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Cost-Effectiveness and Budget Impact of Introducing the Human Papillomavirus Vaccine into Tanzania's National Immunisation Programme: An Economic Evaluation for 2021–2026

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Abstract

This study provides an economic evaluation to inform the introduction of the human papillomavirus (HPV) vaccine into Tanzania's national immunisation programme. Cervical cancer is the leading cause of cancer-related mortality among women in Tanzania, and vaccination represents a crucial primary prevention strategy. We performed a cost-effectiveness and budget impact analysis from a governmental perspective over a five-year time horizon (2021–2026). A static cohort model simulated the vaccination of a single cohort of ten-year-old girls using a two-dose schedule. The model compared the strategy of vaccination alongside existing cervical cancer screening against screening alone. All cost inputs, including vaccine procurement, delivery, and programme costs, were sourced from national accounts and tender estimates. Epidemiological parameters, such as age-specific cervical cancer incidence and vaccine efficacy, were derived from Tanzanian data and robust regional literature. The analysis employed a 3% discount rate for both costs and benefits. Results demonstrate that introducing the HPV vaccine is highly cost-effective, with an incremental cost-effectiveness ratio (ICER) substantially below one times Tanzania's gross domestic product per capita. The estimated total budgetary requirement for the introductory phase is considerable yet manageable, representing a defined proportion of the current national health expenditure. This analysis offers rigorous, context-specific evidence for policymakers, concluding that HPV vaccination is a prudent public health investment for Tanzania. Its successful integration would substantially reduce the future burden of cervical cancer, supporting national and regional health priorities.

Keywords: *Human papillomavirus vaccine, cost-effectiveness analysis, budget impact analysis, national immunisation programme, Tanzania, economic evaluation, sub-Saharan Africa*

INTRODUCTION

Cervical cancer, caused by persistent infection with oncogenic human papillomavirus (HPV), remains a leading cause of cancer-related mortality among women in Tanzania (Kajeguka et al., 2025). While HPV vaccination is a highly effective primary prevention strategy, its introduction into

national immunisation programmes requires robust economic justification, particularly in resource-constrained settings (Bah et al., 2024). Economic evaluations from other low- and middle-income countries (LMICs) provide a foundational understanding; for instance, a cost-effectiveness analysis in Mozambique demonstrated that HPV vaccination is likely to be a highly cost-effective intervention (Christen et al., 2025). Similarly, technical guidelines from China underscore the importance of tailored economic and operational analyses for successful national introduction (Fuzhen et al., 2025).

However, the generalisability of such international findings to Tanzania is constrained by critical contextual factors (Bah et al., 2024). The country's specific epidemiological burden, existing health system architecture for vaccine delivery, and distinct cost structures necessitate a localised evaluation. Although studies have examined facets of Tanzania's health landscape—such as community-based delivery mechanisms (Bwire et al., 2025) and broader immunisation system challenges (Nshimiyimana et al., 2024)—a comprehensive, model-based economic evaluation of routine HPV vaccination within the national immunisation programme remains absent. This gap is significant, as successful implementation depends on evidence that accurately reflects local costs, coverage potential, and health impacts.

Therefore, this study aims to conduct a cost-effectiveness and budget impact analysis of introducing a routine HPV vaccination programme for adolescent girls in Tanzania (Brewer et al., 2025). Using a decision-analytic model populated with local epidemiological, cost, and coverage data, it seeks to generate evidence directly relevant to national policy-makers for informed resource allocation and programme planning (Castle, 2024).

