

Catastrophic Health Expenditures in Urban Tanzania: Magnitude, Determinants, and Financial Risk Across Healthcare Delivery Systems

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ABSTRACT

Background: Achieving Universal Health Coverage (UHC) requires equitable access to healthcare without exposing households to financial hardship. Despite health financing reforms in Tanzania, evidence on healthcare affordability and catastrophic health expenditure (CHE) across healthcare delivery levels remains limited. This study assessed healthcare affordability, catastrophic health expenditure, and determinants of financial vulnerability among outpatient users attending referral, private, and city-led healthcare facilities in Dar es Salaam.

Methods: A comparative cross-sectional design was employed in five healthcare facilities representing referral, private, and city-led healthcare systems. Data were collected from outpatient users using a structured questionnaire. CHE was measured as the proportion of household income spent on healthcare. Descriptive statistics assessed affordability and CHE, while multiple linear regression examined the influence of household income and healthcare expenditure on financial risk.

Results: Findings revealed variations in CHE across facility types. Most respondents experienced low-to-moderate CHE;

however, low-income households, unemployed individuals, widows, and households with large dependency burdens were disproportionately affected. Referral facilities exhibited a higher risk of catastrophic expenditure than primary healthcare facilities. Regression analysis showed that household income was negatively associated with CHE, whereas healthcare expenditure was positively associated with CHE across all facility categories ($p < 0.001$). Model explanatory power ranged from $R^2 = 0.629$ to $R^2 = 0.857$, indicating that household income and healthcare expenditure were the principal determinants of financial hardship. Primary healthcare facilities recorded lower CHE levels, suggesting improved affordability and financial protection.

Conclusion: Healthcare affordability in urban Tanzania is strongly influenced by household economic capacity and healthcare costs. Strengthening primary healthcare financing, expanding insurance coverage, reducing out-of-pocket payments, and implementing targeted financial protection measures are critical for reducing CHE and accelerating progress toward Universal Health Coverage.

Keywords: Healthcare; Affordability; Catastrophic Health Expenditure; Financial Risk Protection; Universal Health Coverage.

INTRODUCTION

Catastrophic health expenditure (CHE) remains a major global public health and health financing concern, particularly in low- and middle-income countries striving to achieve universal health coverage (UHC). In simple terms, CHE refers to out-of-pocket (OOP) health spending that exceeds a substantial proportion of household income or consumption, thereby threatening households' ability to maintain basic living standards, such as food, education, and shelter [1]. In operational terms, CHE is often measured when OOP payments exceed 10% of total household income or consumption, or 25%–40% of non-food expenditure, depending on the monitoring approach used.

At the global level, financial hardship caused by healthcare payments continues to affect millions of households, despite ongoing health financing reforms. According to the 2023 Universal Health Coverage Global Monitoring Report, provided by the World Health Organization (WHO) and World Bank) more than one billion people worldwide experience financial hardship due to healthcare payments, with the burden disproportionately affecting low- and middle-income countries, where reliance on out-of-pocket payments remains high [2]. Similarly, the WHO Global Health Expenditure Report highlighted that nearly two billion people continue to face financial hardship owing to health-related costs, emphasizing persistent inequalities in financial protection across health systems [3].

Evidence from Southeast Asia further demonstrates that CHE remains a substantial barrier to healthcare access and financial risk. Studies conducted across the Association of Southeast Asian Nations

(ASEAN) show that households affected by chronic illnesses, cancer, and hospitalization frequently experience catastrophic payments and distress financing, especially among uninsured and disadvantaged populations [4]. In Bangladesh, for instance, approximately 61% of hospitalized patients experienced distress financing due to hospitalization costs, while non-communicable diseases, such as cancer, imposed high financial burdens on households [5]. Similar findings have been reported in Indonesia, Vietnam, China, and Malaysia, where inadequate financial protection and high dependence on OOP payments continue to expose vulnerable households to severe economic hardships [6].

Catastrophic health expenditure continues to pose a major challenge across Sub-Saharan Africa, largely driven by inadequate financial protection mechanisms, limited insurance coverage, and substantial dependence on direct household payments for healthcare [7]. A recent multi-country assessment estimated that 16.5% of households experienced CHE at the 10% total expenditure threshold, while 8.7% exceeded the 40% non-food expenditure threshold. Studies from Nigeria, Ethiopia, Ghana, and Kenya demonstrate that poorer households, uninsured populations, and households with chronic illnesses are disproportionately affected by CHE due to inadequate financial protection mechanisms [8] [9] [10] [11].

Although existing global and regional studies provide substantial evidence of the magnitude and determinants of catastrophic health expenditure, important contextual gaps remain regarding urban populations in Tanzania. Despite ongoing health financing reforms and the expansion of insurance schemes such as the improved Community Health Fund (iCHF) in Tanzania, catastrophic health expenditure continues to persist among vulnerable populations [12]. Existing evidence indicates that

approximately 7.1% of Tanzanian households experience CHE, with outpatient healthcare costs significantly contributing to household financial hardship [13] [14]. Several factors contribute to catastrophic health expenditures in urban Tanzania, including increasing costs of medicines and diagnostic services, unemployment, informal employment, and dependence on private healthcare facilities where direct payments are common [15]. However, many of these studies have primarily concentrated on general household expenditure patterns and national trends without adequately examining the urban context, where healthcare costs, dependence on private healthcare providers, and informal employment are more prevalent.

Furthermore, there is limited evidence on how socioeconomic factors such as informal employment, low insurance coverage, chronic illnesses, household structure, and healthcare-seeking behaviors interact to influence CHE among urban households in Tanzania. Urban poor populations often face higher healthcare costs and greater reliance on private facilities, where direct payments are common; however, empirical evidence documenting these experiences remains insufficient [16]. In addition, previous studies have inadequately explored the effectiveness of existing financial protection mechanisms in reducing CHE among urban residents, particularly in rapidly growing urban settings characterized by socioeconomic inequalities and rising rates of non-communicable diseases. Therefore, this study seeks to address these gaps by examining the magnitude and determinants of catastrophic health expenditure among urban households in Tanzania within the local context. Specifically, the study aims to generate context-specific evidence on how out-of-pocket healthcare payments affect urban households and identify key socioeconomic and healthcare-related factors associated with CHE.

Despite the growing literature on catastrophic health expenditure globally and in Sub-Saharan Africa, important research gaps remain in understanding the urban Tanzanian context. First, there is limited evidence on the magnitude of catastrophic health expenditure among urban households in Tanzania. Second, there is an inadequate understanding of the socioeconomic and healthcare-related factors influencing CHE in urban settings, particularly among populations relying on informal employment and private healthcare services. Against this backdrop, this study seeks to answer the following key research questions:

- i. What are the incidence, intensity, and determinants of catastrophic health expenditure among urban households within the context of healthcare cost-sharing practices in Tanzania?
- ii. How can healthcare cost-sharing mechanisms be strengthened to enhance financial protection and reduce the risk of catastrophic health expenditures among vulnerable populations?

