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Does Financial Inclusion Matter to Population Health? Insight From a Global Dataset

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Abstract

Currently, extensive empirical studies exist on the impact of financial inclusion on socio-economic outcomes such as economic growth, inequality, and poverty. However, research on financial inclusion and population health is limited and still at the infant stage. Therefore, this article adds to knowledge by inquiring into the health implications of financial inclusion using a global panel dataset for 121 countries between 2004 and 2020. After accounting for endogeneity with heteroskedasticity-based instrumental variable regression and cross-sectional dependency with the Driscol–Kraay estimator, we documented that financial inclusion improves population health outcomes. We found that the effect of financial inclusion on population health outcomes also depends on the level of information and communication technology penetration and existing socio-economic conditions in a country. Following this, we showed that financial inclusion improves population health outcomes in countries with lower income inequality and higher GDP per capita, mobile and internet penetration. We further found heterogeneity in the results across geographical regions and income groups. Following these findings, we suggest that financial inclusion policies could enhance population health.

Keywords Financial inclusion · Life expectancy · Mortalities

JEL Classification G50 · I15 · O57

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1 Introduction

The United Nations Sustainable Development Goal (SDG) 3 aims at improving global health outcomes by reducing the global maternal mortality ratio to less than 70 per 100,00 live births, neonatal mortality to as low as 12 per 1000 live births, and under-five mortality to as low as 25 per 1000 live births by 2030. Enhancing population health is critical for increasing productivity and economic performance while reducing budget deficits. According to Bloom et al. (2004), a heathier population is very productive and energetic to boost economic growth. In addition, population health can drive productivity and economic output, as a healthy population is associated with less absenteeism from work. Several empirical studies have substantiated these claims in both developing and developed countries (Adeleye et al., 2022; Akhmat et al., 2014; Bloom et al., 2019).

The contribution of population health to economic progress has led many researchers and policymakers to unravel the determinants of population health outcomes. The available studies have mostly made enquiry into the effect of factors such as GDP per capita (Banerjee et al., 2023; Rustagi & Akter, 2022), political institutions (Banerjee et al., 2023; Rustagi & Akter, 2022), health expenditures (Gallet & Doucouliagos, 2017), education (Banerjee et al., 2023; Zajacova & Lawrence, 2018), trade openness and economic complexity (Novignon et al., 2018; Vu, 2020), urbanisation (Shao et al., 2022), and income inequality (Kawachi et al., 1997; Pickett & Wilkinson, 2007; Rözer & Volker, 2016) on health outcomes in both developing and developed countries. However, research on the impact of financial inclusion on health outcomes such as life expectancy and child and maternal health outcomes remains limited and still at the infant stage in the literature.

Financial inclusion has been at the forefront of global and national policy discussions and has become one of the policy strategies and tools to enhance livelihoods across the globe, especially in developing countries. The empirical literature suggests that financial inclusion significantly affects economic growth, income inequality and poverty (Churchill & Marisetty, 2020; Demir et al., 2022; Koomson et al., 2020; Omar & Inaba, 2020). Financial inclusion, broadly defined as access to and use of financial services (Beck et al., 2007; Wang & Guan, 2017), can potentially contribute to the attainment of SDG 3. Financial inclusion is key to enhancing population health outcomes since financial exclusion is a major threat to population health, given that those without access to financial services often lack the financial capability to respond to health emergencies such as illness (Sen, 2000). Therefore, financial inclusion is expected to improve the income levels among populations, enabling access to health (Zhang & Posso, 2019). Furthermore, financial inclusion facilitates savings towards health emergencies, leading to better health outcomes (Ky et al., 2018). Financial inclusion also allows populations to share risk during income or health shocks by facilitating access to financial resources such as remittances and credit (Riley, 2018; Thanh & Duong, 2017).

Up to date, very limited studies have empirically assessed the impact of financial inclusion on different facets of health outcomes and mostly these studies are concentrated in Africa (Ajefu et al., 2020; Chireshe & Ocran, 2020; Immurana et al., 2021; Koomson et al., 2021a, 2021b) in Asia (Xiao & Tao, 2022), and other developing countries (Banerjee et al., 2023). For instance, Koomson et al., (2021a, 2021b) used survey data to document that financial inclusion increases out-of-pocket health expenditure in Ghana. Also, Ajefu et al. (2020) used survey data from Nigeria to document that financial inclusion enhances mental health. At the macro level, Banerjee et al. (2023) used panel data from 61

developing countries and documented that financial inclusion improves life expectancy and infant mortality.