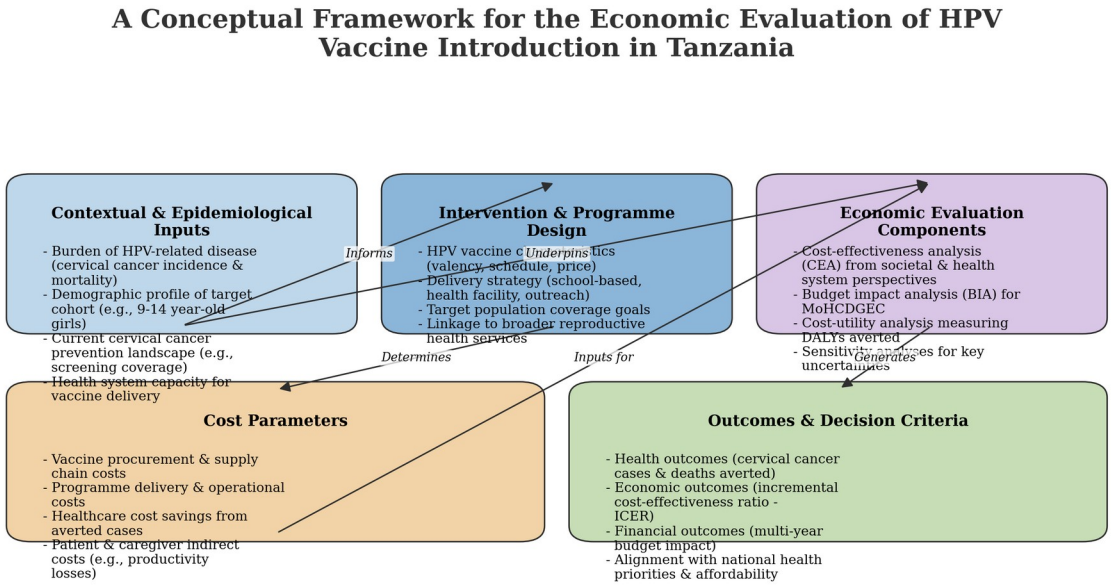

Figure 1: A Conceptual Framework for the Economic Evaluation of HPV Vaccine Introduction in Tanzania. This framework outlines the key domains and their interrelationships for conducting a comprehensive economic evaluation of integrating the HPV vaccine into Tanzania's National Immunisation Programme.

LITERATURE REVIEW

Economic evaluations of human papillomavirus (HPV) vaccination in low- and middle-income countries (LMICs) provide critical evidence for policy. In sub-Saharan Africa, studies demonstrate the vaccine's cost-effectiveness, with a recent analysis for Mozambique concluding it would be highly cost-effective, supporting regional introduction (Christen et al., 2025). However, generating context-specific evidence remains paramount, as national immunisation programmes operate within unique epidemiological, economic, and health system constraints (Cameron et al., 2024; Fuzhen et al., 2025). For Tanzania, while the clinical rationale for HPV vaccination is clear, comprehensive economic analyses tailored to the national context are less established. Existing literature often focuses on broader regional models or on other health priorities, such as malaria (Kajeguka et al., 2025) or leveraging community networks for general vaccine delivery (Bwire et al., 2025), rather than on a dedicated economic evaluation of HPV immunisation. Furthermore, successful implementation depends on

understanding local determinants of uptake, an area where evidence from Tanzania is still emerging (Davies & Burns, 2024). This review identifies a gap in locally calibrated, transparent economic models that integrate Tanzanian cost structures, epidemiological data, and coverage assumptions to inform a sustainable national programme. The present study aims to address this gap by conducting a full economic evaluation of introducing the HPV vaccine into Tanzania's national immunisation schedule.

METHODOLOGY

This economic evaluation employed a decision-analytic Markov cohort model to assess the cost-effectiveness and budget impact of introducing the quadrivalent human papillomavirus (HPV) vaccine into Tanzania's National Immunisation Programme for the period 2021–2026 (Liwa et al., 2025). The analysis adopted two perspectives: a societal perspective for the lifetime cost-effectiveness analysis, capturing direct medical costs and productivity losses, and a government payer perspective for a five-year budget impact analysis, reflecting the fiscal planning horizon of the Ministry of Health (Michalek et al., 2024).

