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Preliminary results from direct-to-facility vaccine deliveries in Kano, Nigeria ☆

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ABSTRACT

Objective: As part of its vaccine supply chain redesign efforts, Kano state now pushes vaccines directly from 6 state stores to primary health centers equipped with solar refrigerators. Our objective is to describe preliminary results from the first 20 months of Kano's direct vaccine delivery operations.
Methods: This is a retrospective review of Kano's direct vaccine delivery program. We analyzed trends in health facility vaccine stock levels, and examined the relationship between stock-out rates and each of cascade vaccine deliveries and timeliness of deliveries. Analysis of vaccination trends was based on administrative data from 27 sentinel health facilities. Costs for both the in-sourced and out-sourced approaches were estimated using a bottoms-up model-based approach.
Results: Overall stock adequacy increased from 54% in the first delivery cycle to 68% by cycle 33. Conversely, stock-out rates decreased from 41% to 10% over the same period. Similar trends were observed in the out-sourced and in-sourced programs. Stock-out rates rose incrementally with increasing number of cascade facilities, and delays in vaccine deliveries correlated strongly with stock-out rates. Recognizing that stock availability is one of many factors contributing to vaccinations, we nonetheless compared pre- and post- direct deliveries vaccinations in sentinel facilities, and found statistically significant upward trends for 4 out of 6 antigens. 1 antigen (measles) showed an upward trend that was not statistically significant. Hepatitis b vaccinations declined during the period. Overall, there appeared to be a one-year lag between commencement of direct deliveries and the increase in number of vaccinations. Weighted average cost per delivery is US$29.8 and cost per child immunized is US$0.7 per year.
Conclusion: Direct vaccine delivery to health facilities in Kano, through a streamlined architecture, has resulted in decreased stock-outs and improved stock adequacy. Concurrent operation of insourced and outsourced programs has enabled Kano build in-house logistics capabilities.

1. Introduction

Although vaccination remains one of the most cost effective life-saving public health interventions [1], immunization coverage rates in Nigeria remain low and inequitable, with northern zones of the country significantly under-performing southern zones [2]. As such, Nigeria remains a large contributor to the global burden of vaccine preventable diseases and associated childhood deaths [3]. Weak vaccine supply chains that fail to guarantee reliable and uninterrupted availability of vaccines at service delivery points are widely recognized as a key barrier to immunization system performance in Nigeria and elsewhere [4–10]. An Effective Vaccine Management (EVM) assessment of Nigeria's vaccine supply chain revealed significant weaknesses, with only one out of nine assessed criteria achieving the ⩾80% threshold between 2010 and 2014 [7].

As of 2012, Kano, despite being the largest and most populous state in northern Nigeria and the epicenter of the country's polio transmission at the time, was experiencing major failures in its vaccine supply chain system. In addition to gaps in cold storage capacity, the government-run vaccine distribution system was largely ineffective, characterized by inadequate and unreliable funding, a complex multi-layered architecture that depended on several decision-makers at the state, LGA and health facility levels, and a poorly executed mixed push-pull distribution mechanism [11,12]. The vaccine supply chain could neither support the

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improved routine immunization coverage that was necessary to prevent a resurgence of polio in the state, nor accommodate the planned introduction of new vaccines [8,13].

Evidence from several countries show that streamlining vaccine supply chain architecture by reducing the number of layers involved in the storage and distribution chain increases efficiency and saves cost [4,5,14–19]. In addition, outsourcing of vaccine distribution has been shown to significantly reduce the inefficiencies that are typical of government-run systems, resulting in improved overall performance, decreased costs, and strengthened in-house government capacity to manage the supply chain [6,14,15,19].

The institution of a tripartite memorandum of understanding (MoU) to strengthen routine immunization between the Kano State Government, Bill and Melinda Gates Foundation and Dangote Foundation in November 2012 [20], provided a platform and funding to reorganize Kano's vaccine supply chain system, in line with UNICEF and WHO's comprehensive EVM framework including a four-step strategy for continuous immunization supply chain improvements, quality management, optimization and innovation [21]. In addition to the funding, the tripartite MoU stimulated political will and commitment which is key to the success of the transformation program. As part of interventions funded through the basket funds occasioned by the MoU, the state's vaccine storage and distribution architecture was redesigned such that vaccines are pushed directly from 6 state stores to primary health centers equipped with solar refrigerators, bypassing the 44 Local Government Authority (LGA) cold stores. In line with the national policy of one fully equipped and functional Primary Health Center per political ward [22], one health facility is equipped with solar refrigerators in each ward and vaccines are 'cascaded' to other health facilities in the ward weekly by designated ward technical officers (WTOs) as illustrated in Fig. 1B.

