ORIGINAL ARTICLE

Cost-Effectiveness Analysis of Various Coronavirus Disease (COVID-19) Vaccines against Emerging Variants of Concern in the Philippines

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ABSTRACT

Objectives. During the early COVID-19 pandemic (2020 to mid-2021), the Philippine government relied on non-pharmaceutical interventions such as lockdowns and Enhanced Community Quarantine (ECQ). With the emergency use authorization of vaccines, assessing their potential impact became essential. This study develops a Philippine model to evaluate the epidemiologic and economic effects of COVID-19 vaccination, estimating its impact on mortality, hospitalization, and mild/asymptomatic cases under various prioritization strategies, including booster doses and the presence of variants of concern.

Methods. A dynamic transmission model (DTM) with an SEIR (Susceptible-Exposed-Infected-Recovered) structure was calibrated using local data, including case numbers, deaths, seroprevalence, vaccination coverage, and intervention costs. The model's outputs informed a cost-effectiveness analysis (CEA) from health system and societal perspectives over a two-year horizon. Incremental Cost-Effectiveness Ratios (ICERs) were calculated, with costs adjusted to 2020 prices and discount rates of 3%-10% applied. Sensitivity analyses, including one-way and probabilistic approaches, assessed robustness, while a budget impact analysis (BIA) estimated government expenditures in 2020 and 2021.

Results. Without vaccination, daily cases could have peaked at 400,000 between February and May 2021. A vaccination campaign was projected to reduce cases to around 20,000, significantly lowering mortality.

From the health system perspective, the estimated cost without vaccination was PhP 14.46 trillion, with 93.83 million QALYs. With vaccination, costs dropped to PhP 2.36 trillion, while QALYs increased to 101.79 million. From the societal perspective, costs were PhP 14.68 trillion without vaccination and PhP 2.38 trillion with vaccination, with the same QALY outcomes.

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CEA results confirmed that vaccination was cost-saving, with ICERs of -PhP 1,520,727.28 per QALY (health system) and -PhP 1,546,171.63 per QALY (societal). Sensitivity analyses supported these findings, with one-way sensitivity analysis showing minimal impact from parameter changes and probabilistic sensitivity analysis confirming cost-saving outcomes. The BIA estimated government expenditures of PhP 983.45 billion in 2020 and PhP 1.47 trillion in 2021 for the vaccine scenario, lower than the no-vaccine scenario.

Conclusion. Indeed, our modeling has shown that COVID-19 vaccines could mitigate the spread of COVID-19 and provide good value for money.

Keywords: COVID-19, cost-effectiveness analysis, vaccine, epidemiologic model, Philippines

INTRODUCTION

COVID-19 is an infectious disease caused by the novel SARS-CoV-2 virus and is primarily transmitted via the respiratory route. The high transmissibility of the virus and the difficulty in mitigating its spread in a globalized world has led to a pandemic situation, triggering the declaration of a public health emergency of international concern by the World Health Organization (WHO) in 2020.[1] Since the first documented case of COVID-19 in the Philippines in early 2020, the ensuing pandemic has led to approximately 4.13 million cases and more than 66,000 deaths as of December 11, 2023.[2]

The impact of the COVID-19 pandemic on the Philippine economy has been severe, with an estimated PhP 2.1 trillion in economic losses[3], 37% of the workforce experiencing unemployment or underemployment[4], and 2.2 million individuals facing severe hunger[5] in just the first eleven months of 2020. These setbacks contributed to economic contraction and delayed the country's trajectory toward upper-middle-income status.[6] Meanwhile, the social consequences of the pandemic include an increase in mental health issues, attributed to prolonged isolation, increased social media use, and limited access to reliable information on COVID-19 treatment and prevention.[7]

The development and roll-out of COVID-19 vaccines in 2021 were critical in resuming economic and social activities disrupted by lockdowns and physical distancing measures. However, the emergence of variants of concern (VoCs) such as Alpha, Beta, Gamma, Delta, and Omicron has complicated disease control efforts. These VoCs exhibit increased transmissibility, potential immune evasion, and varying degrees of resistance to existing treatments and vaccines, necessitating continuous adaptation of vaccination strategies. The Omicron variant, in particular, demonstrated significant immune escape, leading to breakthrough infections even among vaccinated individuals. As a result, booster vaccinations and updated vaccine formulations became essential to maintaining immunity and reducing severe disease outcomes.

As governments, pharmaceutical companies, and international organizations work together toward universal access to vaccines, there is interest in ensuring that limited resources are well spent. Cost-effectiveness research plays a vital role in determining which vaccines should be publicly funded, as seen in countries with taxpayer-funded health systems such as the United Kingdom and Thailand. Evaluating the effectiveness of vaccines against VoCs is a key component of these analyses, particularly in assessing their impact on specific age groups, hospitalization rates, and overall transmission dynamics.

Given the Philippines' transition toward a universal healthcare model, it is imperative to examine the cost-effectiveness of COVID-19 vaccines in the local context. This study aimed to assess the health impact and cost-effectiveness of COVID-19 vaccines in the Philippines while explicitly considering the role of variants of concern, vaccination prioritization strategies, and the influence of public health policies such as physical distancing measures.

Rationale and Significance of the Study

This study is in response to the Call for Proposals from the 2018 Department of Health Advancing Health through Evidence Assisted-Decisions (DOH AHEAD) Program. Health Technology Assessment (HTA) is required for all purchases by the DOH, as per Republic Act 11223 (Universal Health Care Act of 2019). One of the DOH's goals is to maximize health outcomes across the population.

This study can support decision-makers with intricate choices with fairness and responsibility to its different stakeholders in terms of various COVID-19 vaccines while considering variants of concern, as well as scenarios that encompass age groups, policies on physical distancing, and other related variables.

