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RESEARCH ARTICLE

COST EFFECTIVENESS OF CONTRACTING OUT VACCINATION SERVICES IN TWO DISTRICTS OF SINDH, PAKISTAN

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ABSTRACT

OBJECTIVES

To determine the differences in costs of providing vaccination services in contracted and non-contracted primary care facilities, and to analyze their effectiveness using vaccination volume data

DESIGN

Comparative case study

SETTING

The study was conducted from October to December 2024 in two contracted and two non-contracted districts in Sindh Province, Pakistan. Five primary healthcare centers were selected from each district. The CORE PLUS tool was used to estimate the costs.

MAIN OUTCOME MEASURES

Data on actual vaccination volumes, standard treatment guidelines, catchment population, staff salaries, vaccines and supplies, work distribution time, and operating costs were collected for a period of one year. Annual average costs and vaccination service volumes per 10,000 population were estimated and compared between contracted and non-contracted facilities. The incremental cost effectives ratio (ICER) was calculated by dividing the incremental costs by the incremental vaccination service volumes per 10,000 population.

RESULTS

The overall annual standard cost of vaccination services per 10,000 population was 14.8% higher in contracted facilities. Contracted facilities spent significantly more on salaries ($p=0.028$) and operating costs ($p<0.001$). A positive difference of 559.86 incremental vaccination doses per 10,000 population was observed in contracted facilities. The incremental cost effectiveness ratio (ICER) indicates that to provide one extra dose of vaccine, an additional $US1.87 were spent in contracted facilities. Average cost per DALY averted was $US137.12, which was within the threshold for contracting out to be a cost-effective intervention.

CONCLUSION

Contracting vaccination services resulted in higher service provision costs but was also effective in increasing service volumes.

KEYWORDS

cost effectiveness, contracting, vaccination services

INTRODUCTION

Childhood vaccination is one of the most important and cost-effective public health interventions for reducing child mortality, saving between 3.5 and 5 million lives annually [1]. However, one in every five children still lacks access to vaccines, with the majority residing in low and lower middle income countries [2]. Expanding vaccination coverage among underserved populations in these countries is currently a top propriety to achieve the global goal of vaccines for all. Several demand-side and service delivery improvement interventions have been introduced to improve vaccination services in these settings. One such intervention is contracting out the management of services. The evidence on the effect of contracting on vaccination coverage, however, remains mixed. While some studies reporting significant benefits [3-5], others show no substantial effect [6,7]. Vaccination coverage in Pakistan ranges from 66% to 76.5%, while in Sindh province, it is around 49% to 64.7% [8-10]. To address the low coverage in Sindh, the management of the vaccination program was contracted out to a private non-government organization in two districts in 2017 [11]. While most studies assess the effectiveness of different interventions by evaluating service delivery indicators, there is limited evidence on the costs and cost effectiveness of these approaches [12]. Such studies are important to support planning and budgeting in low-resource settings. This study examines the differences in the costs of providing vaccination services in contracted and non-contracted primary care facilities and analyzes their effectiveness using vaccination volume data from both types of facilities.

METHODOLOGY

The study was conducted from October to December 2024 in two contracted districts (Dadu and Khairpur) and two non-contracted districts (Larkana and Sukkur). Twenty Basic Health Units (BHUs), which are the main primary healthcare centers in rural areas, were selected, including 10 contracted and 10 non-contracted facilities. One data collector, MBBS doctors, were hired and trained to collect data from each district. Data collectors submitted completed forms to the Principal Investigator in Karachi daily, who provided regular feedback on data quality. During the review process, completeness and accuracy was ensured. The data was stored in excel file. Data was collected for the period from July 2023 to June 2024.

