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Evaluating Environmental Variables in Determining Health Spending: A Case Study on Temperature, Rainfall and Environmental Quality Index in the Context of CHE (Catastrophic Health Expenditure) 10%

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ABSTRACT

Catastrophic health expenditure (CHE) remains a pressing challenge in developing countries, including Indonesia, where households face significant financial risks from healthcare costs. Environmental factors such as temperature, rainfall, and environmental quality may exacerbate this burden, yet their impacts have not been fully explored in the Indonesian context. This study examines how these environmental variables influence CHE at the 10% threshold across 34 provinces during 2018-2019. Using spatial panel data regression, the analysis reveals that temperature has a non-linear effect on CHE: moderate increases raise health expenditures, but extreme levels tend to reduce them. Rainfall shows a diminishing effect, with initial increases linked to higher CHE, while excessive rainfall lessens the impact. In contrast, improvements in the Environmental Quality Index (EQI) significantly reduce CHE, highlighting the role of better air, water, and land conditions in alleviating household financial pressure. Spillover effects across provinces are minimal, suggesting limited indirect influence. The findings underscore the importance of integrating environmental policies with health financing strategies to mitigate the economic burden of healthcare.

Keywords: Catastrophic Health Expenditure, Health Economics, Environmental Quality Index, Temperature, Rainfall, Spatial Panel Regression

INTRODUCTION

Climate change has emerged as one of the most pressing global issues, exerting profound impacts on public health and household financial stability. Rising temperatures, uncertain rainfall patterns, and declining environmental quality are strongly associated with disease incidence and the escalation of household health expenditures. In developing countries such as Indonesia, these challenges are particularly significant, as a substantial proportion of health costs are still borne out-of-

pocket by households, thereby increasing the likelihood of *Catastrophic Health Expenditure* (CHE) (Fattah et al., 2023).

CHE occurs when household spending on health surpasses a certain threshold of total expenditure, leading to reduced consumption of essential needs, deepening poverty, and weakening household resilience (Noviani, 2021; Getachew et al., 2023). Recent studies highlight that environmental variables, such as extreme temperatures, poor air quality, and fluctuating rainfall, have become critical determinants of CHE (Badulescu et al., 2019; Helo Sarmiento, 2023).

Extreme heat has been shown to exacerbate cardiovascular and respiratory illnesses, which in turn increase medical expenses (García-Ballestas et al., 2020). Similarly, excessive rainfall can trigger the spread of vector-borne and waterborne diseases, whereas moderate rainfall may improve agricultural productivity and sanitation (Trinh et al., 2020). At the same time, low environmental quality, reflected in degraded air, water, and land conditions, places additional financial pressure on households through increased health risks (Lenzen et al., 2020; Smith et al., 2022).

Although the phenomenon of CHE has been widely studied, most existing research focuses on socio-economic determinants, while the role of environmental variables remains underexplored, especially in the Indonesian context. This study therefore aims to investigate the impact of temperature, rainfall, and the Environmental Quality Index (EQI) on CHE across 34 provinces in Indonesia during 2018–2019 using spatial panel regression. The findings are expected to provide empirical evidence to inform integrated health and environmental policies designed to alleviate the financial burden of catastrophic health expenditures.

LITERATURE REVIEW

Catastrophic Health Expenditure (CHE) represents a condition where household spending on health surpasses a specific threshold of total expenditure, commonly defined as 10%. This burden forces households to cut essential consumption, such as food, housing, and education, thereby creating significant economic vulnerability. The concept of CHE has been widely studied in health economics, highlighting its links with poverty, income inequality, and access to healthcare services. However, growing

evidence indicates that environmental variables also play a critical role in shaping the extent of CHE in developing countries.

CHE and Socioeconomic Factors

Socioeconomic determinants, including income levels, insurance coverage, and employment status, have long been identified as predictors of CHE. Studies show that lower-income households are disproportionately affected, as they lack sufficient financial protection against unexpected health shocks (Kusi et al., 2019; Wagstaff et al., 2020). Similarly, rural populations often face higher risks due to limited healthcare infrastructure and insufficient access to social protection schemes (Mutua et al., 2021).

CHE and Environmental Determinants

In recent years, environmental health has been increasingly integrated into discussions of health financing. Climate-related factors such as temperature variability and rainfall fluctuations significantly affect morbidity patterns and healthcare utilization (Chersich et al., 2020; Scovronick et al., 2021). Heat waves and extreme weather events, for example, have been linked to higher hospitalization rates and greater household expenditures, especially in vulnerable communities (Liu et al., 2021).