METHODS

Study Design

A mixed methods design was employed, which includes: (1) desk review activities comprised of reviewing journal articles, unpublished studies, and other gray literature and examining secondary data from different government agencies; (2) a virtual survey of the out-of-pocket (OOP) expenditures of the patients as the total hospital bill does not include OOP. Since the patient's OOP is essential to the study, the team conducted a virtual survey through telephone and other messaging applications; (3) Dynamic Transmission Model (DTM) – in DTM, the likelihood of a susceptible person contracting an infection at any given moment is influenced by the number of infectious individuals in the population. This probability fluctuates over time and influences future infection rates through feedback loops. These complex interactions create transmission dynamics that need to be carefully accounted for when modeling

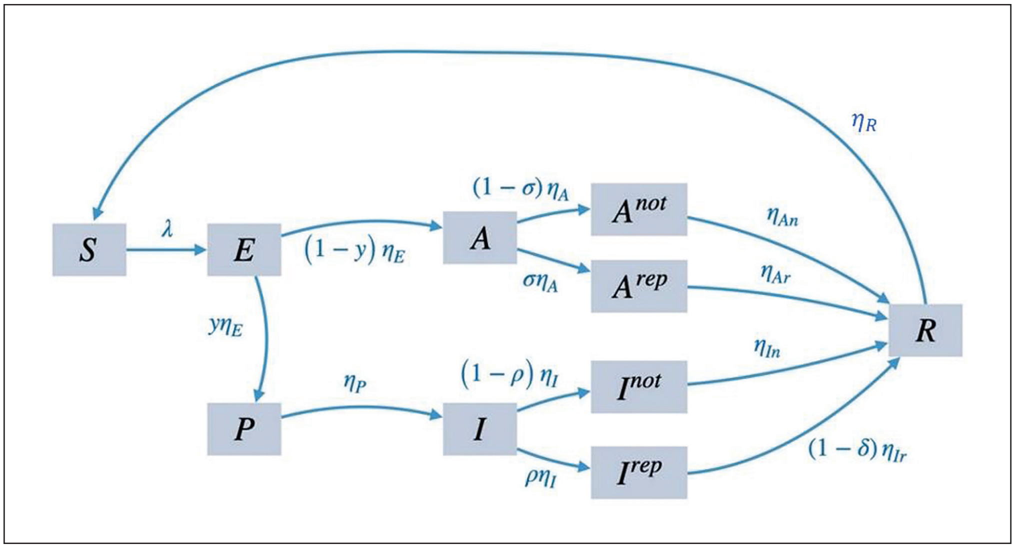

Figure 1. General transmission model for population with different vaccination status.

interventions that affect pathogen transmission.[8] The dynamic nature refers to the changing force of infection that is incorporated into the model. The model, as shown in Figure 1, follows the SEIR (Susceptible-Exposed-Infected-Recovered) layout with a proportion of infections being asymptomatic. The symptomatic cases are further subdivided by different severity levels: mild/moderate, severe, critical, and death, to evaluate the health burden. (4) Cost-effectiveness Analysis (CEA) Model – the CEA model investigates both the costs of providing healthcare and the health outcomes of one or more interventions by comparing each intervention in terms of the costs to the unit of health outcome again.[9] The results from the DTM were used in the CEA model to calculate the costs in different scenarios. To assess the robustness of the results, one-way and probabilistic sensitivity analyses were conducted. One-way sensitivity analysis was performed using TreeAge Pro to evaluate how variations in key parameters influenced cost-effectiveness outcomes. Costs and QALYs were assessed over a range of values from 50% below to 200% above the base case, with bootstrapping conducted in MS Excel to determine the lower and upper limits. Probabilistic Sensitivity Analysis (PSA) was conducted through Monte Carlo simulations with 10,000 iterations, following the recommendations of the International Society of Pharmacoeconomics and Outcomes Research (ISPOR). The PSA accounted for parameter uncertainty by applying probability distributions to key inputs: costs followed a gamma distribution, probabilities followed a beta distribution, and time-based variables followed a log-normal distribution. The upper and lower limit values for each parameter were derived from 95% confidence intervals based on published literature and government data. (5) Budget Impact Analysis (BIA) – the Budget Impact Analysis is only limited to 2020-2021 since the epidemiologic model only covered the same period. Applying the BIA beyond 2021 would require a closer evaluation of the effectiveness of the vaccine over time and whether yearly boosters will be required. The annual Health System costs for 2020 and 2021 were derived from the economic and epidemiologic models. The difference in annual costs between scenarios was computed for 2020 and 2021. Both health system and societal perspectives were adopted in the study. The health system perspective focused on direct medical costs, including hospitalization, vaccine procurement, and adverse event management. The societal perspective extended this by incorporating productivity losses, out-of-pocket expenditures, and indirect economic impacts. The dual perspective provided a more comprehensive assessment of the economic burden of COVID-19 and the potential financial benefits of vaccination.

Study Population and Demographics

The modeling was done for the entire Philippine population. The study considered different age groups and disease severity levels, categorizing cases into mild, moderate, severe, and critical. Demographic characteristics such as sex and regional distribution were documented (Table 1). While socioeconomic and clinical characteristics were not explicitly modeled, they were considered in cost estimates and hospitalization burden. All COVID-19 survivors were randomly selected for the survey. COVID-19 patients who died were assigned a QALY score of zero.

Sample Size

From the DOH list, randomly selected patients were invited to participate. It was assumed that 10% to 20% of those invited might refuse to give consent or be unable to participate for various reasons, therefore, a 30%-50% buffer was applied to the sample size. The sample size computation followed power analysis principles to achieve a confidence level of 95%. Stratified random sampling techniques were

Table 1. Demographics of Interviewed COVID-19 Patients

Sex	COVID-19 Severity	Count	Percentage (%)	Mean Age
Female	hospitalized	243	27.40	42.86 (40.69-45.03)
	ICU	125	14.09	48.86 (45.49-52.24)
	ICU+ventilator	99	11.16	52.33 (48.45-56.21)
	non-hospitalized	236	26.61	37.89 (36.06-39.71)
	pre-hospitalized	184	20.74	46.50 (43.75-49.24)
	Total	**887**	**52.77**	**44.20 (43.01-45.38)**
Male	hospitalized	203	25.57	44.10 (41.81-46.39)
	ICU	116	14.61	47.84 (44.69-50.98)
	ICU+ventilator	94	11.84	51.63 (48.17-55.08)
	non-hospitalized	187	23.55	39.09 (36.91-41.26)
	pre-hospitalized	194	24.43	41.38 (37-98-4377)
	Total	**794**	**47.23**	**43.69 (42.52-44.87)**
Total		**1,681**	**100.00**	**43.96 (43.13-44.79)**

employed, and Stata 14 was used for randomization. A total of 1,925 patients (385 each for the non-hospitalized, pre-hospitalized, hospitalized, hospitalized with ICU support, and hospitalized with ICU and ventilator support, excluding the buffer) were considered in the virtual survey.

