BMJ Open

Cost-effectiveness analysis of a physician deployment program to improve access to healthcare in rural and underserved areas in the Philippines

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To cite: Avanceña AL.V, Tejano KPS, Hutton DW. Cost-effectiveness analysis of a physician deployment program to improve access to healthcare in rural and underserved areas in the Philippines. *BMJ Open* 2019;**9**:e033455. doi:10.1136/bmjopen-2019-033455

► Prepublication history and additional material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2019-033455).

Received 06 August 2019
Revised 01 December 2019
Accepted 05 December 2019

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ABSTRACT

Objectives The objective of this study is to explore the cost-effectiveness of Doctor to the Barrios (DTTB), a physician deployment program in the Philippines.

Design Cost-effectiveness analysis using decision tree models with a lifetime time horizon and probabilistic sensitivity analysis.

Setting Societal and healthcare perspectives.

Population Hypothetical cohort of children under 5 years in two provinces (Aklan and Nueva Ecija) and in a representative rural municipality.

Participants None.

Interventions DTTB's impact on paediatric pneumonia and diarrhoea outcomes compared with a scenario without DTTB.

Main outcome measures Costs, effectiveness (in terms of lives saved and quality-adjusted life years (QALYs) gained) and incremental cost-effectiveness ratio (ICER).

Results DTTB is cost-effective in the two provinces that were included in the study from societal and healthcare perspectives. Looking at a representative rural municipality, base case analysis and probabilistic sensitivity analyses suggest that DTTB has an ICER of 27 192 per QALY gained from a societal perspective. From a healthcare perspective, the base case ICER of DTTB is Philippine pesos (PHP) 71 839 per QALY gained and PHP 2 064 167 per life saved, and 10 000 Monte Carlo simulations produced similar average estimates. The cost per QALY of DTTB from a healthcare perspective is lower than the WHO recommended willingness-to-pay threshold of 100% of the country's per-capita gross domestic product.

Conclusions DTTB can be a cost-effective intervention, but its value varies by setting and the conditions of the municipality where it is implemented. By focusing on a narrow set of paediatric outcomes, this study has likely underestimated the health benefits of DTTB. Additional research is needed to understand the full extent of DTTB's impact on the health of communities in rural and remote areas. Future cost-effectiveness analysis should empirically estimate various parameters and include other health conditions in addition to pneumonia and diarrhoea in children.

Strengths and limitations of this study

- ► This study is the first to explore the cost-effectiveness of a deployment programme for clinicians in the Philippines intended to improve healthcare access in rural and underserved areas.
- ► This study provides evidence that expansion of deployment programme may be a cost-effective policy in some situations.
- ► Robust sensitivity analyses were performed to capture uncertainty in the results, determine key drivers of uncertainty and to illustrate the value of further research.
- ► Societal and healthcare perspectives were considered in the analyses in order to support different policymaking considerations.
- ► Only a narrow set of health outcomes for paediatric populations were considered in this study, which likely underestimates the true benefits of physician deployment in rural and underserved communities.

INTRODUCTION

Like many low-income and middle-income countries, the Philippines suffers not only from a shortage of human resources for health (HRH) but also from their maldistribution. Though 56% of Filipinos reside in rural areas,[1] about 60%–70% of HRH in the Philippines are concentrated in urban centres.[2 3] For example, the physician density in the National Capital Region is 17.5 times higher than in the Autonomous Region in Muslim Mindanao, the poorest and most rural region in southern Philippines.[2] To address this issue, the newly passed Universal Health Care Act,[4 5] signed by President Rodrigo Duterte in February 2019, proposes to establish a National Health Workforce Support System, which scales up existing HRH deployment programme in the public sector such as Doctor to the Barrios (DTTB).

Started in 1993, DTTB is an incentive-based physician deployment programme of the Philippines Department of Health (DoH) that recruits medical doctors (primarily general practitioners though other primary care physicians are also deployed) to work in rural, geographically isolated and underserved municipalities for 2 years. DTTB physicians are offered a higher-than-average salary, living and transportation allowances, hazard pay and professional development trainings, including the opportunity to earn a certificate or Master of Public Health degree.[6] DTTB has deployed 35 groups of physicians so far, and in 2019, 215 physicians were serving as municipal health officers (MHOs) or rural health physicians (RHPs) in rural health units (RHUs), which are the lowest-level health facilities in the Philippines where various preventive and primary care services are provided.[6 7]

Municipalities that do not participate in DTTB fill MHO and RHP vacancies through standard hiring procedures determined by the Local Government Code. Hiring through this process can take long because many physicians prefer to work in large cities; in addition, recruited physicians are paid the average government wage for doctors working in the public sector, which is lower than DTTB and has been associated with physician dissatisfaction and high turnover rates.[7]

Because physicians and other HRH are an essential input to any healthcare system, increasing physician density in rural, isolated and underserved areas can improve population health by improving access to basic and high-quality healthcare services.[8–10] Several studies have reported that HRH density is positively associated with use of preventive healthcare services and negatively associated with disease complications and death from cancer, diabetes, AIDS and other conditions.[11–18] HRH density has also been associated with reductions in under 5 years mortality in various settings.[19 20] In addition to improving health outcomes, physician deployment programmes like DTTB can promote health equity and advance the Philippines's goal to achieve universal healthcare.