Guided by these questions and situated within the institutional and policy context of Tanzania's healthcare system, this study aims to examine and compare the extent to which catastrophic health expenditures can be mitigated across referral hospitals, private healthcare facilities, and city-led public health facilities (health centers and dispensaries). The findings are expected to contribute to ongoing policy discussions on healthcare financing reforms, universal health coverage, and the development of more equitable cost-sharing arrangements that safeguard households from the excessive financial burdens associated with healthcare utilization.

2 THEORETICAL REVIEWS

This study is grounded in three main theories namely Anderson's behavioural

theory, cost-benefit analysis and health financing and financial Risk protection theory

2.1 Andersen's Behavioral Theory

Overview of the Theory

The Andersen Behavioral Theory of Health Services Utilization, developed by Ronald M. Andersen, is one of the most widely used theoretical frameworks for explaining patterns of healthcare utilization and expenditure. The model posits that an individual's use of healthcare services is influenced by a combination of social, economic, demographic, and health-related factors. It was originally developed to understand access to healthcare services and has been applied extensively in studies examining health-seeking behavior, healthcare financing, health equity and financial protection. According to the theory, healthcare utilization is determined by three interrelated categories of factors: predisposing, enabling, and need factors.

Predisposing Factors

Predisposing factors refer to sociodemographic characteristics that influence an individual's propensity to seek healthcare. These factors exist prior to the onset of illness and include age, sex, educational attainment, marital status, occupation, health beliefs and cultural values. Such characteristics shape perceptions of illness, attitudes toward healthcare services, and decisions regarding when and where to seek treatment.

Enabling Factors

Enabling factors represent the resources and conditions that facilitate or constrain access to healthcare. These include household income, health insurance coverage, employment status, availability of healthcare facilities, transportation, and other financial or organizational resources.

Enabling factors are particularly important in determining whether individuals can afford healthcare services and cope with the associated healthcare costs.

Need Factors

Need factors refer to the actual or perceived health status of individuals. These include severity of illness, presence of chronic diseases, disability status, and self-assessed health conditions. Need factors are generally considered the most immediate determinants of healthcare utilization because they directly influence the demand for medical care.

Relevance of the Theory to Study Variables

The Andersen Behavioral Theory supports the selection of the key variables examined in this study. Predisposing factors were represented by demographic and socioeconomic characteristics, such as age, sex, and educational level. Enabling factors are reflected in household income, health insurance status, and the type of healthcare facility utilized. Need factors were captured through the presence of chronic illnesses and the frequency of healthcare utilization. By integrating these factors, the theory provides a comprehensive framework for analyzing the determinants of catastrophic health expenditure and understanding how healthcare cost-sharing arrangements affect financial protection among urban households in Tanzania.

2.2 Cost–Benefit Analysis Theory

Cost–Benefit Analysis (CBA) provides a valuable framework for evaluating healthcare financing policies by systematically comparing the costs of policy interventions with their expected social and economic benefits. According to Drèze and Nicholas Stern (1987), CBA helps determine whether a policy generates net welfare gains and is, therefore, socially

desirable [17]. In Tanzania, CBA informed the introduction of user fees and cost-sharing arrangements in the public health sector as a strategy for improving resource mobilization and financial sustainability. However, the application of CBA extends beyond revenue generation to include the assessment of policies aimed at reducing catastrophic health expenditures (CHE). Within the context of this study, CBA is relevant for evaluating whether the benefits of financial protection measures, such as health insurance expansion, fee exemptions, subsidies for vulnerable populations, and reduced out-of-pocket payments, outweigh their implementation costs. By examining the affordability of healthcare services and the incidence of CHE across different health facilities, this study generates evidence on the economic and social consequences of current cost-sharing arrangements. Therefore, the findings can inform policy decisions on how to optimize healthcare financing mechanisms to minimize financial hardship, enhance equitable access to healthcare, and strengthen financial risk protection while maintaining the sustainability of the health system.

2.3 Health Financing and Financial Risk Protection Theory

Health Financing and Financial Risk Protection Theory provides an important framework for understanding how healthcare financing arrangements influence access to healthcare services, affordability, and the risk of catastrophic health expenditure (CHE). The theory is grounded in the principle that healthcare systems should not only mobilize sufficient resources to provide health services but also protect individuals and households from the financial consequences associated with illness and healthcare utilization. According to the theory, an effective health financing system should ensure that people obtain the healthcare services they need without experiencing financial hardship or being pushed into poverty due to healthcare

expenditures. The central premise of the theory is that healthcare financing mechanisms determine the extent to which households are exposed to financial risks when seeking healthcare services.

CHE occurs when healthcare spending exceeds a household's ability to pay, forcing households to reduce their consumption of essential goods, deplete their savings, incur debt, sell productive assets, or forego necessary healthcare. The commonly applied thresholds of healthcare expenditure exceeding 10% of total household income or 40% of non-subsistence income reflect situations in which healthcare costs impose excessive financial strain on households. Therefore, the incidence and intensity of CHE provide an empirical measure of the effectiveness of a health financing system in protecting populations from financial hardship. The relevance of Health Financing and Financial Risk Protection Theory to this study lies in its ability to explain how different healthcare financing arrangements influence affordability and catastrophic health expenditure among patients attending referrals, private, and city-led health facilities in Dar es Salaam.

3 MATERIALS & METHODS

3.1 Research Approach

This study adopted a comparative mixed-methods research approach, integrating quantitative and qualitative methods within a cross-sectional design complemented by multiple case-study elements. The mixed-methods approach was employed to generate a comprehensive understanding of healthcare affordability and catastrophic health expenditure (CHE) across different categories of health facilities in Dar es Salaam. The quantitative component provided empirical evidence on the magnitude and determinants of healthcare affordability and financial hardship, while the qualitative component explored stakeholders' experiences, perceptions, and

contextual factors influencing healthcare financing and financial risk protection. The integration of both approaches enhanced methodological triangulation, thereby strengthening the validity, credibility, and completeness of the study findings.

The comparative approach enabled a systematic assessment of variations in healthcare affordability and catastrophic health expenditure among patients receiving services from referral-level public, private, and city-led health facilities. By comparing different ownership and service delivery arrangements, the study examined how healthcare financing mechanisms influence out-of-pocket expenditure, financial risk protection, and healthcare utilization among urban residents. The study was conducted in five purposively selected health facilities representing diverse ownership structures and levels of healthcare delivery: Amana Regional Referral Hospital, Cardinal Rugambwa Hospital, Buguruni Health Centre, Vingunguti Dispensary, and Tabata SES Dispensary. These facilities were selected because they reflect variations in healthcare financing arrangements, service costs, patient socioeconomic characteristics, and levels of care, thereby providing an appropriate basis for comparative analysis.

Overall, the mixed-methods comparative approach provided a robust analytical framework for examining the multidimensional nature of healthcare affordability and catastrophic health expenditure. By integrating quantitative measurements with qualitative insights, the study generated comprehensive evidence on the interaction between healthcare financing arrangements, patient socioeconomic conditions, and financial risk protection, thereby informing policies aimed at improving equitable access to healthcare and advancing universal health coverage in Tanzania.