Model Data Input and Its Sources

The input data for dynamic and cost-effectiveness models were gathered from published articles and different government and health agencies such as the DOH, PhilHealth, Health Technology Assessment Division (HTAD), FDA-Philippines, National Vaccination Operations Center, Philippine General Hospital, and others. Local data were prioritized, however, estimates from neighboring countries with similar demographics were used in the absence of local data. Table 2 presents the data inputted to the cost-effectiveness model.

For the numbers of COVID-19 cases and deaths over time and by age and testing over time, the COVID-19 Data Drop of the DOH[10] was utilized. Data Drop is a public and open-access database and serves as a COVID-19 tracker. For the proportion of cases that are hospitalized, severe, need intensive care, and the average length of stay, the PGH records of all COVID-19 patients were summarized and used. The QALY scores were calculated using the responses gathered from the virtual survey and the value set produced in the study of Miguel et al.[11], which is recommended in QALY calculations for the Philippines.

Direct medical costs included the total hospital bill claimed by healthcare facilities to PhilHealth plus the out-of-pocket of the patients and calculated considering mild to moderate COVID-19 patients, severe COVID-19 patients, and COVID-19 patients who are dead. These costs covered hospitalization, intensive care, and ventilator support. Costs attributable to vaccine management included vaccine procurement, administration, logistics, and adverse event monitoring. The population was stratified into five age groups. Vaccine management costs include the cost of vaccine supply management, vaccination administration, and vaccine acquisition. For the scenario with vaccination, the vaccination was rolled out in year 2020 and each person got two doses. The incidence rate of adverse events and the cost of managing the adverse events due to COVID-19 vaccination were obtained from the PhilHealth and Food and Drug Administration in the Philippines. Information on the cost of masks and hygiene was derived from the DOH Memorandum 2021-0223. It was also assumed that each Filipino consumed 1 gallon of alcohol per year. The compliance rate at the population level was assumed to be 93.5% (91% – 96%).[12] For each reported case, the study assumed that six people would be traced[13] and used the average Filipino household size, which is 4.1[14] as the total number of people. The time horizon is two years based on the output from the epidemiological model, and all costs were converted to 2020 prices and subjected to a discount rate of 3% to 10%. However, health outcomes, such as QALYs, were not discounted. Since the study focused on a short-term pandemic response within a two-year time horizon, discounting health outcomes was deemed unnecessary as the effects occurred within a limited period, making discounting less impactful. Total life year loss is calculated using the 2019 WHO Life Table for the Philippines.[15] Health outcomes were measured using both QALYs gained and total life years lost. While life years lost provide an absolute measure of disease burden, QALYs account for the quality of life by weighting survival based on health state utility values. This combined approach allows for a more comprehensive assessment of the benefits of vaccination, capturing both survival and quality of life improvements.

Interventions

The study compared the conduct of vaccination using multiple COVID-19 vaccines granted Emergency Use Authorization (EUA) in the Philippines against a no-vaccination scenario. The interventions included vaccines with varying efficacy rates, transmission reduction potential,

Table 2. Data Inputs to the Cost-effectiveness Model

Variable	Value (PhP)		Source / Remark
Direct Cost			
Mild to Moderate	**PHIC**	**OOP**	16
aged 4 and below	73,434.35	20,803.70	
aged 5 to 14	76,203.70	20,803.70	
aged 15 to 39	96,692.61	16,235.86	
aged 40 to 64	122,877.03	22,549.87	
aged 65 and above	170,361.87	32,665.34	
Severe/Critical			
aged 4 and below	463,642.92	108,277.1	
aged 5 to 14	378,552.36	108,277.1	
aged 15 to 39	499,241.83	59,432.73	
aged 40 to 64	677,043.13	103,295.96	
aged 65 and above	882,916.09	182,285.94	
Others			16
asymptomatic patient	0		
patient who died	633,459.33		
patient with adverse event due to vaccination	138,266.60		
Cost of COVID-19 screening	3,500 – 3,800		17
Cost of mask per person per year	2,757.50		18
Cost of hygiene and sanitizing per person per year	598.66		
Cost of contact tracing per person traced	300.00		Iloilo Provincial Health Office
Cost of quarantine at designated facilities / day	10,000.00		
Other Data Needs			
Productivity Loss	165,039 / 176,142		19
Number of people traced per detected case	1:6		13
Number of people quarantined per detected case	4.1		14
Incidence of adverse event/total vaccinated individual	0.15%		FDA - Philippines
Total Life Year Loss	Life table		15
QALY	mild-moderate: 0.8346		Patient survey
	severe: 0.1636		

Severity	Observation	Average LOS (in days)
PGH Summary of COVID-19 Cases and Length of Stay (LOS)[20]		
Critical guarded	546	13.34
Critical intubated	716	10.35
Mild	1,766	8.30
Moderate	1,739	14.76
Severe	1,463	14.73

and effectiveness in preventing hospitalization and mortality. The comparison aimed to determine the most cost-effective vaccination strategy, particularly in the presence of emerging variants of concern.

Ethical Considerations

The personal information of the interview participants was anonymized upon encoding. All participants were given an opportunity to consult with their trusted ones and with REB before signing consent. This study has been reviewed and was given ethical clearance by the Single Joint Research Ethics Board (SJREB) of the Department of Health, with SJREB Protocol No. 2021-119.

RESULTS

Epidemiologic Model Results

After examining all the data parameters, the epidemiologic model of COVID-19 was simulated and run using R. The model was run to replicate the first actual COVID-19 cases in the Philippines (Figure 2). The projected cases using the model (blue line) are similar to the actual COVID-19 data (red line).

Figures 3 to 6 show the projection of COVID-19 in terms of daily reported cases, asymptomatic cases, symptomatic cases, and cumulative death, assuming that there was no vaccination versus with vaccination.

