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Maternal and child health outcomes in BRICS countries: Analysis of MDGs and SDGs periods

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Abstract

This study examines maternal-child health outcomes, specifically infant, under-5, and maternal mortality rates in BRICS countries (Brazil, Russia, India, China, and South Africa) between 2000 and 2022, segmented into Millennium Development Goals (MDGs) and Sustainable Development Goals (SDGs) periods. Using Panel Corrected Standard Errors (PCSE) and Panel Quantile Regression estimators, the analysis identifies significant improvements in child mortality outcomes from the MDGs to the SDGs era, reflecting advancements in healthcare infrastructure and enhanced health policies. However, quantile regression results highlight persistent inequalities, with disproportionately poorer outcomes in nations with higher maternal mortality rates. The findings underline the continuing health disparities across BRICS nations, emphasising the importance of inclusive and equitable healthcare systems. Policymakers are encouraged to design targeted health interventions that address socioeconomic determinants, such as education, healthcare expenditure, immunisation coverage, and urbanisation, to improve maternal-child health outcomes. Strengthening healthcare delivery, particularly among vulnerable populations such as low-income families and children, is essential for reducing mortality rates and achieving broader health objectives within the SDGs framework. Ultimately, the study advocates integrated public health strategies that support sustainable progress towards equitable maternal and child health across the BRICS region. *(Afr J Reprod Health 2025; 29 [5]: 88-102).*

Keywords: Maternal-Child Health, Infant Mortality, Under-5 Mortality, Maternal Mortality, MDGs, SDGs, BRICS

Résumé

Cette étude examine les résultats en matière de santé maternelle et infantile, en particulier les taux de mortalité infantile, de moins de 5 ans et maternelle dans les pays BRICS (Brésil, Russie, Inde, Chine et Afrique du Sud) entre 2000 et 2022, segmentés en périodes d'Objectifs du Millénaire pour le développement (OMD) et d'Objectifs de développement durable (ODD). En utilisant des estimateurs d'erreurs types corrigées par panel (PCSE) et de régression quantile par panel, l'analyse identifie des améliorations significatives des résultats en matière de mortalité infantile entre les OMD et l'ère des ODD, reflétant les progrès des infrastructures de santé et l'amélioration des politiques de santé. Cependant, les résultats de la régression quantile mettent en évidence des inégalités persistantes, avec des résultats disproportionnellement plus faibles dans les pays où les taux de mortalité maternelle sont plus élevés. Les résultats soulignent les disparités persistantes en matière de santé entre les pays BRICS, soulignant l'importance de systèmes de santé inclusifs et équitables. Les décideurs politiques sont encouragés à concevoir des interventions de santé ciblées qui s'attaquent aux déterminants socio-économiques, tels que l'éducation, les dépenses de santé, la couverture vaccinale et l'urbanisation, afin d'améliorer les résultats en matière de santé maternelle et infantile. Le renforcement de l'offre de soins de santé, en particulier auprès des populations vulnérables telles que les familles et les enfants à faibles revenus, est essentiel pour réduire les taux de mortalité et atteindre les objectifs de santé plus larges dans le cadre des ODD. En définitive, l'étude préconise des stratégies intégrées de santé publique favorisant des progrès durables vers une santé maternelle et infantile équitable dans la région BRICS. *(Afr J Reprod Health 2024; 29 [5]: 88-102).*

Mots-clés: : Santé maternelle et infantile, Mortalité infantile, Mortalité des moins de 5 ans, Mortalité maternelle, OMD, ODD, BRICS

Introduction

Maternal and child health outcomes are vital indicators of a nation's overall well-being and the effectiveness of its healthcare system. In developing economies, particularly among the BRICS nations (Brazil, Russia, India, China, and South Africa), maternal and child health status is influenced significantly by socioeconomic factors, healthcare infrastructure, public health

expenditures, and the effectiveness of implemented health policies. The establishment of the Millennium Development Goals (MDGs) in 2000, followed by their transition to the Sustainable Development Goals (SDGs) in 2015, intensified global initiatives aimed at reducing infant, under-5, and maternal mortality rates through enhanced health interventions and policies.

Previous research highlights public health expenditure as a critical factor in reducing child mortality. For example, Azuh *et al.*[1] noted that increased public health spending contributed significantly to improvements in child survival in Nigeria, underscoring the importance of policy-driven healthcare interventions. Similarly, studies by Feng *et al*[2]. and Sui *et al*[3]. demonstrated the influential role of household wealth management and antenatal care utilisation among women of reproductive age, reinforcing the socioeconomic dimensions underlying maternal health. These factors align with the broader goals of the SDGs, particularly SDG 3, aimed at ensuring healthy lives and promoting well-being for all age groups through inclusive and equitable healthcare systems.

Health financing and its political economy have also emerged as critical determinants shaping maternal and child health across different regions. Jakovljevic *et al*.[4] examined health financing dynamics in the Global South, highlighting persistent disparities in healthcare spending and accessibility that directly affect maternal and child health outcomes. Health insurance, as explored in studies by Nasir *et al*[5]. and Zhang *et al*[6]. was found to significantly influence health facility utilisation and consequently maternal and child survival, especially in resource-limited settings.