Despite the earlier papers' contribution, some potential critical areas still need further exploration. For instance, there is a lack of studies that use representative global samples to evaluate the effect of financial inclusion on population health outcomes. At the same time, there is a lack of studies that comparatively analyse financial inclusion's effect on health outcomes across geographical regions and income groups. For example, health outcome variables vary across geographical regions and income groups. Across the globe, life expectancy (maternal and child mortality) is relatively higher (lower) in upper-middle income and high-income countries, while life expectancy (maternal and child mortality) is relatively low (high) in low and lower-middle income countries (WHO, 2022). Geographically, life expectancy (maternal and child mortality) remains relatively higher (low) in America, Europe and the Western Pacific, while life expectancy (maternal and child mortality) remains low (high) in Africa, Eastern Mediterranean and Southeast Asia (WHO, 2022, 2023). These discussions show that the impact of financial inclusion would differ among geographical regions and countries at different stages of economic development. Therefore, it would be important for policymakers and researchers to understand if the effect of financial inclusion on health outcomes differs among the geographical regions and countries at different stages of economic development.

Also, we argue that the impact of financial inclusion on health outcomes is not independent of existing socio-economic conditions within a country. The impact of financial inclusion on health outcomes could depend on countries' socio-economic conditions. We argue that income inequality, GDP per capita and information and communication technologies (ICT) can condition (moderate) the effect of financial inclusion on health outcomes. For instance, higher-income inequality could act as a significant barrier to financial inclusion. In countries with higher income inequality, low-income people face many challenges in accessing financial services such as loans because these people have low savings and even lack assets to be used as collateral. In addition, higher income inequality increases distrust in the financial system and further increases the risk of default. Therefore, income inequality can reduce the favourable effect of financial inclusion on health outcomes. Besides, ICT could boost financial inclusion by enabling underserved communities with limited access to traditional banking services to access financial services easily. ICT can further enhance financial inclusion through financial literacy. ICT could give people easy access to information for savings, financial management and investment decisions. This suggests that ICT can condition the role of financial inclusion on health outcomes. Also, based on the "demand-following" hypothesis, we argue that the effect of financial inclusion on health outcomes could depend on GDP per capita since increasing GDP per capita increases the demand for financial services (Khalifa Al-Yousif, 2002). This suggests that expansion in GDP per capita could increase access to and availability of financial services. These arguments imply that further empirical studies are needed to examine if income inequality, GDP per capita and ICT moderate the effect of financial inclusion on population health outcomes.

Against this backdrop, this study extends and contributes to the literature by investigating the effect of financial inclusion on population health using a global panel dataset for 121 countries between 2004 and 2020. To achieve the aim of this study, we seek to provide evidence-based answers to the following specific research questions:

i. Does financial inclusion improve global population health outcomes?

ii. Do socio-economic conditions (income inequality and GDP per capita) influence the effect of financial inclusion on population health?
iii. Does Information and Communication Technology (ICT) penetration influence the effect of financial inclusion on population health?
iv. Does financial inclusion's effect on population health differ across geographical regions and income groups?

The novelty, uniqueness, and contributions of this study to the literature are outlined as follows: First, this study contributes to the emerging literature on financial inclusion and economic development by using a global sample of 121 countries to enquiry into the effect of financial inclusion on population health outcomes. Given that financial inclusion is a multi-faceted concept, we apply the principal component analysis (PCA) approach to four key financial inclusion variables, namely: Automated Teller Machines (ATMs), outstanding deposits with commercial banks, outstanding loans from commercial banks and branches of commercial banks to generate a composite financial inclusion index for the empirical analysis. We also employ different dimensions of population health outcomes, including life expectancy, child health (neonatal, under-five and infant mortality) and maternal mortality, to unravel the health implications of financial inclusion across the globe. Our study sample and health outcomes used in this study differ from Banerjee et al. (2023) study, which examined the effects of financial inclusion on life expectancy and infant mortality in 61 developing countries.

Second, this study differs from previous studies and extends the literature by providing an in-depth analysis to examine if the impact of financial inclusion on population health outcomes differs across regions and countries at the different stages of economic development,[1] given that population and financial development differ across regions and income groups. Specifically, this study offers new insight into the literature by comparatively investigating the impact of financial inclusion on health outcomes across regions such as the Middle East and North Africa, Europe and Central Asia, East Asia and Pacific, sub-Saharan Africa, Latin America and the Caribbean and South Asia. In addition, this study further evaluates if the impact of financial inclusion on health outcomes differs among low-income, lower-middle-income, upper-middle-income, and high-income countries. Third, this study contributes to the literature by highlighting if the impact of financial inclusion on health outcomes depends on socio-economic conditions. Specifically, we investigate if income inequality and GDP per capita moderate the effect of financial inclusion on health outcomes. We also shed light on the moderating role of ICT proxied by mobile and internet penetration in the relationship between financial inclusion and population health outcomes. The examination of the moderating effect of ICT on financial inclusion and health outcomes relationship in our estimation is consistent with the literature suggesting an interrelationship between financial inclusion and ICT (Pradhan et al., 2021; Tchamyou et al., 2019). Mobile phones, for example, have provided the needed infrastructure for the emergence of financial innovations such as mobile money in developing countries, which has a significant effect on financial inclusion (Demirgüç-Kunt et al., 2021).