The Philippine government is poised to allocate significant resources on scaling up various deployment programmes including DTTB; however, the cost-effectiveness of these programmes has not been explored before. In this study, we aimed to estimate the cost-effectiveness of DTTB in reducing pneumonia-related and diarrhoea-related mortality among children under 5 years compared with its alternative (ie, standard hiring and recruitment procedures employed by local governments). The target audiences for this study are national and local government policymakers in the Philippines and in other countries exploring the utility of HRH deployment programmes.

After careful discussions with DoH officials, pneumonia and diarrhoea were chosen because these two conditions are in the top five causes of death among young children.[21 22] In 2017, an estimated 3760 children under 5 years died of diarrhoea, which is more than 50% of all diarrhoeal deaths in the country that year.[23] Of the estimated 2.6 million cases of pneumonia among children under 5 years in 2017, about 12 400 resulted in deaths.[23] Pneumonia and diarrhoea were also selected as outcomes because DTTB physicians (as MHOs and RHPs) are uniquely positioned to treat and address these diseases; for example, physicians, unlike other healthcare workers, are trained to determine when and what types of antibiotics are needed and have regulatory authority to dispense these drugs to patients.

Pneumonia and diarrhoea are caused by several pathogens including bacteria and viruses. In the Philippines, pneumonia is commonly caused by *Streptococcus pneumoniae*, *Haemophilus influenzae* type b (Hib), respiratory syncytial virus and influenza virus[24 25] ; for diarrhoeal disease, rotaviruses, noroviruses and bacteria such as *Escherichia coli*, *Campylobacter* spp and others are the main etiologic agents.[26] International and local treatment guidelines specify the administration of antibiotic therapy for bacterial pneumonia and diarrhoea, while antiviral medications are indicated for severe viral pneumonia.[27] Diarrhoea caused by viruses (referred to as viral gastroenteritis) are mainly treated through symptomatic support such as through oral rehydration therapy.[28 29] Vaccines are available for selected pneumonia and diarrhoea pathogens (eg, *S. pneumoniae*, Hib, influenza, rotavirus, cholera and so on) and several have been rolled out in the Philippines.[26 30 31] However, uptake throughout the country has been variable due to several cost and accessibility barriers.[32–34]

MATERIALS AND METHODS

This cost-effectiveness analysis (CEA) follows the guidance proposed by the 2nd Panel on Cost-effectiveness in Health and Medicine (2nd Panel),[35] as well as the Consolidated Health Economic Evaluation Reporting Standards reporting guidelines.[36] We used decision tree models that simulate a hypothetical cohort of children under 5 years to estimate the impact of DTTB on pneumonia-related and diarrhoea-related outcomes and costs.

We conducted two sets of analyses in this study. One set uses, where available, province-specific inputs to estimate the base case cost-effectiveness of DTTB in two conveniently sampled provinces (Aklan and Nueva Ecija). The other set of analyses models a representative rural municipality in the Philippines, where DTTB physicians are typically deployed. The aim of simulating a representative municipality is to determine the conditions in which DTTB is cost-effective outside of the two provinces sampled.

We considered societal and healthcare perspectives in the analysis. In the societal perspective, which is the recommended perspective for economic evaluations in healthcare,[35] all costs and benefits are valued and included, regardless of the payer or beneficiary. In the healthcare perspective, only medical care and intervention costs borne by payers and patients are included.

Table 1 Impact inventory*

Sector	Type of impact	Healthcare perspective	Societal perspective	Notes on sources of evidence
Formal healthcare sector				
Health	Longevity	X	X	
	Health-related quality-of-life effects	X	X	
	Other health effects (eg, caregiver health-related quality of life)			Excluded due to lack of data
	Medical costs paid for by third-party payers	X	X	See table 2
	Medical costs paid for by patients out-of-pocket	X	X	See table 2
	Future-related medical costs			We assumed no related costs after age 3
	Future unrelated medical costs	X	X	See table 2
Informal healthcare sector				
Health	Patient costs			Not applicable due to patients' age
	Unpaid caregiver time costs	X	X	See table 2
	Transportation costs		X	See table 2
Non-healthcare sectors				
Productivity	Formal labour market earnings lost		X	See table 2
	Cost of unpaid lost productivity due to illness			Excluded due to lack of data
	Cost of uncompensated household production			Excluded due to lack of data
Consumption	Future consumption unrelated to health		X	See table 2
Social services	None			
Legal/criminal justice	None			
Education	Impact of intervention on educational achievement of population			Excluded due to lack of data
Housing	None			
Environment	None			

*The Impact inventory allows analysts to consider all the consequences of a health intervention from various perspectives. Marks (X) indicate whether a particular impact was included in the perspective listed at the top of the column.

We generated an impact inventory (table 1) that lists all the health and non-health costs and effects that were included in each perspective.[35]

We examine pneumonia and diarrhoea outcomes during the course of a year and simulate the lifetime outcomes following that illness. We projected benefits in terms of lives saved and quality-adjusted life years (QALYs) gained over the lifetime of a hypothetical cohort. We discounted future benefits to present value using a 3% rate in the base case analysis.

Patient and public involvement

This study was conducted with the support of various stakeholders in the public sector. DoH staff and researchers informed the design of the study and assisted in developing the decision analytic model used in the analysis. DTTB physicians and allied healthcare providers were interviewed to gather expert opinion on select treatment-related inputs in the model.