To estimate the costs of providing vaccination services at the selected facilities, the CORE PLUS tool was used. This tool has been applied in several developing countries to estimate the costs of various primary healthcare services [13-16]. It calculates standard costs for different service categories based on the number of services provided in accordance with standard treatment guidelines (STGs). Separate CORE Plus files were developed for each BHU, incorporating data on actual annual vaccination volumes, STGs, the list and cost of vaccines included in the vaccination program, as well as catchment population, staff salaries, work distribution time, and operating costs. Vaccination volumes were obtained from routine BHU records. These included all vaccines administered to children from birth to 15 months of age: Bacillus Calmette Guerin (BCG), Hepatitis B, oral polio vaccine (OPV), injectable polio vaccine (IPV), pentavalent (PV), pneumococcal vaccine (PCV), rotavirus vaccine, measles-rubella (MR) vaccine, and typhoid conjugate vaccine (TCV). STGs defined the time required by each vaccinator to provide a specific service and the supplies needed. To calculate work distribution time, onsite interviews were conducted with the vaccinators to determine the average time spent on direct service delivery (e.g., administering vaccines) and administrative tasks (e.g., staff meetings, reporting, vaccine inventory maintenance, and temperature charting).

Vaccine prices were obtained from UNICEF's vaccine pricing data as of December 31, 2023 [17]. The information on the catchment populations, staff salaries, and operating costs was collected from the vaccination program's administrative office. Operating costs included utilities, stationery, transport, repairs, and maintenance.

The study was approved by the Institutional Review Board of Dow University of Health Sciences (IRB No. DUHS/IRB/2024/198). Official permission was obtained from the Director General Health Services Sindh to conduct the study.

DATA ANALYSIS

Costing analysis is performed to identify the context-specific needs for adequate resource allocation and financial sustainability. The bottom-up approach for costing services identifies all resources required to provide a service in a given period of time and also explores the cost drivers, including both direct and indirect costs [18-20]. Additionally, cost effectiveness analysis helps in comparing the costs and outcomes of two different interventions. This analysis helps identify the more effective approach in terms of service volumes and any associated incremental costs [21].

For the costing analysis, since the catchment populations of the selected facilities ranged from 10,210 to 44,000 people, overall costs and vaccination volumes were standardized per 10,000 population. This was done by dividing each facility's total estimated costs and volumes by its catchment population and then multiplying by 10,000. The average annual standard cost of vaccination services, along-with a breakdown into salaries, vaccines and supply costs, and operating costs, was compared between contracted and non-contracted facilities. The percentage difference in expenditure was calculated by dividing the non-contracted facility expenditures with those of contracted facilities. The average cost per service (overall and by vaccine) and the average number of vaccinators available per 10,000 population were also estimated and compared. Differences in average service volumes and staffing were analyzed using the Independent T-Test. All cost estimates, which did not meet the assumptions of normality, were compared using the Man-Whitney U Test. A p-value of <0.05 was considered statistically significant.

To assess cost effectiveness, the incremental cost effectives ratio (ICER) was calculated by dividing the incremental costs by the incremental vaccination service volumes per 10,000 population. Incremental costs were obtained by subtracting the average costs per 10,000 population in non-contracted facilities from those in contracted facilities. Similarly, incremental vaccination service volumes were computed by subtracting the average vaccination doses per 10,000 population in non-contracted facilities from those in contracted facilities.

DALYs averted per vaccine dose were estimated using the data from the global burden of disease data, vaccine efficacy figures, and coverage duration assumptions relevant to lower middle income countries. Estimates for Hepatitis B, PV, Rota, PCV and MR were acquired from Vaccine Impact Modelling Consortium (VIMC) data (22-23). For BCG, OPV, IPV, TCV, DALYs averted per dose were derived from literature-supported assumptions (24-28). Table 1 provides details of these assumptions. Cost per DALY averted was derived by dividing each vaccine's ICER by its estimated DALYs averted per dose. This allowed direct comparison with cost-effectiveness thresholds. All estimated costs were converted from Pakistani rupees (PKR) to US dollars (US$) based on exchange rate as of December 31, 2023, with one US$ equal to 281.5 PKR.

