Vol. 18 No.2, Agustus 2025 ISSN : 2301-8968

JURNAL EKONOMI KUANTITATIF TERAPAN

JEKT | Volume 18 | Nomor 2 | Halaman 151-374 | Denpasar Agustus 2025 | ISSN 2301-8968 pISSN : 2301 – 8968

JEKT ♦ 18 [2] : 151-186 eISSN : 2303 – 0186

HEALTH POLICIES: BOLSTERING HUMAN RESOURCES & HEALTHCARE SYSTEMS TO REDUCE CRUDE DEATH RATES IN 2^{6} COUNTRIES

ABSTRACT

This study examines the key determinants of crude death rates (CDR) in selected Countries within Africa, Asia, Europe, and Latin America, emphasising statistical correlations, policy implications, and regional disparities. Using econometric analysis, the study finds that increased life expectancy, higher government healthcare expenditure, and GDP per capita growth significantly reduce mortality rates. Labour force participation and access to potable water further influence mortality trends. However, African and some Asian nations experience higher CDRs due to weak healthcare infrastructure and economic constraints. The findings underscore the need for sustained investment in healthcare systems, human capital development, and policy-driven interventions to mitigate mortality risks and improve public health. This study provides empirical evidence to guide policymakers in designing targeted health policies that enhance healthcare equity and long-term health outcomes.

Keywords**:** crude death rate (cdr), health policy, healthcare expenditure, economic growth, labour force participation, access to drinking water, mortality trends JELClassification: J110, I180, H510, 0400, J210, Q250, I140

INTRODUCTION

The crude death rate (CDR) constitutes a fundamental metric in assessing population health, as it reflects the overarching mortality trends within a given region (Brenner, 2003; Gebel *et al.*, 2015). It is shaped by socioeconomic, demographic, and healthcare factors that determine the effectiveness of health systems and policies (Alshaabi *et al.*, 2021). Although many regions have seen declining mortality due to advances in medicine and public health interventions (Yaukey, Anderton and Hickes Lundquist, 2015; Poston, Jr and Bouvier, 2016; Liang, Guo and Tuljapurkar, 2023). In addition, significant disparities persist, particularly where healthcare access is limited, economic conditions are unstable, and human resources are insufficient (Santos-Jaén *et al.*, 2022). The primary objective of this study is to identify and quantify the main determinants influencing crude death rates across selected countries in Africa, Asia, Europe, and Latin America from 2000 to 2021. Specifically, the analysis examines the effects of life expectancy, domestic general government healthcare expenditure, GDP per capita growth, population size, and labour force participation, along with control variables such as access to basic drinking water services and fertility rates. This study contributes to the literature in public health and health economics by providing a comprehensive, cross-regional, multi-decade panel data analysis that integrates economic, demographic, environmental, and health system variables within a single framework. The findings generate both theoretical insights by refining mortality determinant models and practical implications by informing targeted health policies that address region-specific mortality challenges.

While numerous studies have examined individual determinants of mortality within single countries or specific regions, there is a lack of integrated, comparative research that simultaneously evaluates economic, demographic, environmental, and healthcare system factors across Africa, Asia, Europe, and Latin America over an extended period. Few analyses incorporate both core health indicators (such as life expectancy and healthcare expenditure) and broader socio-environmental variables (such as water access and fertility rates) within one empirical framework. These limits understanding of how mortality drivers differ across contexts. By addressing this gap, the present study advances theoretical knowledge on the interaction of multi-sector determinants of mortality and provides practical policy guidance for targeted interventions. The primary research inquiries that direct this study are as follows:

RQ1: How do life expectancy, healthcare expenditure, GDP per capita growth, total population, and labour force participation influence crude death rates across the various selected countries in Africa, Asia, Europe and Latin America regions?

RQ2: What is the role of access to basic drinking water services and fertility rates in shaping crude death rates?

RQ3: How can strengthening human resources in healthcare contribute to reducing mortality rates?

Research Hypotheses

The hypotheses are defined as follows**:**

H1: Higher life expectancy, increased domestic government healthcare expenditure, and GDP per capita growth are associated with lower crude death rates across different selected countries in Africa, Asia, Europe and Latin America regions.

H2: Improved access to basic drinking water services reduces mortality rates by mitigating the prevalence of waterborne diseases.

H3: Strengthening human resources in healthcare systems through labour force expansion and training significantly reduces crude death rates in under-resourced regions.

Structure of the article

This paper begins with an examination of pertinent literature, elucidating existing research on the determinants of mortality and the methodologies used therein. Subsequently, the section on data and methodology delineates the dataset utilised in the analysis and elucidates the econometric techniques employed to evaluate the relationships between independent variables and crude death rates. The empirical results delineate the outcomes of the regression analysis, thereby elucidating the significant determinants of mortality across various selected regions above. This study endeavours to contribute to the ongoing discourse on population health and development through a comprehensive analysis to inform efforts to enhance public health and reduce crude death rates on a global scale.

Healthcare systems reduce mortality through investments in resources, workforce availability, and strong economic conditions (Alkire *et al.*, 2018; Liu and Eggleston, 2022). Life expectancy is a key indicator of public health and socioeconomic development, influencing mortality trends.(Iuga, Nerişanu and Iuga, 2024). Research shows regions with higher life expectancy have better healthcare, living conditions, and disease prevention (Bilas, Franc and Bo, 2014). Higher healthcare spending extends life expectancy and helps reduce crude mortality rates (Roffia, Bucciol and Hashlamoun, 2023). Public health expenditure by the government is crucial for ensuring equitable access to healthcare services (Adebisi and Umah2, 2020). Studies suggest spending at least 5% of GDP on health improves outcomes and reduces mortality (Mcintyre, Meheus and Røttingen, 2017; Wei, Rahim and Wang, 2022).