Decision tree model

We developed two decision tree models that separately estimate the high-level costs and effectiveness of implementing DTTB compared with a scenario without DTTB on pneumonia and diarrhoea outcomes (figure 1). Structurally, the models for scenarios with and without DTTB are exactly alike; the most significant difference is in the likelihood of physicians being present at the RHU, which,

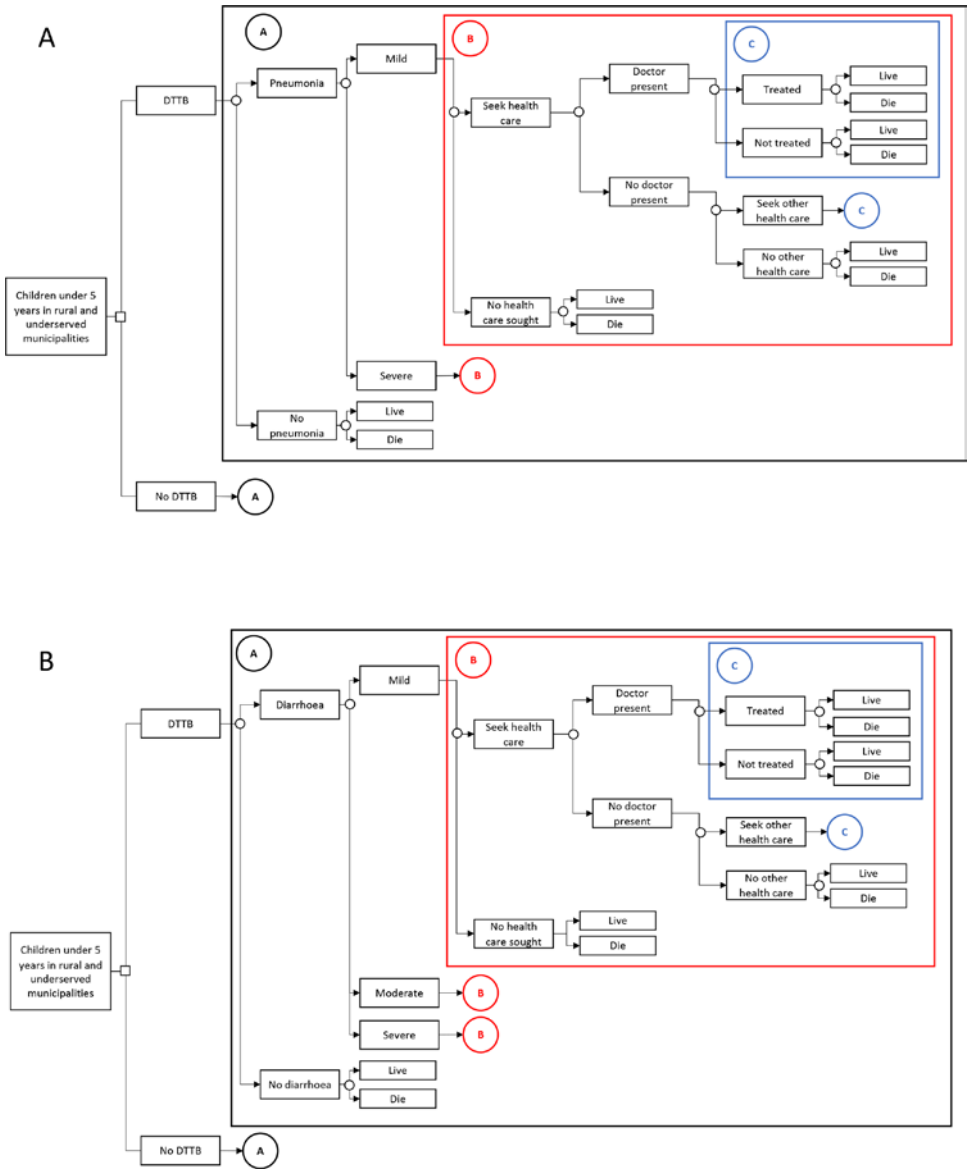

Figure 1 Diarrhoea (A) and pneumonia (B) decision tree models. Squares are decision nodes and circles are chance nodes. Each arrow represents a transition and is associated with a probability. Branches have been grouped, truncated and labelled appropriately for simplicity. The diarrhoea and pneumonia decisions tree models are similar in structure except in the classification of diseases; for pneumonia, mild and severe disease are modelled, while for diarrhoea, mild, moderate and severe diarrhoea are considered. DTTB, Doctor to the Barrios.

based on expert opinion, is assumed to be higher in the DTTB scenario than the without DTTB scenario. Without DTTB, rural municipalities hire MHOs and RHPs through standard procedures, which is often unsuccessful because remuneration for locally recruited physicians is relatively low.

We did not include all stages of disease progression in the decision trees; instead, we focused on care-seeking behaviour, access to care and clinical treatment outcomes (ie, mortality). We modelled mild, moderate and severe diarrhoea, but due to data limitations, we were only able to model pneumonia as either mild or severe. We did not explicitly model comorbidities, though we assumed that some children in the same municipality may, concurrently or successively, experience pneumonia and diarrhoea episodes in 1 year, as documented in the literature.[37 38] The model was reviewed by officials in charge of HRH deployment programmes and health technology assessments at the DoH. Both models were created, and all analyses were conducted, in Microsoft Excel (Microsoft Corp, Redmond, Washington, USA).