TABLE 1: ASSUMPTIONS USED TO ESTIMATE DALYS AVERTED PER VACCINE DOSE

Vaccine	Source	Conversion
BCG	Trunz BB 2006 (24) Menzies NA 2021 (25)	Cases prevented per 100,000 doses: 40 DALYs per case: 12.1 DALYs per dose: (40 × 12.1) / 100,000 = 0.004
OPV	GPEI 2024 (26) Auzebbergs M 2025 (27)	1 case prevented per 625 doses DALYs per case=14 DALYs per dose: 14/625=0.022
Hep B	Toor J etal 2021 (22)	270 DALYs per 1000 fully vaccinated children with 3 Doses 90 per dose per 1000 children=0.09/dose
IPV	GPEI 2024 (26) Auzebbergs M 2025 (27)	1 case prevented per 625 doses DALYs per case=14 DALYs per dose: 14/625=0.022
ROTA	Toor J etal 2021 (22)	44 DALYs per 1000 fully vaccinated children with 2 Doses 22 per dose per 1000 children=0.022/dose
PENTA	Toor J etal 2021 (22)	160 DALYs per 1000 fully vaccinated children with 3 Doses 53.3 per dose per 1000 children=0.053/dose

PCV	Toor J etal 2021 (22)	190 DALYs per 1000 fully vaccinated children with 3 Doses 63.3 per dose per 1000 children=0.063/dose
MR	Toor J etal 2021 (22)	420 DALYs per 1000 fully vaccinated children with 2 Doses 210 per dose per 1000 children=0.21/dose
TCV	Phillips MT 2023 (28)	0.67 DALYs per 1000 doses=0.00067/dose

RESULTS

The availability of vaccination staff per 10,000 population was higher in contracted facilities compared to non-contracted facilities (Table 2). A significantly higher volume of services were provided by contracted facilities. The overall annual standard vaccination services costs per 10000 population were 14.8% higher in contracted facilities; however, this difference was not statistically significant (p=0.059). Vaccines and supplies accounted for nearly two thirds of the of the total costs (63.2% in contracted and 66.2% in non-contracted), followed by salaries and operating costs. While there was no significant difference in expenditures on vaccines and supplies (p=0.151), contracted facilities spent significantly higher on salaries (p=0.028) and operating costs (p<0.001).

TABLE 2: COMPARISON OF THE SERVICE VOLUMES, COSTS AND STAFFING OF VACCINATION SERVICES PER 10,000 POPULATION AT CONTRACTED AND NON-CONTRACTED FACILITIES

	Contracted Facilities Mean (SD)	Non-contracted Facilities	Percentage Difference	p-value
Average Service Volumes	5116.12 (596.42)	4556.26 (426.70)	+10.9	0.027
Average staffing	0.98 (0.32)	0.51 (0.11)	+47.9	0.001
Costs				
Average Salaries cost	US$=2393.62 (476.37) 33.6% of total costs	US$=1955.3 (448.6) 32.2% of total costs	+18.4	0.028
Average Vaccines and Supplies cost	US$=4502.31 (896.01) 63.2% of total costs	US$=4020.11 (922.47) 66.2% of total costs	+10.8	0.151
Average Operating Costs	US$=227.96 (45.37) 3.2% of total costs	US$=97.16 (22.29) 1.6% of total costs	+57.4	<0.001
Average Total Standard Cost per 10,000 population (Min-Max)	US$=7123.92 (1417.75) (5477-9401)	US$=6072.65 (1393.45) (4459-8800)	+14.8	0.059
Independent T-Test applied to compare service volumes Man-Whitney U Test applied to compare staffing and all cost				

No statistically significant differences were found in overall or individual average cost per service between the two groups (Table 3). The overall average cost per service was $US1.47 in contracted facilities and $US1.42 in non-contracted facilities. The highest average cost per service was observed for rotavirus vaccines, followed by IPV and TCV.

A positive difference of 559.86 incremental vaccination doses per 10,000 population was observed in contracted facilities (Table 4). Incremental volumes were particularly higher for OPV, PV, PCV and MR vaccines. The incremental cost effectiveness ratio (ICER) indicates that an additional $US1.87 was spent in contracted facilities to deliver one extra dose of vaccine. ICERs were particularly higher for rotavirus, IPV, TCV and Hepatitis B vaccines. The average cost per DALY averted was $US137.12.