3.1.1 Choice of the Research Strategy

A comparative cross-sectional research design was selected to examine healthcare affordability and catastrophic health expenditure across health facilities operating under different ownership and management arrangements. This approach enabled the collection of empirical data from a diverse sample of patients at a single point in time, while facilitating comparisons among public, private, and faith-based healthcare providers. A facility-based approach was adopted because healthcare expenditures incurred at the point of service use provide reliable information on actual out-of-pocket payments and household financial capacity, thereby improving the accuracy of the catastrophic health expenditure measurements. The comparative design also enabled the assessment of variations in the financial burden across different categories of healthcare facilities.

The use of the 10% income threshold and 40% subsistence income threshold was justified by their widespread application in health economics and healthcare financing research as standard measures of catastrophic health expenditure. These thresholds allowed the study to capture both general financial burden and severe healthcare-induced financial hardships. Overall, the comparative cross-sectional design provided a robust framework for assessing healthcare affordability, identifying the determinants of catastrophic health expenditure, and generating evidence to inform policies aimed at strengthening financial risk protection and promoting equitable access to healthcare in urban Tanzania.

3.1.2 Research Design applied and its characteristics

This study adopted a comparative multiple-case cross-sectional design embedded within quantitative and qualitative explanatory research approaches, a research design characterized by an in-depth investigation of catastrophic health

expenditure within real-life healthcare settings. The design enabled the examination of multiple health facilities representing referral, private, and city-led healthcare providers in Dar-es-Salaam. The design also permitted the comparison and estimation of catastrophic health expenditure incidence and the analysis of factors influencing financial risk protection and healthcare utilization within the context of urban health financing in Tanzania across facility types.

Through the collection of facility-based primary data, this study assessed the relationship between healthcare expenditure, household income, affordability, and catastrophic health expenditure while facilitating cross-case comparisons of financial risk protection and healthcare utilization across different healthcare financing arrangements. The design provided a contextualized and evidence-based understanding of urban health financing challenges and variations in affordability among healthcare users in Tanzania.

3.2 Study Areas, types and levels of health facilities

3.2.1 Study Areas, types and levels of health facilities

The study was conducted in the peri-urban areas of Dar es Salaam, where the selected study sites were relatively accessible because of the expansion of the city's infrastructure. However, the distance between health facilities and the city center varied considerably, ranging from less than 10 km to approximately 25 km from Dar es Salaam's central area. According to the 2022 Population and Housing Census conducted by the National Bureau of Statistics, the catchment areas served by the five health facilities included in this study had a combined population of 419,460 residents, representing 25.43% of the total population of 1,649,912 in the Dar es Salaam City Council (URT, 2022) [18]. Table 3.1 presents additional information on the health facilities included in the study.

Table 3.1: Names and location of health facilities studied

S/No	Name of health facility	Administrative Ward located	Level of the health facility	Ownership type
1	Amana Regional Referral Hospital	Ilala	Referral hospital	Public
2	Vingunguti Dispensary	Vingunguti	Dispensary	Public
3	Bugurun Health Centre	Buguruni	Health Centre	Public
4	Tabata SES Dispensary	Tabata	Dispensary	Private
5	Cardinal Rugambwa Hospital	Ukonga	Full-fledged Hospital	Private

Source: Field data, October 2023

The selection of administrative wards for this cross-case analysis within Dar es Salaam City was informed by the following five key considerations.

- i. **Diverse private healthcare landscapes:** Dar es Salaam and the selected wards host a wide range of private and public health facilities, offering varied service options that

are suitable for comparative assessment.

- ii. **Research site accessibility:** The expansion of urban infrastructure has made the study sites easily accessible, facilitating data collection and improving logistical efficiency.
- iii. **Representative healthcare structure:** The clear continuum from dispensaries to health centers

to referral facilities reflects the National Health Service delivery system, making Dar es Salaam a suitable city for case selection.

iv. **iv. Prevalence of low-income populations:**

Although Dar es Salaam has the lowest regional poverty rate in Tanzania, with 8% of its population living below the basic needs poverty line, poverty is unevenly distributed across the wards. According to the World Bank's poverty assessment based on the 2017/18 Household Budget Survey, ward-level poverty mapping shows that some of the highest poverty levels are found in the Ilala Municipal Council [19]. Specifically, Chanika, Msongola, Makurumla, Buguruni, Vingunguti, and Kivule wards have poverty rates of over 20%, making them some of the most economically disadvantaged areas in the city (World Bank, 2019). Pg 42) [20]. These wards are mainly located in the southwestern part of Ilala and are characterized by rapid peri-urban growth and informal settlements, which often feature high population density, inadequate infrastructure, and many low-income households. Using individual case summary reports, a comparative analysis was

conducted to empirically examine the extent to which CHE affects low-income patients across various aspects of cost-sharing policy.

3.3 Sampling and Respondents

A non-probability sampling technique was used to select respondents relevant to the study's objectives. The sample consisted of the following:

- 525 patients from five healthcare facilities.
- A total of 300 households from six wards were included in the survey.
- The FGDs included 84 participants (six groups of 14 people), including women from low-income households and individuals with disabilities.
- Twenty-three key informants were interviewed, including facility heads, CHMT members, ward committee members, and social welfare officers already inclusive of 827 respondents. Table 3.2 provides a summary of the sample size and total number of respondents. This resulted in 827 total respondents.

Table 3.2: Summary of key Informants and sample size

S/No.	Type of key Informants/ Respondents	Categorization of Sample size	No. of respondents
1	Outpatients and inpatients	Amana referral Hospital (35 outpatients, 35 inpatients and 35 health insurance)	105
		Cardinal Rugambwa Hospital (35 outpatients, 35 inpatients and 35 health insurance)	105
		Buguruni Health Centre, 35 outpatients, 35 health insurance patients	70
		Tabata SES Charitable Dispensary (private) 35 outpatients, 35 health patients	70
		Vingunguti Dispensary 35 outpatients, 35 health insurance patients	70
2	Five Head of Health facilities	1 member from each health facility	7
3	Council Health Management Team (CHMT)	7 CHMT members, only taken from the city health management team	7

4	Ward Health Committee members	WHC secretaries from 5 wards included in the sample, one member from each WHC	5
5	Social welfare officers in public health facilities	Only four social welfare officers were recruited from the public health facilities. Private health facilities do not have such offices, however.	4
6	Heads of Households in the study areas	Household survey data were taken from 6 wards; each ward included 50 households in the sample	300
7	Women from resource-poor households and people with disabilities	Six FG discussions were conducted by me in each ward.	84
	Total		827

Source: Field data, October 2023

3.4 Data collection methods and tools

This study used multiple methods of data collection, including:

- Semi-structured interviews with patients and institutional actors
- Household surveys using structured questionnaires
- FGDs to explore experiences of vulnerable populations
- Documenting the real-time handling of unusual or sensitive cases (e.g., indigent patients, accident victims, and elderly patients).

