination prevents 20 million deaths since 2001 [2]. Furthermore, vaccination is highly cost effective; every $1 of investment on immunization programs can save more than $17 in treating illness [3]. In Nigeria which has one of the highest child mortality in the world [4], vaccine preventable diseases account for more than 20 percent of the child mortality under five [5].

However, the shortage of vaccine stock is a concern around the world [6]; it can not only hinder the potential impact of vaccination on the reduced incidence of vaccine preventable disease, but also can it augment the disease prevalence due to the infectious nature of vaccine-preventable diseases [7]. Lydon et al. [8] found that 38% of sub-Saharan African countries suffer from national level stockouts. In Nigeria, the study site, supply-side issues such as shortage of vaccine is one of the most common reasons why the children dropout of their immunization schedule [9].

This paper examines the simple correlation between the vaccine stockouts and the vaccination rate in Nigeria. While the vaccine stockouts might cause the decrease in the vaccine take-up, we might also observe the reserve causality; the higher vaccination rate causes the stockouts of vaccine, due to the high demand for vaccines. This paper does not address the causal relationship between the vaccine stockouts and vaccination rate. Rather, we describe the geographical patterns of vaccine stockouts and its correlation with the vaccination rate, according to the demand level for the vaccination in each region.

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Received: May 30, 2019, **Accepted**: July 15, 2019, **Published**: July 30, 2019

Citation: Sato R (2019) Relationship between Vaccine Stockouts and Vaccination Rate: Examination of Unique Administrative Data from Nigeria. J Vaccines Vaccin 10:405.

METHODS

Data

We use two datasets. The first data is on vaccine stockouts. We use the health-facility level data, collected through Health Management Information System through District Health Information Software 2 (DHIS2), which has monthly information on all the health facilities in Nigeria overtime.

The second data is the Nigeria Demographic and Health Survey (DHS) conducted in 2013 (National Population Commission and ICF International, 2014). The survey has information on immunization record among respondents' children aged 0 to 59 months.

To evaluate the correlation between vaccine stockouts and immunization rate, we merge these two datasets according to the local government area (LGA) where each health facility from DHIS2 and each respondent from DHS is located. Nigeria has 774 LGAs from 36 states and one federal capital territory (FCT). For the correlation analysis, we only focus on LGAs where respondents in the DHS data were interviewed.

Outcome variable

We use three indicators to capture the vaccination: 1) ever vaccinated, 2) BCG, and 2) third dose of DPT (DPT3).

Independent variable

The main independent variable is vaccine stockouts by LGA level. In particular, we define that a LGA has vaccine stockouts at a particular month if at least one health facility within the LGA experiences vaccine stockouts in each month for 6 months prior to the interview date. The data does not indicate the stockouts of each vaccine antigen, but it only has the information on whether each health facility has stockouts of any vaccine antigen at a particular month.

Statistical analysis

To evaluate the correlation between vaccine stockouts and the vaccination take-up, we employ the logistic regression in the following regression framework:

$$y_{ij} = \alpha + \beta_1 Stockouts_{ij} + X^{'}\mu + \nu_j + \varepsilon_{ij} (1)$$

Where y_{ij} is vaccine take-up of a respondent's child i in a LGA j; indicates whether a LGA j have stockouts in any of health facilities under the LGA for 6 months prior to when the respondent i was interviewed. We control for various sociodemographic characteristics of mothers and children such as age, education level, religion, marital status, number of household members, number of children under 5 years old, wealth level, the type of residence (urban or rural), child's gender and birth order. We also control for zone where LGA belongs to, the population size of and the area size of LGAs.

Table 1: Socio-demographic characteristics of sample (n=19,211).

	(1)	(2)	(3)
	N	Mean	Std Dev
Mother's characteristics			
Age		29.47	6.94
Education attainment			
No education	8,606	44.8%	
Primary	4,005	20.8%	
Secondary	5,419	28.2%	
Higher than secondary	1181	6.1%	
Religion			
Muslim	10711	55.7%	
Non-Muslim	8,500	44.3%	
Marital status			

Married	17,786	92.6%	
Single	1,425	7.4%	
Household members			
Number of household members		7.11	3.61
Number of children under 5		2.27	1.19
Wealth index			
Poorest	4,107	21.4%	
Poorer	4,336	22.6%	
Middle	4,007	20.9%	
Richer	3,673	19.1%	
Richest	3,088	16.1%	
Region of residence			
Urban	6483	33.7%	
Rural	12728	66.3%	
Children's characteristics			
Age (months)		28.01	17.21
Birth Order		3.90	2.55
Gender of children			
Girl	9,545	49.7%	
Boy	9,666	50.3%	

Notes: The sample is 19,447 children aged 0 to 59 months.