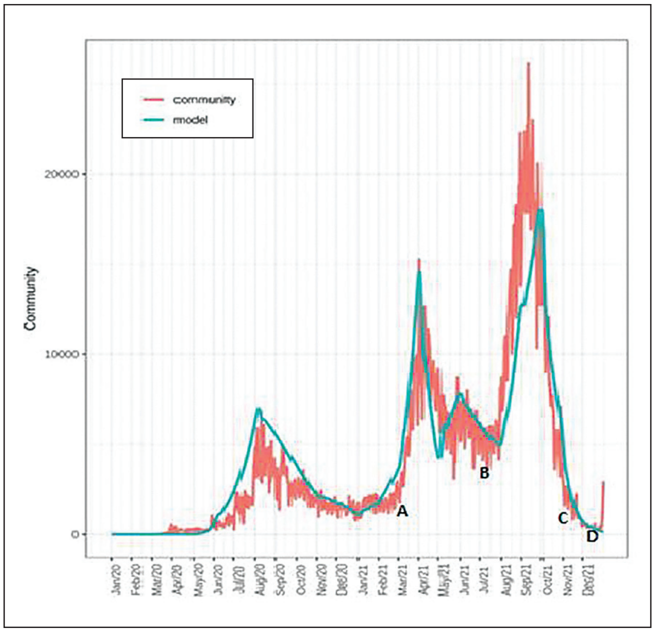

Figure 2. Performance of model.

Figure 3 shows that when there is no vaccine, the highest daily reported cases are between 200,000 and 410,000 from late January to March 2021. The highest was on February 22, 2021, with 410,000 cases. If there is a vaccine, the average daily reported cases are only around 4,300. The highest was on September 29, 2021, with 20,823 cases.

In terms of asymptomatic and symptomatic cases, if there is a vaccine, the total asymptomatic cases is 6.27 million, which is approximately 7.6 times lower, while the total symptomatic cases is 5.50 million, approximately 10 times lower compared to no vaccine (Figures 4 and 5). The averted asymptomatic and symptomatic cases due to vaccination are estimated to be around 41.47 million and 48.76 million, respectively.

For COVID-19 deaths, the projected cumulative death is 496,010 by the end of December 2021, when there is no vaccine. This is almost 11.87 times higher than with the vaccine, with a cumulative death of 41,777.25, by the end of 2021 (Figure 6). Around 454,232 deaths were estimated to be averted due to vaccination.

Cost-effectiveness Analysis Model Results

Table 3 shows the costs of direct medical, and vaccine management, adverse events due to vaccines, masks and hygiene, contact tracing and quarantine, and productivity loss if there was no vaccine and with the vaccine in 2020 and 2021. Direct medical had the highest total cost of approximately PhP 12.9 trillion for both years. This is almost 10 times higher compared to vaccines. Remarkably, the cost of minimum health standards (mask and hygiene) remained the same, while the contact tracing and quarantine were significantly lower. Productivity loss was also 11 times lower when there was a vaccine. The detailed difference in costs is also shown in Table 3.

Even if the cost, in terms of a societal perspective, is higher due to the productivity loss, 98% of the cost is incurred by the health system, as shown in Table 2, which implies that the burden of the pandemic lies heavily on the government providing healthcare and regulating the health system. Higher health spending means less spending or budget for other government projects.

Table 4 presents the health outcomes (death, life year, and QALY) of no vaccination and with vaccination. For death without vaccines in 2020 and 2021, the outcome is 11 times higher than with vaccination in the same years. The same goes for life year loss which is 10 times higher than vaccination.

Incremental Cost-effectiveness Ratio

The model shows that vaccination is good value for money and cost-saving compared to no vaccination but with

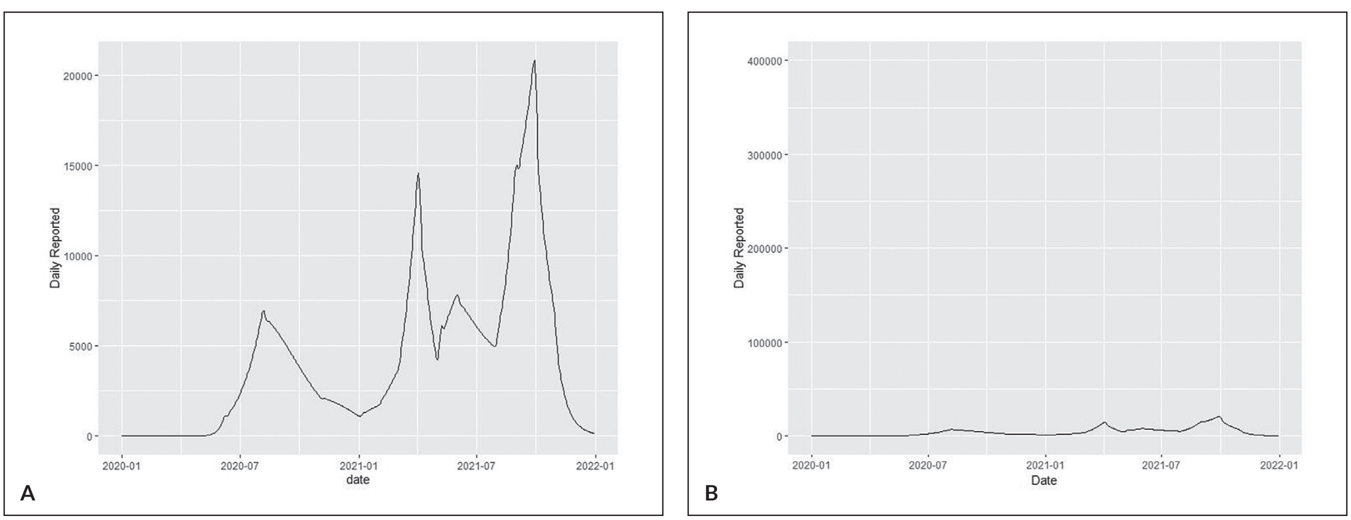

Figure 3. Comparison of daily reported cases **(A)** without vaccine and (B) with vaccine.

