Effect of Vaccine Direct Delivery (VDD) on Vaccine Stockouts and Number of Vaccinations: Case Study from Bauchi State, Nigeria

Abstract

Objective

Vaccine stockouts are prevalent in Africa. Despite the potential importance of this as a barrier to universal vaccination coverage, rigorous study looking at ways to reduce vaccine stockouts has been limited. We causally evaluate the effect of Vaccine Direct Delivery (VDD), an intervention to ensure the vaccine-stock availability at health facilities, on the reduction of stockouts in Bauchi state, Nigeria.

Methods

Employing the interrupted time-series analysis method, we evaluate the change in the occurrence of vaccine stockouts before and after the introduction of VDD in July 2015. We use the health-facility level data, which was collected through the District Health Information Software 2 (DHIS2). The DHIS2 data have monthly information on commodity stockouts and stock balance in all the health facilities in Nigeria over time. To validate the causal relationship between VDD and vaccine stockouts, we conduct two sets of robustness checks. First, we evaluate the effect of VDD on the stockouts of other commodities. Second, we compare the trend of the prevalence of vaccine stockouts among health facilities between Bauchi state where VDD was introduced in 2015, and another state (Adamawa state) where VDD was never introduced.

Results

After the introduction of VDD, the prevalence of vaccine stockouts in Bauchi state decreased by 9 percentage points on average. Since the initiation of VDD, the vaccine stockouts have been decreasing monthly by 0.4 percentage points more than pre-VDD. There was no change in the level of other stockouts after VDD. In Adamawa state, where VDD was never introduced, the prevalence of vaccine stockouts did not change before and after July 2015. In Bauchi state, the

stock balance of target vaccines all increased after VDD introduction; however, we did not observe an increase in the number of vaccinations carried out after VDD.

Conclusions

The VDD intervention resulted in a significant reduction of overall vaccine stockouts and an increase in the vaccine stock balance of all target vaccines, but not an increase in the number of vaccinations performed.

Introduction

Almost 20 million children lack basic immunization worldwide, and 4 million of those children live in Nigeria (WHO, 2017). Particularly in northern Nigerian states, the vaccination rate lags behind the national average (National Immunization Coverage Survey (NICS), 2018). For example, in the northeast, 80 percent of children are not fully vaccinated, while the rate is 56 percent for the southeast. In Bauchi state, the study site and one of the north-eastern states, only 14 percent of children are fully vaccinated (NICS, 2018). Issues related to service delivery, including vaccine stock-outs, account for 28 percent of incomplete vaccination in the region (NICS, 2018).

Vaccine stockouts are a universal problem (Strategic Advisory Group of Experts on Immunization, 2018). However, the incidence of vaccine stockouts is the most severe in sub-Saharan Africa. Lydon et al. (2017) find that 38 percent of sub-Saharan countries experience national-level stockouts. Reasons for stockouts are found to be dominantly internal, such as funding delays and poor stock management. The national-level stockouts are likely to affect the district-level stockouts, which in turn can influence the operation of vaccination services. Indeed, extant studies reveal that vaccine stockouts are one of the main barriers to vaccination worldwide (Favin et al., 2012; Burnett et al., 2018), as well as in Nigeria (Eboreime at al., 2015).

Despite the potential impact of vaccine stockouts on vaccination coverage, and even on long-term health outcomes, rigorous study on ways to reduce their occurrence has been extremely limited. One exception is the study from Aina et al. (2017), which found the positive effect of a logistic intervention on vaccine stockouts in Kano state, one of the north-central states in Nigeria.

This paper evaluates the causal effect of Vaccine Direct Delivery (VDD), which provides logistic support to each health facility, on the prevalence of vaccine stockouts, stock balance of vaccines, and vaccination rates in Bauchi state.

Methods

The Vaccine Direct Delivery (VDD) Project:

We evaluate the effectiveness of the supply-side intervention called Vaccine Direct Delivery (VDD). In July 2015, Bauchi state launched the VDD project, outsourcing the vaccine distribution to health facilities to third party logistics (3PL) providers. Under VDD, the 3PL system provides logistic support to health facilities with the objective of ensuring stock availability of vaccines in every equipped health facility.

VDD aims at providing effective and efficient distribution of vaccines and dry commodities from state coldstores to health facilities at the district (ward) level. Operationally, under VDD, 3PL providers are responsible for administering a cold chain, distributing vaccines from the zonal cold store to cold stores in local government areas (LGAs), and to health facilities which have refrigeration facilities for vaccine storage at the ward level. Only health facilities, which can keep vaccines refrigerated, receive the direct intervention of VDD. Other health facilities which do not have refrigeration can benefit indirectly from the VDD because these health facilities are provided with the vaccines from health facilities which do.