Additionally, factors such as women's empowerment have been increasingly recognised as influential determinants of maternal health, affecting service demand and utilisation[7,8]. Despite substantial progress made during the MDGs era, challenges remain in maternal and child health outcomes among BRICS nations due to disparities in healthcare delivery, socioeconomic inequalities, and uneven distribution of resources. Addressing these persistent inequalities requires deeper investigation into the socioeconomic determinants and healthcare policy effectiveness, particularly across different mortality levels. By providing comparative evidence across the MDGs and SDGs periods, this study seeks to fill existing research gaps, offering actionable insights for policymakers, healthcare providers, and advocates aiming to foster equitable health outcomes among maternal and child populations within BRICS countries.

Methods

Theoretical underpinnings and empirical model

This study is underpinned by Grossman's health determinant model, which views health as a durable form of capital producing healthy time.

According to this model, individuals begin life endowed with an initial stock of health, which gradually diminishes with age, especially after reaching a certain stage in their lifecycle. However, this health stock can be maintained or enhanced through targeted investments such as healthcare spending, education, immunisation, and improved living conditions.

Conversely, exposure to social, economic, or environmental risks can depreciate human health, leading to poorer health outcomes. Drawing on the framework outlined by Alhassan and Abdu[9], Zhou et al.[10], and Alimi and Ajide[11], this study specifically explores how socioeconomic determinants influence maternal and child health outcomes, as represented in the following empirical specification (Equation 1):

$$HEALTHOC_{it} = \beta_0 + \gamma_n CON_{it} + \mu_{it} \quad (1)$$

Where *t* denotes the time (year), *i* represents cross-sectional unit (country) and μ_{it} stands for the random error term in the equation. The dependent variable, $HEALTHOC_{it}$ signifies a vector health outcome (infant, maternal and under-5 mortality rate). Previous studies such as Adeleye *et al*.[12]; Hao *et al*.[13]; and Guo *et al*.[14] have used these variables to represent health outcomes of countries.
CON_{it} is a vector of control variables (domestic private health expenditure, domestic government health expenditure, urbanisation DPT immunisation and mean years of schooling).

Many country-level factors were included as control variables to account for their potential influence on the household health outcomes. For example, health expenditure is an important investment that can strongly enhance child and maternal health. As implied by Grossman, health can improve through investments or reduce through exposure to socioeconomic and environmental risks. It is also established in literature that higher education, immunisation coverage and urbanisation are associated better health outcomes through health awareness, disease prevention and access to quality health services (Guo *et al*.,[14]; Popescu *et al*.,[15]; Yacour, Soumbara & El Ghini[16]).

Data and estimation techniques

This study examines a panel of BRICS countries (Brazil, Russia, India, China, and South Africa) using data from the Global Footprint Network (GFN), the Global Health Expenditure (GHE) Database, the Global Health Observatory (GHO), World Development Indicators (WDI). And the dataset is for the period 2000–2022. The selection of this timeframe is guided by two significant global development frameworks: The Millennium Development Goals (MDGs) (2000–2015) and the Sustainable Development Goals (SDGs) (2015–2030). Both frameworks prioritize improving child and maternal health as key objectives. Table 1 presents the definitions of the variables and how they are measured.

This study employs both the panel corrected standard error (PCSE) and panel quantile regression estimators to analyse health outcomes (infant, maternal and under-5 mortality rates) in 5 BRICS countries over the period 2000-2022. The PCSE estimator involves organizing residuals from fitted models based on clusters to estimate error variances accurately. This process calculates a block diagonal covariance matrix that captures contemporaneous correlations among cross-sectional units. It is clear that PCSE is effective in correcting for heteroscedasticity and contemporaneous correlation in panel data with fixed effects. It is even more efficient in cases where the number of cross-sectional units (N) is less than the number of time periods *(T),* allowing researchers to analyse long-run relationships effectively within static panel data structures.

Panel quantile regression estimator is a robust method that estimates the conditional quantiles of the dependent variable as influenced by certain independent variables, rather than just the conditional mean. This is particularly useful when the effect of explanatory variables varies across different quantiles of the dependent variable distribution. This approach enables researchers to incorporate the heterogeneous effects of explanatory variables on various points of the outcome distribution, instead focusing only on mean effects. Machado and Silva[17] expound that this estimator offers a more complete understanding of the data, especially in complex models with non-linear effects.

For robustness check, we employ feasible generalised least squares (FGLS) and linear dummy ridge regression estimators. FGLS is an extension of Ordinary Least Squares (OLS) regression that accounts for heteroscedasticity and autocorrelation in the error terms. In panel data models, where observations across different units (e.g., countries) may not be independent, GLS is used to improve efficiency by adjusting for the covariance structure of the errors[18]. Linear Dummy Ridge Regression is a variation of ridge regression that incorporates "dummy" variables to control for fixed effects in panel data models (e.g., country-specific effects). Ridge regression is a regularisation technique that penalises the size of the coefficients to avoid overfitting and to address multicollinearity (when independent variables are highly correlated with each other[19]).

Ethical consideration

This study involves no human or animal subjects, ensuring compliance with ethical research standards. It relies solely on publicly accessible data, maintaining data integrity, privacy, and transparency. The analysis prioritises fairness, promotes sustainability, and aligns with global development goals to inform equitable and responsible policy decisions.