Two distribution systems are being implemented in parallel in Kano. From May 2014, the state outsourced distribution of vaccines from the state satellite stores to health facilities in four of its six sub-state zones (Bichi, Nasarawa, Rano and Wudil) to a third party logistics (3PL) provider. In September 2014, the state commenced in-house distribution to the remaining two sub-state zones (Dawakin Tofa and Gwale). Both the out-sourced and in-sourced programs implemented biweekly deliveries from the central state store until August 2015, when the programs were transitioned to monthly deliveries from the state central cold store and 5 state satellite stores to reduce overall program costs and better align with the state's administrative structures.

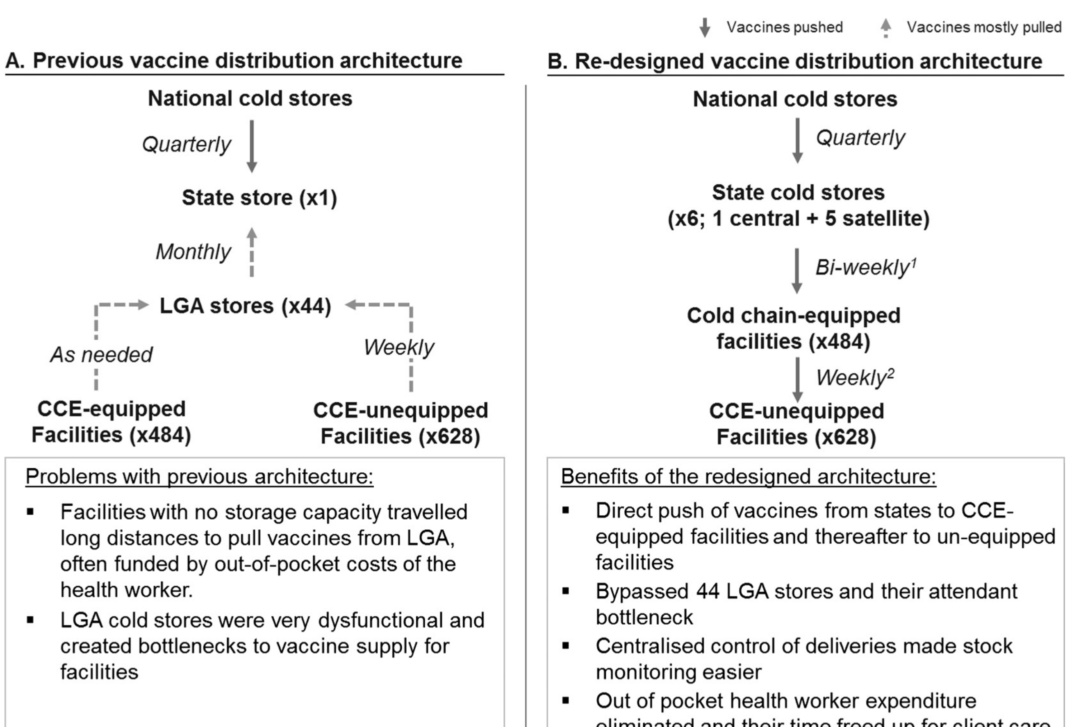
The objective of this paper is to describe the preliminary results from Kano's direct delivery operations. We do not, however, discuss in detail the broader contextual considerations in the immunization program and local political economy that would influence decisions or guide implementers and policy makers on approaches for implementing direct vaccine deliveries.

2. Methods

This study is a retrospective review of data on the performance of the direct vaccine delivery program as of January 2016 (following 20 months of implementation).

2.1. Data collection

Quantitative and qualitative data was collected from stakeholders in both the in-sourced and out-sourced vaccine delivery operations, and from frontline health workers, by trained personnel. Stock data for all 7 vaccines included in Nigeria's routine immunization schedule was obtained through physical stock counts by vaccine distributors during deliveries to each cold chain-equipped health facility, and verified through random spot checks by the review team. Delivery completion and timeliness data was obtained from daily vaccine delivery reports completed by vaccine



1. Deliveries occurred bi-weekly between Q2 2014 and Q3 2015, and monthly thereafter
2. Weekly '**cascade deliveries**' are carried out by ward focal persons (cadre of health workers at facilities) who push vaccines from equipped to unequipped health facilities.