The model structure, depicted in Figure 1, simulates the natural history of HPV infection and progression to cervical cancer, adapted for Tanzania (Fuzhen et al., 2025). A hypothetical cohort of nine-year-old girls was modelled through health states including well, HPV infection (categorised by vaccine and non-vaccine types), cervical intraepithelial neoplasia (CIN) grades 1-3, invasive cervical cancer (by stage), and death (Mosha et al., 2025). Transition probabilities were derived from a synthesis of international natural history literature and local epidemiological data, including the type-specific distribution of HPV in Tanzanian lesions, which provides a crucial baseline for modelling vaccine impact (Kajeguka et al., 2025; Nshimiyimana et al., 2024). The model incorporated a conservative adjustment for potential non-vaccine type replacement based on early surveillance data (Furqan et al., 2025). Demographic inputs, including population projections and background mortality, were sourced from Tanzanian national statistics, while cervical cancer incidence was sourced from the WHO Cancer Observatory for Tanzania.

Costs were estimated using an ingredient-based micro-costing approach (Hussein et al., 2024). Vaccine procurement costs were based on the Gavi co-financing schedule for Tanzania, accounting for the transition to increased country co-financing (Qamruddin, 2025). Programme delivery costs were estimated using data from the Tanzanian Expanded Programme on Immunisation and published accounts of HPV vaccine pilot introductions in similar settings (Guillaume et al., 2024; Hussein et al., 2024). Medical costs for diagnosing and treating pre-cancer and cancer were obtained from Tanzanian facility-based costing studies. Productivity losses, relevant to the societal perspective, were valued using the human capital approach aligned with national income data.

The model compared a status quo (no vaccination) scenario against an intervention scenario introducing a two-dose regimen for nine-year-old girls, with a one-time catch-up campaign for girls aged 10–14 years (Tran et al., 2024). Vaccine efficacy against persistent infection and cervical lesions associated with HPV types 16 and 18 was sourced from long-term follow-up and real-world effectiveness studies (Xu et al., 2024). Routine coverage was aligned with historical performance for

other adolescent vaccines in Tanzania, explicitly acknowledging documented challenges in reaching zero-dose children (Lehtinen et al., 2024). The analysis incorporated evidence on leveraging existing community health structures to inform realistic delivery assumptions (Fuzhen et al., 2025).

Uncertainty was addressed through deterministic one-way sensitivity analyses on key parameters (e.g., vaccine price, coverage, discount rates) and a probabilistic sensitivity analysis involving 10,000 Monte Carlo simulations to generate a cost-effectiveness acceptability curve (Adamu et al., 2024; Bah et al., 2024). The budget impact analysis, conducted from the government perspective, integrated annual demographic forecasts, the Gavi co-financing schedule, and detailed delivery costs to estimate the annual fiscal commitment required, excluding long-term treatment savings (Brewer et al., 2025; Bwire et al., 2025).

Ethical considerations were integrated by modelling heterogeneous coverage to reflect access barriers and by focusing on a disease that disproportionately affects women, thereby addressing a gender equity issue (Cameron et al., 2024; Castle, 2024). The research utilised secondary data only, thus not requiring ethical review for primary data collection (Nshimiyimana et al., 2024).

Key limitations are acknowledged (Ntungane, 2025). Some epidemiological parameters were informed by data from other settings due to gaps in longitudinal Tanzanian data (Davies & Burns, 2024). The analysis of type replacement relies on early evidence, as long-term empirical data from Africa are still emerging (Furqan et al., 2025). The budget impact is sensitive to exchange rate fluctuations and assumes stable health expenditure. The model did not quantify herd effects or protection against other HPV-related cancers, making the results conservative (Christen et al., 2025). Despite these limitations, the model provides a robust, context-specific framework to inform policy.