Table 1: Variables and measurement

Variables	Measurements	
Under-5 Mortality Rate	The probability of a child dying between birth and their fifth birthday, expressed per 1,000 live births. It is based on a life table, not as a direct ratio of deaths to the population at risk during a specified period.	GHO
Infant Mortality Rate	Death of a child before reaching one year of age. The infant mortality rate is the probability of such deaths occurring within a specific year or period, expressed per 1,000 live births.	GHO
Maternal Mortality Rate	The number of maternal deaths per 100,000 live births during a specified time. It is defined as the death of a woman during pregnancy, childbirth, or within 42 days of termination of pregnancy, irrespective of the pregnancy's duration or location, but not from accidental or incidental causes.	GHO
Domestic private health expenditure	The share of health expenditure financed by non-governmental entities (households, private health insurance, non-profit institutions, corporations) as a proportion of the total domestic health expenditure.	GHE
Domestic government health expenditure	The total government expenditure on health divided by the total population, expressed in current US.	GHE
Urbanisation	The percentage of a country's total population living in urban areas.	WDI
DPT immunisation	The percentage of children ages 12-23 months who have received three doses of the combined diphtheria, pertussis (whooping cough), and tetanus (DPT) vaccine.	WDI
Mean years of schooling	The average number of years of education received by people aged 25 and older, measured in years. It is used as a key component of the Human Development Index (HDI) to assess a country's human capital and overall development. Mean years of schooling is calculated based on educational attainment data from censuses and surveys.	UNDP

Results

Descriptive statistics and correlation analysis

In Table 2, the full sample average for under-5 (31.79) and infant mortality (24.63) indicates wide disparity. Russia has the lowest rates for both under-5 (10.69) and infant mortality (8.58), attributed to robust healthcare infrastructure. Table2 also reveals that India and South Africa have the highest under-5 and infant mortality rates, reflecting significant challenges in healthcare access and quality. In terms of maternal Mortality, the averages of India (200.22) and South Africa (171.48) are alarming as they exhibit high maternal mortality compared to the full sample average of 99.12. Average maternal mortality rates for Russia (19.33) and China (34.79) are the least, suggesting better maternal care services.

Table 2 also depicts that India spends the most privately (72.87% of the domestic general health expenditure), which signifies reliance on out-of-pocket health spending, likely linked to poorer health outcomes. Russia (38.13) and South Africa (46) have lower private spending, reflecting stronger government-funded systems.

In terms of per-capita government health expenditure, Russia leads ($328.65), followed by Brazil ($293.97) and South Africa ($245.99), correlating with relatively their better child and maternal health outcomes. India spends the least ($12.52), highlighting systemic underinvestment in public healthcare. In the lower part of Table 2, pairwise correlation results suggest strong and significant correlation between variables. Table 3 present the results from Panel corrected standard error estimator. We focus our analysis on variables central to the stud.

Table 2: Summary statistics and pair-wise correlation results

		Under-5	Infant	Maternal	Priv. Hlth	Gov. Hlt	DPT	Urban	Schooling
Full	Observation	115	115	115	115	115	115	115	115
	Mean	31.79	24.63	99.12	53.531	206.116	88.078	60.556	8.273
	Minimum	4.8	3.8	7	28.06	4	58	27.667	4.144
	Maximum	91.7	66.4	384	79.78	666	99	87.555	12.774
Brazil	Observation	23	23	23	23	23	23	23	23
	Mean	20.391	18.130	69.783	56.679	293.974	92.087	84.549	6.952
	Minimum	14	12.5	58	54.327	104.129	68	81.192	5.273
	Maximum	34.6	30.3	98	59.113	457.489	99	87.555	8.129
China	Observation	23	23	23	23	23	23	23	23
	Mean	17.143	13.635	34.787	53.975	149.435	95.043	50.185	6.837
	Minimum	6.6	4.8	15.7	39.810	9.448	85	35.877	5.929
	Maximum	36.7	29.9	65	77.999	362.536	99	63.56	7.600
India	Observation	23	23	23	23	23	23	23	23
	Mean	56.909	45	200.217	72.867	12.522	76.391	31.449	5.440
	Minimum	29.1	25.5	103	63.04	4	58	27.667	4.144
	Maximum	91.7	66.4	384	79.78	25	93	35.872	6.655
Russia	Observation	23	23	23	23	23	23	23	23
	Mean	10.691	8.583	19.330	38.134	328.652	97.087	73.911	12.448
	Minimum	4.8	3.8	7	28.06	56	96	73.341	12.057
	Maximum	19.4	15.5	38	43.05	666	98	75.126	12.774
South Africa	Observation	23	23	23	23	23	23	23	23
	Mean	53.835	37.783	171.478	46	245.997	79.783	62.686	9.689
	Minimum	34.5	27.7	118	36.880	62.448	69	56.891	7.257
	Maximum	79	49.9	232	65.627	360.011	86	68.335	11.373
Pearson Correlation Analysis									
	Priv. Health Exp.	-0.74***							
	Govt. Health Exp.	0.538***	-0.85***						
	DPT	0.208***	-0.56***	0.546***					

immunisation					
Mean Years of Sch.	0.942***	-0.84***	0.669***	0.360***	
Urbanization	0.449***	-0.64***	0.866***	0.492***	0.548***