Fig. 1. Vaccine supply chain architecture re-design in Kano.

distributors and counter-signed by health facility personnel. Vaccination data was obtained directly from immunization tally sheets at 30 representative health facilities selected through a multistage stratified random sampling, by a team of trained data collectors.

Cost data was obtained for the out-sourced distribution program from expenditure reports and interviews of the 3PL personnel. For the in-sourced program, we computed program costs from a market survey of cost items and interviews with government program officials as the state does not specifically track many of the costs incurred for implementing its program (e.g., staff salary costs, office space). Capital costs were amortized to reflect annual costs.

Qualitative data was obtained through targeted key informant interviews and focus group discussions with relevant stakeholders using structured questionnaires. End-user perspectives were obtained from 8 health facility personnel and immunization focal persons at selected health facilities. Information on program success factors and challenges was collected from 8 members of Kano State management team, 2 staff of the private distributor and 2 representatives of immunization implementing partner organizations.

2.2. Data analysis

All quantitative data was entered in Microsoft excel® databases and analyzed in Stata 13® SE. The primary outcomes for effectiveness were stock out and stock adequacy rates. The stock adequacy rate is a variation of the stocked-according-to-plan rate[23]. To determine stock out and stock adequacy rates for each delivery cycle, each antigen stock balance prior to top up was categorized as stocked out; (completely exhausted), below buffer (less than one week of stock for the target population of that health facility and any cascade facilities but not stocked out); or adequate (at or above the buffer level of one week of stock). With each health facility thus contributing 7 vaccines, the total proportion of vaccines falling in each of the three defined categories across all supplied health facilities was computed as follows:

Stock out rate

$$= \frac{No.\ of\ \ vaccines\ stocked\ out\ across\ all\ supplied\ health\ facilities}{No.\ of\ \ vaccines\ (i.e7) * total\ health\ facilities\ supplied}$$

Below buffer rate

$$= \frac{No.\ of\ \ vaccines\ below\ buffer\ level\ across\ all\ supplied\ health\ facilities}{No.\ of\ \ vaccines\ (i.e7) * total\ health\ facilities\ supplied}$$

Stock adequacy rate

$$= \frac{No.\ of\ \ vaccines\ at\ or\ above\ buffer\ level\ across\ supplied\ health\ facilities}{No.\ of\ \ vaccines\ (i.e7) * total\ health\ facilities\ supplied}$$

Stock out, stock adequacy and stock below buffer rates were tracked for each delivery cycle and simple linear regression models were fit to identify any trends and test for significance of the trend slopes. Trends in stock-out and stock adequacy were examined for the overall program and separately for the in-sourced and out-sourced programs. To determine the effect of cascade deliveries on stock-out rates in the cold chain-equipped facilities, we fitted an ANCOVA model with stock-out rates as the dependent variable, number of cascade facilities as independent variable and cycle as the covariate. We also examined the relationship between timeliness of vaccine deliveries and stock-out rates by computing a Pearson correlation coefficient, *R*.

Understanding that a complex array of factors contribute to the vaccination process, we nonetheless wanted to understand if any significant changes in vaccination rates occurred after the direct deliveries were initiated. We analyzed vaccination administrative data from 27 facilities pre- and post- receiving direct deliveries for which we had complete data for the period January 2013 through September 2015. 30 sentinel facilities were selected using a multi-stage stratified random sampling. First, facilities with functioning cold chain equipment at the start of the direct delivery intervention were stratified based on who delivered vaccines to them - the state or the private vendor. Facilities in each group were further stratified based on geographic distribution into urban and rural locations. Facilities were then randomly selected in each stratum to achieve a ratio of 2 (rural) to 1 (urban), reflecting the approximate overall distribution in the state. That said, a key limitation of this study is that the impact of vaccinations findings from the sentinel facilities are not generalizable to the entire state. 3 selected facilities were excluded from the final analysis due to significant gaps in their vaccination data. For each of 6 vaccines (BCG, OPV_3, $Penta_3$, yellow fever, measles and Hepatitis B vaccine), we analyzed trends in total monthly vaccinations in all 27 health facilities, and performed formal tests of significance of the slopes. We compared average total monthly vaccinations for October 2013 to September 2014 with the period October 2014 to September 2015 to determine if implementation of the direct deliveries was associated with any changes in vaccinations.

Approximate costs for both the out-sourced and in-sourced distribution approaches were determined using a bottom-up modelling approach. Key inputs into either program were identified through interviews and program expenditure reports where available and fair costs were determined for each input based on local market surveys. Based on these fair market prices, we determined the costs per cycle, costs per delivery and total annual costs to the state of the overall program and stratified by in-sourced versus out-sourced delivery program. In addition, we identified the major determinants of costs in each distribution approach.