3PL providers offer regular direct deliveries of vaccines. The deliveries were initially biweekly but later changed to monthly at the start of June 2017. The VDD targets the essential nine (9) vaccines; BCG, Measles, Yellow Fever, OPV, IPV, PCV, Tetanus, HBV, and Pentavalent.

Data:

We use the health-facility level data collected by the Health Management Information System through the District Health Information Software 2 (DHIS2). The DHIS2 data record monthly information on stock balance and stockouts of vaccines and other commodities from all the health facilities in Nigeria since 2013.

Because health facilities with refrigeration are the direct recipients of the VDD intervention, we focus on these health facilities, which compose the cold chain in Bauchi state, for our main analysis. To identify health facilities in the cold chain, we compare two sets of the list of health facilities. One is the census list of health facilities we obtained from the DHIS2 data, and the other is the restricted list of health facilities in the cold chain that we obtained from the 3PL provider in Bauchi state. If a health facility in the DHIS2 data is not listed in the restricted data from the 3PL provider, which means that the health facility is not the direct beneficiary of VDD, we eliminate that health facility from the main analysis.

Outcomes:

We look at three primary outcomes. The first one is the overall stockouts of any vaccines. The DHIS2 data contains a dummy variable, which indicates if any of the essential vaccines have stockouts. The second one is the stock balance of each type of vaccine. Due to the data availability and quality, we focus on four vaccines: BCG, IPV, OPV, and Pentavalent. The third outcome is the number of vaccines given for each type of vaccine. This outcome indicates the number of vaccinations given. Because the DHIS2 does not contain the information about the vaccination numbers for IPV, we focus on three vaccines; BCG, OPV, and Pentavalent. For each outcome, we have the information for each health facility for a particular month of the year.

Statistical Analysis:

Using the DHIS2 data for health facilities in the cold chain, we evaluate the effect of VDD on vaccine stockouts, stock balance, and number of vaccinations given, before and after the introduction of VDD.

To do so, we employ the interrupted time-series analysis approach. In particular, we compare the level and rate of the change in the outcome variable before and after VDD in the following regression framework;

$$y_{it} = \alpha + \beta_1 Time_{it} + \beta_2 After_{it} + \beta_3 Time\_After_{it} + v_i + \varepsilon_{it} \qquad (1)$$

Where y_{it} is an outcome variable such as vaccine stockouts and stock balance; $Time_{it}$ is the time since the initiation of the study; $After_{it}$ is a dummy variable that takes 1 if the VDD project is introduced after the time t; $Time\_After_{it}$ is an interaction term between $Time$ and $After$. We use the health facility fixed effect, v, to control for health facility-specific characteristics. β_1 identifies the time trend since the initiation of the study, before VDD introduction. β_2 indicates the change in the level of the outcome variable before and after the VDD introduction. Under our hypothesis that VDD decreases vaccine stockouts, we expect $\beta_2 < 0$ if the outcome variable is vaccine stockouts. β_3 captures the time trend after VDD introduction, which is additional to the time trend β_1 . $\beta_1 + \beta_3$ identifies the overall time trend of the intervention after its introduction. If we hypothesize that the introduction of VDD reduces the occurrence of vaccine stockouts more rapidly than was the case before VDD introduction, then β_3<0. Furthermore, if we hypothesize that VDD induces the gradual reduction of vaccine stockouts over time, then $\beta_1 + \beta_3 < 0$.

The interrupted time-series analysis has an important limitation. Under this approach, we cannot differentiate the effect of the VDD intervention from the effect of any other events, which might have taken place concurrently with VDD in the same region.

To eliminate the possibility that the change in outcome variables is caused by other factors than VDD, we conduct two sets of robustness checks. First, we use the stockouts of other commodities as the outcome variable in the same regression specification (1) and evaluate the VDD effect on the stockouts of other commodities. The VDD project should only affect the vaccine stockouts but not the stockouts of other commodities.

Second, we run the same exercise, using the data from a different state within the same region, where the VDD was not introduced. Among the north-eastern Nigerian states, of which Bauchi is one, it is only in Adamawa state that the VDD project was never introduced. We restrict the sample to health facilities equipped with refrigeration in Adamawa state and evaluate the hypothetical effect of the VDD intervention. With the absence of VDD, the period after July 2015, the initiation date of VDD in Bauchi state, should not be correlated with a reduction of vaccine stockouts in Adamawa state, if there is no other factor influencing it at the same time.