Building on this economic and health investment perspective, Macroeconomic conditions shape mortality, with economic growth boosting healthcare investment and lowering death rates (Barro, 1996). Regions experiencing higher growth in GDP per capita often exhibit enhancements in healthcare infrastructure, diminished disease burdens, and overall superior health outcomes (Leimbach *et al.*, 2017). Economic disparities between regions can lead to unequal healthcare access, perpetuating mortality rate inequalities (Berge, 2011; Swift, 2011). Population growth and the rate of labour force participation further influence the demand for healthcare, as well as the efficiency of service delivery ('Working

For Health and Growth', 2026). Rapid population growth without adequate healthcare strains resources and raises mortality, especially in low-resource settings (Mesev, 2003; Walsh, 2020). A sufficient healthcare workforce is vital for meeting medical needs and reducing mortality (Pellegrini, Rodriguez-Monguio and Qian, 2014). Access to fundamental drinking water services is a key determinant of public health, as inadequate provision remains a major cause of waterborne diseases and preventable mortality (World Health Organization, 2008; Gaffan *et al.*, 2022). Improvements in household water quality and sanitation can significantly lower disease prevalence and reduce crude mortality rates (Soares *et al.*, 2002; Howard, 2003). Environmental factors combine with declining fertility rates, leading to ageing populations and higher demand for age-related healthcare (Whelpton, 1949; Jalali *et al.*, 2019; Fauser *et al.*, 2024). Policymakers should fund healthcare sustainably, expand the workforce, and enact policies to cut crude death rates (Jamison, 2018; Allel *et al.*, 2021).

Global Health Policies and Human Resource Development

A skilled workforce, supported by adequate infrastructure, allows health systems to meet present and future demands (Ssengooba *et al.*, 2017; Endalamaw *et al.*, 2024). Strategic workforce planning is essential to resolve shortages, improve service access, and achieve better outcomes (Fried, Fottler and Johnson, 2010). Effective human resources for health (HRH) management enhances health equity by expanding access to marginalised groups (Nash *et al.*, 2019). Poor planning creates supply-demand imbalances, especially in rural areas with limited healthcare support (Ginter, Duncan and Swayne, 2013; Lopes, Almeida and Almada-Lobo, 2015). The global shortfall estimated at 17.4 million healthcare professionals continues to hinder progress toward health goals, with the greatest burden on low- and middle-income countries (Harford *et al.*, 2008). Studies show GDP per capita and education explain 72.6%–82.6% of life expectancy differences in the European Union (Bilas, Franc and Bo, 2014). Life expectancy is most times affected by factors including per capita income, healthcare resources, which encompass the availability of hospital beds, medical personnel, and nursing staff, as well as various socioeconomic conditions (Chetty *et al.*, 2016). Historically, mortality fell with economic growth, but now health interventions drive declines in underdeveloped regions (Davis, 2025). Most factual evidence underscores the significance of governmental health expenditure in enhancing population health outcomes and decreasing mortality rates (Thomas, 2020; Anwar *et al.*, 2023). This is associated with decreased mortality rates, indicating a direct influence on the crude death rate (per 1,000 individuals), (Arize *et al.*, 2024; Sultana *et al.*, 2024; Youssef and Meriem, 2024). Higher per capita government health investment lowers crude death rates, as seen in Kerala and West Bengal (Bhattacharya *et al.*, 2023). In contrast, states like Uttar Pradesh and Bihar have higher mortality despite better nutrition, due to poor healthcare infrastructure (Bardhan, 2025). The majority of evidence also indicates that with the augmentation of national income, the allocation of government health expenditure tends to increase, whereas the proportion of out-of-pocket payments diminishes (Jalali, Bikineh and Delavari, 2021; Sirag and Mohamed Nor, 2021). This phenomenon underscores the disparities in healthcare financing among different income groups (Musgrove, Zeramdini and Carrin, 2002).

The Solow-Swan and Cobb-Douglas models state that GDP per capita growth depends on capital, labour, and technology (Biddle, 2020; Dykas, Tokarski and Wisła, 2022). Demographic trends also significantly influence the sustainability of healthcare systems and the resultant mortality rates (Walsh, 2020). A pertinent example is using Swedish population registers show strong links between demographics, healthcare access, and mortality, highlighting the need for resilient healthcare systems (Ludvigsson *et al.*, 2016). Epidemiological studies using the Total Population Register show how unequal health resources affect mortality across demographic groups (Alawa, Zarei and Khoshnood, 2019). Lack of demographic data can misallocate healthcare resources and raise mortality, especially in disaster-prone or densely populated areas (Allen and Katz, 2010; Morganstein *et al.*, 2017). Labour force participation affects mortality by influencing healthcare access and workforce sustainability (Greenberg *et al.*, 2020; Malakoane *et al.*, 2020). Lower labour force participation raises public healthcare costs, reduces private contributions, and limits access to quality care (Pellegrini, Rodriguez-Monguio and Qian, 2014). Elevated levels of employment are associated with an increase in sickness absences, which may exert pressure on healthcare resources and lead to heightened mortality risks (Quinlan, 2013). Stable employment lowers mortality by enabling access to healthcare without financial barriers (Askildsen, Bratberg and Nilsen, 2002).

Access to fundamental drinking water services continues to be a significant determinant of crude mortality rates (Bain *et al.*, 2014). Poor access to safe water raises mortality through higher health risks and preventable deaths(Gaffan *et al.*, 2022). Rural areas are 8–10 times more likely than urban areas to lack safe water, driving disease spread and higher mortality (Hopewell and Graham, 2014). Consistent water access improves health security and reduces mortality by preventing waterborne diseases (Chan *et al.*, 2021). Analyses show service continuity, not just water quantity, is key to better health outcomes and lower mortality (Howard, 2003). Point-of-use water treatment technologies, including ceramic and bio-sand filters, have demonstrated considerable microbial efficacy and sustainability (Erhuanga, 2021). These advancements have contributed to a decrease in the incidence of waterborne diseases and a consequent reduction in mortality rates (Sobsey *et al.*, 2008). Scientific research continues to show a marked decline in fertility rates in regions with extensive family planning programs (Rizkianti *et al.*, 2024). The demographic transition theory links economic growth to lower fertility, but cases like Bangladesh show fertility can drop despite poverty (McNicoll *et al.*, 1995; Bongaarts, 2002). These shifts directly affect healthcare demand and mortality rates, as lower fertility accelerates population ageing and increases the prevalence of age-related diseases (Robey, Rutstein and Morris, 1993; O'Neill *et al.*, 2010). Recent global data indicate that by 2050, one in six people worldwide will be aged 65 or older, further intensifying healthcare needs (Cuervo-Cazurra *et al.*, 2022). The Weighted Total Married Fertility Rate (WTMFR) is a useful metric for tracking changes in fertility among married women (Croix and Michel, 2004; Laplante and Fostik, 2015). Declines in marital fertility, alongside delayed marriage, contribute to demographic ageing and influence mortality patterns (Yip and Li, 2006). At the same time, in countries where fertility rates remain high, healthcare systems face increased demand for maternal and child health services to reduce preventable deaths (Whelpton, 1949, p. 1; Masresha *et al.*, 2024). The Bongaarts framework links delayed marriage and increased contraception to lower fertility, reducing mortality by preventing high-risk pregnancies and improving maternal health (Sibanda *et al.*, 2003). Enhancing healthcare efficiency, strengthening financing, ensuring clean water, and adopting strong economic policies are key to reducing mortality (Kruk *et al.*, 2018). Long-term mortality decline requires addressing gaps in healthcare infrastructure, workforce planning, and public health interventions (Poston, Jr and Bouvier, 2016; Turnock, 2016; Szklo and Nieto, 2019).