TABLE 3: COMPARISON OF AVERAGE COST PER VACCINE DOSE IN CONTRACTED AND NON-CONTRACTED FACILITIES ($US)

	Contracted	Non-contracted	p-value
BCG	0.28 (0.07)	0.26 (0.09)	0.171
Hep B	1.22 (0.21)	1.16 (0.29)	0.129
OPV	0.20 (0.05)	0.19 (0.07)	0.183
PV	2.02 (0.21)	1.96 (0.29)	0.096
PCV	0.73 (0.21)	0.65 (0.25)	0.129
Rota	3.23 (0.21)	3.17 (0.29)	0.095
IPV	2.53 (0.21)	2.47 (0.29)	0.095
MR	0.78 (0.10)	0.74 (0.14)	0.118
TCV	2.23 (0.21)	2.17 (0.29)	0.095
Total	**1.47** (0.17)	**1.42** (0.22)	**0.105**
Man-whitney U Test applied			

TABLE 4: INCREMENTAL COSTS ($US) AND INCREMENTAL VACCINE DOSES PER 10,000 POPULATION IN CONTRACTED AND NON-CONTRACTED BHUS

	Annual Average costs (US$)			Annual Average service volumes					Cost per DALY averted
	C	NC	IC	C	NC	IV	ICER IC/IV	DALY/ Dose	ICER/DALY
BCG	77.29	66.86	10.43	267.07	257.56	9.51	1.09	0.004	**272.50**
Hep B	330.49	295.08	35.41	267.07	257.56	9.51	3.72	0.090	41.33
OPV	220.28	173.19	47.09	1034.48	912.18	122.30	0.38	0.022	17.27
PV	1674.27	1401.54	272.73	816.49	713.90	102.59	2.65	0.053	50.00
PCV	623.49	489.44	134.05	817.90	717.97	99.93	1.34	0.063	21.26
ROTA	1778.34	1566.71	211.63	545.81	496.86	48.95	4.32	0.023	**187.82**
IPV	1348.64	1235.29	113.35	531.07	501.85	29.22	3.87	0.022	**175.90**
MR	450.78	335.93	114.85	562.06	460.13	101.93	1.12	0.21	5.33
TCV	620.28	508.57	111.71	274.18	238.21	35.97	3.10	0.0067	**462.69**
Total Doses	7123.89	6072.65	1051.24	5116.12	4556.26	559.86	1.87		Average=137.12

C=Contracted, NC=Non-contracted, IC=Incremental Costs, IV=Incremental Volumes
ICER=Incremental Cost-effectiveness ratio
DALY=Disability adjusted life years
Red highlighted Costs/DALY indicate that values surpass thresholds recommended by Ochalek etal.

DISCUSSION

This study provides insights into the cost differences in the provision of vaccination services under two distinct management models and evaluates their effectiveness based on vaccination volumes achieved by each. Overall, expenditures in contracted facilities were significantly higher for salaries and operating costs. This additional expenditure contributed to better human resource availability and higher volumes of vaccination services. Incremental volumes were particularly greater for OPV, PV, PCV and MR, suggesting better continuity of vaccination post-birth in the contracted districts.
Although overall costs were higher in contracted facilities, the cost per service was nearly identical. This finding supports the concept of the economies of scale, whereby the cost per service decreases as service volumes increase due to greater operational efficiency [29]. As expected, the cost per service was highest for more expensive vaccines such as rotavirus, IPV, and TCV.

This study found that vaccines and supplies constituted almost two thirds of the total costs followed by salaries and operating costs. In contrast, other studies on costing of vaccination programs have reported salary expenditures to exceed vaccines and supply costs [30-33]. This discrepancy may be attributed to the broader scope of those studies, which included district and provincial level management and transport salaries as well as fewer vaccines in their programs. Since this study was conducted at the facility level, the vaccination and supply costs covering a package of nine different vaccines outweighed the salary costs, which only included the salaries of vaccinators.