The two sets of analyses (described previously) we conducted use different population numbers. For the set of analyses that looks at two specific provinces in the Philippines (Aklan and Nueva Ecija), we multiplied the average fraction of the population under 5 years (9.95% and 9.91%, respectively) with the average low-income population (23 281 and 24 469, respectively) at the municipal level (online supplementary file 1). For the analysis that looks at a representative municipality in the

Philippines, the model starts with a cohort of 1904 children aged 3 years (in the base case) who are susceptible to pneumonia and diarrhoea. This cohort size was estimated by multiplying the average population size in low-income and rural municipalities (15 641) by the average fraction of the population under 5 years (12.17%) in the poorest regions in the Philippines (online supplementary file 1).[39 40]

Across all analyses, we assumed the average age of the population to be 3 years with an undiscounted life expectancy of 69 years; we vary the life expectancy assumption by ±3.45 years in sensitivity analysis. During the course of a year, a proportion of the population experiences diarrhoea and pneumonia based on annual incidence rates, and they progress through the decision tree based on the intervention, epidemiologic variables and transition probabilities and face lifetime outcomes following their disease and intervention.

Data and sources

Transition probabilities

We estimated annual transition probabilities based on medical and public health literature, as well as expert opinion (table 2). Several literature searches were conducted from June to September 2018 using MEDLINE via PubMed. Epidemiological parameters were taken from the Global Burden of Disease Study (GBD), the Philippines Field Health Services Information System (FHSIS) and studies that have classified diarrhoea and pneumonia cases by severity.[22 23 41 42] Province-specific pneumonia and diarrhoea incidence rates were estimated using FHSIS incidence rate ratios that we used to weigh the GBD incidence rates for pneumonia and diarrhoea (see online supplementary file 1). Treatment effectiveness for diarrhoea and pneumonia was taken from a prospective analysis, systematic review and previous modelling studies, and we assume 100% compliance with treatment.[43–46]

Treatment-related probabilities were estimated using data from a convenience sample of provinces in the Philippines (Aklan and Nueva Ecija). We also gathered expert opinion through interviews with DoH staff, provincial health officials and various DTTBs working as MHOs and RHPs conducted from June to October 2018 (online supplementary file 1). MHOs are the chief health officers of municipalities responsible for formulating and implementing medical and public health programs; RHPs provide preventive and curative services and oversee health personnel assigned in a RHU.[47] While MHOs and RHPs are given the same salary grade, MHOs are higher in rank than RHPs.

The annual costs of DTTB were collected from the DoH, which include salaries and benefits given to DTTB physicians and costs associated with administering the deployment programme. Annual costs for physicians hired without DTTB were taken from the Department of Budget and Management compensation guide.[48] We assumed that RHUs under with and without DTTB scenarios have equal numbers of allied healthcare staff, whose costs cancel out at the end and were therefore not valued. Similarly, we excluded municipal-level costs for recruiting MHOs and RHPs under the assumption that both DTTB and non-DTTB municipalities bear similar human resources costs.

Healthcare costs borne by payers and patients were estimated based on various published and unpublished studies from the Philippines.[49–52] These costs include healthcare service costs (eg, physician and facility fees), drug costs and hospitalisations for severe disease. For the societal perspective, we calculated caregiver costs using the average daily income of workers in the Philippines weighted by the average length of stay of each disease and by disease severity.[53] Other costs that are listed in the impact inventory were valued using different methodologies recommended by the 2nd Panel (online supplementary file 1).[35]

All costs are in 2017 Philippine pesos (50.40 Philippine pesos (PHP)=US$1); historical costs were inflated using general consumer price indices from the World Bank.[54] Lifetime production and consumption are discounted, but healthcare costs were not discounted because we only considered a 1 year implementation of DTTB.

Utilities and health outcomes

The decision tree model looks at two outcomes for diarrhoea and pneumonia, namely dead or alive. Death was assigned a utility of 0, and living was assigned 1 (this value was varied from 0.9 to 1 in the sensitivity analyses). The exclusion of various intermediary morbidity states associated with diarrhoea and pneumonia in the model will likely underestimate the effectiveness of prompt and effective treatment for both with and without DTTB scenarios.

Two measures of effectiveness were estimated, namely QALYs gained and lives saved. Each life year lost from premature death due to diarrhoea, pneumonia or other causes was represented by one lost QALY in the base case. Lifetime discounted QALYs gained were calculated by multiplying the number of surviving children in the cohort by the discounted life expectancy of 28.73 years.

Analysis

Cost-effectiveness

We added the results of the two decision trees for pneumonia and diarrhoea to derive the total costs and effectiveness of the scenarios with and without DTTB. The physician deployment costs were added only after the total costs of the diarrhoea and pneumonia decision trees were calculated since these costs are shared between these two diseases.