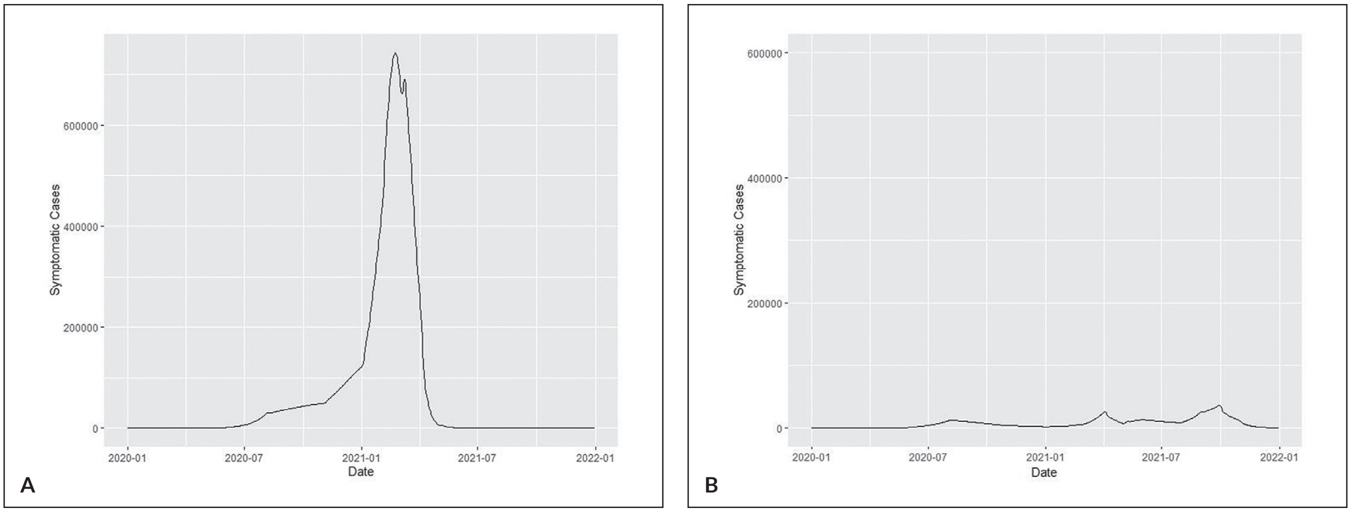

Figure 4. Comparison of symptomatic cases **(A)** without vaccine and (B) with vaccine.

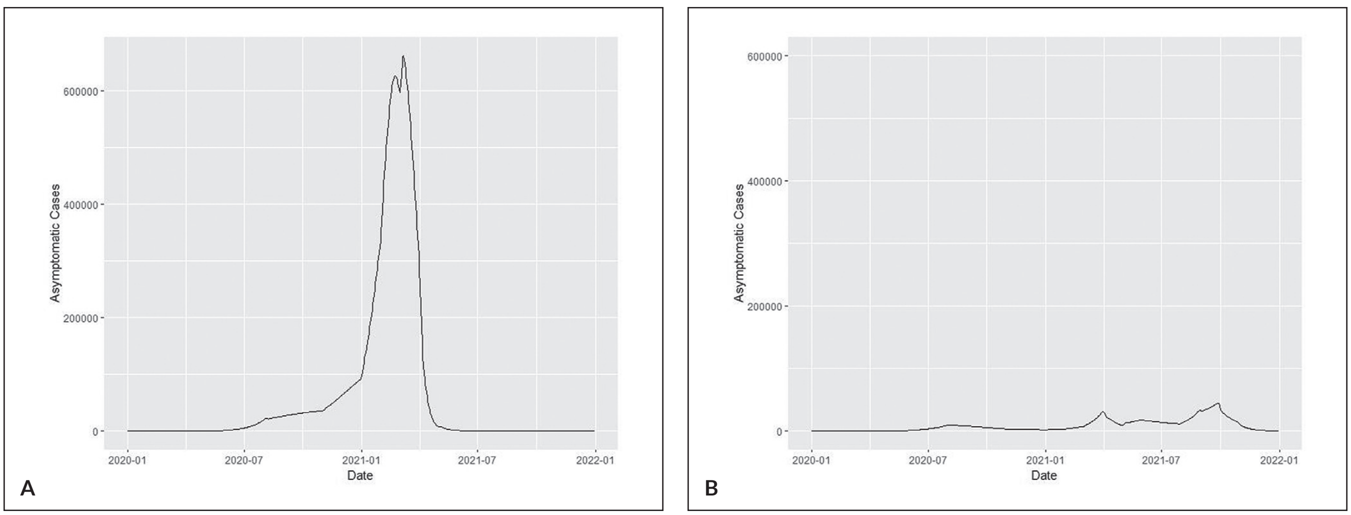

Figure 5. Comparison of asymptomatic cases **(A)** without vaccine and (B) with vaccine.