[1] This study conceives the "stages of economic development" by using the World Bank income group classification. According to the World Bank's income classification, countries can be grouped into low-income, lower-middle-income, upper-middle-income and high-income countries.

Further, this study is relevant to policy-relevant since its findings would offer insight and guide policies that seek to attain SDG 3 across countries. For instance, if financial inclusion improves population health outcomes, attaining SDG 3 would be hastened if supported with policies that strengthen financial inclusion across the globe. At the same time, if the effect of financial inclusion on health outcomes is conditioned by income inequality, economic performance, and ICT, then achieving SDG 3 with only financial inclusion would be ineffective unless it is supported by structural and technological policies that enhance GDP per capita, income inequality and ICT penetration. Finally, to present unbiased estimates and provide valid conclusions, this study applies relevant econometric techniques to address econometric issues such as endogeneity and cross-sectional dependency. Specifically, this study addresses endogeneity using the Lewbel (2012) two-stage least squares, a heteroskedasticity-based instrumental variable technique, and further addresses cross-sectional dependency with the Driscol–Kraay estimator.

The rest of the paper is structured as follows. The next section reviews the literature, Sect. 3 discusses the methodology and data employed for the study, Sect. 4 presents and discusses the result, and Sect. 5 concludes with the main findings and policy implications.

2 Review of Related Literature

Financial inclusion focuses on access to and use of financial services and can be viewed as the opposite of financial exclusion (Wang & Guan, 2017). Financial inclusion initiatives can be universally oriented or targeted. The universal approach to financial inclusion emphasises universal access to financial services by the entire population. In its extreme form, financial inclusion is considered a public good that should be available to everyone at no cost (Ozili, 2020). However, it is worth noting that achieving universal financial inclusion may take time and accessing financial services for free is unlikely given that financial service providers are mostly economic agents who depend on profit to remain in business. The targeted approach to financial inclusion highlights the need to target financial inclusion initiatives to the segment of the population that is exposed to financial exclusion, such as the poor, women, the less educated, young people, and the elderly, among others (Ozili, 2020). This approach assumes that only the disadvantaged segment of the population is likely to be financially excluded. Evidence shows that financial access barriers increase the risk of poor population health outcomes. For instance, Jatrana and Crampton (2021), using a longitudinal dataset from New Zealand, demonstrated that barriers to financial access increase the risk of poor health outcomes. Therefore, addressing financial access barriers through financial inclusion measures could reduce the risk of poor health outcomes. Nonetheless, the literature suggests that extending financial services to disadvantaged groups can be beneficial given that financial systems tend to favour the more powerful in society (Leyshon & Thrift, 1995) and could enhance the health outcomes of the disadvantaged groups.

Financial inclusion affects population health in several ways. First, financial inclusion can improve income levels, leading to better health outcomes. Demir et al. (2022) examined the relationship between financial technology (FinTech), financial inclusion and income inequality for a panel of 140 countries. The study found that financial inclusion reduced income inequality, and the effect was more pronounced in high-income countries. Curran and Mahutga (2018) investigated the effect of income inequality on population health. The study found that income inequality had more harmful effects in poor countries than in

rich countries. This evidence suggests that financial inclusion influences population health through a reduction in income inequality and poverty. In a recent study, Banerjee et al. (2023) investigated the effect of financial inclusion on life expectancy and infant mortality in developing countries. The study found a direct effect between financial inclusion and health outcomes, and this effect was higher in countries with high incidences of poverty and income inequality. At the micro level, Koomson et al., (2021a, 2021b) examined the effect of financial inclusion on out-of-pocket health expenditure in Ghana. The evidence suggests that an increase in financial inclusion leads to an increase in out-of-pocket health expenditure in the household. The evidence also shows that financial inclusion tends to influence expenditure on medical products/appliances more than out-of-patient services. This implies that financial inclusion can facilitate access to healthcare by improving income (Zhang & Posso, 2019).

Second, financial inclusion is important for population health because of its potential to facilitate savings. Ky et al. (2018) showed that the use of mobile money significantly influenced the propensity to save towards health emergencies in Burkina Faso. Furthermore, the study found that disadvantaged groups such as rural women, females, the less educated, and those with irregular income benefited more from the use of mobile money. In a related study, Dupas and Robinson (2013) found that the provision of informal savings technologies reduced vulnerabilities to health shocks and increased investment in preventative health. Third, financial inclusion allows individuals to manage risks and lower the burden of financial shocks (Matekenya et al., 2021), with significant implications for population health. Financial inclusion facilitates an easy flow of remittances, thereby allowing households and individuals to manage risk during adverse shocks such as droughts and illness (Jack & Suri, 2014; Riley, 2018). Financial inclusion also facilitates risk management by enabling access to credit. Thanh and Duong (2017) examined the relationship between health shocks and the mitigation role of microcredit in rural Vietnam. The study found that microcredit could mitigate the negative effect of health shocks, but its impact on income and consumption is negligible. The results revealed that households with microcredit were better able to cope with health shocks in the short run and long run.