3. Results

390. of the 484 political wards in Kano state had cold chain-equipped health facilities as at the time of review and were included in this study. Direct delivery data was obtained and analyzed for a total of 20 months for the out-sourced program (comprising 27 biweekly and 6 monthly cycles) and 17 months for the in-sourced program (comprising 20 biweekly cycles and 6 monthly cycles). The 2 state zones being supplied by the state covered 158 political wards and had 142 cold chain-equipped and 212 cascade health facilities (ratio 1:1.5). The 4 outsourced state zones covered 326 political wards with 248 equipped and 454 cascade facilities (ratio 1:1.8).

3.1. Vaccine stock performance

Fig. 2 shows the overall trends in stock adequacy, below buffer and stock out rates across all supplied health facilities between May 2014 when direct deliveries commenced and January 2016. Overall stock adequacy increased from 54% in the first delivery cycle to 68% by cycle 33. Conversely, stock-out rates decreased from 41% to 10% over the same period, even as the number of health facilities served increased from an initial quarterly average of 90 to 408 by January 2016. Similar trends were observed in analysis restricted only to facilities that had cold chain equipment at the start of the intervention, with stock-outs decreasing from 40% to 13%, and stock adequacy increasing from 46% to 70% over the period.

Results of analysis of trends in stock adequacy and stock-out rates are shown in Table 1. Overall, there is a statistically significant downward trend in stock-out rates (slope −0.48, $p = 0.005$). There is a slight statistically insignificant upward trend in stock adequacy rates overall. In the disaggregated analysis, stock-out rates trended downwards (slope −0.49, $p = 0.001$) and stock

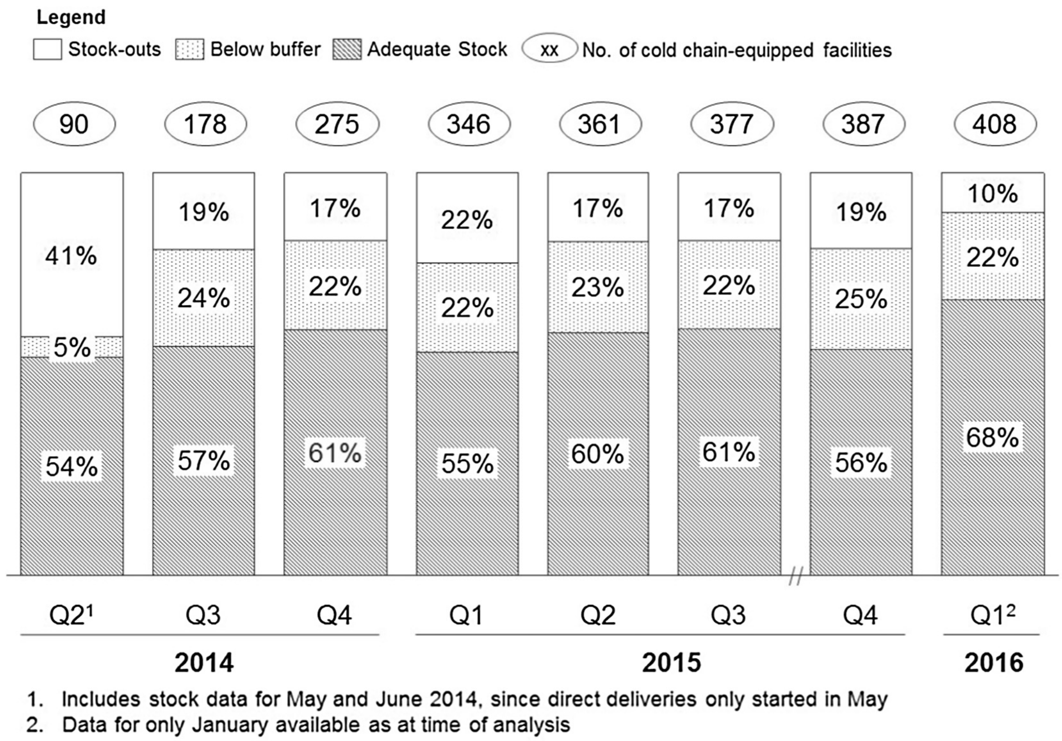


Fig. 2. Aggregate quarterly stock levels in health facilities receiving direct vaccines deliveries in Kano. Deliveries occurred bi-weekly between Q2 2014 and Q3 2015, and monthly thereafter.