The summary metric of cost-effectiveness analyses is the incremental cost-effectiveness ratio (ICER), defined as the cost per unit of health outcome gained. The ICER is calculated by dividing the incremental net costs by the incremental net benefits of one alternative versus the other. An intervention is typically considered cost-effective if its ICER meets or is below a decision-maker's

Table 2 Values for model variables*

Variable	Base	Range	Distribution	Reference
Population				
Population of children under 5 years in representative rural municipality	1904	280–6883	Normal	†[39]
Population of children under 5 years in Aklan‡	2318	NA	NA	†[39 40]
Population of children under 5 years in Nueva Ecija‡	2424	NA	NA	†[39 40]
Undiscounted life expectancy at 3 years	69	65.55–72.45*	Normal	[58]
Epidemiology				
Pneumonia				
Probability of getting pneumonia in representative rural municipality	0.1028	0.0838–0.1233	Beta	[23]
Probability of getting pneumonia in Aklan‡	0.1301	NA	NA	†[22 23 59]
Probability of getting pneumonia in Nueva Ecija‡	0.0502	NA	NA	†[22 23 59]
Proportion of cases that are severe	0.10	0.05–0.15*	Beta	[41]
Diarrhoea				
Probability of getting diarrhoea in representative rural municipality	0.7379	0.6835–0.7928	Beta	[23]
Probability of getting diarrhoea in Aklan‡	0.5863	NA	NA	†[22 23 59]
Probability of getting diarrhoea in Nueva Ecija‡	0.4872	NA	NA	†[22 23 59]
Proportion of cases that are moderate	0.347	0.10–0.4995*	Beta	[42]
Proportion of cases that are severe	0.5	0.05–0.10*	Beta	[42]
Annual transition probabilities				
Pneumonia				
Probability of dying at age three for causes other than pneumonia	0.004	0.0038–0.0041	Beta	†[60]
Probability of seeking treatment given mild disease	0.89	0.50–1*	Beta	[61]
Probability of dying with treatment of mild disease	0.035	0.0263–0.0438*	Beta	[43 44]
Probability of dying without treatment of mild disease	0.05	0.02–0.065*	Beta	[44]
Probability of seeking treatment given severe disease	0.91	0.50–1*	Beta	[61]
Probability of dying without treatment of severe disease	0.21	0.05–0.25*	Beta	[44]
Probability of dying with treatment of severe disease	0.1477	0.110–0.184*	Beta	[43 44]
Diarrhoea				
Probability of dying at age 3 for causes other than diarrhoea	0.0046	0.0045–0.0047	Beta	†[60]
Probability of seeking treatment given mild disease	0.4175	0.362–0.447	Beta	†[62]
Probability of dying given no treatment of mild disease	0.0018	0.0012–0.0027	Beta	[46]
Probability of dying with treatment of mild disease	0.0012	0.0009–0.0014*	Beta	[45 46]
Probability of seeking treatment given moderate disease	0.4175	0.362–0.447	Beta	†[62]

Continued

Table 2 Continued

Variable	Base	Range	Distribution	Reference
Probability of dying given no treatment of moderate disease	0.0018	0.0012–0.0027	Beta	46
Probability of dying with treatment of mild disease	0.0012	0.0009–0.0014*	Beta	45 46
Probability of seeking treatment given severe disease	0.4175	0.362–0.447	Beta	†62
Probability of dying given no treatment of severe disease	0.0058	0.0039–0.0087	Beta	46
Probability of dying given treatment of severe disease	0.0014	0.001–0.0022	Beta	45 46
Treatment				
Probability that doctor is at the RHU with DTTB	0.9	0.8–1	Beta	Expert opinion
Probability that doctor is at the RHU without DTTB§	0.15	0.075–0.225*	Beta	Expert opinion
Probability that patient is treated when doctor is present	0.75	0.50–1	Beta	Expert opinion; FHSIS
Probability that patient has other source of care when doctor is not present¶	0.8	0.7–1*	Beta	Expert opinion; FHSIS
Probability that patient is treated by other source of care when doctor is not present	0.75	0.50–1	Beta	Assumed by authors
Costs (in 2017 PHP)**				
Pneumonia				
Societal cost of treating severe pneumonia episode	48 721	33 395–64300	Gamma	†49–51
Healthcare cost of treating severe pneumonia episode	47 101	32 577–61626	Gamma	†49–51
Societal cost of treating mild pneumonia episode	6765	4694–7457	Gamma	†49 50 62
Healthcare cost of treating mild pneumonia episode	5485	4377–6582	Gamma	†49 50 62
Diarrhoea				
Societal cost of treating a mild diarrhoea episode	6765	5343–8222	Gamma	†49 51 62
Healthcare cost of treating a mild diarrhoea episode	6457	5165–7748	Gamma	†49 51 62
Societal cost of treating a moderate diarrhoea episode	11 960	6629–17363	Gamma	†49 62
Healthcare cost of treating a moderate diarrhoea episode	11 406	6323–16488	Gamma	†49 62
Societal cost of treating a severe diarrhoea episode	27 575	19 949–35617	Gamma	†49 62 63
Healthcare cost of treating a severe diarrhoea episode	25 709	19 234–32183	Gamma	†49 62 63
Other costs (discounted)				
Lifetime consumption (in thousands)	1697	1079–2817	Gamma	64
Lifetime productivity (in thousands)	2235	1406–3830	Gamma	64
Human resources (in thousands)				
Annual cost of deploying a DTTB physician	1721	1500–2500	Gamma	DoH data

Continued

Table 2 Continued

Variable	Base	Range	Distribution	Reference
Annual cost of MHO or RHP hired locally by municipality	926	880–976	Gamma	DBM data†
Utilities				
Alive	1	0.9–1	Beta	Assumed by authors
Dead	0	NA	NA	Assumed by authors
Discount rate	0.03	0.02–0.08	NA	Assumed by authors