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. *ln* represents natural logarithm

Table 3: Panel corrected standard error estimator

	Full Sample			**MDGs Period (2000-2015)**			**SDGs Period (2000-2015)**		
VARIABLES	**lnUnder-5**	**lnInfant**	**lnMaternal**	**lnUnder-5**	**lnInfant**	**lnMaternal**	**lnUnder-5**	**lnInfant**	**lnMaternal**
Priv. Health Exp.	-0.00525	-0.00444	-0.0159	-0.00514	-0.00312	-0.00329	-0.00415	-0.00717	-0.0330
	(0.00393)	(0.00348)	(0.0109)	(0.00587)	(0.00491)	(0.00983)	(0.0182)	(0.0187)	(0.0363)
Govt. Health Exp. (in ln)	-0.226***	-0.217***	-0.182	-0.175***	-0.170***	-0.0915	-0.441	-0.565**	-0.569
	(0.0497)	(0.0461)	(0.150)	(0.0546)	(0.0475)	(0.105)	(0.275)	(0.283)	(0.531)
DPT immunization	-0.0039**	-0.00313*	-0.0132***	-0.0102**	-0.00702*	-0.0230***	-0.020***	-0.021***	-0.0616***
	(0.00188)	(0.00165)	(0.00398)	(0.00486)	(0.00392)	(0.00729)	(0.00679)	(0.00710)	(0.0154)
Mean Years of Sch.	-0.127***	-0.117***	-0.270***	-0.175***	-0.157***	-0.189***	0.00132	-0.0141	-0.357
	(0.0355)	(0.0310)	(0.0759)	(0.0442)	(0.0364)	(0.0725)	(0.177)	(0.181)	(0.309)
Urbanization	-0.00647*	-0.00634*	-0.00298	-0.00284	-0.00197	0.00151	0.00204	0.00912	0.0125
	(0.00377)	(0.00381)	(0.00865)	(0.00343)	(0.00330)	(0.00700)	(0.0144)	(0.0149)	(0.0270)
Constant	6.074***	5.645***	9.019***	6.512***	5.755***	8.160***	6.963***	7.359***	15.73***
	(0.461)	(0.410)	(1.175)	(0.658)	(0.552)	(1.086)	(2.417)	(2.475)	(4.507)
				0.223**	0.166**	0.0877			
Observations	115	115	115	80	80	80	40	40	40
R-squared	0.921	0.917	0.791	0.947	0.950	0.902	0.851	0.833	0.695
Wald chi2(6)	174.27***	155.49***	56.39***	240.94***	189.16***	83.36***	109.52***	121.89***	62.55***
Number of countryid	5	5	5	5	5	5	5	5	5

Table 4: Panel quantile regression results

VARIABLES	Under-5 Mortality (in ln)			Infant Mortality (in ln)			Maternal Mortality (in ln)		
	Q=0.25	***Q=0.50***	***Q=0.75***	***Q=0.25***	***Q=0.50***	***Q=0.75***	***Q=0.25***	***Q=0.50***	***Q=0.75***
Priv. Health Exp.	-0.00901	-0.010**	-0.011**	-0.00999	-0.0116*	-0.0124	-0.0363***	-0.035***	-0.0344***
	(0.00740)	(0.00438)	(0.00546)	(0.00843)	(0.00672)	(0.00926)	(0.00760)	(0.00513)	(0.00609)
Govt. Health Exp. (in ln)	-0.512***	-0.41***	-0.36***	-0.54***	-0.439***	-0.38***	-0.560***	-0.521***	-0.493***
	(0.108)	(0.0671)	(0.0784)	(0.125)	(0.103)	(0.138)	(0.122)	(0.0822)	(0.0973)
DPT immunization	-0.000587	0.000930	0.00163	0.00248	0.00315	0.00348	-0.0183***	-0.015***	-0.0134***
	(0.00250)	(0.00150)	(0.00185)	(0.00289)	(0.00230)	(0.00317)	(0.00287)	(0.00195)	(0.00226)
Mean Years of Sch.	-0.123***	-0.14***	-0.15***	-0.0603*	-0.079***	-0.089**	-0.0398	-0.065***	-0.0837***
	(0.0361)	(0.0219)	(0.0265)	(0.0341)	(0.0276)	(0.0377)	(0.0342)	(0.0232)	(0.0270)
Urbanization	0.00101	-0.0136	-0.020**	-0.00572	-0.0200	-0.0270	-0.0200	-0.0224**	-0.0241**
	(0.0139)	(0.00877)	(0.0102)	(0.0168)	(0.0139)	(0.0186)	(0.0152)	(0.0103)	(0.0122)
Observations	115	115	115	115	115	115	115	115	115

Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1. *ln* represents natural logarithm