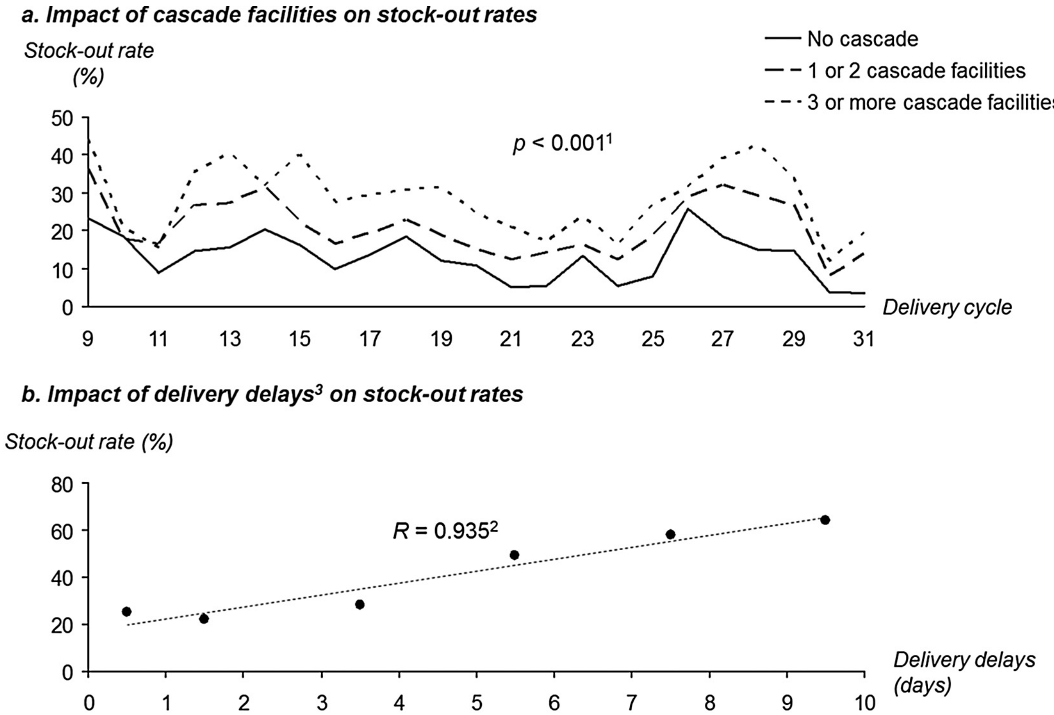
Table 1
Slope of vaccine stock performance trend line.

Delivery model	Number of cycles	Stock-outs		Below buffer		Adequate stock	
		Slope	p-Values[a]	Slope	p-Values[a]	Slope	p-Values[a]
All cycles							
Combined	33	−0.48	0.005	+0.41	0.111	−0.07	0.789
Insourced	26	−0.49	0.001	−0.73	0.006	+1.22	0.002
Outsourced	33	−0.33	0.110	+0.40	0.192	−0.07	0.828
Excluding outlier cycles[b,c,d]							
Combined	28	−0.65	<0.001	+0.59	<0.001	+0.10	0.627
Insourced	21	−0.52	0.004	−0.79	0.018	+1.31	0.007
Outsourced	28	−0.55	0.005	+0.53	<0.001	+0.02	0.936

[a] 2 Sided test of null hypothesis that slope = 0 at alpha of 0.05.
[b] Cycle 9 excluded because of poor performance following 5 days delays in commencement of the delivery cycle due to state wide stock-out of 5 antigens.
[c] Cycle 16 (Feb 2015) excluded due to outlier poor performance following 2 missed cycles caused by state-wide health worker strikes.
[d] Cycles 28, 29 and 30 excluded due to poor performance caused by back to back transitions from bi-weekly to monthly deliveries and from one state store to six satellite stores.

adequacy trended upwards (slope 1.22, p = 0.002) in the in-sourced program. Trends in both stock-out and stock adequacy were not statistically significant in the out-sourced program. Reanalysis of the trends excluding 5 cycles with outlier performance due to factors external to the direct delivery programs (health worker strikes, transition from one to six state stores) yielded statistically significant downward trends on both outsourced and insourced programs. It is unclear why the outsourced program may be more sensitive to these external disruptions. Notably, while the below buffer rates decreased in the insourced program, it increased in the outsourced program. It is important to note that even though below buffer status meant vaccine stock was low in the health facilities, vaccines were available for immunization activity.