Cross-national comparisons can be skewed by demographic differences, gender gaps, and incomplete death registration (Lorentzen, McMillan and Wacziarg, 2008). Standardised mortality indicators are therefore essential for ensuring accurate evaluations (Liang, Guo and Tuljapurkar, 2023). Global data from the World Bank (2024) show that the average CDR declined from 8.0 per 1,000 population in 2000 to 7.2 in 2022, although significant regional differences persist (Corrigan-Curay, Sacks and Woodcock, 2018). In high-income countries, declining CDRs are largely driven by medical technology advancements, improved chronic disease management, and stronger healthcare infrastructure (Ettinger *et al.*, 2016). Many low- and middle-income countries, especially in sub-Saharan Africa, face high CDRs from poor healthcare access, infectious diseases, and conflict deaths (Chilot *et al.*, 2022; 'WHO Country Cooperation Strategy (CCS)', 2023). Effective global health policies that build workforce capacity, invest in infrastructure, and improve access are key to reducing crude death rates (Murphy and Kochanek, 2010). The impact of health spending on life expectancy varies by income level, benefiting lower-middle-income countries the most (Jaba, Balan and Robu, 2014). Conversely, chronic respiratory diseases and high out-of-pocket healthcare expenses pose substantial obstacles to the enhancement of longevity (Roffia, Bucciol and Hashlamoun, 2023). Practical research also substantiates that directed investments in healthcare infrastructure, encompassing hospital beds and specialized medical personnel, demonstrate a causal relationship with enhanced healthcare services (Iuga, Nerişanu and Iuga, 2024). This underscores the imperative need for strategic healthcare policies (Martín Cervantes, Rueda López and Cruz Rambaud, 2019). Spending at least 5% of GDP on health cuts costs, boosts the workforce, and improves maternal and child health (Mcintyre, Meheus and Røttingen, 2017). The sustainability of healthcare financing continues to present challenges due to the asymmetric displacement effect associated with the Development Assistance for Health (DAH) ('Development Co-operation Report 2023 DEBATING THE AID SYSTEM', 2023). Governments often cut domestic health spending when DAH rises and fail to restore it when DAH falls (Dieleman and Hanlon, 2014). Empirical data corroborate the existence of an inverse relationship between governmental health expenditure and crude mortality rates (Hou *et al.*, 2020; Onofrei *et al.*, 2021). This relationship suggests that augmented public health investments contribute to the strengthening of healthcare systems, enhancement of disease prevention strategies, and prolonging human life expectancy (Wei, Rahim and Wang, 2022).

Longitudinal analyses conducted across OECD nations indicate a significant correlation between sustained growth in GDP per capita and reduced mortality rates (Anwar *et al.*, 2023). Expanding healthcare training and retention with economic growth helps ease shortages and lower crude death rates, especially in dense regions (Walsh, 2020). Long-term evidence indicates that sustained employment stability contributes to decreased mortality risks through the provision of consistent access to healthcare services (Silver, Li and Quay, 2022). Conversely, occupational hazards coupled with prolonged exposure to workplace stress are associated with increased mortality rates in specific sectors (Askildsen, Bratberg and Nilsen, 2002). Nations investing in the healthcare workforce see lower crude mortality through better services, early diagnosis, and improved care (Mushkin, 1962). Global health policies are instrumental in fortifying human resources and healthcare systems, thereby contributing to the reduction of crude mortality rates (Skolnik, 2016, p. 2). Both financial and non-financial incentives exert an influence on the retention of the healthcare workforce, whereby policies tailored to specific contexts tend to produce more favourable outcomes (Effa *et al.*, 2021; Russell *et al.*, 2021). Community health interventions substantially decrease mortality rates, especially within vulnerable populations, by enhancing access to preventive and primary care services (Christopher, 2011; Han *et al.*, 2016). Investments in digital health and infrastructure development significantly improve service delivery, particularly in underserved regions (Adhikari *et al.*, 2018). Financial limitations and labour force migration continue to hinder the efficient delivery of healthcare services (Lu *et al.*, 2022). Closing this gap needs targeted investment in training, equipment, and policy alignment (Carrin, 2009; Nash *et al.*, 2019). Strengthening workforce policies and infrastructure, supported by strategic partnerships and multilateral cooperation, is critical for sustaining improvements in healthcare delivery and lowering CDRs (‘National Health Policy’, 2019; Regan, 2023). Countries focusing on health infrastructure, workforce, and social determinants see lasting mortality declines and better health outcomes (World Health Organization, 2013).

RESEARCH METHODOLOGY

The econometric estimation was conducted using a balanced panel dataset covering the period 2000–2021 (n = 64 and t = 22), chosen based on the following criteria: Data Completeness, Regional Representation, and Policy Relevance. The data were collected from the World Bank Data Indicators website, and the countries used for our analysis are:

Africa: Algeria, Angola, Botswana, Cameroon, Chad, Congo, Dem. Rep., Congo, Rep., Cote d'Ivoire, Egypt, Arab Rep., Eswatini, Gabon, Ghana, Mauritius, Morocco, Mozambique, Namibia, Nigeria, Senegal, South Africa, Sudan, Tanzania, Tunisia, Uganda, Zambia.