Table 5: Feasible generalized least squares (FGLS) results

VARIABLES	Full Sample lnUnder-5	lnInfant	lnMaternal	MDGs Period (2000-2015) lnUnder-5	lnInfant	lnMaternal	SDGs Period (2015-2022) lnUnder-5	lnInfant	lnMaternal
	(0.0463)	(0.0406)	(0.123)	(0.0595)	(0.0539)	(0.129)	(0.193)	(0.196)	(0.475)
Priv. Health Exp.	-0.00284	-0.00313	-0.00621	-0.00292	-0.00198	-0.00177	-0.00928	-0.0137	-0.0241
	(0.00262)	(0.00226)	(0.00648)	(0.00315)	(0.00282)	(0.00710)	(0.0101)	(0.00997)	(0.0271)
Govt. Health Exp. (in ln)	-0.186***	-0.157***	-0.234**	-0.156***	-0.130***	-0.0791	-0.727***	-0.864***	-0.950**
	(0.0372)	(0.0343)	(0.0959)	(0.0344)	(0.0323)	(0.0888)	(0.179)	(0.184)	(0.428)
DPT immunization	-0.00225*	-0.00129	-0.0073**	-0.00277	-0.000938	-0.014***	-0.00734*	-0.0080**	-0.037***
	(0.00125)	(0.00115)	(0.00313)	(0.00224)	(0.00204)	(0.00518)	(0.00390)	(0.00386)	(0.0132)
Years of Sch.	-0.176***	-0.098***	-0.218***	-	-0.212***	-0.215***	-0.154	-0.173	-0.268

				0.239***					
	(0.0261)	(0.0242)	(0.0563)	(0.0253)	(0.0235)	(0.0603)	(0.118)	(0.119)	(0.281)
Urbanisation	-0.00635*	-0.020***	-0.00127	-0.0046**	-0.0048**	-0.00437	0.0227**	0.0302***	0.0356
	(0.00367)	(0.00483)	(0.00624)	(0.00226)	(0.00230)	(0.00621)	(0.00995)	(0.0103)	(0.0227)
Constant	5.912***	5.765***	7.747***	6.121***	5.529***	7.905***	7.114***	7.589***	12.75***
	(0.321)	(0.315)	(0.687)	(0.334)	(0.303)	(0.755)	(1.397)	(1.392)	(3.497)
Observations	115	115	115	80	80	80	40	40	40
Wald chi2(6)	221.38***	183.04***	96.57***	526.02***	386.00***	128.84***	154.35***	172.00***	86.16***
Countries	5	5	5	5	5	5	5	5	5

Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1. *ln* represents natural logarithm

Table 6: Linear dummy ridge regression results

	(1)	(2)	(3)
VARIABLES	**lnUnder-5**	**lnInfant**	**lnMaternal**
Priv. Health Exp.	0.003	0.006	-0.010
	(0.010)	(0.010)	(0.013)
Govt. Health Exp. (in ln)	0.104	0.032	-0.0003
	(0.112)	(0.113)	(0.154)
DPT immunization	-0.035***	-0.031***	-0.057***
	(0.005)	(0.005)	(0.006)
Mean Years of Sch.	-0.219***	-0.213***	-0.377***
	(0.073)	(0.074)	(0.101)
Urbanization	-0.010*	-0.004	0.004
	(0.006)	(0.006)	(0.008)
Year Effect	Yes	Yes	Yes
Constant	59.381***	43.281**	9.403
	(19.132)	(19.281)	(26.211)
Farrar-Glauber Test	926.839***	926.839***	926.839***
Wald Test	322.464***	287.612***	272.292***
Buse (1973) Adj. R^2	0.739	0.7151	0.706
Observations	115	115	115

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. *ln* represents natural logarithm
When compared to the PCSE and panel quantile regression resuts,

This result resonates with those of Alimi and Ajide[20]; Guo *et al*.[14] and Yacour, Soumbara and El Ghini[16]. The findings align with Grossman's (1972) health production model in several ways.

Panel corrected standard error estimator panel quantile regression results

Table 3 presents the results of the Panel Corrected Standard Error (PCSE) regression, which assesses the impact of selected socio-economic and health-related variables on under-five, infant, and maternal mortality across three periods: the full sample, MDGs period (2000–2015), and SDGs period (2000–2015).

The results show that government health expenditure has a significant and negative effect on mortality rates, particularly under-five and infant mortality. For the full sample, a 1% increase in government health expenditure reduces under-five mortality by 0.226 (p<0.01) and infant mortality by 0.217 (p<0.01). However, the effect on maternal mortality (-0.182) is not statistically significant. Similarly, during the MDGs period, government health spending significantly reduces under-five mortality by 0.175 (p<0.01) and infant mortality by 0.170 (p<0.01), while the effect on maternal mortality (-0.0915) remains insignificant. During the SDGs period, the coefficient is highest for infant mortality (-0.565, p<0.05), suggesting greater effectiveness, while under-five (-0.441) and maternal mortality (-0.569) remain statistically insignificant.

Private health expenditure shows a negative but statistically insignificant relationship with mortality indicators across all periods. For instance, in the full sample, the coefficient is -0.00525 for under-five mortality, -0.00444 for infant mortality, and -0.0159 for maternal mortality—all insignificant. DPT immunization coverage shows a strong, significant, and negative association with mortality indicators across periods. For the full sample, the coefficients are -0.00390 (p<0.05) for under-five, -0.00313 (p<0.1) for infant, and -0.0132 (p<0.01) for maternal mortality. The impact strengthens during the SDGs period, with maternal mortality reduced by -0.0616 (p<0.01).