To determine the effect of cascade deliveries on stock performance, equipped facilities were grouped into three categories – those who do not cascade vaccines (n = 91), those who cascade to 1 or 2 other facilities (n = 175), and those who cascade to 3 or more facilities (n = 68). One-way analysis of covariance showed a significant effect of cascade category on stock-outs, after controlling for cycle, ($F(3, 65) = 18.02$, $p < 0.001$). Results of the Tukey post hoc test showed that stock-out rates rose incrementally with increasing number of cascade facilities. The 1 or 2 cascade facility group had higher stock-out rates than the no cascade group (7.99 ± 2.29%, p = 0.002). Stock-out rates further increased with the 3 or more cascade facility group, compared to the 1 or 2 cascade facility group (by 7.46 ± 2.29%, p = 0.005). Also, as shown in Fig. 3, delays in vaccine deliveries correlated strongly with stock-out rates ($R = 0.935$). 78% of deliveries on the outsourced program were timely. No timeliness data was available for the insourced program.



1. One-way ANCOVA testing difference between mean stock-out rates across the three groups.
2. Pearson's correlation coefficient between delivery delays (in days) and stock-out rates.
3. Deliveries are on time if completed on the scheduled day; otherwise, they are delayed

Fig. 3. Impact of cascade deliveries and delivery delays on stock-out rates.

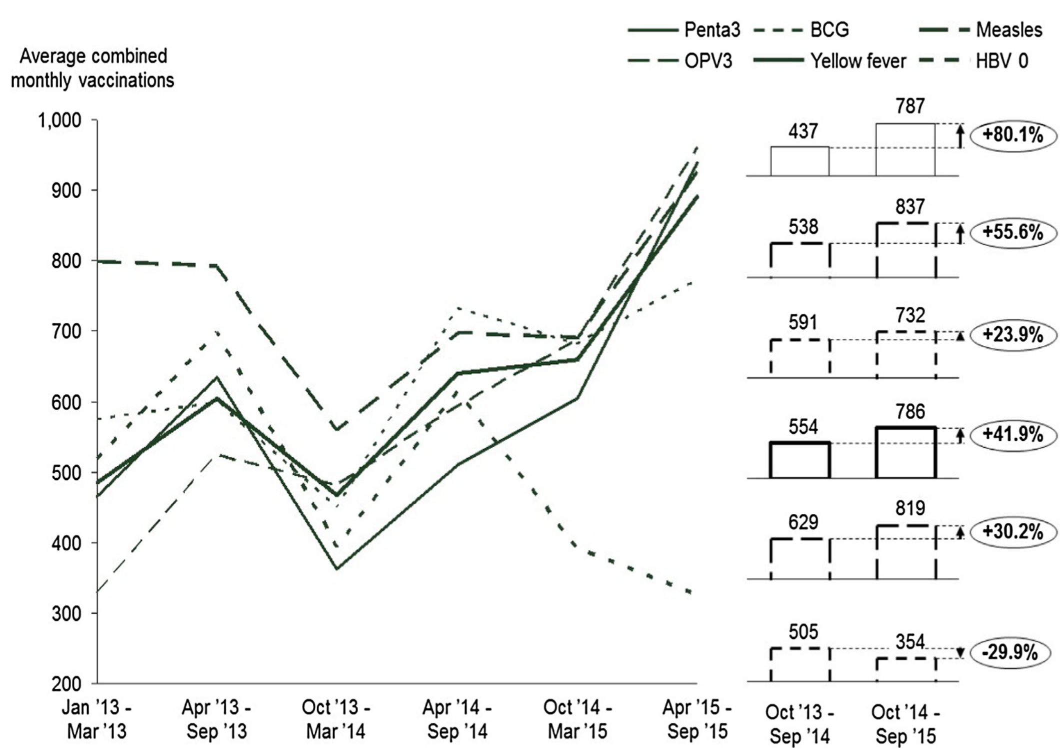


Fig. 4. Trends in vaccinations in health facilities receiving direct vaccine deliveries.

3.2. Vaccinations

Trends in vaccinations in selected facilities during the review period are graphed in Fig. 4. We used simple linear regressions to test for linearity and determine the slope of the change for each vaccine antigen. Four vaccines: Penta 3 (slope = 12.8, $p = 0.003$); OPV 3 (slope = 18.5, $p < 0.001$); BCG (slope = 8.4, $p = 0.001$); yellow fever (slope = 12.1, $p = 0.001$) showed significant upward trends.