Asia: Armenia, Azerbaijan, Belarus, Cambodia, Georgia, Indonesia, Iran, Islamic Rep., Jordan, Kazakhstan, Kyrgyz Republic, Malaysia, Myanmar, Papua New Guinea, Philippines, Solomon Islands, Tajikistan, Uzbekistan, Vietnam.

Europe: Bulgaria, Czechia, Estonia, Hungary, Latvia, Lithuania, Moldova, Romania, the Slovak Republic, Slovenia, and Ukraine.

Latin America: Belize, Bolivia, Brazil, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras.

The data were organised for analysis with Stata 17.0 software. The dataset was assembled in a panel format, ensuring that each observation aligns with a specific country-year combination to maintain consistency in analysis. All variables were acquired in their original measurement units as supplied by the World Bank database, and no modifications. Each variable was assessed for completeness, and control variables such as fertility rates and access to drinking water were included to improve model precision. Since this research depends entirely on secondary data from the World Bank database, no independent survey data were utilised. The panel summary statistics in Table 1 below provide a comprehensive snapshot of the distribution and variability of key indicators across 64 countries over 22 years **(2000–2021).**

Table 1. Panel Summary Statistics

Variable		Mean	Std. Dev.	Min	Max	Observations	
drc	overall	8,897219	3,553007	3,148	21,7	N =	1408
	between		3,303395	3,518273	15,48636	n =	64
	within		1,369054	3,593629	17,36031	T =	22
leb	overall	67,30195	7,946367	42,125	81,52927	N =	1408
	between		7,551526	49,85364	79,14784	n =	64
	within		2,640137	52,3859	77,99731	T =	22
dhe	overall	45,71993	19,78979	4,056784	92,08267	N =	1408
	between		18,88445	9,982197	85,15526	n =	64
	within		6,351061	24,36534	74,01902	T =	22
gdpppg	overall	2,678564	4,426638	-16,2171	33,03049	N =	1408
	between		1,837122	-0,88468	7,043521	n =	64
	within		4,033669	-17,0701	28,84136	T =	22
pop	overall	2,95E+07	4,60E+07	240799	2,77E+08	N =	1408
	between		4,59E+07	321831,8	2,48E+08	n =	64
	within		5881674	-1,45E+07	7,76E+07	T =	22
labour	overall	1,27E+07	2,16E+07	86164	1,37E+08	N =	1408
	between		2,16E+07	133417,3	1,19E+08	n =	64
	within		2879737	-6021723	3,70E+07	T =	22
drinki~r	overall	81,47133	19,13725	22,71351	100	N =	1408
	between		18,68298	36,70273	100	n =	64
	within		4,731855	63,40835	102,1758	T =	22

fertil	overall	3,073735	1,501061	1,078	7,249	N =	1408
	between		1,482174	1,325773	6,875182	n =	64
	within		0,298553	1,792598	4,244144	T =	22
lpop	overall	16,30812	1,415572	12,39172	19,43865	N =	1408
	between		1,420861	12,67031	19,32427	n =	64
	within		0,123009	15,92654	16,68375	T =	22
llabour	overall	15,42552	1,416883	11,36401	18,73859	N =	1408
	between		1,421025	11,77279	18,58776	n =	64
	within		0,135589	15,01674	15,87422	T =	22
_est_fe	overall	1	0	1	1	N =	1408
	between		0	1	1	n =	64
	within		0	1	1	T =	22
_est_re	overall	1	0	1	1	N =	1408
	between		0	1	1	n =	64
	within		0	1	1	T =	22

Note: Data Extracted from World Bank Database by the Author, Calculated in STATA 17.0

In the panel summary above, the key variables show notable variation across countries and over time. The mean crude death rate of 8.89 per 1,000 people signifies the overall mortality status across the panel, with a notable variation from 3.15 to 21.7 per 1,000 people, indicating diversity in health outcomes among nations. Examining GDP per capita growth, which ranges from -16.21% to 33.03% annually, reflects the economic heterogeneity and potential disparities in resource allocation for healthcare. Government health expenditure as a percentage of total health expenditure ranges from 4.06% to 92.08%, showcasing significant variation in how countries prioritise public healthcare funding. Similarly, life expectancy at birth**,** a critical indicator of health and longevity, has a mean of 67.30 years**,** with a standard deviation of 7.95 years and a range from 42.12 to 81.53 years. This suggests that while many nations have relatively high life expectancy, some still experience significantly lower longevity, potentially due to disparities in healthcare access, economic development, and public health interventions.

Moreover, the substantial variability in government health expenditure, ranging from 4.06% to 92.08% of total health spending, underscores the differential prioritisation of public health investments among nations. Countries with higher government health expenditures likely experience better healthcare accessibility and outcomes, potentially contributing to lower mortality rates and increased life expectancy. The GDP per capita growth rate, which spans from -16.21% to 33.03%, reflects the economic volatility in different regions. The standard deviation of 4.43 further illustrates the variation in economic performance among these countries. Economic downturns can lead to diminished healthcare resources and increased mortality rates, whereas sustained growth is associated with improved health infrastructure and living conditions. Population characteristics exhibit significant variation. The mean total population is approximately 29.5 million, but ranges from 240,799 to 277 million, capturing the diverse demographic structures among the observed nations. The labour force also varies widely, from 86,164 to 137 million, reflecting differences in employment opportunities and economic development levels. A larger labour force is often associated with a more dynamic economy, which may support better public health infrastructure and lower mortality rates. Access to clean drinking water, a fundamental determinant of health outcomes, ranges from 22.71% to 100% of the population, with a mean of 81.47%. The considerable disparity highlights the impact of infrastructure and public health initiatives on population health. Countries with limited access to clean drinking water may experience higher rates of waterborne diseases, which can contribute to increased mortality. The fertility rate, with values ranging from 1.07 to 7.25 births per woman, further influences mortality trends. Higher fertility rates are often linked to increased maternal and infant mortality, particularly in regions with inadequate healthcare services. In contrast, lower fertility rates tend to be associated with more developed healthcare systems and better economic conditions. The overall summary statistics highlight the significant economic, healthcare, and demographic differences among the countries under study. These factors collectively shape mortality trends and emphasise the need for targeted public health and economic policies to improve population health outcomes.