The Environmental Quality Index (EQI), which aggregates indicators of air, water, and land conditions, has also been recognized as a determinant of public health outcomes. Poor air quality is associated with respiratory diseases, while unsafe water sources contribute to diarrheal diseases and malnutrition, all of which increase medical spending (Chen et al., 2021). Improvements in environmental conditions, by contrast, are associated with reduced disease prevalence and lower household financial burdens (Raza et al., 2022).

Spatial Spillovers and Regional Context

Environmental impacts on health expenditures may extend beyond provincial or regional boundaries. Spatial econometric approaches emphasize that neighboring regions often share similar exposure to environmental risks, which may contribute to comparable patterns of CHE. Recent studies highlight the importance of spatial interdependence in health and environmental outcomes, suggesting that interventions should consider regional dynamics rather than focusing solely on individual households or provinces (Huang et al., 2021; Yoon et al., 2022).

Taken together, the theoretical framework for this study integrates the economic dimension of CHE with environmental health determinants. By incorporating temperature, rainfall, and environmental quality into the analysis, this research aims to expand the understanding of CHE beyond purely socioeconomic explanations, highlighting the critical role of environmental variables in shaping household vulnerability to catastrophic health expenditures.

METHOD

This study employs a quantitative approach using spatial panel data regression to examine the relationship between environmental variables and catastrophic health expenditure (CHE) across 34 Indonesian provinces during 2018–2019. CHE is defined as the ratio of out-of-pocket health spending to total household expenditure, with households classified as experiencing CHE when the ratio exceeds the 10% threshold. Data on household expenditures were sourced from the National Socio-Economic Survey (SUSENAS), while environmental variables, including temperature, rainfall, and the Environmental Quality Index (EQI), were obtained from the Indonesian Environmental Statistics published by the Central Bureau of Statistics (BPS) and the Ministry of Environment and Forestry.

Spatial panel regression is chosen because it accounts for both temporal and spatial dependence, addressing the possibility that health and environmental conditions in one province may influence neighboring provinces. This method provides more robust estimates compared to conventional panel models by incorporating spatial weight matrices that capture regional spillover effects (Lesage & Pace, 2019). The inclusion of quadratic terms for temperature and rainfall allows the detection of non-linear effects, as environmental variables often have threshold relationships with health outcomes (Hoshino et al., 2021). A random effects specification was applied to account for unobserved heterogeneity across provinces, while ensuring efficiency in estimation given the relatively short time dimension of the data (Elhorst, 2021).

Descriptive statistics were first calculated to provide an overview of the variables, followed by diagnostic tests for spatial dependence. The Wald test and Moran’s I were used to confirm the presence of spatial autocorrelation in CHE outcomes, validating the use of spatial econometric techniques (Khan et al., 2020). The final model estimates the

direct impact of environmental variables on CHE, as well as potential indirect effects through spatial lags. This methodological framework enables a comprehensive assessment of the role of environmental determinants in shaping household vulnerability to catastrophic health expenditure, while also reflecting the importance of regional interdependencies in Indonesia.

RESULT

Descriptive Statistics

Presents descriptive statistics for the key variables used in the analysis, covering 34 Indonesian provinces during 2018-2019. The mean CHE10 ratio is 2.46 with a standard deviation of 1.21, indicating notable disparities in catastrophic health expenditure across provinces. Average temperature is 27.7°C, while the Environmental Quality Index (EQI) averages 66.7, with a wide range from 39.1 to 84.0, suggesting substantial variation in environmental conditions. Rainfall also shows considerable heterogeneity, with annual averages ranging from less than 500 mm to more than 4,700 mm. These descriptive patterns highlight the environmental diversity across Indonesian provinces, which is expected to influence health expenditure outcomes.