RESULTS

There were a total of 23,037 children aged 0 to 59 months in DHS, of which the analytical sample is 19,211 children with no missing information on vaccine take-up and covariates.

Table 1 presents the descriptive statistics of the sample. Mother's age is on average 29.5 years old, and 44.8 percent of mothers have no educational attainment, while only 6.1% of them have educational attainment that is higher than secondary school. More than half of mothers are Muslim (55.7%) while the rest is Christian. More than 90 percent (92.6%) of mothers are married. The average number of household members is 7.1 and the number of children under five in the household is 2.3. The sampled households are almost equally divided into 5 categories in terms of wealth level (poorest, poorer, middle, richer, and richest) with higher proportion of households belonging to the poorest (21.4%) and the poorer (22.6%) and less proportion under the richest (16.1%). The average age of children is 28 months and the average birth order of the children in the sample is 3.9. Almost half of the children in the sample are girl (49.7%).

Table 2 presents the correlation between the stockouts and the vaccination coverage, using the logistic regression. After controlling for individuals' characteristics, we find that vaccine stockouts in a LGA is associated with the 16.6 percent [OR: 0.834, 95% CI=0.774 – 0.898] decrease in the likelihood of getting ever vaccinated among children who resides in the LGA (column 1). Similarly, the stockouts is associated with the reduced likelihood of getting BCG and DPT3 by 17.0% [OR: 0.830, 95% CI=0.768 – 0.898] and 16.4% [OR: 0.836, 95% CI=0.771 – 0.905], respectively.

Table 2: Stockout and Vaccination rate.

Outcome:	Ever vaccinated	BCG	DPT3
	(1)	(2)	(3)
stockouts	0.834***	0.830***	0.836***
	[0.774,0.898]	[0.768,0.898]	[0.771,0.905]
N	19211	19211	19211
covariate	X	X	X

Notes: The sample is 19,211 children aged 0 to 59 months. The independent variable "stockouts" takes 1 if the LGA always have vaccine stockouts in at least one health facility in each month for the 6 months prior to the interview date. Covariates include age, education level, religion, marital status, number of household members, number of children under 5 years old, wealth level, the type of residence (urban or rural), child's gender and birth order, zone, and the population size of and the area size of LGAs. * significant at 10%; ** significant at 5%; *** significant at 1%

Table 3 presents the correlation between the stockouts and the vaccination coverage, according to the state average of the vaccination rate. In particular, we divide the sample into two groups; 1) high state, where the state average of the vaccination rate is above the national average, and 2) low state, where the state average is below the national average. The national average for the proportion of ever vaccinated was about 78%. The national average for both BCG and DPT3 was about 50% respectively.

Table 3: Stockout and Vaccination: sub-group analysis by the state- average vaccination rate.

State:	Low rate	High rate	Low rate	High rate	Low rate	High rate
Outcome:	Ever vaccinated		BCG		DPT 3	
	(1)	(2)	(3)	(4)	(5)	(6)
stockouts	0.618***	1.257***	0.812***	0.982	0.757***	1.002
	[0.559,0.682]	[1.109,1.424]	[0.714,0.923]	[0.874,1.103]	[0.675,0.850]	[0.890,1.129]
N	8600	10611	8645	10566	10656	8129
covariate	X	X	X	X	X	X

Notes: The sample is 19,211 children aged 0 to 59 months. The independent variable "stockouts" takes 1 if the LGA always have vaccine stockouts in at least one health facility in each month for the 6 months prior to the interview date. The "low rate" state is the state with vaccination coverage lower than the national average. The "high rate" state is the state with vaccination coverage higher than the national average. Covariates include age, education level, religion, marital status, number of household members, number of children under 5 years old, wealth level, the type of residence (urban or rural), child's gender and birth order, zone, and the population size of and the area size of LGAs. * significant at 10%; ** significant at 5%; *** significant at 1%

Among children in a low state with the low vaccination coverage, the stockouts is associated with the reduced likelihood of getting ever vaccinated by 38.2 percent [OR: 0.618, 95% CI=0.559 – 0.682] (Table 3, column 1). On the other hand, among children reside in a high state, the stockouts is rather positively correlated with the likelihood of getting ever vaccinated by 25.7% [OR: 1.257, 95% CI=1.109 – 1.424] (column 2).