Measles vaccinations also showed an upward trend but it was not statistically significant (slope = 3.7, p = 0.327). Hepatitis B vaccinations declined significantly during the review period (slope = −10.3, p = 0.004). A comparison of absolute vaccination numbers between two periods – October 2013 to September 2014, and October 2014 to September 2015 – showed absolute gains of between 24% and 80% across all vaccine vaccines except hepatitis b, which dropped by 30%. Overall, there appeared to be a one-year lag between the commencement of the direct delivery intervention and the increase in number of vaccinations.

3.3. Cost

A summary of the estimated costs of the Kano direct delivery program is presented in Table 2. Total cost of operating the biweekly deliveries for a year is US$372k, 32% of which goes for capital expenses. While the annual cost of the insourced program is US$104k, the outsourced program costs US$268k. The difference largely reflects the significantly larger scale of the outsourced program. Overall, the weighted average cost per delivery is US$29.8. Also, overall cost per child immunized is US$0.7 per year.

Cost structures differed slightly between both programs. The top 3 contributors to program costs in the insourced program were vehicle depreciation, cascade deliveries and vehicle maintenance costs, contributing, respectively, 33%, 22% and 17%. In the outsourced program, the top 3 contributors to cost were personnel (27%), vehicle depreciation (26%) and cascade deliveries (18%). It is important to note that differences in terrains covered and distances covered limit the utility of direct comparisons between costs of the two models.

3.4. Other benefits

All health workers interviewed strongly approved of the direct delivery program, regardless of whether they were served by the insourced or outsourced model. One indirect benefit of direct vaccine deliveries frequently cited by interviewees is the elimination of the need for health workers to leave their duty posts to go collect vaccines. Frontline health workers can now focus their time on patient care and improved health facility management. Other potential benefits of the program worth examining by future studies include its effect on program data management capacity, and cold chain inventory management. Reverse logistics (waste collection) from service points is a complementary intervention that can be added to the direct delivery program.

Table 2
Summary of cost of Kano's direct vaccine delivery program.

	Insourced	Outsourced	Overall
Primary facilities	142	248	390
Cascade facilities	212	454	666
Annual program cost[a] (*USD thousands*[b])			
Vehicle depreciation	34.4	68.8	103.2
Cold chain equipment	3.7	6.7	10.4
Communication	0.4	3.6	4.0
Furniture	0.3	0.3	0.5
Capex	38.8	79.3	118.1
Personnel	11.9	72.1	84.0
Cascade deliveries	22.4	47.9	70.3
Trainings	0.4	0.8	1.1
Vehicle maintenance	17.3	35.1	52.3
Vaccine insurance	9.3	9.3	18.7
Office overhead	3.6	23.6	27.2
Opex	64.9	188.8	253.7
Grand total	103.7	268.1	371.8
Unit costs (*USD*[b])			
Cost per child[c]	0.6	0.8	0.7[f]
Cost per ward[d]	28.1	41.6	36.7[f]
Cost per delivery[e]	22.0	34.1	29.7[f]
No. of children	170,929	331,803	502,732
No. of wards	142	248	390
No. of deliveries	26	26	26

[a] Bi-weekly delivery costs for a year. Costs of insourced and outsourced not comparable as they are not on the same scale.
[b] Naira value converted to USD @197NGN/USD.
[c] Annual cost of vaccine distribution per child.
[d] Annual cost of distribution per ward – includes cost of cascade deliveries.
[e] Unit cost per delivery to a health facility.
[f] Cost are weighted insourced and outsourced scale.

4. Discussion

Results from the first 20 months of direct vaccine deliveries in Kano contribute to the literature on vaccine distribution architecture re-design, direct vaccine delivery to service delivery points and outsourcing components of vaccine distribution to the private sector. Although there are a number of model-based studies on architecture re-design [5,16–18], Kano joins only a few such efforts actually Implemented at scale [6,14,15,24].

The improvement seen in health facility vaccine stocks as the direct deliveries progressed is consistent with other reports and WHO recommendations [6,10,14,25,26]. However, differences in results between the insourced and outsourced programs point to an important consideration in supply chain outsourcing. The insourced program achieved both decreased stock-outs and increased stock adequacy, while the outsourced program shifted health facility stock performance largely from stock-outs into the below buffer category. This, as we found in interviews, is because the insourced program operators revised health facility stock allocations frequently to better match consumption, but the 3PL operators were unable to adjust stock allocations as frequently as was needed. The 3PL is held to account for timely deliveries and effective vaccine management practices, while the state retained overall responsibility for stock adequacy in facilities. It is clear that for outsourcing of vaccine distribution to be maximally effective, the 3PL needs to be given full responsibility for stock performance in the facilities and an upstream role in health facilities stock allocations. This is especially important in scenarios such as in Kano where vaccine consumption is rapidly evolving due to such factors as number of cascade facilities or changing demand due to population migration. Where vaccine consumption is well defined and relatively fixed, biweekly deliveries are not any more effective than monthly deliveries, as long as the storage capacity exists in health facilities for monthly supplies. However, more frequent deliveries work better when the optimal consumption levels are not well defined or in circumstances where demand for vaccines is labile, as shorter intervals between deliveries reduce impact on stock performance.