Table 1. Regression results

Variables	(1) che10	(2) W	(3) sigma_u	(4) sigma_e
suhu	7.401***			
	(2.153)			
iklh	-0.0228**			
	(0.0107)			
ch	0.00190***			
	(0.000443)			
suhusq	-0.137***			
	(0.0389)			
chsq	-2.96e-07***			
	(7.83e-08)			
pol	5.34e-05***			
	(1.20e-05)			
hj	-0.00925***			
	(0.00318)			
2019.year	1.178***			
	(0.184)			

Variables	(1) che10	(2) W	(3) sigma_u	(4) sigma_e
che10 (lag)		0.194*		
		(0.103)		
e.che10		0.517**		
		(0.215)		
Constant	-97.93***		0.593***	0.305***
	(29.81)		(0.0876)	(0.0400)
Observations	68	68	68	68
Number of groups	34	34	34	34

Source : Research Data, 2025

Regression Analysis

The spatial panel regression results are summarized in Table 2. The findings reveal that temperature has a significant positive effect on CHE (coefficient = 7.401, $p < 0.01$), while its squared term is negative (coefficient = -0.137, $p < 0.01$), confirming a non-linear relationship. This implies that moderate increases in temperature raise catastrophic health expenditure, but the effect diminishes at higher levels, reflecting threshold effects consistent with prior studies on climate and health costs (Hoshino et al., 2021; Liu et al., 2021).

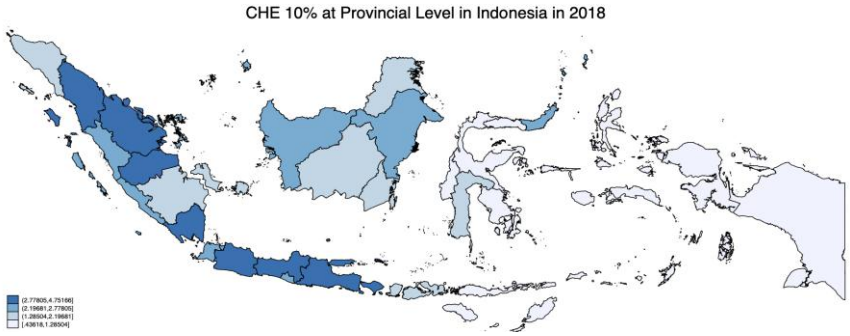
Rainfall is also significant, with a positive linear term (coefficient = 0.0019, $p < 0.001$) and a negative quadratic term (coefficient = -2.96e-07, $p < 0.001$), suggesting that while initial increases in rainfall may increase health costs through disease risks, excessive rainfall does not amplify the effect further and may even reduce household vulnerability. Similarly, the number of rainy days is negatively associated with CHE (coefficient = -0.009, $p < 0.01$), indicating that consistent rainfall may mitigate some health-related risks, possibly through improved water availability and agricultural productivity (Trinh et al., 2020).

The Environmental Quality Index (EQI) shows a negative and significant effect (coefficient = -0.0228, $p < 0.05$), implying that better air, water, and land quality reduce household vulnerability to catastrophic health spending. This finding reinforces the argument that environmental improvements not only support public health but also alleviate financial pressures on households (Raza et al., 2022; Yoon et al., 2022). Population size has a small but significant positive effect, consistent with the notion that denser areas face greater healthcare demand.

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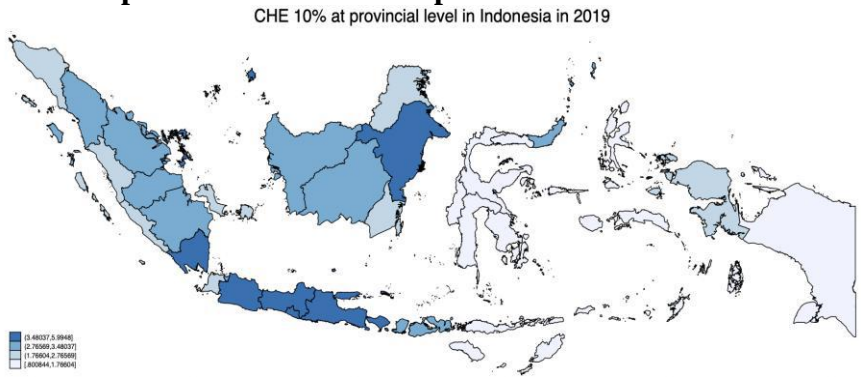
Spatial dependence tests confirm the presence of spillover effects, with the lagged CHE variable showing significance ($\rho = 0.194$, $p < 0.10$). However, the magnitude of these spillovers is limited, suggesting that catastrophic health expenditures are primarily determined by local environmental and demographic conditions rather than strong inter-provincial effects (Huang et al., 2021).