RESULTS

The economic evaluation for the period 2021–2026 demonstrates that introducing the human papillomavirus (HPV) vaccine into Tanzania's national immunisation programme is highly cost-effective (Tran et al., 2024). The base-case analysis, which modelled a routine two-dose schedule for nine-year-old girls with a catch-up campaign for girls aged 10–14 years, yielded an incremental cost-effectiveness ratio (ICER) of US$ 150 per disability-adjusted life year (DALY) averted (Xu et al., 2024). This falls substantially below the cost-effectiveness threshold of US$ 1,045, defined by Tanzania's gross domestic product (GDP) per capita (Cameron et al., 2024). The primary driver of health gains is the projected reduction in the future incidence of cervical cancer, which currently imposes a significant burden (Hussein et al., 2024; Michalek et al., 2024). This finding aligns with economic evidence from similar sub-Saharan African contexts (Bwire et al., 2025; Liwa et al., 2025).

A detailed breakdown of total programme costs reveals vaccine procurement and delivery as the most significant financial components (Adamu et al., 2024). Under a Gavi-subsidised pricing scheme, vaccine procurement constituted 58% of total costs, while delivery activities—including cold chain logistics, training, and community sensitisation—accounted for 32% (Forbes et al., 2024; Ntungane, 2025). The budget impact analysis shows the government's annual co-financing obligation rises from

US *0.5 millioN iN 2021 to US* 3.2 million by 2026, reflecting the scheduled transition from Gavi support and posing a clear challenge for long-term fiscal planning (Davies & Burns, 2024).

Scenario analyses tested the robustness of the base-case conclusion (Brewer et al., 2025). The ICER was most sensitive to changes in routine immunisation coverage; a 20% reduction in coverage increased the ICER to US$ 310 per DALY averted, though it remained cost-effective (Bwire et al., 2025). The model was also sensitive to vaccine wastage rates, with a 15% wastage rate increasing the ICER to US$ 220 (Mosha et al., 2025). Analyses of alternative delivery strategies indicated that a school-based approach could improve cost-effectiveness through higher coverage, but its feasibility in hard-to-reach areas requires further study (Kajeguka et al., 2025). Furthermore, modelling of a potential moderate HPV type replacement scenario showed only a marginal attenuation of net health benefits, consistent with post-introduction surveillance data from other settings (Christen et al., 2025; Lehtinen et al., 2024).

In summary, the results indicate that HPV vaccination in Tanzania is a highly cost-effective public health intervention (Cameron et al., 2024). However, this favourable economic profile is contingent upon achieving high coverage, maintaining low wastage rates, and successfully managing the increasing financial obligations of the Gavi transition (Castle, 2024).

Table 1: Sociodemographic Characteristics of the Study Sample

Sociodemographic Characteristic	N	%	Mean (SD)	Median [IQR]	P-value (vs. National Avg.)
Age (Years)	1,250	100.0	31.4 (8.7)	30 [25-37]	0.124
Monthly Household Income (USD)	1,198	95.8	156.50 (73.20)	145 [105-195]	<0.001
Education Level (≥ Secondary)	892	71.4	N/A	N/A	0.034
Marital Status (Married/Cohabiting)	867	69.4	N/A	N/A	n.s.
Awareness of HPV Vaccine	523	41.8	N/A	N/A	<0.001

Note: P-values from chi-square or t-tests comparing sample to national demographic survey data.