*Value assumed or set by authors.
†Base value and range calculated by authors based on the references cited.
‡No ranges and distributions are specified because only base case analyses were conducted using these data.
§Municipalities who do not participate in DTTB may still successfully hire a full-time physician to work as a RHP or MHO, or occasionally receive temporary physicians deployed by the provincial government or by a non-governmental organisation.
¶In many rural and underserved municipalities, RHUs are the only source of care, though some communities have privately practicing physicians or district hospitals nearby.
**Details behind cost calculations are found in the online supplementary file 1.
DBM, Department of Budget and Management; DoH, Department of Health; DTTB, Doctors to the Barrios; FHSIS, Field Health Services Information System; MHO, municipal health officer; NA, not applicable; PHP, Philippine pesos;RHP, rural health physician; RHU, rural health unit.

willingness-to-pay (WTP) threshold. In this study, we adopted the WHO-recommended WTP threshold, which is 100% of a country's per capita gross domestic product (GDP). In 2017, the GDP per capita of the Philippines was PHP 150 654.[55]

We report two sets of base case results; one set pertains to ICERs for Aklan and Nueva Ecija that uses selected province-specific inputs such as population size and disease incidence. Another set of ICERs is for the representative rural municipality that DTTBs are deployed to.

Sensitivity analyses

To address parameter uncertainty, we conducted one-way and probabilistic sensitivity analyses (PSA) for the representative rural municipality. Where data were available, low and high values were based on ranges in the literature; for parameters estimated through expert opinion, the authors determined reasonable bounds. For the PSA, 10 000 Monte Carlo simulations were conducted using distributions of the variables (table 2). We generated cost-effectiveness acceptability curves using the simulation results to plot the probability that each scenario is cost-effective over a range of WTP thresholds.

RESULTS

Tables 3 and 4 summarise the base case costs, effectiveness and cost-effectiveness of the scenarios for the two sets of analyses. Compared with a no DTTB scenario, DTTB has an ICER of PHP 13 042 per QALY gained in Aklan and PHP 47 077 per QALY gained in Nueva Ecija using a societal perspective; these ICERs are respectively 9% and 31% of the WHO-recommended WTP threshold for the Philippines. ICERs for Aklan and Nueva Ecija are both

Table 3 Base case results for Aklan and Nueva Ecija*

	Aklan		Nueva Ecija	
Cost-effectiveness of DTTB	Societal perspective	Healthcare perspective	Societal perspective	Healthcare perspective
Incremental lives saved	1.95	1.95	0.80	0.80
Incremental QALYs gained†	56.11	56.11	23.13	23.13
Incremental costs	731 853	2 673 611	1 088 886	2 336 538
Cost per life saved (in PHP)	374 743	1 369 014	1 352 661	2 902 548
Cost per QALY gained†(in PHP)	13 042	47 646	47 077	101 018

*All costs are in 2017 PHP and have been discounted to present time.
†QALYs are discounted to the present value.
DTTB, Doctors to the Barrios;PHP, Philippine pesos; QALY, quality-adjusted life year.

Table 4 Base case results for representative rural municipality

	Societal perspective		Healthcare perspective	
Outcome	**With DTTB**	**Without DTTB**	**With DTTB**	**Without DTTB**
Lives saved	3765	3763	3765	3763
QALYs gained†	108 166	108 129	108 166	108 129
Cost (in thousands PHP)	–2 018 691	–2 019 692	6144	3499
Cost-effectiveness of DTTB	**Societal perspective**		**Healthcare perspective**	
Cost per life saved (in PHP)	781 312		2 064 167	
Cost per QALY gained† (in PHP)	27 192		71 839	

*All costs are in 2017 PHP and have been discounted to present value. Negative costs denote that the programme is cost saving.
†QALYs are discounted to the present time.
DTTB, Doctors to the Barrios;PHP, Philippine pesos; QALY, quality-adjusted life year.

lower than the WHO-recommended WTP threshold form a healthcare perspective (32% and 67%, respectively).

Modelling a representative rural municipality provides additional insight on the factors that make DTTB a cost-effective intervention for increasing access to pneumonia and diarrhoea treatment for children under 5 years (table 4). Having one DTTB doctor over the course of a year is expected to save about two lives and gain 89 discounted QALYs. From a societal perspective, DTTB has an ICER of PHP 27 192 per QALY gained, which is only 18% of the WHO-recommended WTP threshold. From a healthcare perspective, the ICER of DTTB is PHP 71 839 per QALY gained, which is 48% of the WHO-recommended WTP threshold.

Figure 2 shows the partial results of the one-way sensitivity analysis from a healthcare perspective. The extreme values of two parameters—(1) the probability that a patient is treated by another source of care and (2) the probability that a patient is treated when doctor is present—cause the scenario with DTTB to be dominated by the scenario without DTTB. At these extremes, the overall probability a child is treated is higher in the without DTTB than with DTTB. The extreme values of four other parameters (ie, probability of dying without treatment of severe pneumonia, population size, probability of dying after treatment of severe pneumonia and discount rate) shift the ICER enough to surpass the WHO-recommended WTP threshold.

Across 10 000 simulations, DTTB on average has ICERs of PHP 21 362 per QALY gained and PHP 610 615 per life saved from a societal perspective; about 17% of simulations estimated that DTTB is cost saving (ie, negative net costs and positive net benefits). From a healthcare perspective, the average ICERs of DTTB are about PHP 75 568 per QALY gained (50% of the WHO-recommended WTP threshold) and PHP 2.2 million per life saved.

