Cost-Of-Illness Study for Dengue Disease: A Quantile Regression Analysis (A Case Study of District Nowshera)

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Abstract

This study examines the economic burden of dengue fever in Nowshera District, a region highly vulnerable to climate change due to intensified monsoon rainfall and recurrent flooding. Data was collected from 322 dengue patients through a structured questionnaire, and a bottom-up micro-costing approach was applied to conduct a cost-of-illness analysis. The study quantified both direct costs (medical and non-medical expenses) and indirect costs (income loss, productivity decline, and related expenditures). Quantile regression analysis revealed heterogeneous effects across cost distributions. At the 0.25 quantile, being male increased direct costs by PKR 0.017 and rural residency added PKR 0.003, while treatment in public hospitals reduced direct costs by PKR 0.060. For indirect costs at this quantile, being male increased expenditures by PKR 0.46, and public hospital treatment was associated with a PKR 0.468 rise. At the 0.75 quantile, the effect of male gender on direct costs diminished to PKR 0.004, rural residency reduced direct costs by PKR 0.040, and public hospital treatment continued to lower direct costs by PKR 0.073. However, indirect costs at this higher quantile still increased by PKR 0.217 for those treated in public hospitals. Overall, the findings highlight the significant economic burden posed by dengue fever in climate-sensitive regions, with notable variations across socio-demographic groups and healthcare settings. The results underscore the need for climate-adaptive, cost-effective public health policies in Nowshera and similar vulnerable districts of Pakistan.

Keywords: climate change, cost of illness, Out-of-pocket cost, direct cost and indirect cost of dengue.

1. Introduction

Climate change has emerged as one of the greatest threats to human health in the twenty-first century. It not only alters the physical environment but also affects natural and human systems, including social and economic structures and the functioning of health systems. The World Health Organization (2023) describes climate change as a “threat multiplier,” undermining decades of progress in public health. Increasingly frequent extreme weather events such as storms, floods, droughts, and heatwaves intensify health risks by contributing to deaths, non-communicable diseases, and public health emergencies. Current estimates suggest that 3.6 billion people live in regions highly vulnerable to climate change, and between 2030 and 2050, climate change may cause an additional 250,000 deaths annually due to undernutrition, malaria, diarrhea, and heat stress (IPCC, 2022).

Vector-borne diseases, transmitted by parasites, bacteria, and viruses through vectors such as mosquitoes, are particularly sensitive to climatic changes. They already account for more than 17% of all infectious diseases worldwide, causing over 700,000 deaths each year. Diseases such as malaria, dengue, schistosomiasis, chikungunya, and yellow fever disproportionately affect tropical and subtropical regions and remain a major challenge for low-income populations. Dengue fever, in particular, is one of the most widespread viral infections transmitted by Aedes mosquitoes. It is estimated that more than 3.9 billion people across 132 countries are at risk of dengue, with about 100–400 million infections and 40,000 deaths annually (WHO, 2023). Although many dengue cases are asymptomatic or mild, severe forms can require hospitalization and pose significant threats to public health systems. Reported cases have risen dramatically, from only 505 in 2000 to 5.2 million in 2019, highlighting the disease's rapid global spread. Pakistan is one of the countries severely affected by dengue, particularly during the rainy season from June to September. Changing climatic conditions, such as erratic monsoon patterns and recurrent floods, have further exacerbated the incidence of dengue in vulnerable regions. For example, the 2022 floods in Nowshera District, Khyber Pakhtunkhwa, intensified dengue outbreaks, reflecting the close link between climatic events and vector-borne diseases. Despite the growing prevalence of dengue in Pakistan, especially in climate-sensitive districts, little is known about the true economic burden of the disease at the household and healthcare system level.

This research seeks to address this critical gap by comprehensively quantifying the economic burden of dengue fever in Nowshera District. Specifically, the study will assess both the direct costs (such as medical expenses, hospitalization, and transportation) and indirect costs (such as loss of income and productivity) borne by households, alongside the public healthcare expenditures related to prevention and treatment. Furthermore, the research will investigate how climate change factors influence the scale and variability of these costs, providing localized evidence on how climate-induced health risks translate into economic pressures. The absence of district-level studies on dengue's economic burden in Pakistan restricts policymakers' ability to design effective and climate-resilient interventions. By focusing on Nowshera, a district highly vulnerable to climate change, this research aims to generate crucial evidence to inform targeted, cost-effective, and adaptive health policies. Ultimately, the findings will not only contribute to strengthening local healthcare responses but also support broader strategies for enhancing resilience against vector-borne diseases in climate-vulnerable regions.