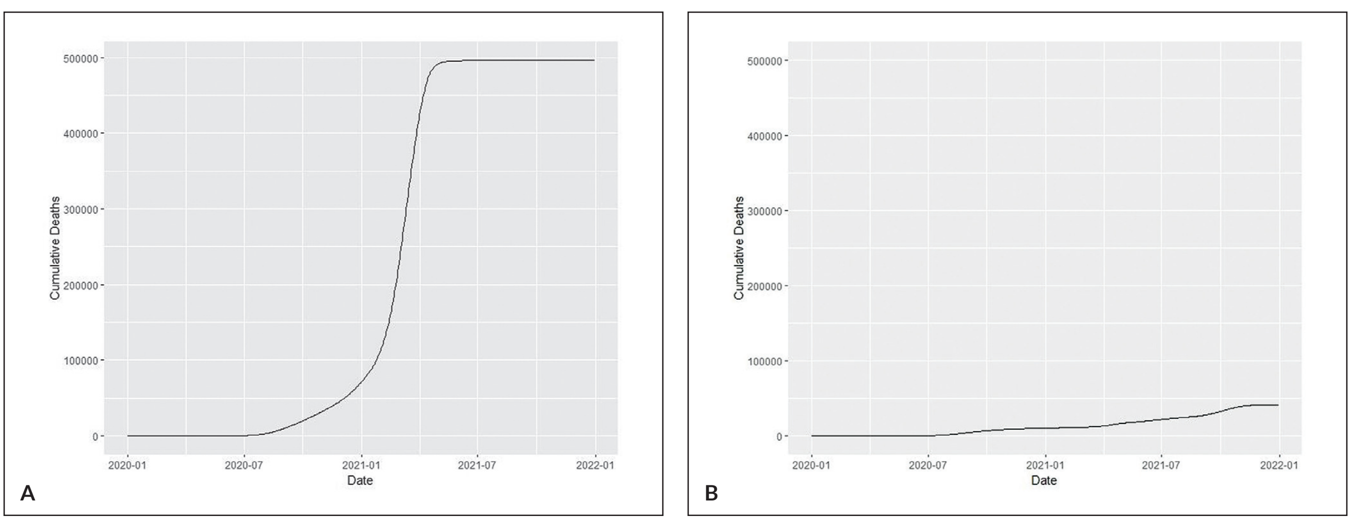

Figure 6. Comparison of cumulative deaths **(A)** without vaccine and (B) with vaccine.

Table 3. Costs of No Vaccination vs. With Vaccination in 2020 and 2021 (in billion pesos)

Scenario	Direct Medical	Vaccine Management	Adverse Event	Mask and Hygiene	Contact Tracing and Quarantine	Productivity Loss	Health System	Societal Perspective
No Vaccine								
No vaccine 2020	2,275.96	-	-	349.00	217.16	30.36	2,842.12	2,872.48
No vaccine 2021	11,007.60	-	-	346.76	1,071.75	205.32	12,426.12	12,631.44
No vaccine Total	**12,962.95**	**-**	**-**	**685.66**	**1,257.70**	**229.70**	**14,906.31**	**15,136.01**
With Vaccine								
Vaccine 2020	309.46	271.83	23.02	349.02	30.12	4.21	983.45	987.66
Vaccine 2021	1,018.79	-	-	348.01	104.44	16.73	1,471.24	1,487.96
Vaccine Total	**1,298.57**	**271.83**	**23.02**	**686.89**	**131.52**	**20.46**	**2,411.84**	**2,432.29**
Difference between no vaccine and with vaccine								
2020	(1,966.50)	(271.83)	(23.02)	(0.03)	(187.04)	(26.15)	(1,858.66)	(1,884.81)
2021	(9,988.81)	(0.00)	(0.00)	(1.24)	(967.31)	(188.59)	(10,954.89)	(11,143.48)
Total	**(11,664.38)**	**(271.83)**	**(23.02)**	**(1.23)**	**(1,126.18)**	**(209.25)**	**(12,494.48)**	**(12,703.72)**

Table 4. Health Outcomes of No Vaccination vs. With Vaccination

	Death	Life year loss	Total QALY
No Vaccine			
No vaccine 2020	25,540.27	1,765,739.55	110,895,823.15
No vaccine 2021	159,432.13	10,717,808.03	110,132,894.23
No vaccine Total	**184,972.40**	**12,483,547.58**	**217,820,963.17**
With Vaccine			
Vaccine 2020	3,862.56	267,743.81	110,984,261.29
Vaccine 2021	12,358.33	911,425.21	110,934,238.86
Vaccine Total	**16,220.89**	**1,179,169.02**	**218,687,405.82**

Table 5. Incremental Cost-effectiveness Ratio Using a Health System Perspective

Discount Rate	No Vaccine		With Vaccine		ICER (PhP/QALY)
	Cost (PhP)	QALY	Cost (PhP)	QALY	
3%	12,462,871,026,571.00	97,868,661.70	2,016,487,713,351.78	106,165,462.17	(1,259,085.76)
5%	12,270,744,661,690.40	95,850,751.15	1,993,740,225,077.21	103,976,483.57	(1,264,748.08)
7%	12,085,800,590,824.10	93,832,840.60	1,971,843,110,196.08	101,787,504.97	(1,271,449.93)
10%	11,820,994,307,538.20	90,805,974.78	1,940,490,422,979.93	98,504,037.06	(1,283,505.32)

Table 6. Incremental Cost-effectiveness Ratio Using a Societal Perspective

Discount Rate	No Vaccine		With Vaccine		ICER (PhP/QALY)
	Cost (PhP)	QALY	Cost (PhP)	QALY	
3%	15,136,012,181,474.50	97,868,661.70	2,432,290,645,461.37	106,165,462.17	(1,531,159.10)
5%	14,902,421,034,660.90	95,850,751.15	2,404,773,960,081.45	103,976,483.57	(1,538,033.30)
7%	14,677,562,267,167.40	93,832,840.60	2,378,285,935,837.22	101,787,504.97	(1,546,171.63)
10%	14,138,589,345,659.80	90,805,974.78	2,340,359,901,123.89	98,504,037.06	(1,532,623.28)

NPI for both health systems and societal perspectives, with an ICER of -1,520,727.28 PhP /QALY and -1,546,171.63 PhP /QALY, respectively (Tables 5 and 6). The ICER measures the economic value of an intervention compared to an alternative by dividing the difference in cost by the difference in health outcomes. The alternative intervention is cost-effective (less costly and more effective) when it is lower than the willingness to pay threshold. For the Philippines, the willingness to pay threshold is equivalent to the latest GDP per capita of PhP 174,286 (USD 3,538.80) as of 2021. When the ICER is negative, it is cost-effective and cost-saving since the alternative intervention is cheaper and more effective. This is shown in Tables 5 and 6, where Vaccine and NPI have lesser cost and higher QALY than No Vaccine and NPI for both perspectives.

Further examination of the cost components driving the results revealed that direct medical costs were the most influential factor affecting the ICER. In the absence of vaccination, direct medical costs reached approximately PhP 12.9 trillion for 2020 and 2021 combined — almost ten times higher than the total vaccine-related costs of PhP 1.3 trillion. The costs for minimum health standards (mask and hygiene) remained constant in both scenarios, while expenses related to contact tracing and quarantine were substantially lower in the vaccination scenario. Productivity losses were also notably reduced with vaccination, reflecting the lower number of cases and deaths. This substantial reduction in healthcare costs and productivity losses largely explains why the vaccination program resulted in both improved health outcomes and overall cost savings.