The overall ICER was $US1.87, with values ranging from $US0.38 to $US4.32 for individual vaccines. As anticipated, higher ICERs were observed for more expensive vaccines. While few studies are available on incremental volumes of vaccination services resulting from contracting [3-5], there is no evidence available on cost effectiveness of contracting vaccination services. ICERs of other interventions aimed at improving vaccination coverage have ranged from $US0.66 to $US161.95 per child vaccinated, depending on the context, intervention costs, and the number of vaccines included. These interventions include community education campaigns [34-36], mop-up campaigns [37,38] and improvements in service availability [39].

The average cost per DALY averted was $US138.7, ranging from $US5.33 to $US462.69 across individual vaccines. According to the World Health Organization, an intervention is considered cost-effective if the cost per DALY averted is less than average GDP per capita [40], which was $US1574 for Pakistan in 2024 [41]. However, more recent thresholds account for country's economic capacity and health system feasibility, and recommend for a more conservative cutoff of $US138–175 per DALY averted for Pakistan [42]. Using both thresholds, the average cost per DALY averted shows that contracting out was a cost-effective strategy. Nevertheless, costs per DALY were higher for vaccines with a lower effect on DALYs- such as BCG, ROTA, IPV and TCV- exceeding the threshold suggested by Ochalek etal.

LIMITATIONS

There are a few limitations in the study that may have led to underestimation of costs. First, the cost estimates exclude district level management and supervisory costs, focusing only on staff directly involved in provision of vaccination services. Second, the cost analysis was conducted solely from the provider's perspective and did not include costs incurred by service users, such as travel and time. Third, only recurrent costs were considered; capital costs, such as infrastructure and equipment, were excluded. Although, UNICEF estimates for cost per vaccine dose account for expected wastage, actual wastage data for the evaluation facilities was not available. Additional limitations include small scale of the study; limited to catchment areas of 20 facilities; and the skewed nature of data, which restricted the performance of a sensitivity analysis.

CONCLUSION

Contracting vaccination services resulted in higher service provision costs but also proved to be effective in increasing service volumes. This study lay the foundation for conducting similar assessments on a larger scale and over a longer

duration of time in future to assess the feasibility and long-term benefits of scaling up contracting management of vaccination services. Similar exercises for other health service reforms should also be conducted to enhance the allocative and technical efficiency of health services.