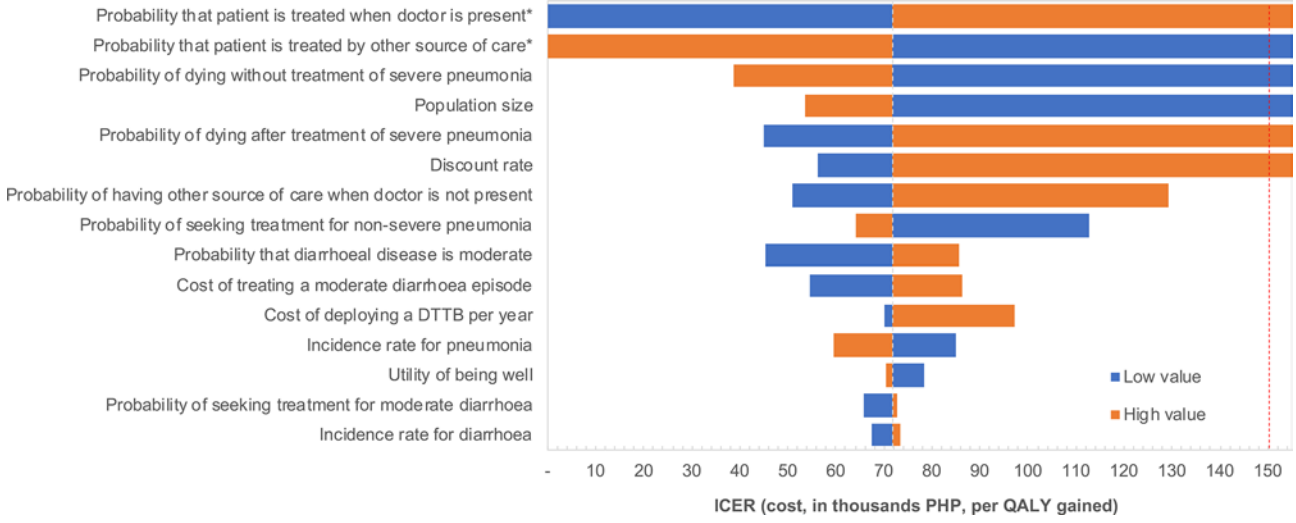

Figure 2 Tornado diagram showing results of one-way sensitivity analysis from a healthcare perspective. A tornado diagram shows the full ICER range when a parameter value in the model is varied from its lowest to highest bounds while keeping the other parameter values constant. The grey vertical dashed line represents the ICER in the base case for the healthcare perspective, and the red vertical dashed line represents the WHO-recommended WTP threshold. Asterisks (*) denote that extreme values of the parameter cause the with DTTB scenario to be dominated by the without DTTB scenario. Only the top 15 most influential parameters are included in this figure. DTTB, Doctor to the Barrios; ICER, incremental cost-effectiveness ratio; PHP, Philippine pesos; QALY, quality-adjusted life year; WTP, willingness-to-pay.

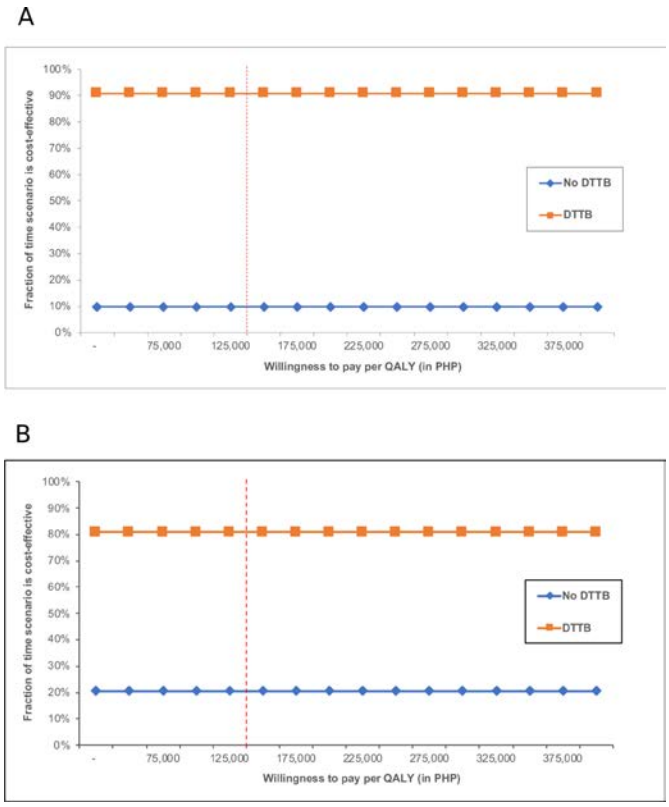

Figure 3 Cost-effectiveness acceptability curves for the (A) societal and (B) healthcare perspectives. These curves plot the probability that each alternative is cost-effective (ie, has a higher net monetary value) over a range of WTP thresholds. The red vertical dashed line represents the WHO-recommended WTP threshold. DTTB, Doctor to the Barrios; PHP, Philippine pesos; QALY, quality-adjusted life year; WTP, willingness-to-pay.

Figure 3 shows the cost-effectiveness acceptability curves for the societal and healthcare perspectives. Across different WTP values, the scenario with DTTB is much more likely to be the optimal choice when compared with without DTTB from both the societal and healthcare perspectives.