The results show that even with different discount rates (3%, 5%, 7%, and 10%), the scenario of "With Vaccine" will still be cost-effective and cost-saving for both the Health System and the Societal Perspective. The small difference in ICER between the two perspectives can be due to the minimal difference in cost between the two. Both perspectives have similar costs, with only the cost of productivity loss being added for the Societal Perspective.

Budget Impact Analysis (BIA)

The annual expenses of the Philippine government for each scenario are summarized in Table 7. Only the health system costs were considered since these are subsidized by the government, including vaccination, treatment of infected (moderate to severe) individuals, contact tracing, and quarantine. The direct medical costs borne by the government were calculated by analyzing PhilHealth reimbursements per age category and disease severity. It was assumed that PhilHealth utilized case rates to reimburse patients. The annual average cost per age group, taking into account the severity of conditions, was used as an estimate for the government's expenses in treating COVID-19 patients.

The budget impact shows that the estimated government expenses for the vaccine scenario reached 983.45 billion in 2020 and 1.47 trillion in 2021. This is less than the estimated expenses for the no-vaccine scenario. This shows that the government saved 1.967 trillion in 2020 and 9.989 trillion in 2021 when the vaccination program was rolled out compared to no vaccination.

Sensitivity Analysis

The tornado diagram indicates that changes in the parameters have little impact on the results, and demonstrates that the vaccine scenario remains a cost-effective option as all of the ICERs are below the WTP of 174,286 despite changes in the parameters (Figure 7).

The PSA showed that ICERs were Cost Saving 76.22% of the time, Cost Effective 21.53% of the time, and Indifferent 2.25% of the time (Figure 8). These results reinforced the base case estimation that vaccination for COVID-19 was cost-saving compared to no vaccination.

DISCUSSION

This study provides a detailed simulation of the COVID-19 situation in the Philippines during 2020 and 2021, demonstrating that COVID-19 vaccines are highly effective in mitigating the spread of the virus and offer strong value for money. Our findings align with previous economic evaluations in high-income countries (HICs) and lower-middle-income countries (LMICs), which have also found that vaccination strategies reduce transmission, morbidity, and mortality, while offering cost-saving benefits in healthcare systems and have a positive impact on countries from a social and economic perspectives.[21-24] The results of the model indicate that in the absence of vaccines, the projected deaths for 2021 were approximately 12 times higher than the actual cumulative deaths recorded. Similarly, the highest number of daily reported cases in a no-vaccine scenario reached 400,000 between February and May 2021, compared to only around 20,000 daily cases in the vaccination scenario.

Findings from HICs, such as the United States and England, have demonstrated that vaccination programs not only prevent severe cases and hospitalizations but also predicted to generate substantial economic savings by reducing healthcare costs and productivity losses.[25-27] Similarly, cost-effectiveness analyses in upper-middle-income and lower-middle-income countries, including India, Thailand, and 27 countries in Africa, have shown that even with constrained healthcare resources, vaccine deployment remains cost-effective due to its ability to reduce hospitalization costs and prevent economic disruptions.[21,28-31] Reducing vaccine procurement costs and enhancing vaccine efficacy can strengthen the economic benefits of COVID-19 vaccination programs.

The cost-effectiveness analysis (CEA) further underscores the value of vaccination, revealing that vaccination is cost-saving when compared to a no-vaccine scenario from both societal and health systems perspectives. Specifically, the vaccine scenario led to estimated savings of PhP 1.967 trillion in 2020 and PhP 9.989 trillion in 2021 for health system costs. Moreover, the calculated ICERs were -1,520,727.28 PhP / QALY and -1,546,171.63 PhP /QALY, indicating significant cost savings in terms of health outcomes. These results are consistent with findings from other evaluations in similar contexts, reinforcing the economic benefits of vaccination.

Despite these significant benefits, vaccine implementation in LMICs often faces challenges such as funding constraints, vaccine hesitancy, and logistical barriers. Unlike HICs, where mass vaccination campaigns were swiftly rolled out, many LMICs, including the Philippines, faced supply chain issues and delays in procurement, which may have influenced the overall impact of vaccination efforts. Future

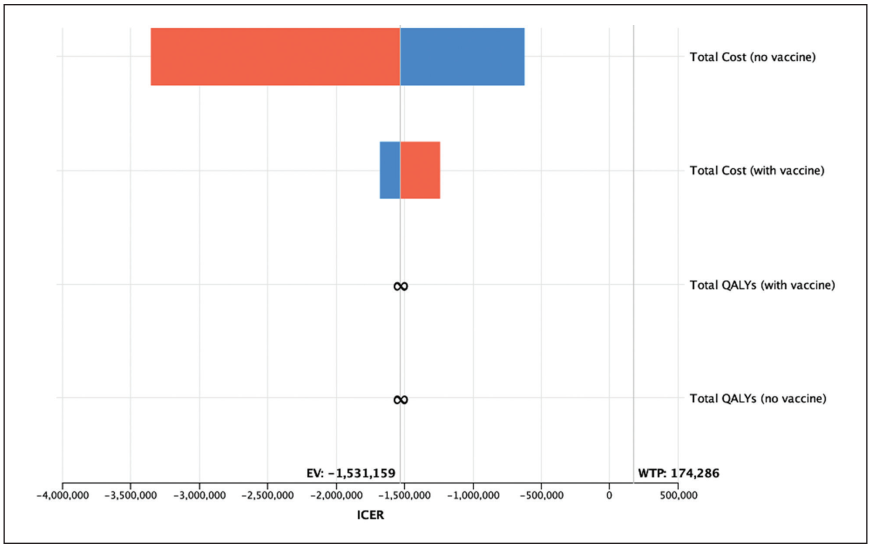

Figure 7. Tornado diagram: With Vaccine versus No Vaccine (WTP = PhP 174,286).