RESEARCH METHODOLOGY

This study adopts a quantitative research design using balanced panel data for 64 countries across Africa, Asia, Europe, and Latin America from 2000 to 2021 (n = 64; t = 22). All variables were sourced from the World Bank World Development Indicators, ensuring standardised definitions and measurement units across countries. The long-time span and diverse country coverage enhance external validity, allowing the findings to be relevant across various socio-economic and demographic contexts.

Rationale for Sample Selection

The countries were selected to ensure representation from multiple regions with varying levels of economic development, healthcare infrastructure, and demographic characteristics. This diversity allows for the identification of both common and region-specific determinants of crude death rates, strengthening the policy relevance of the findings.

Research model

The general form of the estimated regression model is:

$drc\_it = \beta_0 + \beta_1\ leb\_it + \beta_2\ dhe\_it + \beta_3\ gdpppg\_it + \beta_4\ pop\_it + \beta_5\ lab\_it + \beta_6\ drinki{\sim}r\_it + \beta_7\ frt\_it + e\_it$

Where: i represents the country and t represents the year (i = 1, 2, 3, ..., 64 and t = 1, 2, 3, ..., 22).

Estimation Technique

Panel regression models were employed:

Pooled Ordinary Least Squares (OLS) – baseline estimation.

Fixed Effects (FE) – controls for time-invariant unobserved heterogeneity across countries.

Random Effects (RE) – captures both within- and between-country variation.

The choice between FE and RE was determined using the **Hausman test**.

The principal variables examined in this research are explained in Table 2 below:

Table 2. Variables

Variable Type	Variable Symbol	Variable Definition
Dependent Variable	drc	Death rate, crude (per 1,000 people)
Independent Variables:	leb	Life expectancy at birth, total (years)
	dhe	Domestic general government health expenditure (%

		of current health expenditure)
	gdpppg	GDP per capita growth (annual %)
	pop	Population, total
	Labour	Labor force, total
Control Variables:	drinki~r	People using at least basic drinking water services (% of population)
	frt	Fertility rate, total (births per woman)

Variables and Theoretical Justification

Dependent Variable:

Crude death rate (drc) – a standard demographic measure of mortality (per 1,000 people).

Independent Variables:

Life expectancy at birth (leb) – reflects overall population health and longevity.

Domestic general government health expenditure (dhe) – measures state investment in healthcare, influencing access and quality.

GDP per capita growth (gdpppg) – captures macroeconomic trends affecting living standards and health outcomes.

Population size (pop) – indicates the scale of healthcare demand.

Labour force (lab) – reflects human resource availability and productivity.

Control Variables:

Access to basic drinking water (drinki~r) – proxy for environmental and public health infrastructure.

Fertility rate (frt) – captures demographic transition effects influencing age structure and healthcare needs.

The variables were selected based on established empirical evidence linking them to mortality trends in public health and health economics literature.

The correlation coefficient is calculated using the standard formula:

$$\frac{\sum(xi - \bar{x})(yi - \bar{y})}{\sqrt{(\sum(xi - \bar{x})^2 \sum(yi - \bar{y})^2)}}$$

Where xi and yi denote individual observations, whereas $\bar{x}$ and represent their respective mean values.

Validity and Confounding Control

Internal validity was enhanced by including control variables known to influence mortality (drinking water access and fertility rates).

External validity is supported by the multi-region coverage and long observation period.

Stationarity Considerations

Given the long-term scope of this study (22 years), it was essential to test for stationarity to avoid spurious regression results caused by non-stationary series. Panel unit root tests were conducted to verify whether the variables are stationary over time.

RESULT AND DISCUSSION

The findings highlight a clear link between improved life expectancy and reduced crude death rates, underscoring the need for targeted policy actions (Thomas, 2020). Governments should boost health budgets to expand access, especially in underserved areas, and strengthen infrastructure to improve care and outcomes (Arize *et al.*, 2024). Nationwide screening, vaccination, and health education can tackle preventable causes of mortality (Anand and Bärnighausen, 2007). These measures, supported by sustainable financing mechanisms, would enhance public health resilience and further reduce crude death rates (Allel *et al.*, 2021).

Table 3. Correlation Matrix

Variable	drc	leb	dhe	Gdpppg	Lpop	fertil	drinking~r	llabour
drc	1.0000							
leb	-0.4382	1.0000						
	(0.0000)							
dhe	0.0105	0.5198						
	(0.6942)	(0.0000)	1.0000					
Gdpppg	0.1272	0.0349	-0.0294	1.0000				
	(0.0000)	(0.1909)	(0.2703)					
Lpop	-0.1221	-0.1145	-0.3566	0.0099	1.0000			
	(0.0000)	(0.0000)	(0.0000)	(0.7092)				
Fertile	0.1029	-0.7977	-0.5220	-0.1744	0.1878	1.0000		
	(0.0001)	(0.0000)	(0.0000)	(0.0000)	(0.0000)			
drinking~r	-0.2060	0.8072	0.5307	0.0411	-0.1759	-0.8440	1.0000	
	(0.0000)	(0.0000)	(0.0000)	(0.1231)	(0.0000)	(0.0000)		
Llabour	-0.0877	-0.0709	-0.3213	0.0383	0.9900	0.1239	-0.1352	1.0000
	(0.0010)	(0.0078)	(0.0000)	(0.1509)	(0.0000)	(0.0000)	(0.0000)	

Note: Data Extracted from World Bank Database by the Author, Calculated in STATA 17.0

Keynote: Numbers in parentheses indicate p-values (statistical significance). The matrix is symmetric, meaning that the values above the diagonal would mirror those below.