Table 3.3: Data Collection Protocols

S/N	Data Source	Data Collection Method	Purpose of the Data	Data Collection Tool
1	Patients (exit interviews and inpatients)	Semi-structured interviews	Collect information on healthcare accessibility and affordability from patients at discharge and during hospitalization.	Semi-structured interview guide
2	Heads of health facilities	Semi-structured interviews	Examine management of out-of-pocket payments and health insurance within health facilities.	Semi-structured interview guide
3	Ward Health Committees	Semi-structured interviews	Assess the role of Ward Health Committees in facilitating access to affordable healthcare for vulnerable populations.	Semi-structured interview guide
4	Social welfare officers in public health facilities	Semi-structured interviews	Assess management of exemption and waiver schemes for indigent patients.	Semi-structured interview guide
5	Council Health Management Team (CHMT)	Semi-structured interviews	Explore strategies for planning and promoting affordable healthcare services.	Semi-structured interview guide
6	Households and individuals with extreme vulnerability who fail to access healthcare	Focus Group Discussions (FGDs)	Explore experiences of impoverished women and persons with disabilities in accessing and affording healthcare.	FGD checklist
7	Households	Household survey	Assess socioeconomic and demographic characteristics	Household survey

			influencing healthcare access and affordability.	questionnaire
8	Health facilities and healthcare processes	Observation	Document implementation of cost-sharing policies, patient flow, payment processes, exemption mechanisms, and barriers to financial accessibility.	Observation checklist

Source: Researcher's construct (2026).

3.5 Data processing and analysis

This study adopted a mixed-methods analytical approach, in which quantitative and qualitative data were analyzed separately and later integrated to provide a comprehensive understanding of the research problem. Quantitative data were analyzed using IBM SPSS Statistics (version 25) to generate descriptive statistics and examine the relationships and differences between variables using chi-square and t-tests. Qualitative data obtained from focus group discussions (FGDs) and key informant interviews were analyzed using MAXQDA, where transcripts were coded and organized to identify recurring themes and patterns relevant to the study objectives.

4 RESULTS

This section presents the findings of a comparative analysis conducted across five health facilities representing different levels of healthcare delivery and ownership

structures, including a referral hospital, private hospitals, and city-led health centers and dispensaries. The analysis examined variations in catastrophic health expenditure (CHE) among outpatient service users and assessed the influence of key socioeconomic and demographic factors on financial risk protection outcomes. At the referral level, for instance, Amana Regional Hospital, as a unit of analysis, revealed that, despite the relatively higher affordability proportion for both directly and moderately affordable, the study found varying levels and incidences of catastrophic health expenditures, some of which were at the brink of becoming outliers. These extreme cases, even if some patients afford healthcare costs, experience instances of acute poverty and impoverishment due to the high cost of care, especially diagnostic examination and medication, particularly for non-communicable diseases and those patients with repetitive schedules to health facilities. Table 3.4 shows a summary of CHE incidences at the Amana referral hospital captured during the study period.

Table 4.1: Overall CHE Distribution where N=35 outpatients who used out of pocket payment

CHE Level	Frequency	Percentage
Low (<10%)	22	62.9%
Moderate (10–20%)	11	31.4%
Severe (>20%)	2	5.7%
Total	35	100%

The analysis of catastrophic health expenditure (CHE) revealed varying levels of financial burdens among outpatient households. Many respondents (62.9%) allocated less than 10% of their household income to healthcare expenditures, suggesting that healthcare costs remained

relatively affordable for most participants and did not pose a significant threat to household financial stability, as shown in Table 4.1. However, a substantial proportion of respondents (31.4%) experienced moderate catastrophic health expenditure, indicating notable financial strain associated

with healthcare utilization. More importantly, 5.7% of the study participants incurred severe catastrophic health expenditure. These severe cases were predominantly concentrated among low-income households with limited economic resources and coping mechanisms, highlighting the disproportionate vulnerability of economically disadvantaged populations to healthcare-related financial crises. The findings underscore persistent inequalities in financial risk protection and suggest the need for targeted interventions to strengthen affordability and reduce the incidence of catastrophic health expenditures among vulnerable groups.

4.1 The influence of demographic and socio-economic factors

The findings indicate that catastrophic health expenditure (CHE) is influenced by a combination of demographic and socioeconomic factors. Household income emerged as the most significant determinant, with higher-income households exhibiting greater healthcare affordability and lower susceptibility to CHE, whereas lower-income households faced a disproportionately higher financial burden. Employment status was also strongly associated with affordability, as employed respondents generally reported lower CHE than their unemployed counterparts. Furthermore, lower educational attainment, larger household size, and limited opportunities for resource sharing among single and widowed respondents increased their vulnerability to catastrophic expenditure. Although older individuals experienced greater healthcare needs due to chronic and age-related conditions, their risk of CHE was moderated by income and economic support.

4.2 Regression Analysis of Determinants of Catastrophic Health Expenditure

A multiple linear regression analysis was conducted to examine the influence of respondents' income and health expenditure on the percentage of health expenditure incurred by patients attending the Amana Regional Referral Hospital. The regression model was statistically significant ($R^2 = 0.629$, $p < 0.001$), indicating that approximately 62.9% of the variation in the percentage of health expenditure was explained by income and the health expenditure. The results showed that respondents' income had a negative effect on the percentage of health expenditure ($\beta = -0.000006554$, $P < 0.001$). This implies that as household income increases, the proportion of income spent on healthcare decreases. Therefore, higher-income households are less likely to experience catastrophic health expenditures. Conversely, health expenditure had a positive effect on the percentage of health expenditure ($\beta = 0.000115$, $p < 0.001$). This indicates that an increase in out-of-pocket healthcare spending significantly increases the likelihood of incurring catastrophic health expenditure.

The estimated regression model is as follows:

$$\% \text{ Health Expenditure} = 8.882 - 0.000006554(\text{Income}) + 0.000115(\text{Health Expenditure})$$

This model suggests that healthcare affordability is largely influenced by household income and medical expenditure. Patients with lower incomes and higher healthcare costs face a greater risk of catastrophic health expenditure.

Table 4.2: Regression analysis table

Variable	Coefficient (β)	Std. Error	t-value	p-value
Constant	8.882	...	...	<0.001
Income	-0.000006554	...	...	<0.001
Health Expenditure	0.000115	...	...	<0.001

Note: $R^2 = 0.629$, Adjusted $R^2 = 0.605$, $F = 27.07$, $p < 0.001$.

Table 4.3: Regression Coefficients

Variable	Coefficient	p-value	Interpretation
Constant	8.882	<0.001	Baseline level
Income	-0.000006554	<0.001	Higher income reduces CHE
Health Expenditure	0.000115	<0.001	Higher medical costs increase CHE

Source: Field data, October 2023

The regression model explains approximately 62.9% of the variation in catastrophic health expenditure and, analysis indicates:

- Income had a statistically significant negative effect on CHE.
- Medical expenditure had a statistically significant positive effect on CHE.
- Lower-income households are more likely to experience catastrophic spending.
- Rising healthcare costs substantially increase the risk of CHE.