DISCUSSION

This study suggests that DTTB, a physician deployment programme in the Philippines, can be a cost-effective intervention; however, its value varies by setting the characteristics of the municipality in which it is implemented. The results support the continued use and expansion of DTTB in areas with little to no sources of medical care to prevent pneumonia-related and diarrhoea-related mortality in children under 5 years. The sensitivity analysis also highlights the importance of the availability of the deployed DTTB physician to treat patients; if the physicians are largely unavailable to provide medical care (for reasons such as being pulled into municipal events or meetings, or leaving the municipality to attend trainings or conferences), then the economic efficiency of DTTB decreases.

There are several limitations associated with this study that are worth noting. First, we combined different sources of data to estimate costs and health benefits, and some secondary sources were not specific to the Philippine context. Thus, there is considerable parameter uncertainty that we tried to mitigate through the use of wide parameter ranges in sensitivity analyses. The parameter estimates derived through expert opinion may also be biased since we primarily interviewed DTTB physicians who view their work positively. We also did not include as a parameter the costs associated with death. (We detail other data limitations and assumptions in the online supplementary file.) Future research should focus on empirically estimating the value of parameters provided by experts, particularly those that had a significant impact on the ICER (see figure 2). Second, we have likely underestimated the health benefits of DTTB by considering a narrow set of health outcomes in children. This is a significant limitation of the study, which can be addressed in future cost-effectiveness analyses where other health conditions (eg, prevention, diagnosis and treatment of cardiovascular diseases) can be included in the model. Future studies can also look at the health-related quality of life of intermediate health states between alive and dead. Third, the convenience sample of municipalities on which several parameter estimates were based may not be representative of all rural and underserved municipalities in the Philippines.

Fourth, the decision tree model, though intended to be a simplification of actual healthcare-seeking processes, may exclude certain events that affect the estimation of DTTB's health benefits. For example, timing of treatment and availability of appropriate drugs are likely to impact treatment effectiveness, but we made simplifying assumptions around these factors. We also did not differentiate pneumonia and diarrhoea cases by aetiologic agent, and we did not model how treatment of pneumonia and diarrhoea in children may prevent others from contracting the disease. We did, however, try to address these limitations by ensuring that DoH staff and other experts were consulted in the development of the decision models. Finally, the generalisability of this study is limited; the CEA only generates average estimates of cost-effectiveness based on the current design and specifications of the DTTB programme. Thus, any changes to the DTTB programme may alter the estimation of costs, benefits and the ICER. For example, we assumed that DTTB physicians are deployed to municipalities with limited to no access to other healthcare providers (so-called 'doctorless municipalities'); if DTTB physicians are deployed to areas with more healthcare providers that patients can access, the impact of DTTB may change.

This study contributes to the limited literature on the cost-effectiveness of various strategies to improve HRH density in rural and underserved areas. A study by Lagarde and colleagues found that offering a study leave to rural nurses and recruiting nurses from rural areas were the most cost-effective strategies compared with the status

quo with an ICER of South African Rand 2 00 215–2 41 073 per nurse-year (roughly 27 108–32 640 per nurse-year in 2017 US$).[56] The main limitation of this study is that the effectiveness of the strategies was estimated in nurse-years and not health outcomes; thus, the findings of the study cannot be compared with other health interventions.

Another study by Keuffell *et al* explored the cost-effectiveness of 15 separate non-wage financial incentive packages (eg, transportation allowances, housing incentives) for new physicians in Lao People's Democratic Republic (Lao PDR).[57] Effectiveness was calculated using a WHO analysis that estimates the potential (non-linear) reductions in infant mortality, under 5 years mortality and maternal mortality from increases in physician density. This feature of the study was a major limitation as the WHO analysis is based on a cross-national sample; thus, the estimates of health impact may or may not be applicable to the Lao PDR context.[11] Nonetheless, the authors found that a package consisting of housing and transportation allowance and career promotion opportunities was the most cost-effective option over a 5 year time horizon (compared with a no programme scenario) with an ICER of about US$ 1454 per QALY gained (2012 US$).

This study is the first CEA to evaluate an HRH deployment programme in the Philippines and has demonstrated that DTTB can be cost saving or cost-effective depending on the perspective used. The methods we employed can be used evaluate the cost-effectiveness of other HRH deployment programmes in the country (eg, midwife deployment to increase facility-based deliveries). However, empirical analyses are needed to understand the total health impact of deployment programmes which can inform future cost-effectiveness models using other simulation techniques such as state-transition models. Results from this study can be used by national and local government officials to inform HRH allocation decisions.

Acknowledgements The authors extend their gratitude to Dr Kenneth Ronquillo, Dr Beverly Ho, and several staff members of the Health Policy Development and Planning Bureau of the Philippines Department of Health for their support for this project. The authors also thank the various physicians working as Doctors to the Barrios who provided critical information for this study (full list of interviewees is found in the Supplemental File).

Contributors ALVA conceived and designed the study, collected and analysed the data, prepared the manuscript and is the guarantor of the study. KPST implemented the study and prepared the manuscript. DWH designed the study, analysed the data, prepared the manuscript and provided oversight throughout the study. All authors have approved the final submitted version.

Funding This study was supported by grants from the University of Michigan's International Institute and the Office of Global Public Health at the School of Public Health.

Competing interests None declared.

Patient consent for publication Not required.

Ethics approval This study did not involve patients and qualifies as an evaluation, which is exempt from ethical review.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data relevant to the study are included in the article or uploaded as supplementary information. All input parameters in the model are reported in the main text and supplementary materials.

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