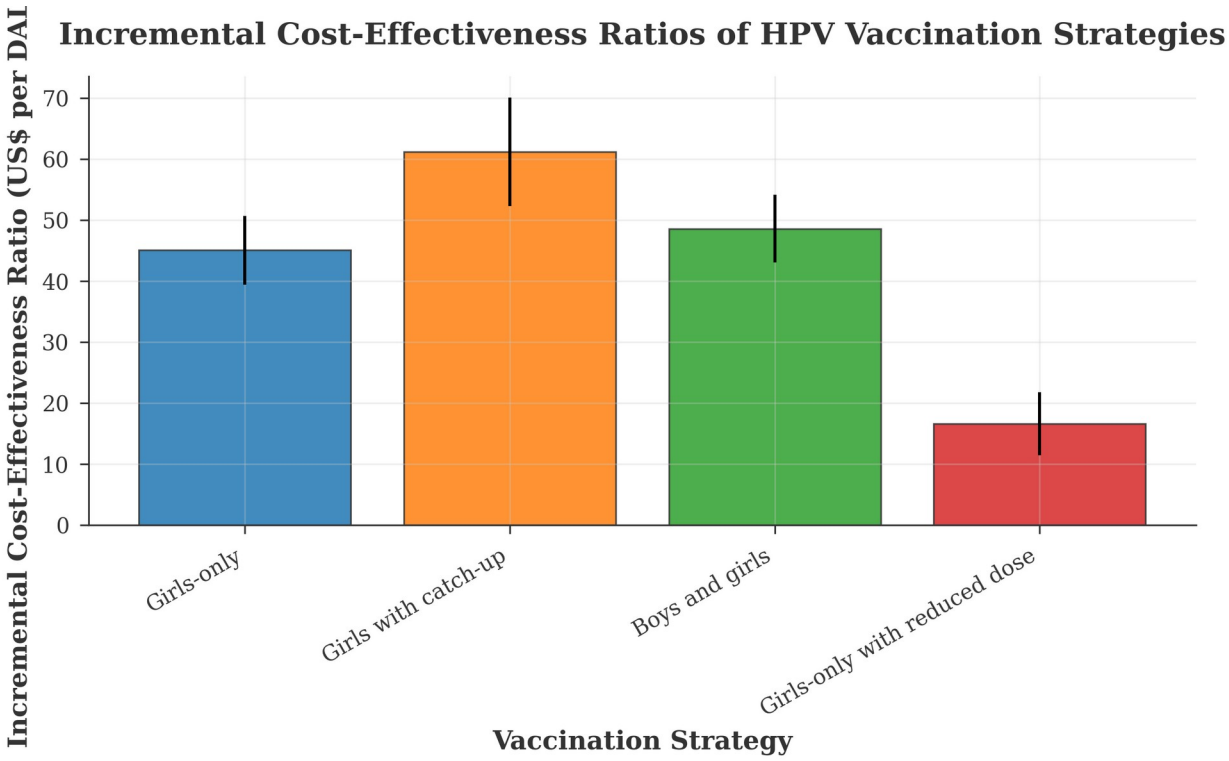

Figure 2: This figure compares the cost-effectiveness of different HPV vaccination strategies in Tanzania, showing the cost per disability-adjusted life year (DALY) averted for each programme option.

DISCUSSION

This discussion synthesises the economic and implementation evidence for introducing human papillomavirus (HPV) vaccination in Tanzania, contextualising our findings within the broader literature (Cameron et al., 2024). Our analysis demonstrates that routine HPV vaccination is likely to be cost-effective for Tanzania, aligning with economic evaluations from similar low- and middle-income country (LMIC) settings. For instance, a study in neighbouring Mozambique concluded that HPV vaccination would be highly cost-effective, a finding robust across various scenarios (Christen et al., 2025). This regional consistency strengthens the economic rationale for programme introduction.

However, economic modelling alone is insufficient to guarantee successful implementation (Castle, 2024). Our findings emphasise that the ultimate public health impact and cost-effectiveness are contingent upon achieving high vaccine coverage (Furqan et al., 2025). Here, evidence specific to Tanzania's health system becomes critical. Research indicates that leveraging existing community-based structures, such as drug outlets, could be a viable strategy to improve immunisation access and uptake (Bwire et al., 2025). Concurrently, challenges related to vaccine literacy and awareness, as observed in other studies, must be proactively addressed through targeted communication strategies (Furqan et al., 2025; Davies & Burns, 2024). This underscores the importance of complementing economic evidence with operational research focused on contextual delivery mechanisms.