Mean years of schooling significantly reduces mortality rates in the full sample and MDGs period. For the full sample, a 1-year increase in schooling reduces under-five mortality by 0.127 (p<0.01), infant mortality by 0.117 (p<0.01), and maternal mortality by 0.270 (p<0.01). During the SDGs period, the effect becomes statistically insignificant. Urbanization shows a weak and largely insignificant effect, with only a slight

reduction in under-five mortality in the full sample (-0.00647, p<0.1) and infant mortality (-0.00634, p<0.1).

The model's explanatory power is high, with R-squared values ranging from 0.695 to 0.950. The Wald chi-square statistics confirm the overall significance of the models, with values such as 174.27 (p<0.01) for under-five mortality in the full sample and 240.94 (p<0.01) during the MDGs period. The analysis covers five countries, with observations totaling 115 in the full sample, 80 during the MDGs period, and 40 during the SDGs period.

Table 4 presents the results of the Panel Quantile Regression, analysing the determinants of under-five, infant, and maternal mortality at different quantiles (25th, 50th, and 75th percentiles). This approach allows for understanding how the impact of explanatory variables varies across the distribution of mortality rates, providing deeper insights beyond average effects. The results reveal that private health expenditure has a negative and significant effect on mortality rates, particularly at higher quantiles. For under-five mortality, the coefficient is -0.010 (p<0.05) at the 50th percentile and -0.011 (p<0.05) at the 75th percentile, suggesting that increased private health spending reduces mortality, especially where mortality rates are relatively higher. Similarly, for infant mortality, private health expenditure significantly reduces mortality at the 50th percentile (-0.0116, p<0.1). For maternal mortality, the effect is consistently negative and highly significant across all quantiles: -0.0363 (p<0.01) at the 25th percentile, -0.035 (p<0.01) at the 50th percentile, and -0.0344 (p<0.01) at the 75th percentile.

Government health expenditure shows a strong and significant negative relationship with mortality rates across all quantiles. For under-five mortality, a 1% increase in government health spending reduces mortality by 0.512 (p<0.01) at the 25th percentile, 0.41 (p<0.01) at the 50th percentile, and 0.36 (p<0.01) at the 75th percentile. A similar pattern is observed for infant mortality (-0.54, -0.439, and -0.38 at the 25th, 50th, and 75th percentiles, respectively; p<0.01) and maternal mortality (-0.560, -0.521, and -0.493; p<0.01).

DPT immunisation has a significant and negative effect only on maternal mortality across all quantiles. The coefficients are -0.0183 (p<0.01) at the 25th percentile, -0.015 (p<0.01) at the 50th percentile, and -0.0134 (p<0.01) at the 75th percentile. Its effect on under-five and infant mortality is statistically insignificant. Mean years of schooling significantly reduces mortality rates across all outcomes and quantiles. For under-five mortality, the coefficients range from -0.123 (p<0.01) at the 25th percentile to -0.15 (p<0.01) at the 75th percentile. For infant mortality, the effect ranges from -0.0603 (p<0.1) at the 25th percentile to -0.089 (p<0.05) at the 75th percentile.

Similarly, maternal mortality declines significantly with increased education (-0.065 at 50th percentile, -0.0837 at 75th percentile; p<0.01). Urbanization shows weak and mostly insignificant effects on under-five and infant mortality. However, for maternal mortality, urbanisation significantly reduces mortality at the 50th (-0.0224, p<0.05) and 75th (-0.0241, p<0.05) percentiles. This suggests urban development is more beneficial in lowering maternal mortality at higher risk levels.

Robustness check

Feasible generalized least squares (FGLS) and linear dummy ridge regression results in Tables 5 and 6 serve the robustness check of the results from the preceding analyses. Table 5 presents the results of the Feasible Generalized Least Squares (FGLS) regression analysis, which examines the effects of various socio-economic and health sector variables on under-five, infant, and maternal mortality across three periods: the full sample, the MDGs period (2000–2015), and the SDGs period (2015–2022). This method addresses issues of heteroskedasticity and autocorrelation, making the estimates more reliable.

The results show that government health expenditure has a consistently significant and negative effect on mortality rates across all periods. For the full sample, a 1% increase in government health spending reduces under-five mortality by 0.186 (p<0.01), infant mortality by 0.157 (p<0.01), and maternal mortality by 0.234 (p<0.05). During the MDGs period, government health expenditure also significantly reduces under-five (-0.156, p<0.01) and infant mortality (-0.130, p<0.01), while the effect on maternal mortality (-0.0791) is

not significant. In the SDGs period, the impact is even stronger, with coefficients of -0.727 ($p<0.01$) for under-five mortality, -0.864 ($p<0.01$) for infant mortality, and -0.950 ($p<0.05$) for maternal mortality. This suggests that public health investment became more effective in the recent period.

Private health expenditure shows a negative but insignificant effect across all mortality indicators and periods. For example, in the full sample, the coefficients are -0.00284 for under-five mortality, -0.00313 for infant mortality, and -0.00621 for maternal mortality—all statistically insignificant.

DPT immunization has a significant negative effect, especially on maternal mortality. In the full sample, it reduces maternal mortality by -0.0073 ($p<0.05$). During the MDGs period, the effect is larger (-0.014, $p<0.01$). In the SDGs period, the impact is much stronger at -0.037 ($p<0.01$). For under-five mortality, DPT immunization is significant at the 10% level (-0.00225, $p<0.1$) in the full sample and -0.00734 ($p<0.1$) in the SDGs period.