The correlation matrix above reveals significant relationships between crude death rate (drc) and key economic, health, and demographic indicators. These findings directly address the research question on the socio-economic and health determinants of mortality and test the hypothesis that improvements in these factors reduce crude death rates. Life expectancy at birth (-0.4382) shows a strong negative correlation with the crude death rate, supporting the hypothesis that higher life expectancy reduces mortality. Regression estimates confirm this effect, with coefficients of -0.453 (OLS), -0.461 (FE), and -0.459 (RE), all statistically significant at $p < 0.01$, indicating that every additional year of life expectancy lowers the crude death rate by approximately 0.453–0.461 per 1,000 people. This aligns with Preston (2012) and Lorentzen et al. (2008), who report that longevity improvements reflect better healthcare, nutrition, and disease prevention, all contributing to reduced mortality. Access to at least basic drinking water services (-0.2060) demonstrates a moderate negative relationship with crude death rate, in line with the hypothesis that improved sanitation lowers mortality. Regression coefficients of 0.0193 (OLS, $p < 0.05$), 0.0579 (FE, $p < 0.01$), and 0.0585 (RE, $p < 0.01$) indicate that increased access to clean water significantly reduces mortality rates. These results support Fewtrell et al. (2005), who find that clean water access reduces waterborne diseases and child mortality, thereby improving population health.

Labour force participation (-0.0877) shows a weak negative correlation with crude death rate, suggesting an indirect link through economic growth, as hypothesised. Regression results reveal a strong and significant association between labour force size and mortality reduction (coefficients: 5.305 OLS, 6.990 FE, and 6.972 RE; all $p < 0.01$). This supports Bloom and Canning (2000), who emphasise the role of a productive workforce in driving economic growth and expanding healthcare access. Population, total (-0.1221) exhibits a weak negative correlation with crude death rate, consistent with the hypothesis that larger populations with younger age structures may experience lower mortality. Regression findings (-5.461 OLS, -7.583 FE, -7.715 RE; all $p < 0.01$) indicate that larger populations are linked to reduced mortality, likely due to economies of scale in healthcare and a larger workforce. This is consistent with Cutler and Deaton (2006), who highlight the advantages of larger populations in sustaining public health systems. Fertility rate (0.1029) shows a weak positive correlation with crude death rate, appearing to contradict the hypothesis. However, regression models present mixed effects: negative in OLS (-0.852, $p < 0.01$) but positive in FE (0.885, $p < 0.01$) and RE (0.748, $p < 0.01$). This pattern aligns with demographic transition theory, where high fertility initially lowers mortality due to a younger population but may later raise mortality as healthcare resources become strained, as noted by Bongaarts (2009).

GDP per capita growth (0.1272) shows a weak positive correlation with crude death rate, initially inconsistent with the hypothesis. However, FE (-0.0179, $p < 0.05$) and RE (-0.0170, $p < 0.05$) estimates indicate that economic growth reduces mortality, supporting the hypothesis and aligning with Pritchett and Summers (1996), who find that economic expansion improves infrastructure, healthcare, and living standards. The positive OLS coefficient (0.0337) may reflect unobserved cross-country differences not accounted for in the pooled analysis. Domestic general government health expenditure (0.0105) has an insignificant correlation with crude death rate, which appears to contradict the hypothesis. However, regression estimates show a positive and statistically significant association (0.0358 OLS, 0.0177 FE, and 0.0188 RE; all $p < 0.01$), suggesting that increased spending may often be reactive to health crises rather than preventive. This supports Gupta et al. (2003), who argue that the effectiveness of health spending depends more on efficient allocation than on total expenditure levels.

The R-squared values for the models indicate their explanatory power:

OLS: 0.473 (47.3%)

FE: 0.740 (74.0%)

Subgroup 1: 0.929 (528 observations)

Subgroup 2: 0.332 (880 observations)

The fixed effects model provides a better fit, explaining a larger proportion of the variation in crude death rates by accounting for unobserved heterogeneity among countries. The subgroup analysis highlights variation in model performance across different sample groups, with one subset (528 observations) achieving a much higher explanatory power ($R^2 = 0.929$) than the other (880 observations, $R^2 = 0.332$).

The Breusch-Pagan / Cook-Weisberg test for heteroskedasticity confirms that the variance of errors remains constant, with a test statistic of 3.25 ($p = 0.0714$). Since the p-value exceeds 0.05, the null hypothesis of homoscedasticity is not rejected, indicating no strong evidence of heteroskedasticity in the model.

Table 4. Regression Analysis

Variables	(1) all	(2) fe	(3) re
Leb	-0.453***	-0.461***	-0.459***
	(0.0162)	(0.0120)	(0.0113)
Dhe	0.0358***	0.0177***	0.0188***
	(0.00447)	(0.00313)	(0.00311)
Gdpppg	0.0337**	-0.0179**	-0.0170**
	(0.0164)	(0.00496)	(0.00502)
Lpop	-5.461***	-7.583***	-7.715***
	(0.401)	(0.488)	(0.454)
Fertile	-0.852***	0.885***	0.748***
	(0.103)	(0.103)	(0.0890)
Drinkingwater	0.0193**	0.0579***	0.0585***
	(0.00761)	(0.00674)	(0.00665)
Llabour	5.305***	6.990***	6.972***
	(0.395)	(0.456)	(0.442)
Constant	45.94***	47.56***	50.20***
	(1.480)	(4.509)	(2.710)
Observations	1,408	1,408	1,408
R-squared	0.473	0.740	-
Number of c_id	-	64	64

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Data Extracted from World Bank Database by Author, Calculated in STATA 17.0

The Hausman test was performed to determine whether the fixed effects (FE) model or the random effects (RE) model provides a better fit for the panel data analysis. This test assesses whether the differences in coefficients between these two models are systematic, guiding the appropriate choice of model specification.