2. Literature Review

Global literature consistently underscores dengue fever as a growing public health and economic challenge, particularly in regions vulnerable to climate variability. A systematic review of studies conducted in Southeast Asian (SEA) countries between 2010 and 2020 revealed that dengue imposes a substantial and increasing financial burden on health systems (Zamzuri, 2025). Using PRISMA guidelines, 13 original articles were analyzed, highlighting variations in cost estimation methods such as direct medical, direct non-medical, and indirect costs. The economic impact of dengue varied across countries depending on incidence rates, with health expenditure ranging between less than 0.001% to 0.1% of GDP per capita. Hospitalization and ambulatory care emerged as the dominant cost drivers, underscoring dengue's role as a costly and persistent public health threat.

Evidence from non-endemic countries also demonstrates significant resource implications. For instance, an analysis of statutory health insurance claims in Germany (2015–2018) identified 440 dengue patients, with incidence rates of 1.4–1.7 per 100,000 individuals (Goodman, 2025). Although cases were non-severe, patients recorded markedly higher healthcare utilization, including a threefold increase in hospitalization and multiple additional outpatient visits. This translated into higher per-patient healthcare costs (€769.8), with inpatient expenses accounting for half the total. Such findings emphasize that even in non-endemic regions, dengue imposes measurable healthcare costs, warranting preventive interventions. In Latin America, the Global Burden of Disease Study (2019) reported that Suriname, Colombia, Guyana, Venezuela, and Brazil exhibited the highest dengue-related disability-adjusted life years (DALYs), with significant increases in burden observed between 2000 and 2010 (Navarro, 2025). Although reductions were recorded between 2010 and 2019, the overall impact remained substantial. Similarly, in Colombia, a systematic review estimated dengue's annual aggregated cost at USD 159.6 million, with hospitalization and ambulatory care accounting for 75% of the total, and indirect costs (lost income and caregiving) reaching USD 92.8 million (Khondaker, 2025). These results highlight the dual burden on households and health systems in middle-income settings. Singapore, despite its robust vector control programs, continues to face repeated dengue outbreaks. A review of 333 reports spanning 2000–2022 revealed an incidence peak of 621.1 cases per 100,000 person-years in 2020, with rising economic costs from SGD 58–110 million in the 2000s to SGD 148 million in the 2010s (Rodriguez-Morales, 2024). Notably, indirect costs constituted up to 63% of total expenditures, reflecting broader socioeconomic impacts beyond direct medical spending. The link between climate change and dengue transmission has been well established in the literature. Abbasi (2025) and Islam (2025) both demonstrated strong correlations between rising temperatures, altered rainfall patterns, and the geographic expansion of Aedes aegypti into previously non-endemic regions. Projections indicate a 25% increase in dengue spread by 2050, particularly in Southeast Asia, sub-Saharan Africa, and South America. These studies emphasize the need for climate-adaptive interventions, including enhanced surveillance and vector control. Meteorological factors also play a significant role in shaping epidemic dynamics. Kamal (2024), analyzing dengue incidence from 2013 to 2021, found strong seasonal patterns explained by rainfall, humidity, and sunshine hours. Rainfall increases were associated with higher dengue cases, while higher humidity showed a negative relationship. The study concluded that integrating weather indicators into prevention programs can improve public health preparedness. Complementary evidence from South America highlights urbanization, prior viral circulation, and prolonged temperature anomalies as major drivers of increasing dengue incidence, even in areas previously protected by altitude (Hossain, 2023). A bibliometric analysis of climate change and dengue transmission research (2014–2023) revealed that while temperature, rainfall, and humidity dominate as explanatory variables, there is still a lack of longitudinal, region-specific studies in highly vulnerable low- and middle-income countries (Ferreira, 2024). This gap constrains the development of localized, evidence-based adaptation strategies.

Overall, existing research confirms that dengue fever is both a climate-sensitive disease and a major source of direct and indirect economic costs across diverse contexts. However, most studies are either regional or national in scope, with limited district-level evidence from highly vulnerable countries such as Pakistan. While dengue's link with climate change has been well established, little is known about how these dynamics translate into household-level economic burdens in climate-sensitive districts. This gap is particularly evident in regions like Nowshera District, where recurrent flooding and climatic shifts have intensified dengue outbreaks, but the true economic costs remain undocumented.