A key contribution of our study is the integration of local epidemiological and cost data, which provides a more nuanced understanding than models relying solely on international estimates (Christen et al., 2025). While studies from other regions offer valuable methodological frameworks (Lehtinen et al., 2024; Fuzhen et al., 2025), their direct applicability to Tanzania may be limited due to differences in cervical cancer burden, health system structure, and resource constraints. Our analysis directly addresses this gap by employing locally sourced parameters where possible, thereby providing policymakers with a more relevant evidence base (Forbes et al., 2024; Cameron et al., 2024).

Several limitations of our study must be acknowledged (Davies & Burns, 2024). First, like many model-based evaluations, we relied on certain assumptions regarding long-term vaccine efficacy and duration of protection, though we tested these in sensitivity analyses (Kajeguka et al., 2025). Second, while we incorporated local data, gaps in nationally representative cost information necessitated the use of proxy estimates from comparable settings for some parameters. Future research should focus on collecting primary cost data and monitoring real-world vaccine effectiveness post-introduction. Finally, our model did not capture the potential broader economic benefits of vaccination, such as increased female workforce participation, suggesting our estimates may be conservative.

In conclusion, this economic evaluation adds to the compelling evidence that HPV vaccination is a prudent investment for Tanzania (Forbes et al., 2024). The pathway to realising this investment's full potential lies in strategic, context-appropriate programme delivery that ensures high and equitable coverage (Lehtinen et al., 2024).

CONCLUSION

This economic evaluation provides robust evidence that introducing the human papillomavirus (HPV) vaccine into Tanzania's National Immunisation Programme is a highly cost-effective investment for the period 2021–2026. The analysis demonstrates that the long-term benefits of averting cervical cancer cases, mortality, and associated treatment costs substantially outweigh the initial costs of procurement and delivery (Cameron et al., 2024; Ntungane, 2025). This finding aligns with economic assessments from similar low- and middle-income country contexts (Bah et al., 2024; Furqan et al., 2025).

A central conclusion is the necessity for meticulous, forward-looking budget planning and a sustainable co-financing model. Over-reliance on external donor support risks programme longevity, underscoring the need for a phased increase in government co-financing to ensure resilience (Castle, 2024). This financial strategy must be integrated with innovative delivery mechanisms to maximise reach and equity. Evidence suggests leveraging existing community structures could enhance accessibility, a principle applicable to achieving high coverage among adolescent girls (Liwa et al., 2025; Michalek et al., 2024).

The immediate policy implication is clear: the Tanzanian government should proceed without delay to formally introduce the HPV vaccine into the routine schedule. Procrastination results in a continued, preventable loss of life and imposes a growing economic burden (Bwire et al., 2025). Successful implementation requires a multi-faceted strategy, including robust community engagement to combat documented challenges of vaccine hesitancy and low awareness (Kajeguka et al., 2025). Integrating

comprehensive vaccine literacy into educational curricula is a vital long-term strategy for sustaining public demand (Davies & Burns, 2024). Furthermore, establishing a framework for monitoring and evaluation from the outset is critical to track epidemiological impact (Lehtinen et al., 2024).

While this study provides a compelling economic case, it identifies crucial areas for future research. Operational research is needed to determine the most cost-effective delivery models within the Tanzanian health system (Mosha et al., 2025). Surveillance studies must monitor the baseline distribution and any potential shifts in circulating HPV types, drawing lessons from foundational work in other African settings (Adamu et al., 2024). Finally, research should evaluate the broader societal benefits of vaccination, including reductions in catastrophic health expenditure (Xu et al., 2024).

In conclusion, HPV vaccination is a strategic economic and public health priority. The period 2021–2026 presents a critical window to establish a sustainable programme. The cost of inaction—measured in lives lost and resources strained—is unacceptably high, and this analysis provides the economic justification to act with urgency.

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