Table 5. Hausman Test for Panel Data

Variable	FE Coefficients (b)	RE Coefficients (B)	Difference (b-B)	sqrt(diag(V_b-V_B)) (S.E.)
Leb	-0.4608157	-0.4592086	-0.0016071	0.0039556
Dhe	0.017692	0.0187671	-0.0010751	0.0003229
Gdppppg	-0.0178613	-0.0170486	-0.0008127	
Lpop	-7.583348	-7.715024	0.1316762	0.1773775
Fertile	0.8852581	0.7484052	0.1368529	0.0516141
drinkingwar~r	0.0578656	0.0585112	-0.0006456	0.0010873
Llabour	6.990056	6.971892	0.018164	0.1125841

Note: Data Extracted from World Bank Database by the Author, Calculated in STATA 17.0

b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg
Test Hypothesis (Ho): The difference in coefficients is not systematic.
Chi2(7) = (b - B)' [(V_b - V_B) ^ (-1)] (b - B)
= 113.90
Prob>chi2 = 0.0000
Note: (V_b-V_B is not positive definite)

From Table 5, the test statistic $Chi^2(7) = 113.90$ is highly significant ($p = 0.0000$), indicating strong evidence against the null hypothesis that the difference in coefficients is random. This means that the assumptions necessary for the random effects model are violated, and the fixed effects model is statistically more appropriate for this dataset. The rejection of the null hypothesis suggests that individual-specific effects significantly influence the dependent variable (death rate, crude per 1,000 people). Therefore, adopting a fixed effects model allows the analysis to control for unobserved heterogeneity across countries, ensuring that country-specific characteristics do not bias the estimated relationships between the independent variables and the death rate. By using the fixed effects approach, the model captures within-country variations over time, making it more reliable in explaining the determinants of mortality trends. This selection improves the model’s accuracy by eliminating bias that could arise from unobservable factors that remain constant within a country but vary across countries.

Robustness Test

Unit-root test

Table 6 below presents the diagnostic test results of the unit root to check for stationarity in the variables. Before performing any significant regression analysis, it is essential to evaluate the existence of unit roots in these variables. If data are non-stationary, it could lead to inconsistency, spurious results and poor forecasts. Consequently, the variables in the study need to demonstrate stationarity. Examining non-stationary variables may result in misleading regression outcomes when ostensibly correlated variables yield ambiguous conclusions. To address this issue, it is crucial to utilise suitable tests for stationarity on the relevant variables. Additionally, transforming certain variables into natural logarithms (ln) enhances the statistical features of the data and simplifies the interpretation of correlations between variables in empirical analysis. This investigation commenced with unit root testing to assess the stationarity of the variables, employing the Augmented Dickey-Fuller (ADF) and co-integration tests. The main aim of stationarity testing is to mitigate the possibility of spurious regression and poor forecasting. The unit root test results, displayed in Table 6, reveal the ADF test results of each variable under none. The results indicate that all variables demonstrate integration of order I(0) or I(1). In the model, DRC LEB DGGHE GDPPPG PT and FRT exhibit stationarity at the level, whereas LFT and PULBDWS attain stationarity following first differencing.

Table 6 Augmented Dickey-Fuller (ADF)

Variables	Test with None I(0) level	Test with None at I(1) level	Order of integration
DRC	0.0000	0.0000	I(0)
LEB	0.0000	0.0000	I(0)
DGGHE	0.0219	0.0000	I(0)
GDPPPG	0.0000	0.0000	I(0)
PT	0.0000	0.0000	I(0)
LFT	1.0000	0.0138	I(1)

FRT	0.0000	0.0000	I(0)
PULBDWS	0.2940	0.00326	I(1)

Source: Author's computation using Stata 17.0

Table 7. Average of Variables for each selected country in Africa, Asia, Europe and Latin America (2000–2021)

Countries	Drc	Leb	Dhe	Gdpppg	Pop	Labour	drinki~r	frt
Algeria	4.78	73.7	69.67	1.17	37069951.36	11159694.86	92.35	2.8
Angola	11.73	56.02	52.74	1.09	24370061.59	10219178.27	50.43	6.07
Bostwana	9.78	58.74	62.47	1.59	2041584.64	817967.73	83.49	3.02
Cameroon	10.72	57.15	14.64	1.09	20319933.68	8543015.86	63.15	5.08
Chad	15.11	50.12	23.76	2.12	12762026.0	4154637.68	45.04	6.88
Congo, Dem.Rep.	11.69	56.36	9.98	1.38	71748785.27	26384763.18	36.7	6.51
Congo, Rep.	8.65	60.48	38.1	-0.56	4488920.55	1784320.64	66.15	4.61
Cote d'Ivoire	11.25	55.04	18.29	0.97	23090783.0	8593800.82	71.74	5.1
Egypt, Arab Rep.	6.0	69.74	32.5	2.24	91250327.68	27523814.55	98.55	3.21
Eswatini	14.23	49.85	46.88	2.18	1116702.73	353282.41	62.62	3.37
Gabon	8.3	63.88	50.79	-0.88	1784033.91	548612.64	83.54	4.03
Ghana	8.5	61.49	41.37	3.26	25910903.64	11020661.86	76.18	4.2
Mauritius	7.62	73.22	46.05	2.87	1243174.0	576846.09	99.67	1.62
Morocco	5.99	70.91	36.07	2.51	32695814.95	11187226.05	75.53	2.55
Mozambique	11.55	55.13	29.89	3.29	23941834.91	10646827.23	40.78	5.35
Namibia	10.89	56.65	45.9	1.1	2210439.32	792221.05	80.99	3.59
Nigeria	14.79	50.66	17.59	2.51	170430571.82	78173387.77	60.95	5.83
Senegal	7.58	63.91	32.09	1.45	13153848.64	3706104.41	72.4	4.97
South Africa	10.84	59.88	49.36	1.11	53380785.64	21820944.59	89.66	2.43
Sudan	8.01	62.22	29.18	-0.21	36543096.64	9383827.32	52.51	4.95
Tanzania	8.94	60.44	31.06	3.04	46688501.41	22092260.0	44.12	5.27
Tunisia	5.54	75.07	54.77	1.63	10881947.41	3839850.91	92.59	2.1
Uganda	9.25	57.0	19.53	2.74	33611075.5	13203095.09	41.36	5.87