References

1. Vaccines and Immunization. World Health Organization [cited 8th October 2024] Available from: https://www.who.int/health-topics/vaccines-and-immunization
2. Fast facts on immunization. Center for Disease Control 2023 [cited 16th January 2024]. Available from https://www.cdc.gov/globalhealth/immunization/data/fast-facts.html
3. Schwartz JB, Bhushan I. Improving immunization equity through a public-private partnership in Cambodia. Bull World Health Organ. 2004 Sep;82(9):661-7.
4. Heard A, Nath DK, Loevinsohn B. Contracting urban primary healthcare services in Bangladesh - effect on use, efficiency, equity and quality of care. Trop Med Int Health. 2013 Jul;18(7):861-70. doi: 10.1111/tmi.12113
5. Imtiaz A, Farooq G, Haq ZU et al. Public Private Partnership and Utilization Of Maternal And Child Health Services In District Abbottabad, Pakistan. J Ayub Med Coll Abbottabad. 2017 Apr-Jun;29(2):275-279. PMID: 28718247
6. Zaidi S. Private sector engagement to improve access and quality of primary healthcare in Sindh Technical Report Commissioned by World Bank 2021 [cited 27th January 2024]. Available from: file:///C:/Users/SYSTEMINN/Downloads/PPPSindhReport-FinalRevised Abridgedversion%20(1).pdf
7. Abbasi IN, Fatmi Z, Siddiqi S. Does contracting out lead to improvement in service volumes at primary and secondary health services? Evidence from rural districts of Sindh, Pakistan. J Pak Med Assoc. 2022 Oct;72(10):1947-1953. doi: 10.47391/JPMA.2235. PMID: 36660980.
8. National Institute of Population Studies. Pakistan Demographic Health Survey 2018 [cited 16th January 2024]. Available from: https://dhsprogram.com/pubs/pdf/FR354/FR354.pdf
9. Hussain I, Khan A, Rhoda DA, Ahmed I, Umer M, Ansari U etal. Routine Immunization Coverage and Immunization Card Retention in Pakistan: Results From a Cross-sectional National Survey. Pediatr Infect Dis J. 2023 Mar 1;42(3):260-270. doi: 10.1097/INF.0000000000003804. Epub 2023 Jan 2. PMID: 36728580; PMCID: PMC9935567.
10. Multiple Indicator Cluster Survey Sindh. Survey findings report 2018-19. Bureau of Statistics Planning and Development Board Government of Sindh and UNICEF [cited 16th January 2024]. Available from: https://reliefweb.int/report/pakistan/sindh-multiple-indicator-cluster-survey-2018-19-survey-findings-report-monitoring
11. PPHI Sindh Head Office Karachi, Sindh, Pakistan. PPHI Annual Report 2018-19 [cited 19th January 2024]. Available from: https://pphisindh.org/home/report-archive.php
12. Munk C, Portnoy A, Suharlim C, Clarke-Deelder E, Brenzel L, Resch SC, Menzies NA. Systematic review of the costs and effectiveness of interventions to increase infant vaccination coverage in low- and middle-income countries. BMC Health Serv Res. 2019 Oct 22;19(1):741. doi: 10.1186/s12913-019-4468-4. PMID: 31640687; PMCID: PMC6806517.
13. Collins D, Jarrah Z, Gupta P: Cost and revenue comparisons for a Sample of Contracted and Non-contracted Health Centers, Ministry of Health, Royal Government of Cambodia. [cited 24th October 2024]. Available from: file:///C:/Users/SYSTEMINN/Downloads/CostandRevenueComparisons-Cambodia.pdf
14. Collins D, Jarrah Z: Costing the basic package of health services at clinics and health centres in liberia: Rebuilding Basic Health Services Project (RBHS). USAID 2009. [cited 24th October 2024]. Available from: file:///C:/Users/SYSTEMINN/Downloads/CostingtheBasicPackageofHealthServicesLiberia.pdf
15. Collins, D., and D. Donaldson. Modelling the Cost of Primary Health Care Services in the Eastern Cape. The EQUITY Project. Boston: Management Sciences for Health, Mar. 2000. [cited 24th October 2024] Available from: https://pdf.usaid.gov/pdf_docs/PDACA698.pdf
16. Collins D, E. Lewis. A Cost Analysis of Primary Health Care Services in Benoni. The EQUITY Project. Boston: Management Sciences for Health, May 2003 [cited 24th October 2024] Available from: file:///C:/Users/SYSTEMINN/Downloads/ACostAnalysisofPrimaryHealthCareServicesinBenoni%20(1).pdf
17. Vaccine Pricing Data UNICEF updated January 2024 [accessed 7th April 2024] Available from: https://www.unicef.org/supply/vaccines-pricing-data
18. Špacírová Z, Epstein D, García-Mochón L, Rovira J, Olry de Labry Lima A, Espín J. A general framework for classifying costing methods for economic evaluation of health care. Eur J Health Econ. 2020 Jun;21(4):529-542. doi:

10.1007/s10198-019-01157-9. Epub 2020 Jan 20. Erratum in: Eur J Health Econ. 2021 Jul;22(5):847. doi: 10.1007/s10198-021-01313-0. PMID: 31960181; PMCID: PMC8149350.
19. Prinja S, Jeet G, Verma R, Kumar D, Bahuguna P, Kaur M, Kumar R. Economic analysis of delivering primary health care services through community health workers in 3 North Indian states. PLoS One. 2014 Mar 13;9(3):e91781. doi: 10.1371/journal.pone.0091781. PMID: 24626285; PMCID: PMC3953597.
20. Dalaba MA, Akweongo P, Savadogo G, Saronga H, Williams J, Sauerborn R, Dong H, Loukanova S. Cost of maternal health services in selected primary care centres in Ghana: a step down allocation approach. BMC Health Serv Res. 2013 Jul 26;13:287. doi: 10.1186/1472-6963-13-287. PMID: 23890185; PMCID: PMC3728079.
21. Okoroiwu, K.L., Okoroiwu, H.U., Ude, L.O. et al. Global bibliometric analysis of cost effectiveness analysis in healthcare research from 2013 to 2023. Cost Eff Resour Alloc 22, 68 (2024). https://doi.org/10.1186/s12962-024-00576-7
22. Toor J, Echeverria-Londono S, Li X, Hallett TB, Ferguson NM, Walker N, et al. Lives saved with vaccination for 10 pathogens across 112 countries in a decade. eLife. 2021;10:e67635. doi:10.7554/eLife.67635
23. World Health Organization (WHO). Guide for standardization of economic evaluations of immunization programmes. 2nd ed. Geneva: World Health Organization; 2021. [cited 8th July 2025] Available from: https://www.who.int/publications/i/item/9789240037744
24. Trunz BB, Fine P, Dye C. Effect of BCG vaccination on childhood tuberculous meningitis and miliary tuberculosis worldwide: a meta-analysis and assessment of cost-effectiveness. Lancet. 2006 Apr 8;367(9517):1173-80. doi: 10.1016/S0140-6736(06)68507-3. PMID: 16616560.
25. Menzies NA, Quaife M, Allwood BW, et al. Lifetime burden of disease due to incident tuberculosis: a global reappraisal including post-tuberculosis sequelae. The Lancet. Global Health. 2021 Dec;9(12):e1679-e1687. DOI: 10.1016/s2214-109x(21)00367-3. PMID: 34798027; PMCID: PMC8609280.
26. Global Polio Eradication Initiative. Why OPV cessation. 2024. [cited 7th July 2025] Available from: https://polioeradication.org/polio-today/preparing-for-a-polio-free-world/opv-cessation/
27. Auzenbergs M, Abbas K, Peak CM, Voorman A, Jit M, O'Reilly KM. Vaccination strategies against wild poliomyelitis in polio-free settings: outbreak risk modelling study and cost-effectiveness analysis. BMJ Glob Health. 2025 Mar 22;10(3):e016013. doi: 10.1136/bmjgh-2024-016013. PMID: 40122528; PMCID: PMC11931904.
28. Phillips, M.T., Antillon, M., Bilcke, J. et al. Cost-effectiveness analysis of typhoid conjugate vaccines in an outbreak setting: a modeling study. BMC Infect Dis 23, 143 (2023). https://doi.org/10.1186/s12879-023-08105-2
29. Suwanthawornkul T, Praditsitthikorn N, Kulpeng W, Haasis MA, Guerrero AM, Teerawattananon Y. Incorporating economies of scale in the cost estimation in economic evaluation of PCV and HPV vaccination programmes in the Philippines: a game changer? Cost Eff Resour Alloc. 2018 Feb 20;16:7. doi: 10.1186/s12962-018-0087-x. PMID: 29483848; PMCID: PMC5819712
30. Goguadze K, Chikovani I, Gaberi C, Maceira D, Uchaneishvili M, Chkhaidze N, Gotsadze G. Costs of routine immunization services in Moldova: Findings of a facility-based costing study. Vaccine. 2015 May 7;33 Suppl 1:A60-5. doi: 10.1016/j.vaccine.2014.12.034. PMID: 25919177
31. Janusz CB, Castañeda-Orjuela C, Molina Aguilera IB, Felix Garcia AG, Mendoza L, Díaz IY, Resch SC. Examining the cost of delivering routine immunization in Honduras. Vaccine. 2015 May 7;33 Suppl 1:A53-9. doi: 10.1016/j.vaccine.2015.01.016. PMID: 25919175
32. Le Gargasson JB, Nyonator FK, Adibo M, Gessner BD, Colombini A. Costs of routine immunization and the introduction of new and underutilized vaccines in Ghana. Vaccine. 2015 May 7;33 Suppl 1:A40-6. doi: 10.1016/j.vaccine.2014.12.081. PMID: 25919173
33. Schütte C, Chansa C, Marinda E, Guthrie TA, Banda S, Nombewu Z, Motlogelwa K, Lervik M, Brenzel L, Kinghorn A. Cost analysis of routine immunisation in Zambia. Vaccine. 2015 May 7;33 Suppl 1:A47-52. doi: 10.1016/j.vaccine.2014.12.040. PMID: 25919174.
34. Andersson N, Cockcroft A, Ansari NM, Omer K, Baloch M, Ho Foster A, Shea B, Wells GA, Soberanis JL. Evidence-based discussion increases childhood vaccination uptake: a randomised cluster controlled trial of knowledge translation in Pakistan. BMC Int Health Hum Rights. 2009 Oct 14;9 Suppl 1(Suppl 1):S8. doi: 10.1186/1472-698X-9-S1-S8. PMID: 19828066; PMCID: PMC3226240.
35. Powell-Jackson T, Fabbri C, Dutt V, Tougher S, Singh K. Effect and cost-effectiveness of educating mothers about childhood DPT vaccination on immunisation uptake, knowledge, and perceptions in Uttar Pradesh, India: A