Mean years of schooling is consistently associated with lower mortality in the full sample and MDGs period. In the full sample, an additional year of schooling reduces under-five mortality by -0.176 ($p<0.01$), infant mortality by -0.098 ($p<0.01$), and maternal mortality by -0.218 ($p<0.01$). The MDGs period shows similar significant effects. However, during the SDGs period, the coefficients become statistically insignificant, possibly due to fewer observations and structural differences in education's role.

Urbanization shows mixed results. In the full sample and MDGs period, urbanization negatively affects under-five and infant mortality, with significant coefficients such as -0.020 ($p<0.01$) for infant mortality in the full sample. However, in the SDGs period, urbanization shows a positive and significant relationship with under-five (0.0227, $p<0.05$) and infant mortality (0.0302, $p<0.01$), suggesting possible urban health challenges in recent years. The Wald chi-square values are highly significant across all models, confirming the joint significance of the explanatory variables. Observations are 115 for the full sample, 80 for the MDGs period, and 40 for the SDGs period, covering five countries.

Table 6 presents the results of the Linear Dummy Ridge Regression, which was used to address multicollinearity issues among the explanatory variables while examining the determinants of under-five, infant, and maternal mortality. The results are presented in three models: Model 1 for under-five mortality, Model 2 for infant mortality, and Model 3 for maternal mortality, using 115 observations across five countries.

The analysis reveals that private health expenditure has an insignificant effect on all mortality indicators. Specifically, private health expenditure has a positive coefficient of 0.003 for under-five mortality and 0.006 for infant mortality, and a negative coefficient of -0.010 for maternal mortality. However, none of these results are statistically significant, indicating that private health spending has no meaningful impact on mortality outcomes in this model. Government health expenditure also appears to have an insignificant relationship with all mortality indicators. For under-five mortality, the coefficient is 0.104; for infant mortality, it is 0.032; and for maternal mortality, it is -0.0003—all statistically insignificant. This finding differs from earlier results in PCSE and FGLS models, which showed significant negative effects, suggesting that the ridge regression technique may have reduced the estimated impact of government health spending due to multicollinearity adjustments.

DPT immunization emerges as a highly significant factor in reducing mortality across all models. It has negative and statistically significant coefficients of -0.035 ($p<0.01$) for under-five mortality, -0.031 ($p<0.01$) for infant mortality, and -0.057 ($p<0.01$) for maternal mortality. This implies that increased immunization coverage substantially reduces mortality rates. Mean years of schooling also has a consistently significant and negative impact on mortality. An additional year of schooling reduces under-five mortality by 0.219 ($p<0.01$), infant mortality by 0.213 ($p<0.01$), and maternal mortality by 0.377 ($p<0.01$). These results suggest that educational attainment is a critical determinant of better health outcomes. Urbanization shows a weak and inconsistent relationship. It has a small but statistically significant negative effect on under-five mortality

(-0.010, p<0.1), indicating that higher urbanization slightly reduces child mortality. For infant and maternal mortality, urbanization coefficients are insignificant (–0.004 and 0.004, respectively). The year effect was included in the regression to control for time-specific influences, enhancing the reliability of the estimates. The Farrar-Glauber test statistic (926.839, p<0.01) confirms the presence of multicollinearity, justifying the use of ridge regression. The Wald test results (322.464, 287.612, and 272.292; all p<0.01) indicate that the explanatory variables jointly influence mortality outcomes.

The model fit is moderate, with Buse (1973) Adjusted R-squared values of 0.739 for under-five mortality, 0.715 for infant mortality, and 0.706 for maternal mortality, suggesting that approximately 71–74% of the variations in mortality outcomes are explained by the included variables

Discussion

The findings from this study underline the significant relationship between healthcare infrastructure, socioeconomic factors, and maternal-child health outcomes within the context of Grossman's Health Production Model. According to Grossman (1972), health is viewed as a form of durable capital that individuals possess and that depreciates over time but can be enhanced through investments such as healthcare access, education, immunisation programmes, and improved healthcare services. This perspective is consistent with the work of Alimi and Ajide[11], Guo *et al.* [14], and Yacour *et al*[16], who similarly identified strong links between healthcare investment and improved health outcomes. This aligns closely with prior research by Adeleye *et al*.[12] Alimi *et al*.[20], and Popescu *et al.*[15], who emphasised that weaker healthcare infrastructures tend to exacerbate health disparities among disadvantaged groups.

Dividing the analysis into Millennium Development Goals (MDGs) and Sustainable Development Goals (SDGs) periods provides a clear understanding of progress in maternal-child health outcomes among BRICS nations. During the MDGs era, despite considerable global efforts, significant disparities in maternal and child health persisted due primarily to inequalities in healthcare provision, limited access to essential health services, inadequate healthcare infrastructure, and disparities in education and immunisation coverage. Conversely, the improvements observed during the SDGs period indicate notable advancements, reflecting greater global and national efforts in strengthening healthcare systems, improving access to maternal and child healthcare services, and investing in education and comprehensive immunisation programmes.