3. Methodology and Model

This study employed a cross-sectional, cost-of-illness (COI) design to estimate the economic burden of dengue fever in Nowshera District during the June–December 2024 outbreak. A census approach was adopted, covering all 322 confirmed dengue patients reported by the District Headquarters (DHQ) hospital. Primary data were collected through structured questionnaires administered to patients and their caregivers, capturing direct medical costs (consultations, diagnostic tests, medications, hospitalization), direct non-medical costs (transportation, dietary needs, accommodation), and indirect costs (income and productivity losses due to patient or caregiver absenteeism, and school days lost). A bottom-up micro-costing approach was used, with indirect costs estimated using the human capital method based on average local wages. Data analysis involved descriptive statistics to summarize cost distributions and quantile regression to identify demographic and socioeconomic determinants of variation, focusing particularly on gender, residence type, and type of healthcare facility. Ethical standards were observed by ensuring informed consent and confidentiality of participants' information.

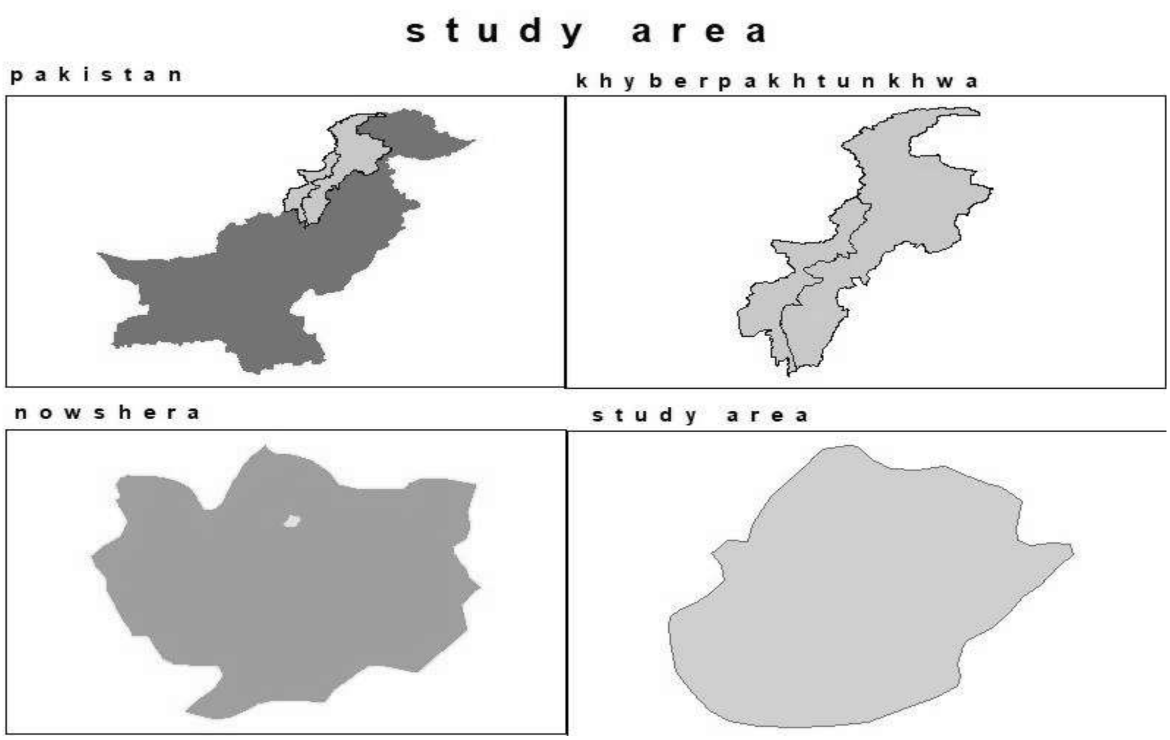

Figure 1: Study Area of Sample Collection

Figure 1 presents the study area, Nowshera District in Khyber Pakhtunkhwa, where 322 dengue cases were reported between June and December 2024 by the District Headquarters (DHQ) Hospital. Data from these patients formed the basis for estimating the economic burden of dengue using the Cost-of-Illness (COI) model, which accounts for direct medical costs, direct non-medical costs, indirect costs (productivity losses), and intangible costs such as pain and suffering (Hansen, 2024). The COI approach is particularly suitable for Nowshera as it provides a holistic estimate of economic burden by capturing not only treatment-related medical expenditures but also substantial non-medical and productivity-related costs—an essential consideration in a region where many households rely on informal labor and limited transport infrastructure. Evidence from Pakistan suggests that non-medical expenses can constitute up to 43% of total direct costs, underscoring the importance of including these components. By quantifying the total societal cost in monetary terms, the COI framework generates critical evidence for policymakers to allocate resources effectively, justify investments in dengue prevention and control, and highlight the potential cost savings of reducing disease incidence. Moreover, disaggregated household-level data allows for identifying socioeconomic disparities, as poorer households often bear a disproportionate financial burden, which can inform targeted social protection measures. The estimates also provide a valuable baseline for future evaluations, such as assessing the cost-effectiveness of emerging interventions like dengue vaccines. Finally, given the unique socioeconomic and healthcare landscape of Nowshera, localized COI analysis offers more accurate and actionable insights than national or global averages, ensuring evidence-based prioritization of healthcare resources in this climate-vulnerable region.