5 Calculating Catastrophic Health Expenditure Levels at Cardinal Rugambwa Hospital (n = 35)

In private health facility for example, Catastrophic Health Expenditure was assessed using the percentage of household income spent on outpatient healthcare services. Following the conventional healthcare financing thresholds, patients were categorized into four CHE levels.

5.1 Levels of Catastrophic Health Expenditures

Table 4.4: CHE Category	Threshold (% of Income Spent on Healthcare)	Number of Patients	Percentage
Low CHE	<10%	20	57.1%
Moderate CHE	10–24.9%	11	31.4%
High CHE	25–39.9%	3	8.6%
Severe CHE	$\geq 40\%$	1	2.9%
Total		35	100%

Analysis of catastrophic health expenditure (CHE) at Cardinal Rugambwa Hospital revealed that most patients (57.1%) spent less than 10% of their household income on outpatient healthcare, indicating relatively good affordability and financial protection.

However, 42.9% of patients experienced moderate CHE, suggesting a notable financial burden among a substantial proportion of households. Despite this, healthcare services remained generally affordable for most patients, as the observed

CHE levels among affected households largely remained below 15% of the household income.

The incidence of CHE was disproportionately concentrated among socioeconomically vulnerable groups, particularly low-income households, unemployed individuals, widowed patients, those with limited educational attainment, and those with large numbers of dependents.

The most severe case involved a 70-year-old widowed and unemployed woman who allocated 58% of her household income to healthcare, illustrating the heightened risk of financial hardship faced by disadvantaged populations. These findings suggest that while healthcare services are generally affordable for most patients, significant gaps in financial risk protection persist among vulnerable groups.

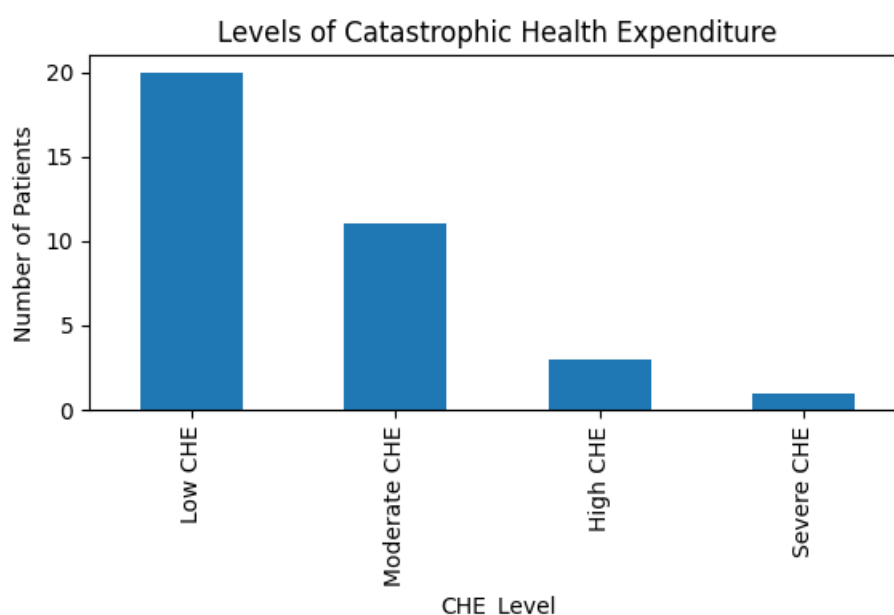


Figure 5.1: Incidences of Catastrophic Health Expenditures

The scatter plot in figure 5.2 reveals a clear inverse relationship between monthly household income and the proportion of income spent on health care. Households with lower incomes exhibited higher and more variable healthcare expenditure burdens, with some households allocating more than 20% of their income to healthcare services.

Conversely, higher-income households consistently spent a smaller share of their income on healthcare, generally remaining

below the commonly used catastrophic expenditure threshold. These findings suggest that healthcare costs impose a disproportionate financial burden on low-income households and reinforce the importance of household income as a key determinant of healthcare affordability and catastrophic health expenditures. This means that the poorer the household, the greater the financial burden of healthcare and the higher the risk of catastrophic health expenditure.

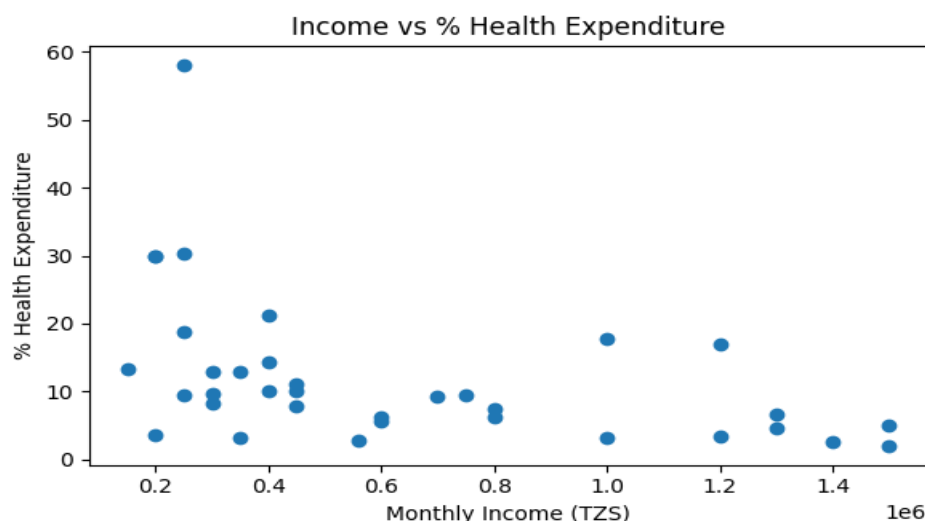


Figure 5.2: Patient's monthly incomes and % of health expenditures

5.3 Regression analysis

Based on the 35 patients investigated, we estimated a multiple linear regression model with Catastrophic Health Expenditure (CHE %) as the dependent variable and Household Income and Healthcare Expenditure (Total Cost Incurred) as the explanatory variables. A multiple linear regression model was estimated to examine the determinants of catastrophic health expenditure in the study population. The model demonstrated substantial explanatory power, accounting for approximately 68.8% of the variation in catastrophic health expenditure ($R^2 = 0.688$; Adjusted $R^2 = 0.669$).

The overall regression model was statistically significant ($F = 35.29$, $p < 0.001$), indicating that the selected predictors jointly explained a substantial proportion of the observed variation in the financial burden associated with healthcare utilization. Household income exhibited a statistically significant negative association with catastrophic health expenditure ($\beta = -0.000008$, $p < 0.001$), suggesting that higher-income households are less likely to experience financial hardship arising from healthcare spending. Conversely, healthcare expenditure demonstrated a statistically significant positive relationship with

catastrophic expenditure ($\beta = 0.000102$, $p < 0.001$), indicating that increases in out-of-pocket healthcare costs substantially increase the financial burden on households. The standardized coefficients further revealed that healthcare expenditure ($\beta = 0.842$) and household income ($\beta = -0.830$) exerted comparably strong influences on catastrophic expenditure, highlighting the importance of both healthcare costs and household economic capacity in determining financial risk. These findings support the Financial Risk Protection Theory, which posits that catastrophic expenditures occur when healthcare payments exceed a household's ability to pay. The results suggest that policies aimed at reducing out-of-pocket payments, expanding health insurance coverage, and strengthening financial protection mechanisms for low-income households could substantially reduce the incidence of catastrophic health expenditures and improve equity in access to healthcare services.