Similarly, if children resides in a low state for BCG vaccination, the stockouts is associated with the reduced likelihood of receiving BCG by 18.8% [OR: 0.812, 95% CI=0.714 – 0.923] (column 3), while the association is not significantly differently from zero if they live in a high state for BCG. We observe the same trend for DPT3 vaccine take-up: the negative association by 24.3% for the low state, and no significant association for the high coverage state.

DISCUSSION

This paper evaluates the association between the vaccine stockouts and the vaccination rate. We observe the high prevalence of vaccine stockouts all across Nigeria. Between 2012 and 2013, the national average stockouts rate was 82.7 percent. Over time, we see the gradual decline in the stockouts with some seasonal fluctuation. Geographically, the upper northern states generally have higher stockouts rate than other states. Among southern states, southwestern regions, including the economic capital of Lagos, also observe the high stockouts rate.

The coverage of DPT3 vaccination has a clear geographical trend. The southern states have the higher coverage of DPT3 than the northern states. Many northwest and northeast states do not reach even 15 percent of the DPT 3 take-up. People in the northern states are historically considered to have conservative or skeptical views on vaccination. For example, three northern states boycotted the polio vaccine campaigns in 2003, which led to the spread of wild polio virus across country

as well as to neighboring countries [5]. This low vaccination coverage might be attributed to the distrust of vaccines.

Overlaying the geographical pattern of DPT3 (Figure 1) and vaccine stockouts (Figures 2 and 3), two patterns reveal. The first pattern is that we broadly observe the negative correlation between the DPT 3 coverage and the stockouts rate; the regions with the lower DPT 3 tend to have higher stockout rates, especially in the northern states. The second pattern is particularly for three southwestern regions, especially Oyo, Ogun, and Lagos states. Among these three southwestern states, the association between the stockouts and DPT3 coverage seem to go against this first pattern. In these states, DPT 3 coverage as well as the stockouts rate is both high.

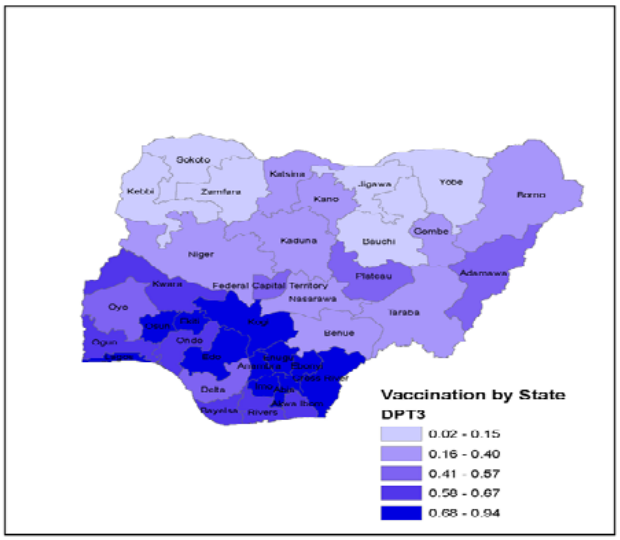

Figure 1: Vaccination coverage of DPT3 by state, using DHS data. The southern part of Nigeria has the higher coverage of DPT3 than the northern part.

This visual exercise helps us understand the intercorrelation between vaccine stockouts and coverage. Vaccine stockouts and vaccine coverage can influence with each other. On one hand, vaccine stockouts can refrain people from receiving the vaccine, thus reducing the vaccine coverage. In this case, the inadequate level of the health system might cause the frequent vaccine stockouts, which leads to the lower vaccination rate. On the other hand, the higher demand for vaccination can also cause the vaccine stockouts. In this case, the health system might be significantly better than the former case, but not to the extent to keep up with the high demand of vaccines.

The first pattern, the negative association between the stockouts and DPT 3 coverage, is confirmed by the regression analysis (Table 2). Through the regression analysis, we find that the stockouts is significantly associated with the lower vaccination coverage. This result implies that, on average, the Nigerian health system on the vaccine provision is at an inadequate level, which hinders the vaccination coverage.