$$\mathrm{COI} = \mathrm{B0} + \mathrm{B1DC} + \mathrm{B2IC} + \mathrm{Ui} \tag{1}$$

$$\mathrm{LogDC} = \mathrm{B0} + \mathrm{B1Gender} + \mathrm{B2LOGInc} + \mathrm{B3Loc} + \mathrm{B4TDF} + \mathrm{B5LogHI} + \mathrm{B6THC} + \mathrm{B7HS} + e \tag{2}$$

$$\mathrm{LogIDC} = \mathrm{B0} + \mathrm{B1Gender} + \mathrm{B2LogInc} + \mathrm{B3Loc} + \mathrm{B4TDF} + \mathrm{B5LogHI} + \mathrm{B6THC} + \mathrm{B7HS} + e \tag{3}$$

Quantile regression is an advanced statistical technique that goes beyond traditional Ordinary Least Squares (OLS) regression by modeling the conditional quantiles of a dependent variable rather than focusing only on its conditional mean (Regression, 2017). While OLS estimates the average effect of independent variables, quantile regression provides estimates across different points of the distribution, such as the 25th, 50th (median), and 75th percentiles. This approach enables researchers to capture how explanatory variables influence outcomes at various levels, offering a more detailed and nuanced understanding of heterogeneous effects within the data. For example, the impact of socioeconomic factors on healthcare costs may differ substantially between lower-cost households (e.g., 25th quantile) and higher-cost households (e.g., 75th quantile). By analyzing these variations, quantile regression produces a richer picture of relationships, making it particularly valuable for studies where the effects of predictors are not uniform across the outcome distribution.

$$Q\tau\,(DC) = \beta 1(\tau) + \beta 2(\tau)GEN + \beta 3(\tau)loc + \beta 4(\tau)THF + \beta 5(\tau)TDF + \beta 6(\tau)HS + \beta 7(\tau)INC + \beta 8(\tau)HI + E1 \quad (4)$$

$$Q\tau\,(IDC) = \beta 1(\tau) + \beta 2(\tau)GEN + \beta 3(\tau)loc + \beta 4(\tau)THF + \beta 5(\tau)TDF + \beta 6(\tau)HS + \beta 7(\tau)INC + \beta 8(\tau)HI + E1 \quad (5)$$

$Q\tau(\cdot|\cdot)$ denotes the τ-th conditional quantile. $\beta 0(\tau)$ is the intercept for the τ-th quantile. $\beta j(\tau)$ (for j=1,…,8) are the regression coefficients for each independent variable, specific to the τ-th quantile. This means the effect of each variable on direct cost can be different at different parts of the direct cost distribution (e.g., at the 10th percentile vs. the 90th percentile).

Based on the World Health Organization's (WHO, 2025) guidelines for assessing the financial impact of infectious diseases, this study employed a **bottom-up micro-costing approach** to calculate the cost of illness for each dengue patient episode. This method involves identifying and valuing all relevant cost components at the most detailed level. To capture the household's financial burden, both direct and indirect costs were included. Direct costs comprised medical expenses (medicines, diagnostic tests, consultation and registration fees) and non-medical expenses (transportation, lodging, food, and payments for informal assistance) (Arshad, 2024; Al T. et al., 2025). Indirect costs reflected productivity losses due to work absenteeism or reduced activity by patients and caregivers, as well as school absenteeism in some cases (RIOUS, 2025). These were estimated using the Human Capital Approach (HCA), which values lost income and unpaid caregiving time based on self-reported wage rates. By combining these measures, the study provides a comprehensive estimate of the economic burden of dengue on households in Nowshera.