5.4 Policy Implications

- i. Strengthening financial protection mechanisms for low-income households.

- ii. Targeted fee exemptions or subsidies for elderly and widowed patients should be introduced.
- iii. Improving social support systems for vulnerable households.
- iv. Enhancing community-based health financing schemes to reduce out-of-pocket expenditure is also recommended.

6 Levels of Catastrophic Health Expenditure (CHE) at Tabata SES Dispensary

Catastrophic health expenditure (CHE) at the Tabata SES Dispensary, a private entity was assessed using established healthcare financing thresholds based on the proportion of household income allocated to healthcare services. The results showed that most patients (74.3%) incurred low CHE, spending less than 10% of their household income on healthcare, whereas 25.7% experienced moderate CHE. No cases of severe CHE were identified. These findings indicate that primary healthcare services at the Tabata SES Dispensary generally provide an adequate level of financial protection for most patients. However, the occurrence of moderate CHE among approximately one-quarter of the respondents suggests that healthcare expenditures continue to impose a notable financial burden on economically vulnerable households, highlighting persistent gaps in financial risk protection.

6.1 Determinants of Catastrophic Health Expenditure in Private Primary Healthcare Facilities

The findings indicate that catastrophic health expenditure (CHE) in private primary healthcare facilities is largely driven by socioeconomic factors. Household income emerged as the strongest determinant, with low-income households allocating a significantly greater share of their resources to healthcare than high-income households. Employment status also played a critical

role, as unemployed patients were more likely to experience CHE because of limited financial capacity and reliance on informal coping mechanisms. Additionally, lower educational attainment was associated with higher CHE, reflecting reduced income-generating opportunities and a lack of financial resilience. Larger households face increased vulnerability because healthcare expenses compete with other essential household needs. Collectively, these findings suggest that low income, unemployment, limited education, and large family size are key predictors of catastrophic health expenditure, underscoring the need for strengthened financial risk protection mechanisms to enhance healthcare affordability and equity in the country.

6.2 Regression Analysis

Ordinary Least Squares (OLS) regression analysis revealed that household income and healthcare expenditure were significant predictors of catastrophic health expenditure among outpatient clients. The model demonstrated that household income was negatively associated with the percentage of income spent on healthcare, and healthcare expenditure was positively associated with catastrophic health expenditure. This indicates that higher-income households are less likely to experience financial hardship from healthcare payments, whereas households incurring higher healthcare costs face a greater risk of catastrophic expenditure.

The regression coefficient for household income was negative ($\beta_1 < 0$) and statistically significant ($p < 0.05$), implying that an increase in household income significantly reduced the proportion of income allocated to health care. Conversely, healthcare expenditure exhibited a positive and statistically significant coefficient ($\beta_2 > 0$; $p < 0.05$), indicating that higher out-of-pocket payments substantially increased the financial burden borne by households. The

statistical significance of both variables suggests that the observed relationships are unlikely to occur by chance. This analysis indicates that:

- i. Higher income protects households from incurring CHE.
- ii. Higher healthcare costs increase the risk of CHE.
- iii. Low-income households are the most vulnerable groups.
- iv. Reducing out-of-pocket payments through insurance and subsidies can significantly lower the CHE.
- v. Income and healthcare costs are the two most important economic

determinants of healthcare affordability across primary, secondary, and referral healthcare facilities.

7 Levels of Catastrophic Health Expenditure (CHE) for Vingunguti Dispensary

Vingunguti is a publicly owned dispensary, and the empirical analysis indicates varying levels of CHE. Using the percentage of health expenditure relative to household income, the levels of catastrophic health expenditure vary as follows:

HE Level	Interpretation
1–3%	Low financial burden
4–5%	Moderate financial burden
>5%	High financial burden / risk of CHE

The highest CHE was observed among low-income, unemployed households with limited education and dependent children, suggesting substantial vulnerability to financial stress.

Catastrophic health expenditure (CHE) was assessed as the proportion of household income spent on healthcare. For analytical purposes, CHE levels were categorized as low (1–3%), moderate (4–5%), and high financial burdens (>5%). The analysis revealed that the average CHE across the study population was approximately 4.1%, indicating that, on average, households allocated approximately four percent of their income to healthcare expenses. CHE values ranged from a minimum of 1% to a maximum of 13%, demonstrating substantial variation in the financial burden associated with healthcare utilization among patients attending the facility. A notable pattern emerging from the dataset is that higher CHE levels were concentrated in socioeconomically disadvantaged households. Patients experiencing the greatest financial burden were predominantly characterized by lower

income levels, unemployment, limited educational attainment, and the presence of dependent children. Overall, the results indicate that while most patients attending the Vingunguti Primary Healthcare Unit were able to meet healthcare costs without experiencing severe financial distress, a small but important proportion of households remained exposed to catastrophic expenditure.

7.1 Regression analysis

Regression analysis identified household income and healthcare expenditure as significant predictors of catastrophic health expenditure (CHE). Household income was negatively associated with CHE ($\beta = -0.000008$, $p < 0.001$), indicating that the risk of catastrophic expenditure decreases as income increases, and vice versa. In contrast, healthcare costs exhibited a positive and statistically significant relationship with CHE ($\beta = 0.000235$, $p < 0.001$), suggesting that higher medical expenses increase the financial burden on households. The model explained 67% of the variation in CHE ($R^2 = 0.67$),

demonstrating strong explanatory power and highlighting the central role of household economic capacity and healthcare costs in determining financial vulnerability.

The negative coefficient implies that *as 'household resources increase, healthcare payments constitute a smaller proportion of total income, thereby reducing financial vulnerability.'* This finding confirms that lower-income households are disproportionately exposed to healthcare-related financial risks and are more likely to experience economic hardship when seeking medical care than higher-income households. Conversely, healthcare expenditure was positively and statistically significantly associated with CHE ($\beta = 0.000235$, $p < 0.001$). *A positive coefficient indicates that increases in out-of-pocket healthcare costs are associated with higher levels of catastrophic expenditure.*

The statistical significance of both explanatory variables ($p < 0.001$) provides strong evidence that household income and healthcare expenditure are important determinants of catastrophic health expenditure in the study population. Therefore, the findings suggest that CHE is primarily driven by the interaction between a household's ability to pay and the magnitude of healthcare costs incurred. These results are consistent with the

Financial Risk Protection Theory, which posits that catastrophic expenditure occurs when healthcare payments exceed a household's financial capacity and threaten its economic welfare.