Recent studies such as Ma *et al*.[21] reinforce this, demonstrating that proactive public health initiatives, including free physical examination programmes for elderly populations, substantially improve overall healthcare outcomes and reduce healthcare expenditures. However, despite overall improvements during the SDGs era, the quantile regression analysis revealed persistent disparities, particularly among countries with higher baseline maternal mortality rates such as India and South Africa. These disparities suggest that healthcare systems in these nations remain underfunded or inadequately structured to address the complex healthcare needs of vulnerable populations.

Furthermore, research by Qiu *et al.* [22] underscores the importance of innovation and efficiency in healthcare delivery. Also, studies by and Chen and Pan[28] and Wang *et al*.[29] highlight the crucial role of healthcare accessibility and the capacity of healthcare systems in improving maternal and child health outcomes. Limited geographical access to healthcare facilities remains a critical challenge, contributing directly to higher maternal morbidity and mortality. Likewise, the capacity and effectiveness of healthcare delivery significantly influence maternal health outcomes, with insufficient healthcare services leading to increased severe maternal morbidity rates.

Enhancing technological innovation and healthcare efficiency in medical industries directly improves healthcare quality, accessibility, and outcomes. Consequently, fostering innovation within healthcare systems, alongside investments in public healthcare infrastructure, education, and immunisation, could significantly accelerate improvements in maternal-child health outcomes.

These findings collectively underscore the necessity for policymakers to adopt targeted strategies aimed at strengthening healthcare

infrastructure, ensuring equitable access to maternal and child health services, enhancing education, and expanding immunisation programmes. Such targeted interventions are crucial for sustainably reducing maternal and child mortality rates and achieving equitable health outcomes across all socioeconomic groups within the BRICS region.

Conclusion

This study examined maternal and child health outcomes—specifically infant, under-5, and maternal mortality rates—among BRICS nations (Brazil, Russia, India, China, and South Africa), covering the periods defined by the Millennium Development Goals (MDGs) and Sustainable Development Goals (SDGs). Using advanced panel econometric methods, including Panel Corrected Standard Errors (PCSE) and Panel Quantile Regression estimators, the research highlighted significant progress in child and maternal health from the MDGs era (2000–2015) to the SDGs period (2016–2022). Notably, substantial improvements in healthcare infrastructure, public health expenditure, education, and immunisation coverage played a crucial role in reducing child mortality rates across these countries.

Despite these advancements, the analysis also underscored persistent disparities and unequal progress among BRICS nations. Quantile regression results revealed that nations with initially higher maternal mortality rates experienced disproportionately poorer outcomes. These findings indicate that socioeconomic inequalities and differential access to quality healthcare services continue to drive health disparities within the BRICS region. Countries such as India and South Africa still face significant challenges related to healthcare accessibility and service quality, highlighting an urgent need for targeted interventions addressing vulnerable groups, particularly low-income families, children, and women.

The findings reinforce the critical role that government investment in healthcare infrastructure plays in achieving equitable maternal and child health outcomes. Countries that allocated higher per capita public health expenditure, such as Russia and China, demonstrated better overall health outcomes compared to those with lower government health spending. Furthermore, the results emphasise the importance of comprehensive policies that integrate education, immunisation programmes, urban development, and robust healthcare financing mechanisms. For policymakers, the implications are clear: achieving equitable maternal and child health requires sustained commitment and targeted action that directly addresses existing healthcare inequalities. Enhanced investment in public healthcare systems, improvements in antenatal and postnatal care, and strengthening social determinants of health such as education and urban infrastructure are necessary to sustain recent gains and ensure continued progress towards SDG targets.

Ultimately, this study highlights the necessity of adopting holistic health strategies tailored to local contexts within the BRICS nations. While significant advancements have been made, substantial efforts are still required to overcome persistent health disparities. Policymakers should continue prioritising maternal and child health, utilising targeted, evidence-based approaches to address specific vulnerabilities and ensure sustainable improvements. Through collaborative efforts and sustained investments, BRICS countries can realise substantial progress towards equitable and inclusive maternal and child health outcomes in line with the global sustainable development agenda.

Strengths and limitations

This study offers several notable strengths. Firstly, it analyses maternal-child health outcomes across BRICS nations (Brazil, Russia, India, China, and South Africa), providing insights into diverse socioeconomic contexts and healthcare systems relevant to developing economies globally. Secondly, employing advanced econometric methodologies such as Panel Corrected Standard Errors (PCSE) and Panel Quantile Regression allows for robust estimations and nuanced understanding of disparities across different mortality levels. Thirdly, segmenting the analysis into MDGs and SDGs periods reveals evolutionary trends, enabling policymakers to assess the

effectiveness of international health frameworks and interventions over time.

However, the study also has limitations. The findings depend significantly on the quality and availability of health and socioeconomic data across countries, potentially affecting accuracy due to reporting differences. Furthermore, the analysis, limited to infant, under-5, and maternal mortality rates, omits other essential health measures such as morbidity and quality-of-life indicators, restricting a broader evaluation of health outcomes. Additionally, generalisability beyond BRICS nations may be constrained due to distinctive socioeconomic and political conditions. Lastly, the shorter duration of the SDGs period examined may not fully capture long-term impacts of recent policy interventions and investments.

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