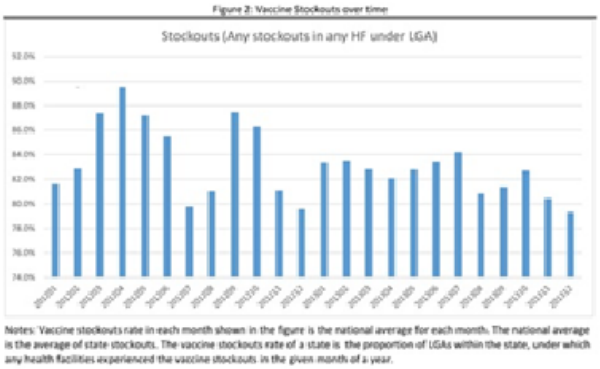

Figure 2: Presents the stockouts prevalence over time. The vaccine stockouts rate of a state is expressed as the proportion of LGAs within the state, under which any health facilities experienced the vaccine stockouts in the given month of a year. Generally, all the months between 2012 and 2013 observed the high rate of stockouts, ranging from 79.3% in December 2013 to 89.5% in April 2012.

Nigerians, however, face the large geographical inequality in terms of the economic level and the access to health services [10]. Especially people in the southern regions of Nigeria are on average significantly better-off in terms of the economic level as well as the access to health services. For example, the proportion of the poorest is 34.3% in the north, while it is only 3.3% in the south. On the other hand, the richest account for only 6.9% in the north, while it is 26.1% in the south (Nigeria DHS, 2013). The vaccination coverage of BCG, DPT3 and Measles in the north is merely 35.6%, 22.6%, and 27.9% respectively. On the other hand, the vaccine coverage for these vaccines in the south is 83.7%, 65.6%, and 60.9%.

Because the southern Nigeria are better-off in terms of access to health care, we expect that the quality of health care is much better in Lagos, for example, the economic capital of Nigeria situated in southwest, than in other regions. However, vaccine stockouts in Lagos state (northwest) is high, while the vaccine coverage is also high. This is consistent with the second pattern described above; high level of both the vaccination coverage and vaccine stockouts, presumably due to the high demand for vaccines.

Thus, the association between vaccine stockouts and the vaccination coverage might be different, according to the level of demand for the vaccines. We consider the regional vaccination coverage as a proxy for the level of demand for the vaccines in that region. Then, Table 3 contrasts the differential association pattern between vaccine stockouts and the vaccination coverage, by the level of demand for the vaccines. The hypothesis is as follows; the high regional vaccine coverage implies the high demand for vaccines, which causes the high vaccine stockouts. On the other hand, in a region where the average vaccine coverage is low, the health service might not be adequately established, which causes the frequent vaccine stockouts. This vaccine stockouts in turn causes the lower vaccine take-up.

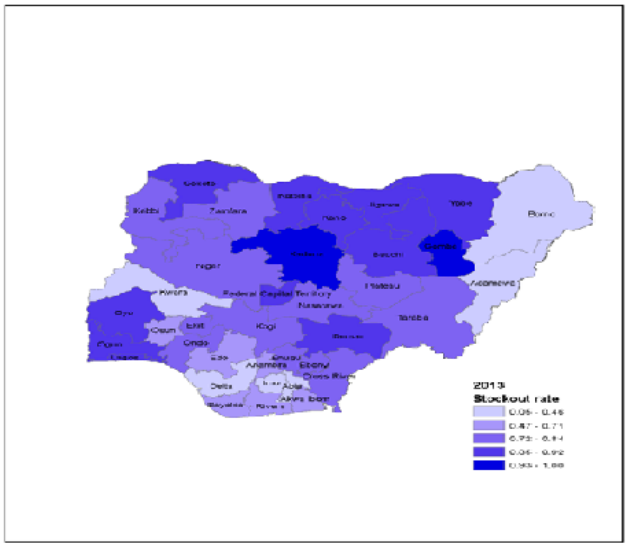

Figure 3: Presents the stockouts rate by state. Most of the states, regardless of the geographical region, has high stockouts rate. However, the upper northern state has the highest stockouts rate.