8 Levels of Catastrophic Health Expenditure (CHE) for Buguruni Health Centre

In the Buguruni Health Centre, the findings revealed considerable variation in the financial burden across households, with CHE ranging from 1% to 22% of household income. Four out of 35 patients recorded expenditure levels above the commonly applied financial protection thresholds, notably those with CHE values of 22%, 14%, 13%, and 12%, indicating an elevated risk of financial hardship. Although most households incurred relatively low healthcare expenditure burdens, a substantial proportion experienced spending levels that could compromise their ability to meet other essential household needs. Higher CHE was predominantly concentrated among low-income households, individuals with unstable employment, lower educational attainment, and households with dependents, suggesting that socioeconomic disadvantage remains a key driver of financial vulnerability and inequitable access to health care.

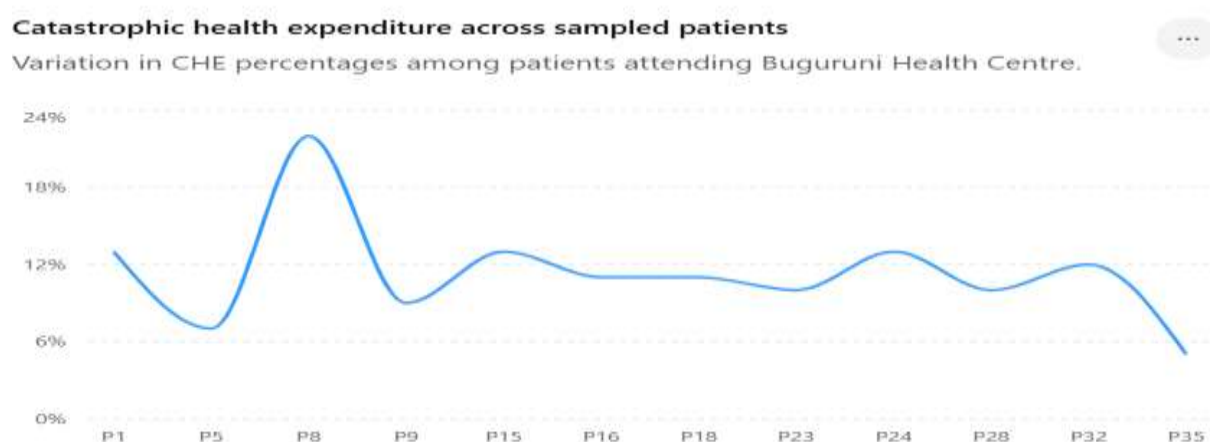


Figure 8.1: Affordability and Catastrophic Health Expenditure among Patients Attending the Buguruni Health Centre.

Given the contextual analysis, the drop-line graph in figure 8.1 highlights the substantial heterogeneity in healthcare financial burdens across patients. While some respondents incurred relatively low expenditure shares, several households recorded CHE levels exceeding 10%, with the highest value of 22%. These spikes indicate the presence of households facing considerable financial stress due to healthcare payments. The concentration of high CHE values among lower-income and unemployed respondents suggests that financial risk is unevenly distributed across the study population.

8.1 Regression Analysis of Determinants of CHE

The following model was estimated: $CHE_i = \beta_0 + \beta_1 Income_i + \beta_2 HealthCost_i + \varepsilon_i$

Regression Results were noted and statistics value were:	
R ²	0.857
Income p-value	<0.001
Healthcare Cost p-value	<0.001

9 DISCUSSIONS

The model produced an R² of 0.857, indicating that approximately 85.7% of the variation in catastrophic health expenditure was explained by household income and healthcare expenditure. This represents a very strong model fit and suggests that these variables are the principal determinants of the financial burden among patients attending the Buguruni Health Center. Household income was significantly and negatively associated with CHE ($p < 0.001$). This finding implies that higher-income households are less likely to experience catastrophic expenditures because healthcare payments constitute a smaller proportion of their available resources. In contrast, healthcare expenditure demonstrated a statistically significant positive relationship with CHE ($p < 0.001$), indicating that increases in out-of-pocket medical payments substantially increase the risk of catastrophic spending. The extremely low p-values provide strong evidence that both variables are significant predictors of CHE and that the observed relationships are unlikely to have occurred by chance. Therefore, the findings confirm that catastrophic expenditure is primarily driven by the interaction between a household's economic capacity and the magnitude of healthcare costs incurred.

This study examined healthcare catastrophic health expenditure (CHE) across urban Tanzania's referral, city-led, and private healthcare facilities. The findings demonstrate that although most patients incurred relatively low levels of catastrophic expenditure, a substantial proportion of households remained vulnerable to financial hardship arising from healthcare utilization. Across all facility types, household income and healthcare expenditure emerged as the most consistent determinants of CHE, suggesting that financial vulnerability is primarily driven by the interaction between a household's economic capacity and direct healthcare costs.

At the referral level, Amana Regional Referral Hospital exhibited relatively higher affordability for most patients; however, a significant proportion of households experienced moderate to severe CHE. The occurrence of severe CHE among some patients suggests that referral hospitals may expose households to greater financial risk because of more complex diagnostic investigations, costs for specialist consultations, and long-term management of chronic and non-communicable diseases. Similar findings have been reported in several Sub-Saharan African countries, where referral facilities are associated with higher out-of-pocket expenditures and an

increased risk of catastrophic spending, particularly among low-income [21] [22].

The findings from Cardinal Rugambwa Hospital and Tabata SES Dispensary suggest that private healthcare facilities provide relatively affordable services for many patients, although significant inequalities persist. While most patients experienced low CHE, vulnerable groups, including widowed individuals, unemployed respondents, and households with limited income, remained disproportionately exposed to financial hardship. Similar patterns have been documented in Southeast Asia, where private healthcare utilization is frequently associated with higher direct payments, but financial risk is moderated by income and insurance coverage [23]. In Latin America, studies have likewise shown that households with lower socioeconomic status experience significantly higher risks of CHE despite healthcare reforms aimed at expanding access [24].

The findings from the Vingunguti Dispensary and Buguruni Health Centre further demonstrate that city-led primary healthcare facilities provide an important buffer against catastrophic expenditures. Nevertheless, significant heterogeneity in CHE was observed, particularly among households characterized by low income, unemployment, low educational attainment, and large family size. These findings are consistent with evidence from Kenya, Ghana, Ethiopia, where household poverty, unemployment, and large dependency burdens have been identified as major predictors of catastrophic expenditures [25] [26] [27]. Similar determinants have also been reported in Vietnam and Indonesia, where lower-income households allocate a disproportionately large share of household resources to healthcare [28].

Regression analyses consistently demonstrated that household income was negatively associated with CHE, whereas healthcare expenditure was positively

associated with CHE across all facility categories. The explanatory power of the regression models was substantial, with R^2 values ranging from 0.629 at the referral hospital to 0.857 at the Buguruni Health Centre. These findings indicate that healthcare affordability is fundamentally determined by the balance between the ability to pay and the costs incurred during healthcare use. This observation aligns closely with the Financial Risk Protection Theory and supports international evidence indicating that CHE occurs when healthcare payments exceed a household's capacity to finance essential needs without compromising their living standards [29].