randomised controlled trial. PLoS Med. 2018 Mar 6;15(3):e1002519. doi: 10.1371/journal.pmed.1002519. PMID: 29509769; PMCID: PMC5839535.

36. Pandey P, Sehgal AR, Riboud M, Levine D, Goyal M. Informing resource-poor populations and the delivery of entitled health and social services in rural India: a cluster randomized controlled trial. JAMA. 2007 Oct 24;298(16):1867-75. doi: 10.1001/jama.298.16.1867. PMID: 17954538.
37. Improving immunisation coverage in rural India: clustered randomised controlled evaluation of immunisation campaigns with and without incentives. BMJ. 2016 Nov 29;355:i6423. doi: 10.1136/bmj.i6423. Erratum for: BMJ. 2010 May 17;340:c2220. doi: 10.1136/bmj.c2220. PMID: 27899349; PMCID: PMC5127207.
38. Byberg S, Fisker AB, Thysen SM, Rodrigues A, Enemark U, Aaby P, Benn CS, Griffiths UK. Cost-effectiveness of providing measles vaccination to all children in Guinea-Bissau. Glob Health Action. 2017;10(1):1329968. doi: 10.1080/16549716.2017.1329968. PMID: 28580855; PMCID: PMC5496167.
39. Hayford K, Uddin MJ, Koehlmoos TP, Bishai DM. Cost and sustainability of a successful package of interventions to improve vaccination coverage for children in urban slums of Bangladesh. Vaccine. 2014 Apr 25;32(20):2294-9. doi: 10.1016/j.vaccine.2014.02.075. Epub 2014 Mar 12. PMID: 24631083.
40. Bertram MY, Lauer JA, De Joncheere K, Edejer T, Hutubessy R, Kieny MP, Hill SR. Cost-effectiveness thresholds: pros and cons. Bull World Health Organ. 2016 Dec 1;94(12):925-930. doi: 10.2471/BLT.15.164418. Epub 2016 Sep 19. PMID: 27994285; PMCID: PMC5153921
41. Focus Economics. Pakistan GDP per capita 2014. [cited 7th July 2025]. Available from: https://www.focus-economics.com/country-indicator/pakistan/gdp-per-capita-usd/#:~:text=GDP%20per%20Capita%20in%20Pakistan,capita%2C%20visit%20our%20dedicated%20page.
42. Ochalek J, Lomas J, Claxton K. Estimating health opportunity costs in low-income and middle-income countries: a novel approach and evidence from cross-country data. Health Econ. 2018;27(1):e5–e21. doi:10.1002/hec.3731