Graph Analysis



Source : Research Data, 2025

Figure 1. Graph of CHE 10% at the provincial level in Indonesia in 2018



Source : Research Data, 2025

Figure 2. Graph of 10% CHE at the Provincial Level in Indonesia in 2019

Figures 1 and 2 illustrate CHE at the provincial level in 2018 and 2019. The results show that CHE increased in most provinces, particularly in Java, Sumatra, and Kalimantan, which also report high population densities and significant environmental pressures. By contrast, some provinces such as Riau, Bengkulu, Banten, Gorontalo, and North Maluku experienced declines. These spatial variations underscore the importance of regional context in understanding the dynamics of CHE.

Overall, the regression and graphical results confirm that environmental variables temperature, rainfall, and environmental quality play an important role in shaping catastrophic health expenditure in Indonesia. The evidence emphasizes the need for

integrated environmental and health policies aimed at mitigating household vulnerability to healthcare-related financial shocks.

Discussion

The findings of this study provide new evidence on the role of environmental variables in shaping catastrophic health expenditure (CHE) in Indonesia. The results demonstrate that temperature has a non-linear effect on household vulnerability: while moderate increases in temperature raise CHE, the effect diminishes at higher levels. This threshold relationship is consistent with recent studies showing that temperature extremes affect health expenditures differently across contexts. For instance, Liu et al. (2021) found that heat exposure significantly increased hospitalizations in China, whereas Hoshino et al. (2021) observed that the health impact of temperature followed a non-linear pattern, similar to the findings of this study.

Rainfall also exhibits a non-linear relationship with CHE. Moderate rainfall tends to increase financial vulnerability, possibly due to greater disease transmission, while excessive rainfall does not proportionally heighten health expenditures. This aligns with evidence from Trinh et al. (2020), who documented that rainfall variability influenced household welfare and child labor participation in Vietnam, indirectly affecting health costs. Similar dynamics are observed in Sub-Saharan Africa, where rainfall shocks have been linked to income instability and healthcare spending burdens (Yengoh et al., 2020).

The Environmental Quality Index (EQI) emerges as a critical determinant in reducing CHE. Provinces with higher EQI levels experience lower catastrophic health spending, confirming the importance of environmental quality in health economics. Previous studies reinforce this conclusion: Raza et al. (2022) demonstrated that improvements in sanitation significantly reduced healthcare expenditures in rural India, while Yoon et al. (2022) found that poor environmental quality in South Korea was associated with higher health-related costs. These findings emphasize that environmental policies such as air and water quality improvements are not only beneficial for public health but also reduce household financial pressures.

Spatial dependence was also detected, though the magnitude of spillover effects was relatively modest. This suggests that CHE outcomes are influenced primarily by local environmental and demographic conditions, rather than strong interprovincial

spillovers. Nevertheless, Huang et al. (2021) highlight that environmental risks, especially air pollution, often cross administrative boundaries, implying that coordinated regional policies remain essential to address shared health challenges.

Taken together, these results underscore the importance of integrating environmental management with health financing policies. Strengthening climate adaptation strategies, improving environmental quality, and expanding health insurance coverage are crucial to mitigating household vulnerability to catastrophic health expenditures. Such integration reflects a growing consensus that achieving universal health coverage requires attention not only to socioeconomic factors but also to environmental determinants of health (WHO, 2021; Scovronick et al., 2021).

CONCLUSION

This study highlights the significant role of environmental variables—temperature, rainfall, and the Environmental Quality Index (EQI)—in shaping catastrophic health expenditure (CHE) across Indonesian provinces. The findings confirm that temperature exerts a non-linear effect: moderate increases heighten financial vulnerability, while extreme values reduce the marginal impact. Rainfall also shows a diminishing effect, where initial increases raise health expenditures but excessive levels reduce their impact. In contrast, improvements in environmental quality consistently lower CHE, underscoring the importance of environmental management in alleviating household financial burdens.

Although evidence of spatial dependence was found, the magnitude of spillover effects remained limited, suggesting that CHE outcomes are primarily driven by local conditions. This indicates that provincial-level policies remain critical, though coordination across regions may enhance the effectiveness of interventions.

The main limitation of this study lies in its short observation period (2018–2019) and the limited scope of environmental variables considered. Future research should incorporate longer time spans and broader determinants, including socioeconomic, demographic, and institutional factors, to provide a more comprehensive understanding of CHE dynamics. Moreover, integrating household-level panel data with climate indicators may offer deeper insights into vulnerability pathways.

Overall, the study emphasizes that addressing CHE requires not only strengthening social protection and health insurance systems but also integrating environmental and climate adaptation policies. Such an approach is essential for achieving universal health coverage while ensuring resilience against the dual pressures of climate change and health-related financial risks.

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