An important finding of this study is that primary healthcare facilities, particularly health centers and dispensaries, appear to provide a degree of financial protection against catastrophic health expenditure. Across the city-led facilities included in the study, most patients experienced low or moderate CHE, whereas severe financial hardship was relatively uncommon compared with referral-level facilities. This pattern reflects the deliberate policy orientation of primary healthcare services in Tanzania, where treatment costs are generally maintained at relatively low levels to promote the affordability, accessibility, and utilization of essential healthcare services. Consequently, patients seeking primary care are less likely to incur substantial out-of-pocket expenditures, thereby reducing the risk of catastrophic spending.

The findings suggest that current financing arrangements at primary healthcare facilities contribute positively to financial risk protection, particularly among low-income households. Although poorer households remain more vulnerable to financial hardship than wealthier households, the relatively low CHE levels observed at health centers and dispensaries indicate that primary healthcare services are functioning as an important safeguard against

healthcare-induced poverty. This finding is consistent with evidence from Sub-Saharan Africa, where Eze et al. reported that affordable primary healthcare services and financial protection mechanisms were associated with lower risks of catastrophic expenditure among vulnerable populations [30]. Likewise, evidence from Indonesia suggests that strengthening primary healthcare and expanding insurance coverage reduces households' exposure to catastrophic health spending, particularly among low-income populations [31]. These findings collectively reinforce the proposition that primary healthcare serves not only as the first point of service delivery but also as a critical financial risk-protection mechanism.

Further evidence suggests that investing in primary healthcare may yield substantial financial protection benefits by preventing the progression of illnesses that would otherwise require costly treatment at referral hospitals. Therefore, strengthening primary healthcare should be viewed not only as a service delivery strategy but also as a health financing intervention capable of enhancing affordability, promoting equity, reducing healthcare-induced poverty, and accelerating progress toward Universal Health Coverage.

10 Policy Implications

These findings have important implications for urban health financing reforms in Tanzania. Referral hospitals should prioritize financial risk protection mechanisms for patients requiring specialized and long-term care. Expanding insurance coverage for diagnostic investigations, chronic disease management, and specialist services could substantially reduce CHE in vulnerable households. Strengthening referral financing mechanisms under ongoing Universal Health Insurance reforms may also reduce reliance on out-of-pocket payments.

City-led facilities (health centers and dispensaries): Primary healthcare facilities should receive increased public financing to ensure the continuous availability of medicines, diagnostics, and preventive services. Strengthening primary healthcare financing can reduce the need for costly referrals and improve financial protection among low-income urban populations. Targeted exemptions for poor households, elderly people, widows, and unemployed individuals should be expanded.

Private hospitals and primary facilities: Private providers play an increasingly important role in healthcare delivery in urban Tanzania. However, stronger purchasing arrangements between health insurance schemes and private providers are required to ensure affordability. This finding suggests that private faith-based hospitals can complement government efforts to achieve Universal Health Coverage by implementing exemption schemes and social support mechanisms for vulnerable patients, thereby reducing catastrophic health expenditures among disadvantaged populations. This is a particularly strong policy message because it demonstrates that private facilities can contribute not only to service delivery but also to equity and financial protection in healthcare.

11 Strengths and Limitations

A major strength of this study is its comparative design, which examined healthcare affordability and catastrophic health expenditure across multiple levels of healthcare delivery and ownership structures, including referral hospitals, city-led health centers and dispensaries, and private healthcare facilities. This approach provides a comprehensive understanding of financial risk protection within the urban healthcare system and allows for meaningful comparisons between public and private providers. Furthermore, the use of patient-level expenditure data and regression analysis enabled the

identification of key determinants of catastrophic health expenditure and facilitated a robust assessment of healthcare affordability across different service-delivery contexts.

Another important strength of this study is the inclusion of Cardinal Rugambwa Hospital, a private faith-based healthcare facility that implements exemption and support mechanisms for vulnerable and destitute patients. Unlike many private healthcare providers that rely primarily on direct user payments, Cardinal Rugambwa Hospital extends financial protection to disadvantaged groups through fee waivers, exemption, and social support arrangements. The inclusion of such a facility provided an opportunity to examine how targeted financial protection interventions within private healthcare settings can influence affordability and reduce the risk of catastrophic health expenditures among vulnerable populations.

Nevertheless, several limitations of this study were discovered. First, the study employed a cross-sectional design, which limits the ability to establish causal relationships between socioeconomic characteristics and catastrophic health expenditures. Second, the analysis relied on self-reported income and healthcare expenditure data, which may be subject to recall bias and inaccuracy. Third, the sample size was relatively modest and confined to selected facilities in Dar es Salaam, potentially limiting the generalizability of the findings to other Tanzanian regions. Finally, the regression models focused primarily on household income and healthcare expenditure and therefore may not fully capture the influence of other important determinants, including health insurance status, disease severity, household assets, and healthcare-seeking behaviors. Despite these limitations, this study provides valuable empirical evidence on healthcare affordability and catastrophic health expenditure across different

healthcare delivery models and offers important insights for strengthening financial risk protection and advancing Universal Health Coverage in urban Tanzania.

12 CONCLUSIONS

This study demonstrates that the affordability of healthcare and catastrophic health expenditure in urban Tanzania is fundamentally shaped by the interaction between household income and healthcare costs. While most patients across referral, city-led, and private healthcare facilities were able to access healthcare without experiencing severe financial hardship, a significant proportion of vulnerable households remained exposed to catastrophic expenditure. The burden was disproportionately concentrated among low-income households, unemployed individuals, widows, patients with limited educational attainment and households with large dependency ratios.

The findings further reveal that primary healthcare facilities, particularly health centers and dispensaries, play a critical role in financial protection by maintaining relatively affordable treatment costs and reducing the likelihood of healthcare-induced poverty. In contrast, referral-level care was associated with higher financial risks because of the costs of specialized investigations, chronic disease management, and repeated healthcare utilization. Across all facility categories, household income consistently reduced the risk of catastrophic expenditure, whereas increased healthcare costs significantly elevated financial vulnerability.

The central message of this study is that access to healthcare alone does not guarantee financial protection. A health system can only be considered truly equitable when individuals can obtain the healthcare services they need without sacrificing their economic well-being.

Therefore, strengthening primary healthcare financing, expanding health insurance coverage, reducing out-of-pocket payments, and protecting economically vulnerable populations must remain central priorities in Tanzania's pursuit of Universal Health Coverage. Ultimately, the success of health financing reforms should be measured not only by the number of people receiving healthcare services but also by the extent to which the health system protects households from falling into poverty because they sought care.

Declaration by Authors: We declare that this manuscript is original and has not been published previously, nor is it under consideration for publication elsewhere. All authors contributed significantly to the conception, design, analysis, and writing of the manuscript. All authors have read and approved the final version of the manuscript and agree to its submission for publication.

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