4. Results and interpretation

This study first employed descriptive analysis to examine the direct and indirect costs of dengue in Nowshera, followed by normality testing of cost data across different time frameworks. Ordinary Least Squares (OLS) estimation was conducted alongside serial correlation testing to ensure model reliability. The research is based on a cross-sectional design, using primary data collected through structured questionnaires from 322 confirmed dengue patients across diverse socio-economic groups in Nowshera District. The questionnaire was designed to capture both direct costs (such as medical expenses, diagnostic tests, and transportation) and indirect costs (including productivity losses and caregiver time), providing a comprehensive assessment of the financial burden on households. Quantile regression was then applied as the main analytical technique, chosen for its ability to evaluate how explanatory variables affect different points in the cost distribution rather than only the average outcome, thereby offering deeper insights into variations in economic impact across households. This methodological framework, supported by robust sampling, data validation, and the use of appropriate statistical software, ensures the empirical rigor of the findings and provides a sound basis for interpreting the economic burden of dengue and informing climate-adaptive public health interventions.

Table 1 Background information of the study participant, (n = 302).

Variables	Public hospital (n=180) Mean (SD)	Private hospital (n=142) Mean (SD)	Overal (n=322) Mean (SD)
Gender of dengue patient			
Male	113(52.32)	88(33.07)	202(85.45)
Female	67(42.06)	53(41.32)	120(75.27)
Geoghraphical locations			
Rural	124(45.42)	77(37.33)	202(85.34)
Urban	56(38.57)	64(34.01)	120(75.23)
Household size of patients			
Less than 3	59(39.66)	55(33.54)	114(73.63)
3 to 4	42(32.300)	31(24.11)	73(56.45)
5 and more	79(44.59)	55(33.54)	135(78.34)
Type of dengue fever			
Classic	136(45.56)	102(32.21)	239(89.60)
DHF/DSS	44(32.200)	39(28.21)	83(61.60)
Household income	298326(436027)	247829.2(25541)	275885.21(36754)
Household monthly income by quintile			
Poorest	9(11.24)	18(15.80)	27(20.12)
Middle	23(14.72)	11(9.80)	44(51.10)
Richer	54(22.2)	41(28.65)	95((61.10)
Richest	84(30.55)	33(25.27)	117(70.12)
Income level	74494.3(95945)	69631.2(88275)	72304(92404)

Table 1 presents the descriptive analysis of the dengue patients included in the study. The findings indicate that male patients outnumbered females in both types of healthcare facilities, with 113 cases reported in public hospitals and 88 in private hospitals. A higher prevalence of dengue was observed among residents of rural areas, accounting for 124 cases in public facilities and 77 in private hospitals. Family size also emerged as a significant factor, as 135 patients belonged to households with more than five members, suggesting greater vulnerability in larger families. In terms of disease classification, classic dengue cases were predominant, with 239 patients, compared to relatively fewer cases of dengue shock syndrome (DSS). The analysis further shows that the **average individual income** of dengue patients was PKR 72,304, while the **average household income** was PKR 275,885.21. Household income was further divided into quintiles, highlighting that poorer groups bore a disproportionately higher burden of dengue fever in the study area.

2 Household cost of dengue treatment per-episode per-person (PKR)

Type of cost	Cost components	Public hospital n=180			Private hospital (n=142)			Overal n=322		
		Mean	SD	% of total cost	Mean	SD	% of total cost	Mean	SD	% of total cost
Direct medical	medicines cost	7641.6	2190.	11.9	7624	1964	13.1	7634	2090	12.45
	equipment charges	4193.1	1220	6.55	4182	1996	7.21	4188	1165	6.83
	Room charge	1061.6	362.7	1.66	1030	1944	1.77	1047	354	1.70
	doctor fees	972.7	593.6	1.52	1522	843	2.62	1215	764	1.98
	Cost of test	2983.3	2136.2	4.66	3767	1918	5.49	3329	2537	5.42
	Reception	357.1	575.1	0.55	1255	561	2.16	753.2	722.9	1.22
	Total medical cost	**17209**	**7078.**	**26.9**	**19380**	**9226**	**32.4**	**18166**	**7632.**	**28.63**
Direct non-medical	food cost	4691.1	1668.7	7.33	4609	1986	7.92	4655	1589	7.59
	Transportation	575.2	349.96	0.89	1522	843.3	2.62	1512	764	2.46
	caregiving expenditure	946.6	269.52	1.48	946.2	308.5	1.63	946.2	286.5	1.54
	other cost	690.27	220.83	1.07	660.5	275.8	1.13	677.2	246.5	1.10
	Total non-medical cost	**6903.5**	**2509.1**	**10.8**	**7737**	**3413**	**13.3**	**7790**	**2886**	**12.70**
	Total direct cost	**24112.5**	**9587.3**	**37.7**	**27117**	**12639**	**45.7**	**25956**	**10518**	**41.33**
Indirect cost	indirect cost	38067	27186	59.5	30156	23929	52.0	34578	26060	56.40
	caregiver indirect expenditure	1748.8	603.9	2.73	1670	524.6	2.88	1714	570.8	2.79
	Total indirect cost	39815.6	27789	62.2	31826	24453	54.8	36292	26630	59.19
Total cost		**63928.3**	**37377.**	**100**	**58943.7**	**37093**	**100**	**62248**	**37149**	**100**