The sub-group analysis in Table 3 confirms this hypothesis. Among children who reside in regions with the lower vaccine coverage, the vaccine stockouts is negatively associated the likelihood of vaccine take-up. We interpret this result as the vaccine stockouts causing the lower vaccine take-up. On the other hand, among children who reside in regions with the higher vaccination coverage, the vaccine take-up is positively associated the likelihood of vaccine stockouts, presumably due to the high demand for vaccine within a better health system. In high states, the stockouts rate is not significantly associated with the particular vaccine take-up: BCG nor DPT3. This insignificant association might imply that the supply-side has the ability to accommodate the high demand for the vaccines to some extent for these vaccines.

The differential association between vaccine stockouts and vaccination coverage has important policy implications. In low states where the regional average of the vaccination coverage is low, the potential benefit of the reduced stockouts prevalence on the improved vaccination rate can be large. One way to reduce the vaccine stockouts is to strengthening the logistics of vaccine delivery. Some of northern states have adopted the interventions to ensure the availability of vaccine supplies [11]. The future study needs to evaluate the causal effect of the intervention on vaccine stockouts and on the vaccine take-up.

In high states where the regional average of the vaccination coverage is already high, on the other hand, ensuring the vaccine stock might not increase the vaccination rate as much as it could have in low states.

LIMITATIONS

There are two main limitations on this study. First, we do not have the information on the stockouts on each antigen. The lack of data makes it challenging to evaluate the one-to-one relationship between the vaccine stockouts and vaccination coverage for each type of vaccine. Second, the analysis is not causal but the result only shows the correlation. Future studies should explore the causal relationship between vaccine stockouts and immunization rate.

CONCLUSION

This paper reports the prevalence of the vaccine stockouts in Nigeria. We also evaluate the correlation between vaccine stockouts rate and the vaccine take-up. We use the unique administrative data on monthly vaccine stockouts at each health facility existent in Nigeria, as well as Demographic and Health Survey (DHS) for the vaccination rate. We find that, overall, there is a negative association between vaccine stockouts and the vaccine take-up. However, in a state where the vaccination coverage reaches the higher level, the stockouts is rather positively associated with the vaccine take-up, implying that the high demand for vaccines causes vaccine stockouts.

An important policy implication emerges from the study. For achieving the higher vaccination rate across the country, it is the most effective to strengthen the health system where the vaccination coverage is low to ensure the vaccine availability.

AUTHORS' CONTRIBUTIONS

RS conceived and designed the analysis, performed the analysis, and wrote the paper.

FUNDING

There were no funding.

COMPETING INTERESTS

The author declares no conflict of interest.

ETHICAL APPROVAL

The ethical approval was not obtained for the study.

REFERENCES

1. Orenstein, Walter AO, Rafi Ahmed. Simply put: Vaccination saves lives. Proceedings of the National Academy of Sciences. 2017;114:4031-4033.
2. Ozawa S, Clark S, Portnoy A, Grewal S, Stack ML, Sinha A, et al. Estimated economic impact of vaccinations in 73 low-and middle-income countries, 2001 – 2020. Bull World Health Organ. 2017;95:629-638.
3. Ozawa, Sachiko, Samantha C, Allison P, Simrun G, Logan B, et al. Return on investment from childhood immunization in low-and middle-income countries, 2011–20. Health Affairs 35;2:199-207.
4. United Nations Inter-agency Group for Child Mortality Estimation (2018).
5. Kaoje AU, Mohammed Y, Raji MO, Sanusi H, Jibril A, Aliyu HA. Prevalence of vaccine preventable diseases and utilization of routine immunizations services by parents of under-one children in a semi-urban community of Sokoto State, Nigeria. Global Journal of Medicine and Public Health. 2017;6(4):10.
6. Hinman AR, Walter AO, Jeanne MS, Lance ER, Stephen LC. Vaccine shortages: history, impact, and prospects for the future. Annu Rev Public Health. 20006;27:235-259.

7. World Health Organization (WHO). Addressing the global shortage of and access to, medicines and vaccines. 2013.
8. Lydon P, Schreiber B, Gasca A, Dumolard L, Urfer D, Senouci K. Vaccine stockouts around the world: Are essential vaccines always available when needed? Vaccine. 2017;35:2121-2126.
9. The World Bank. Nigeria Multiple Indicator Cluster Survey 2016-2017.
10. Archibong B. Historical origins of persistent inequality in Nigeria. Oxford Development Studies. 2018;46:325-347.
11. Aina, Muyi, Uchenna I, Leke J, Rabiu F, Adam T, et al. Preliminary results from direct-to-facility vaccine deliveries in Kano, Nigeria. Vaccine 2017;35: 2175-2182.