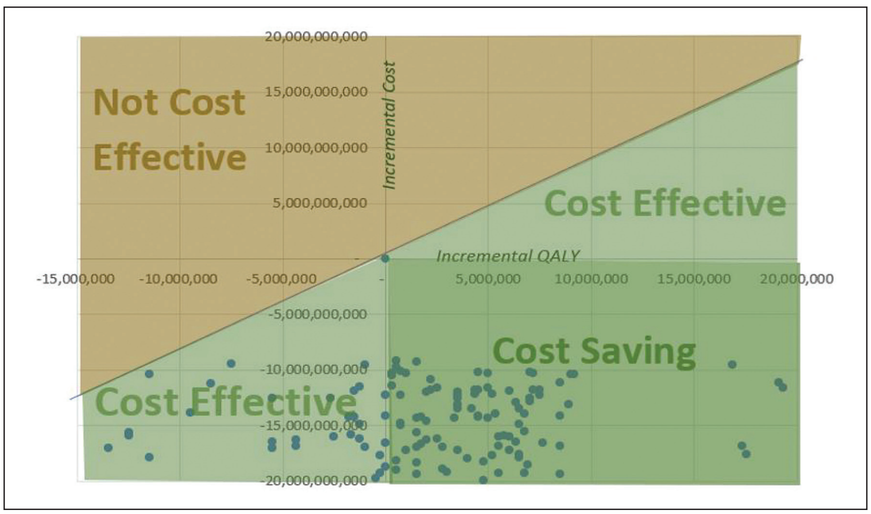

Figure 8. Scatter plot of probabilistic sensitivity ICERs in a cost-effectiveness plane.

Table 7. Health System Costs and Budget Impact (in billion pesos)

Variables	2020	2021
No Vaccine		
Direct medical cost	2,275.96	11,007.60
Vaccine cost	-	-
Adverse event	-	-
Mask and hygiene	349.00	346.76
Contact tracing and quarantine	217.16	1,071.75
Total cost	2,842.12	12,426.12
With Vaccine		
Direct medical cost	309.46	1,018.79
Vaccine cost	271.83	-
Adverse event	23.02	-
Mask and hygiene	349.02	348.01
Contact tracing and quarantine	30.12	104.44
Total cost	983.45	1,471.24
Budget Impact		
Total cost with no vaccine	2,842.12	12,426.12
Total cost with vaccine	983.45	1,471.24
Difference in total cost	(1,966.50)	(9,988.81)

studies should explore how to optimize vaccine distribution and ensure equitable access, particularly in resource-limited settings where the economic burden of infectious diseases is disproportionately high.

Limitations

We acknowledge several limitations in this study that may influence the interpretation of the results. First, the study relied on key assumptions due to data limitations, particularly in estimating the QALY values for mild and moderate COVID-19 conditions. One notable assumption in this analysis is assigning the same QALY value of 0.8346 to both mild and moderate COVID-19 cases. However, it is possible that individuals with mild and moderate symptoms experience different impacts on their quality of life, which may be influenced by varying access to healthcare, socio-economic conditions, or cultural factors. Given that the majority of COVID-19 cases in the model were either mild or moderate, the use of a single QALY value for both conditions may have affected the total QALYs gained, and subsequently, the ICER. To address this uncertainty, sensitivity analyses were conducted to assess the potential impact of varying these QALY values on the results.

Second, certain parameters were not captured in the model due to data unavailability. For instance, costs related to long COVID, mental health consequences, indirect effects of prolonged NPIs (e.g., disruption in other health services), and emergence of new COVID-19 variants or other potential developments beyond the 2020-2021 timeframe were not included. These missing parameters may have led to a conservative estimate of the benefits of vaccination, as including them would likely increase both the health gains and potential cost savings from preventing COVID-19 infections. Despite these limitations, the study conducted extensive sensitivity and scenario analyses to explore the uncertainty around key parameters and assumptions, supporting the robustness of the findings.

Another limitation concerns the calculation of productivity loss, which was confined to patients, without considering the broader economic impact. While the analysis focused on the productivity loss of infected individuals, the implications for the macroeconomy were not assessed. Additionally, the productivity loss model did not factor in the age of patients, which may influence the magnitude of economic losses, as younger populations may contribute more to the economy. Incorporating age-specific productivity loss estimates could provide more granular insights into the economic burden.

Finally, as with all modelling studies, the results are dependent on the assumptions made and the quality of the available data. Future studies using updated or local real-world data, particularly on healthcare utilization and long-term impacts of COVID-19, are recommended to further refine these estimates.

CONCLUSION AND RECOMMENDATIONS

In conclusion, this study provides a comprehensive analysis of the COVID-19 landscape in the Philippines throughout 2020 and 2021, demonstrating that COVID-19 vaccines played a crucial role in reducing transmission, hospitalizations, and deaths. The findings align with economic evaluations from high-income and lower-middle-income countries, reinforcing that vaccination strategies not only protect public health but also generate significant economic benefits. The comparison between scenarios with and without vaccination highlights the substantial cost savings associated with widespread vaccine deployment, including reduced direct medical expenses, lower productivity losses, and overall health system savings. The negative incremental cost-effectiveness ratios further emphasize that vaccination is a cost-saving intervention. However, challenges such as vaccine accessibility, procurement costs, and logistical barriers in lower-resource settings must be addressed to maximize the benefits of future vaccination programs. Strengthening vaccine distribution strategies and ensuring equitable access will be key to enhancing economic resilience and pandemic preparedness in the years to come.

Building on the study's findings that COVID-19 vaccination is both health-improving and cost-saving, it is essential to strengthen existing vaccination strategies in the Philippines through targeted policy and programmatic actions. Policy-wise, enhancing vaccine procurement through advance purchase agreements and supporting regional manufacturing collaborations would help secure timely and affordable vaccine access, consistent with the UHC Act and pandemic preparedness goals. Integrating vaccination services within local health service delivery networks (SDNs), improving real-time data systems for tracking vaccine coverage and health outcomes, and investing in local capacity for disease modeling are critical to sustaining pandemic response efforts. At the program level, expanding evidence-based health promotion campaigns to address vaccine hesitancy, improving last-mile vaccine delivery, particularly in rural and disadvantaged areas, and supporting further research on long COVID and its economic impact are necessary to maximize the benefits of vaccination, strengthen health system resilience, and guide future policy directions.

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Statement of Authorship

All authors certified fulfillment of ICMJE authorship criteria.

Author Disclosure

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