Table 2 summarizes the cost of illness for dengue patients in Nowshera. The average total cost of treatment was **PKR 62,248**, of which **Out-of-Pocket (OOP) expenses accounted for PKR 25,956 (41.3%)**. Direct medical costs represented **28.63%** of the total, with medicines contributing **12.4% (PKR 7,632)** and medical equipment **6.83% (PKR 4,188)**. Indirect costs were substantially higher, averaging **PKR 36,292**, and made up nearly **60%** of the overall burden, with food and accommodation emerging as the most significant components among direct non-medical expenses. Comparisons between hospital types revealed that OOP costs constituted **37%** of the total in public hospitals versus **45%** in private hospitals, indicating a heavier financial burden on patients treated in private facilities. Overall, the study found that the average cost of illness borne by households was **PKR 34,578 (56% of the total)**, underscoring the considerable economic strain that dengue fever imposes on affected families in the region.

Table 3 Cost burden and health expenditure in different socio-economic conditions, PKR.

Income group	Average monthly income	Average total OOP cost	OOP costs as a percentage of monthly household income
Poorest quintile	34240.45	26111.21	76.25%
2nd quintile	76313.12	23890.71	31.30%
3rd quintile	152990.8	24741.3	16.17%
4th quintile	459294.0	25330.2	5.51%
Overall	180709.2	25018.36	32.22%
Rich-poor ratio	13.41	0.97	0.072%
Difference	425053.2	-781.01	-70.78%

Table 3 presents the distribution of dengue-related Out-of-Pocket (OOP) expenditures across household income quintiles in Nowshera. The findings reveal a stark inequality, with the lowest income quintile, earning an average monthly income of PKR 34,240, bearing a disproportionate share of the burden—PKR 26,111, or 76% of the total OOP cost. The second quintile, with an average monthly income of PKR 76,313, accounted for 31% of OOP costs, while the third quintile (average income PKR 152,991) contributed 16%. By contrast, the fourth quintile represented only 5.5% of total OOP costs, and the wealthiest quintile bore a negligible share. These results demonstrate that the poorest households face the heaviest economic strain, with dengue treatment costs exceeding their average monthly income. The calculated rich-poor income gap amounted to PKR 425,053, with a rich-poor income ratio of 13.41 percent, while the rich-poor ratio in terms of OOP cost was just 0.97 percent. Overall, the data highlight a severe imbalance in the financial burden of dengue, underscoring the vulnerability of low-income households in Nowshera.

Table 4 Heteroscedasticity tests of OLS estimators

Variables	Direct cost F-statistics(pro)	Indirect cost F-statistics (pro)
Breusch-pagan-Godfrey	2.234(0.049)	3.10(0.002)
White test	4.43(0.0007)	1.85(0.008)

Table 4 reports the diagnostic tests for heteroscedasticity in the OLS regression model. The Breusch-Pagan-Godfrey test indicated that the probability values for both direct and indirect costs of dengue were less than the 5 percent significance level, leading to the rejection of the null hypothesis and confirming the presence of heteroscedasticity. Similarly, the White test results also suggested heteroscedasticity, as the probability values were below 5 percent. Given that the error terms were not homoscedastic and showed signs of correlation, the study proceeded with Quantile Regression (QR) analysis, which is more robust in handling heteroscedasticity and allows for a more comprehensive examination of the determinants of dengue-related costs (Fiebig, 2001).

Table 5 Quantile regression of direct cost

Variables	Direct cost of dengue 0.25 Coefficient(prob)	0.50 Coefficient(prob)	0.75 Coefficient(prob)
C	10.00(0.000)	10.07(0.000)	10.55(0.000)
Male	0.017(0.046)	0.0076(0.0032)	0.004(0.010)
Rural	0.003(0.003)	-0.029(0.034)	-0.040(0.015)
Fever type 1	-0.014(0.55)	0.005(0.85)	0.0021(0.95)
Healthcare 1	-0.060(0.0068)	-0.081(0.003)	-0.073(0.049)
Family Size 2	0,024(0.39)	-0.005(0.84)	-0.051(0.779)
Family size 3	0.029(0.021)	0.027(0.04)	0.009(0.023)
Income level	-0.0022(0.03)	0.027(0.043)	0.091(0.047)
Household income	0.0016(0.001)	-0.019(0.044)	-0.102(0.049)
Pseudo R-square	0.024	0.038	0.053