Zambia	10.09	55.83	36.79	2.17	14397922.77	4647482.73	58.09	5.2
Armenia	9.59	72.87	19.07	6.24	3067195.45	1491349.77	98.08	1.55
Azerbaijan	6.04	69.22	33.31	6.87	9089631.0	4479588.68	86.24	1.88
Cambodia	6.63	66.86	20.51	5.92	14648293.41	7817893.32	65.85	2.89
Georgia	12.36	71.9	25.07	5.87	3819220.45	1993617.41	94.66	1.87
Indonesia	7.63	68.45	37.17	3.62	247567892.3	118811516	84.71	2.39
Iran, Islamic Rep.	5.06	73.24	41.25	1.7	77754644.91	25095299.41	96.02	1.87
Jordan	3.52	73.98	51.84	0.72	7888218.82	1965965.59	98.78	3.5
Kazakhstan	8.93	68.94	63.99	4.85	17216167.91	8990474.68	93.47	2.54
Kyrgyz Republic	6.41	69.63	45.92	2.35	5673764.73	2632257.45	85.54	2.89
Malaysia	4.9	74.58	52.44	2.51	28806050.27	13201384.86	97.01	2.2
Myanmar	9.38	63.31	13.69	7.04	49384209.36	22877982.77	64.46	2.41
Papua New Guinea	7.04	63.40	67.09	0.62	7754281.41	2644248.68	38.85	3.86
Philippines	5.71	70.66	35.12	3.03	97142313.41	38297783.86	90.15	3.22
Solomon Islands	5.53	68.82	67.23	-0.20	572407.55	287433.36	73.12	4.39
Tajikistan	5.85	67.82	23.36	5.33	7907296.32	2110852.64	70.12	3.46
Uzbekistan	5.03	69.05	41.18	4.77	28910139.5	11695094.77	92.05	2.51
Viet Nam	6.21	73.56	41.24	5.01	87837998.68	49315867.59	89.13	1.96
Belarus	13.91	71.16	69.74	4.58	9562614.86	5007698.77	98.38	1.46
Bulgaria	15.26	73.4	57.08	4.21	7408371.91	3384606.18	99.43	1.47
Czechia	10.6	77.28	85.16	2.47	10425924.09	5247578.95	99.85	1.47
Estonia	12.38	74.97	74.95	4.1	1340166.0	685563.77	98.98	1.56
Hungary	13.34	74.2	68.34	2.79	9962378.64	4578113.09	99.97	1.39
Latvia	14.59	72.96	58.22	4.83	2102077.32	1053529.0	98.3	1.48
Lithuania	13.58	73.27	67.42	5.31	3099398.23	1523599.68	94.38	1.47
Moldova	13.21	68.91	50.91	4.91	2828598.86	1444537.14	87.08	1.67
Romania	12.93	73.38	78.93	4.54	20468996.86	8724348.91	100.0	1.54
Slovak Republic	10.0	75.33	77.81	3.51	5404842.32	2690501.18	98.85	1.38

Slovenia	9.56	79.15	71.77	2.16	2041043.86	1016948.18	99.5	1.46
Ukraine	15.49	69.77	51.85	3.01	46639147.41	22258953.18	95.32	1.33
Belize	5.1	71.51	61.47	0.66	321831.77	133417.32	93.92	2.73
Bolivia	8.16	65.53	60.88	2.06	10272783.73	4730676.27	87.54	3.22
Brazil	6.45	72.87	43.04	1.34	193648123.95	95475029.68	96.59	1.86
Colombia	5.31	74.43	72.09	2.29	44974962.09	21744609.5	94.84	2.05
Costa Rica	4.71	78.67	69.38	2.56	4555764.32	2099523.41	97.85	1.92
Dominican Republic	6.01	71.83	47.78	3.47	9879046.91	4065202.64	94.04	2.52
Ecuador	5.05	75.14	47.0	1.83	15197635.73	6838997.59	89.65	2.54
El Salvador	6.89	71.26	52.55	1.73	6095516.27	2503734.27	89.55	2.27
Guatemala	5.43	70.59	34.78	1.44	14666788.91	5509285.0	90.42	3.44
Haiti	9.27	60.94	14.37	-0.18	9863197.68	4107906.64	62.26	3.47
Honduras	4.54	71.0	40.5	1.66	8445246.45	3311129.05	90.66	3.07

Note: Data Extracted from the World Bank Database, Author's Calculations (ΣX / N).

The results reveal clear and significant differences across regions and countries. For instance, several African countries such as Chad (CDR 15.11) and Nigeria (CDR 14.79) continue to record high mortality rates despite notable government health expenditure shares (Dhe 23.76% and 17.59%, respectively). In contrast, many European countries, including Czechia (Dhe 85.16) and Slovenia (Leb 79.15, CDR 9.56), achieve considerably lower mortality rates alongside higher life expectancy and robust health spending. These findings indicate that the impact of health expenditure and economic growth on mortality is not uniform across contexts. In countries with strong governance, effective infrastructure, and political stability, increased spending translates into substantial mortality reductions. Conversely, in settings affected by conflict, weak institutions, or systemic inefficiencies, higher budgets alone are insufficient to improve health outcomes. This underscores the need for tailored, context-specific policies that combine financial investment with governance reforms, infrastructure strengthening, and targeted service delivery improvements.

CONCLUSION

Sustainable reductions in crude death rates require resilient health financing, robust governance, and reduced reliance on unstable external aid. Priorities include expanding and retaining the healthcare workforce through decentralised training, equitable staff distribution, and targeted retention incentives. WASH strategies must go beyond basic access to improve infrastructure quality, hygiene education, and integration with primary care and disease surveillance. Securing a minimum national health expenditure of 5% of GDP, with transparent allocation and performance-based monitoring, is critical, alongside expanding primary care, maternal–child health coverage, and implementing conflict-sensitive delivery models. Increasing skilled health personnel to at least 4.45 per 1,000 population, deploying mobile health and telemedicine services, and accelerating WASH upgrades in high-mortality regions can significantly reduce preventable deaths. Regionally, pooled procurement of essential medicines can lower costs, while harmonised workforce training standards and real-time digital mortality monitoring will improve cross-border responsiveness. Integrating digital health solutions such as interoperable medical records and workforce data systems will strengthen service targeting, monitoring, and long-term planning. Sustained mortality reduction will depend on combining secure financing, institutional reforms, targeted interventions in health and WASH, digital innovation, and robust evidence generation. When adapted to local contexts and guided by reliable data, these strategies can transform investments into lasting public health gains.

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