Results

Descriptive Statistics

There are 175 health facilities in Bauchi state which are equipped with refrigeration. The duration of the study period is from 2013 January to 2018 December. We selected this starting date because we do not have sufficient data points prior to this date in the DHIS2 data.

Table 1 shows the descriptive statistics on the prevalence of vaccine stockouts, the stock balance, and the number of vaccinations given per month before and after the initiation of VDD. The prevalence of the vaccine stockouts decreased from 38.9 percent to 17.2 percent. The stock balance increased for all the 4 vaccines, although mostly insignificantly. The exception is IPV; the vaccine stock significantly increased from 1.47 to 4.0 units. The number of vaccines given did not change before and after the intervention mostly, although the number of vaccinations given with pentavalent significantly increased from 86.45 to 91.92.

Effect of VDD Intervention

Figure 1 visually presents the trend of vaccine stockouts over time before and after the introduction of VDD. The vertical line at “2015A” indicates the initiation of the VDD intervention. Before the introduction of VDD, there seems already a negative trend in vaccine stockouts. After the intervention, the level of vaccine stockouts drops and the slope of the reduction of the vaccine stockouts seems to get steeper.

Table 2 (column 1) presents the effect of the VDD intervention on vaccine stockouts experienced by health facilities, employing the interrupted time-series analysis expressed in the specification (1). The main outcome is the dummy variable which indicates if a health facility experiences stockouts of any vaccines in a particular month. We found that, after the introduction of the VDD project, the prevalence of vaccine stockouts decreased by 9 percentage points on average. The slope of the reduction of vaccine stockouts got steeper by 0.4 percentage points per month after the intervention, more than the slope before VDD. Overall, vaccine stockouts significantly decreased by 0.5 (=0.4+0.1) percentage points per month after VDD introduction.

Table 2 (column 2) presents the first robustness check for the effect of the VDD intervention, focusing on the stockouts of other commodities. We examine the effect of the VDD project on the stockouts of anti-TB drugs. After the introduction of the VDD project, the prevalence of stockouts of anti-TB drugs was not significantly different from the stockouts before the project introduction. The prevalence of stockouts increased over time after the intervention by 0.4 percentage points by month more than before the introduction of the VDD project. The overall time trend of stockouts of anti-TB drugs after VDD, however, is not different from zero.

Table 3 presents the second robustness check, evaluating the stockouts in Adamawa state, where the VDD project was never introduced. After July 2015, which is the initiation date of the VDD project in Bauchi state, the vaccine stockouts in Adamawa state did not increase nor decrease (column 1). There is no differential time effect of the intervention on the slope of the change in vaccine stockouts between before and after the VDD project initiation. However, the time trend on vaccine stockouts after July 2015 is negative and significant.

After July 2015, the stockouts of anti-TB drugs did not increase nor decrease in Adamawa state (Table 3 column 2). There is no differential time effect on the stockouts between before and after the hypothetical intervention introduction. The time trend on stockouts of anti-TB drugs is not different from zero after 2015 July.

Table 4 presents the effect of the VDD intervention on the stock balance for each type of vaccine in Bauchi state, using the specification (1). The main outcome is the number of available vaccines (stock balance) for each type of vaccine in a health facility. Overall, VDD increased the average stock balance by the following amounts; 5.28 units for BCG, 3.97 for IPV, 18.60 for OPV, and 11.22 for Pentavalent. While the vaccine stock balance was decreasing during the early part of the study period, this trend of the decreasing stock balance was reversed after the VDD introduction.

Table 5 presents the effect of the VDD project on the number of vaccinations given in each health facility. We use the same specification as above. VDD did not induce a significant increase in the number of any vaccines given. Before the introduction of the VDD project, the number of vaccines given had been increasing. The trend has been reversed after the VDD introduction.

Discussions

Our study rigorously evaluates the effect of Vaccine Direct Delivery (VDD), an intervention which provides the logistic support for achieving the objective of ensuring the stock availability of vaccines in each health facility in a cold chain. Bauchi state government contract with third party logistic (3PL) providers for VDD. In northern Nigeria where the vaccination rate is low, evaluating the potential impact of interventions to reduce vaccine stockouts is crucial. This is because one of the main barriers to vaccination is supply-side constraints, including vaccine stockouts, and thus the reduction of vaccine stockouts can potentially have a large effect on the number of vaccinations given. This study contributes to the growing literature that emphasizes the importance of the stock availability of vaccines in Africa.

This paper finds that ensuring the availability of vaccine availability through VDD successfully and significantly decreases vaccine stockouts and increases the stock balance at health facility level. After the introduction of the intervention, the level of the vaccine stockouts decreased and the rate of the reduction in the vaccine stockouts got steeper over time.