Table 5 presents the quantile regression results for the direct cost of dengue at the 0.25, 0.50, and 0.75 quantiles. At the 0.25 quantile, being male is associated with a PKR 0.017 increase in direct costs, while rural residence adds PKR 0.003. Treatment at a public hospital is linked to a PKR 0.060 decrease in direct costs, reflecting a cost advantage compared to other facilities. A family size of three is associated with a PKR 0.029 increase, whereas higher income levels reduce direct costs by PKR 0.0022. Conversely, household income is associated with a PKR 0.0016 increase. The constant of PKR 10 represents the baseline direct cost at this quantile. At the 0.50 quantile (median), being male increases direct costs by PKR 0.0076, while rural residence reduces them by PKR 0.029. Public hospital treatment shows a stronger association with cost reduction (PKR 0.081), while a family size of three adds PKR 0.027. At this quantile, income level contributes to a PKR 0.027 increase in direct costs, while household income reduces costs by PKR 0.019. The constant at this level is PKR 10.07. At the 0.75 quantile, representing patients with higher costs, being male increases direct costs by PKR 0.004, while rural residence is associated with a PKR 0.040 decrease. Public hospital treatment continues to reduce direct costs (PKR 0.073), and a family size of three adds PKR 0.009. At this quantile, income level is linked to a substantial PKR 0.091 increase in costs, suggesting that wealthier individuals may spend more on treatment, whereas household income reduces direct costs by PKR 0.102. The constant at this quantile is PKR 10.55, representing the baseline cost when independent variables are at their reference values.

Table 6 Quantile regression of indirect cost

Variables	Indirect cost of dengue 0.25 Coefficient(prob)	0.50 Coefficient(prob)	0.75 Coefficient(prob)
C	8.95(0.000)	9.32(0.000)	9.84(0.000)
Male	0.46(0.0013)	0.377(0.0071)	0.113(0.345)
Rural	-0.181(0.151)	-0.278(0.0313)	-0.205(0.0492)
Fever type 1	-0.271(0.078)	-0.21(0.136)	0.024(0.826)
Healthcare 1	0.468(0.0003)	0.0245(0.048)	0.217(0.0315)
Family Size 2	0.097(0.556)	0.123(0.43)	0.3047(0.0473)
Family size 3	0.057(0.002)	0.1287(0.0015)	0.687(0.0031)
Income level	0.649(0.000)	0.889(0.000)	0.897(0.000)
Household income	-0.543(0.002)	-0.7286(0.009)	-0.7335(0.0009)
Pseudo R-square	0.119	0.118	0.070

Table 6 presents the quantile regression results for the indirect cost of dengue at the 0.25, 0.50, and 0.75 quantiles. At the 0.25 quantile, being male is associated with a PKR 0.46 increase in indirect costs, while experiencing classical fever is linked to a PKR 0.271 decrease. Treatment in a public hospital, although shown to reduce direct costs, is associated with a PKR 0.468 increase in indirect costs, suggesting that while medical expenses are lower, opportunity costs such as lost productivity may be higher. A family size of three adds PKR 0.057 to indirect costs, while higher income levels are strongly linked to an increase of PKR 0.649. In contrast, household income is associated with a PKR 0.543 decrease in indirect costs, indicating a mitigating role of household wealth at the lower cost distribution. The baseline constant at this quantile is PKR 8.95. At the

0.50 quantile (median), being male contributes to a PKR 0.377 increase in indirect costs, while rural residence reduces costs by PKR 0.278. Treatment in a public hospital is associated with a small PKR 0.0245 increase, suggesting limited relief for indirect costs at the median. A family size of three raises indirect costs by PKR 0.1287, while income level shows a strong positive association of PKR 0.889, reflecting higher opportunity costs for wealthier individuals. Household income, however, reduces median indirect costs by PKR 0.7286. At the 0.75 quantile, representing patients with the highest indirect cost burdens, being male is linked to a smaller increase of PKR 0.113, while rural residence continues to reduce indirect costs by PKR 0.205. Public hospital treatment remains associated with an increase in indirect costs (PKR 0.217), and a family size of three adds PKR 0.687, indicating higher vulnerability in larger households. Income level continues its strong positive association, with a PKR 0.897 increase in indirect costs, while household income reduces costs significantly by PKR 0.7335. These results suggest that while higher income levels amplify opportunity costs, greater household wealth provides a consistent protective effect across all quantiles of indirect cost burdens.