Although we cannot necessarily generalize trends in the few sentinel facilities to the entire state, it is encouraging nonetheless that vaccinations are trending upwards. Also, vaccinations in the sentinel facilities rose as vaccine stocks improved, but it is important to note that improved stock alone is often inadequate to increase vaccinations. In Kano, other interventions occasioned by the tri-partite MOU, like improved funding for outreaches and better supportive supervision, were ongoing at the same time, and presumably contributed to the increase in vaccinations observed. The decline in hepatitis b vaccinations during the review period was due to a policy mishap, where an attempt by the government to promote administration of hepatitis b vaccine to newborns within first 24 h of life [27] was misconstrued by health workers as a directive to not administer beyond 24 h. The one year lag before vaccinations started to rise following improvement in vaccine availability in health facilities could be due to the slow reestablishment of trust in the health system, following a prolonged history of eroded confidence and dampened demand for immunization services by the communities [28,29].

Our bottom-up estimates of the delivery costs for the insourced and outsourced programs serve only as a guide for planning in similar settings, and both costs may not be directly comparable for two reasons – the costs are outside-in estimates based on average market prices of program inputs and may not precisely reflect actual costs incurred by these programs; and the insourced cost estimates exclude costs associated with technical assistance provided to the state-run program by multiple development partners, which is significant. Furthermore, several factors impact the cost-competiveness of each option. For example, the private distributor landscape is nascent with few players, and the vendor in this case is a non-profit organization. Variations in local salaries and operating costs will significantly impact costs of both options.

This study has a number of limitations. The 27 health facilities from which vaccination data was obtained are few compared to the total number of facilities in Kano, and as such, the findings may not be generalizable to the entire state. Secondly, we made an effort to ensure accuracy of the vaccination data by collating directly from immunization registers and vaccination tally sheets, but we recognize that quality concerns with administrative immunization data remain. Also, multiple confounding factors were at play that make attribution of the increase in vaccinations to direct deliveries alone inappropriate. Because the security challenges in the northeastern parts of Nigeria have caused migration of displaced persons to more stable states including Kano, there might have been changes in the catchment population of some of these facilities, making any inferences about coverage inappropriate.

5. Conclusion

We have outlined the results of the direct vaccine delivery program in Kano. However, policy makers and implementers need to interpret these findings and make program decisions that take into account their own broader contexts to ensure ownership and sustainability.

Direct vaccine delivery to health facilities in Kano, through a streamlined supply chain architecture, has benefitted the routine immunization program in a number of ways. Stock-outs have decreased in cold chain equipped health facilities, and preliminary data suggests that more children are being vaccinated. Data collection during deliveries has enabled full visibility into health facility stock levels, which aids program planning and decision making. Frontline healthcare workers, who hitherto spent valuable time and money picking up vaccines, now report dedicating more of their time to direct patient care. Furthermore, concurrent operation of both insourced and outsourced programs has enabled Kano to build in-house capabilities in vaccine logistics, while benefiting from private sector innovations.

As newer, more expensive vaccines are introduced into national EPI programs and existing supply chain systems are further stretched, reformer governments can improve their capacity and drive innovation through partnerships with the private sector. Decisions on outsourcing of vaccine logistics and distribution require an appraisal of the local 3PL landscape, as many poorly resourced settings may have an inadequate pool of existing competent options [13,30]. In addition, sustainable and reliable funding is required to manage third party contracts—something that the MOU in Kano has provided for the past four years, but that the State will need to continue post MOU from 2017 onwards.

Authorship

MA and UI conceptualized the study and developed the methodology. LJ, RF, AT and NM collected the data and participated in its analysis and interpretation. MA and UI developed the manuscripts while all authors provided critical review and approved the final version.

Conflict of interest

MA, UI and LJ are consultants engaged to support Kano state's routine immunization program. RF and NM are officials of Kano state government directly involved in the insourced distribution program. AT is an employee of the 3PL engaged to run the outsourced program. To mitigate the potential conflicts of interest, all authors were involved in the review and vetting of data and manuscript for accuracy.

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