Robustness checks strengthen the evidence of the significant effect of VDD on vaccine stockouts. In particular, we did not observe reduced stockouts of other commodities after the VDD introduction in Bauchi state. We also did not find any hypothetical effect of VDD on vaccine stockouts in Adamawa state where VDD was never introduced. These robustness checks confirm that the VDD intervention causally reduced vaccine stockouts and increased the vaccine stock balance.

While the VDD intervention was successful in increasing the vaccine stock balance, it had no effect on the number of vaccinations given. It is possible that it takes some time for the demand side to respond to the supply side intervention. If the demand for the vaccine is low, then the supply-side intervention such as VDD might have to be accompanied with demand-side intervention as well, to encourage the vaccine take-up from the demand side.

We also observe that the positive time trend of vaccination was reversed after the VDD introduction. It is possible that different types of constraint that health facilities face, other than vaccine stock management, makes the transformation from the vaccine stock to the actual utilization of the vaccines difficult. However, specific reasons for this reversal trend are not clear. Although the logistic intervention to ensure the availability of the vaccine stock has been effective in reducing vaccine stockouts in Bauchi state, future study needs to explore other potential barriers which hinder the vaccination coverage. In particular, we should actively think how to improve the system to provide the vaccination service to the population.

Limitations

The main limitation we face in this paper is the quality of data and data availability in the DHIS2 data. Especially in Adamawa state, we are unable to conduct robustness checks on vaccine stock balance and vaccination cases due to the unavailability of data. As we are unable to obtain the list of restricted health facilities with refrigeration facilities in Adamawa state, the robustness check using health facilities in Adawama state includes all the health facilities.

Conclusions

Vaccine Direct Delivery (VDD) interventions, which ensure the availability of vaccine stocks through a third-party logistics service contracted with state governments, significantly decrease the stockouts and increase the stock balance at health facility level. Future work needs to explore how to translate the improvement in reliable stock availability into an improvement in vaccination coverage.

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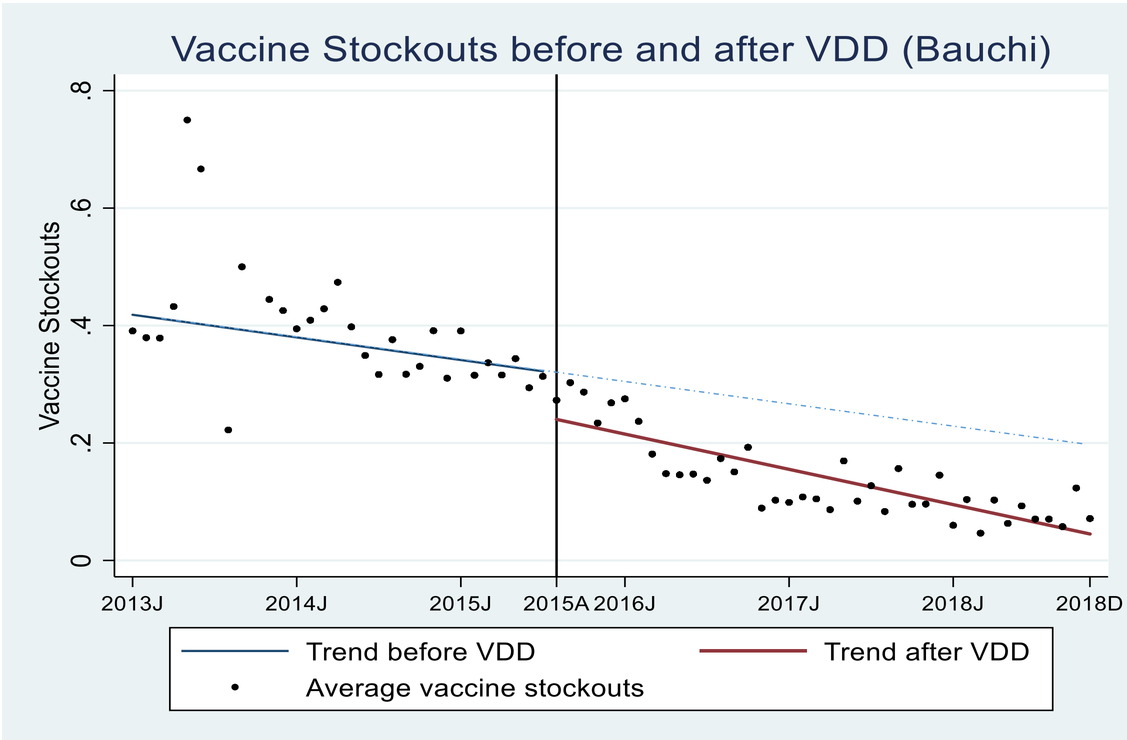
Figure 1: Effect of VDD on Vaccine Stockouts (%)



Notes: "Vaccine Stockouts" in y axis indicates the percentage of health facilities experienced the stockouts in a particular month.