5. Result discussion, Conclusion and Recommendations

The average cost to society of a dengue episode has been estimated at USPKR 479.02, ranging between USPKR 341.67 for patients treated in public hospitals and USPKR 567.12 for those treated in private hospitals (Al S. et al., 2014). Out-of-pocket (OOP) expenditures contribute the largest share of the burden, representing around 66 percent of total costs, with poorer households shouldering a disproportionately higher share compared to wealthier quintiles (Huseynli, 2022). A systematic review of 160 records, from which 14 studies were extracted, confirmed that hospitalization is the primary driver of direct medical costs, with per-case expenditures ranging from USD 823 to 1,754 (BU, 2022). Annual aggregated costs of dengue approach USD 159.6 million, with ambulatory care (USD 90 million) and fatal cases (USD 30.7 million) accounting for nearly three-quarters of the total, while indirect costs due to productivity losses reached USD 92.8 million (Arshad, 2024). Beyond dengue, climate change is expected to exacerbate health risks, with projections estimating 250,000 additional annual deaths by 2050 from malnutrition, diarrhea, dengue, and heat stress, and direct health damage costs rising to USPKR 2–4 billion annually by 2030 (BU, 2022).

The results from Nowshera highlight the heterogeneous financial impact of dengue across households. Quantile regression analysis of direct costs shows that at the 0.25 quantile, being male increases costs by PKR 0.017, rural residence adds PKR 0.003, while treatment in a public hospital reduces costs by PKR 0.060. At the 0.50 quantile, the cost advantage of public hospitals becomes even stronger (PKR 0.081 reduction), while rural residence lowers costs by PKR 0.029. At the 0.75 quantile, public hospitals continue to reduce direct costs (PKR 0.073), although higher individual income is associated with an increase of PKR 0.091, suggesting that wealthier individuals tend to spend more on treatment. Household income, however, consistently reduces direct costs at all quantiles, indicating a buffering effect against financial strain.

For indirect costs, the findings reveal contrasting patterns. At the 0.25 quantile, being male increases indirect costs by PKR 0.46, while classical fever reduces them by PKR 0.271. Public hospital treatment, despite reducing direct costs, is associated with a PKR 0.468 increase in indirect costs, likely due to lost work time and extended caregiving. At the 0.50 quantile, indirect costs rise by PKR 0.377 for men and by PKR 0.889 with higher income, while household income reduces them by PKR 0.7286. At the 0.75 quantile, males experience only a marginal increase (PKR 0.113), rural residence lowers indirect costs (PKR 0.205), but public hospital treatment adds PKR 0.217. Larger families are especially vulnerable, with a family size of three adding PKR 0.687 to indirect costs. Income level remains positively associated with indirect costs across quantiles, reflecting higher opportunity costs among wealthier households, whereas household income consistently mitigates these burdens.

The study reveals that dengue imposes a substantial financial burden on households in Nowshera, with an average total cost of PKR 62,248. Out-of-pocket expenditures account for 41.3 percent of this total, with the poorest quintile bearing 76 percent of the OOP burden despite very low incomes. The regressive nature of these expenditures highlights how dengue pushes already vulnerable households into deeper financial distress. Public hospitals offer a clear cost advantage in terms of direct expenditures compared to private facilities, but they do not alleviate indirect costs, which constitute nearly 60 percent of the overall burden. Quantile regression analysis underscores that household income acts as a protective factor across all quantiles, while individual income and family size exacerbate cost pressures, especially for indirect costs.

The findings underscore the need for multi-pronged policy action to reduce the financial burden of dengue in climate-vulnerable regions such as Nowshera. First, targeted financial assistance programs should be introduced for the poorest households, such as direct cash transfers, subsidized treatment packages, or dedicated dengue relief funds, modeled on initiatives like Punjab's Aaghosh program. Second, expanding subsidized health insurance or universal coverage could protect low-income families from catastrophic OOP expenditures. Third, addressing the high indirect costs in public hospitals requires improvements in patient flow, reduced waiting times, and stipends or wage-compensation mechanisms for caregivers. Fourth, investment in rural healthcare infrastructure—through strengthening basic health units and rural health centers—can improve access, reduce travel costs, and lower income losses. Fifth, vector control must remain a top priority through larviciding, fumigation, and community-led clean-up campaigns supported by real-time surveillance. Sixth, community awareness initiatives should be tailored to low-income groups, focusing on early symptom recognition, care-seeking behavior, and preventive practices. Finally, policymakers should establish a robust cost-of-illness surveillance system and conduct regular impact assessments to evaluate the effectiveness of interventions and ensure resources are effectively targeted.

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