Table 1: Descriptive Statistics on Vaccines

		Before VDD	After VDD	Difference (p=value)
		(1)	(2)	(3)
Stockout (any vaccines, 0/1)		0.389	0.172	0.000
Stock Balance (#)				
	BCG	5.231	6.953	0.378
	IPV	1.470	4.001	0.084
	OPV	10.629	13.33	0.318
	Pentavelent	6.625	9.281	0.242
# Vaccines given				
	BCG	30.867	30.63	0.924
	OPV	120.478	116.663	0.107
	Pentavalent	86.449	91.921	0.002

Notes: The data includes 175 health facilities in the cold chain in Bauchi state.

Table 2: Main Result (Bauchi)

	Stockouts	
	Vaccine	TB
	(1)	(2)
Time	-0.001	-0.003
	(0.002)	(0.002)
Intervention period (After)	-0.090***	0.032
	(0.034)	(0.034)
Time after interruption (Time_After)	-0.004*	0.004*
	(0.002)	(0.002)
Constant	0.417***	0.463***
	(0.032)	(0.040)
N	5964	5964
r2	0.085	0.003
Time+Time after interruption (p=value)	0.000	0.212

Notes: The sample includes 175 health facilities in the cold chain in Bauchi state. We include observations if the data for both "vaccine" and "TB" are available in a particular month."Vaccine": Stock out vaccine supplies in the past one month. "TB": Stock out of anti-TB drugs for 7 consecutive days in the last 1 month. * significant at 10%; ** significant at 5%; *** significant at 1%

Table 3: Robustness (Adamawa)

	Stockouts	
	Vaccine	TB
	(1)	(2)
Time	0.000	-0.001
	(0.003)	(0.003)
Intervention period (After)	-0.000	-0.055
	(0.033)	(0.037)
Time after interruption (Time_After)	-0.005	-0.000
	(0.003)	(0.004)
Constant	0.200***	0.594***
	(0.056)	(0.073)
N	3936	3936
r2	0.038	0.009
Time+Time after interruption (p=value)	0.000	0.574

Notes: The sample includes 138 health facilities in the cold chain in Adamawa state. We include observations if the data for both "vaccine" and "TB" are available in a particular month."Vaccine": Stock out vaccine supplies in the past one month. "TB": Stock out of anti-TB drugs for 7 consecutive days in the last 1 month. * significant at 10%; ** significant at 5%; *** significant at 1%

Table 4: Stock Balance (Bauchi)

	Vaccine Balance (in stock)			
	BCG	IPV	OPV	Pentavalent
	(1)	(2)	(3)	(4)
Time	-0.666**	-0.039	-2.507***	-1.390**
	(0.315)	(0.129)	(0.793)	(0.542)
Intervention period (After)	5.281*	3.967**	18.597***	11.216***
	(3.169)	(1.835)	(4.325)	(3.281)
Time after interruption (Time_After)	0.551*	-0.047	2.076**	1.165**
	(0.319)	(0.148)	(0.805)	(0.552)
Constant	24.598**	2.955	81.192***	45.722***
	(9.644)	(3.723)	(23.610)	(16.059)
N	6892	6892	6892	6892
r2	0.001	0.001	0.005	0.002
Time+Time after interruption (p=value)	0.207	0.167	0.001	0.025

Notes: The sample includes 175 health facilities in the cold chain in Bauchi state. * significant at 10%; ** significant at 5%; *** significant at 1%

Table 5: Number of vaccines given (Bauchi)

	BCG	OPV	Pentavalent
	(1)	(2)	(3)
Time	0.484***	2.795***	2.746***
	(0.155)	(0.458)	(0.409)
Intervention period (After)	3.393	2.593	6.187
	(2.995)	(5.538)	(3.855)
Time after interruption (Time_After)	-0.773***	-4.011***	-3.711***
	(0.189)	(0.488)	(0.434)
Constant	18.457***	52.751***	20.658**
	(4.514)	(10.700)	(10.051)
N	6558	6558	6558
r2	0.002	0.069	0.083
Time+Time after interruption (p=value)	0.000	0.000	0.000

Notes: The sample includes 175 health facilities in the cold chain in Bauchi state. * significant at 10%; ** significant at 5%; *** significant at 1%