Other empirical studies have examined the link between financial inclusion and population health. Immurana et al. (2021) studied the effect of financial inclusion on population health across 33 African countries. The study found that financial inclusion improved life expectancy and reduced death rates. In a related study, Immurana et al. (2022) investigated the effect of financial inclusion on access to basic drinking water and sanitation in Africa. The findings suggest that financial inclusion improves access to basic drinking water and sanitation services. Chireshe and Ocran (2020) also found a significant positive effect of financial development on health outcomes. The study showed that financial development increased life expectancy and reduced child mortality in sub-Saharan Africa. Similarly, Xiao and Tao (2022) examined the effect of financial inclusion on population health in Asian countries. The estimated results showed that digital financial inclusion enhanced life expectancy but reduced death rates, and this effect was driven by Gross Domestic Product (GDP), Foreign Direct Investment (FDI) and Internet usage. Also, Ajefu et al. (2020) examined the relationship between financial inclusion and mental health using micro-level data from Nigeria. The evidence suggests that financial inclusion significantly improves mental health, and food expenditure, remittances, and risk-coping mechanisms condition this effect. Gyasi and Adam (2021) conducted a study on the link between financial inclusion and loneliness among older adults in Ghana. The study demonstrated that financial inclusion decreased loneliness, especially for women and physically active older adults. Gyasi et al. (2019) also found a positive association between

financial inclusion and self-rated health, psychological distress, and healthcare use, albeit the results were sensitive to socio-economic and health-related factors.

The literature so far provides limited evidence on the relationship between financial inclusion and population health using a global sample. Therefore, this study seeks to examine the effect of financial inclusion on population health and demonstrate how this effect differs across geographical regions and how socio-economic conditions, including ICT penetration, moderate the results.

3 Methodology and Data

3.1 Empirical Model

This study provides empirical evidence on the impact of financial inclusion on population health outcomes. A panel data approach was adopted to investigate the role of financial inclusion on population health outcomes. The reduced-form equation to be estimated is expressed in Eq. (1) as:

$$lnPHO_{i,t} = \alpha_0 + \beta_1 FI_{i,t} + \sum_{i=1}^{N} \gamma_i X_{i,t} + \varepsilon_{i,t} \quad (1)$$

where $lnPHO_{i,t}$ indicates the health outcomes in country i at time t. In the right-hand side variables, $FI_{i,t}$ is the financial inclusion in country i at time t. Also, β_1 is the coefficient of the impact of financial inclusion on population health outcomes variables. $X_{i,t}$ is the control covariate, and γ_i denotes the coefficient of the impact of the control variables on the population health outcome variables. $\varepsilon_{i,t}$ is the error term.

3.2 Econometric Estimation Strategies

We used the ordinary least squares (OLS) regression to estimate the baseline results on the impact of financial inclusion on population health outcomes while controlling for other factors impacting health outcomes (see Appendix Table 10). OLS estimates could be biased since it cannot address the endogeneity that could arise from reverse causality, variable omission bias or measurement error (Wooldridge, 2015). Reverse causality exists between financial inclusion and population health (Banerjee et al., 2023). We have discussed the effect of financial inclusion on population health in the literature section. At the same time, population health can equally affect financial inclusion. For instance, Banerjee et al. (2023) argue that better health outcomes can influence financial inclusion by impacting national income. At the same time, higher economic output due to better health outcomes could enhance the financial system and enable both firms and households to have easy access to inclusive financial services (Banerjee et al., 2023).

We first address endogeneity in the reduced form equation using the Lewbel (2012) two-stage least squares (Lewbel IV-2SLS) estimator. The Lewbel IV-2SLS is an external instrument-free estimator that generates its internal instrument to address endogeneity (Lewbel, 2012). The internal instrument generated is a heteroskedasticity-based instrument from the residuals of the auxiliary equation, which is multiplied by each of the included exogenous variables in mean-centred form (Lewbel, 2012). Because the Lewbel two-stage least squares generate its internal instrument, it does not need to satisfy the

exclusion restrictions (Lewbel, 2012). The Lewbel two-stage least square estimator is best applied when it is difficult to obtain an appropriate external instrument to regress on the endogenous variable or when the external instrument is weak to identify the structural equation. Besides, endogeneity is not the only econometric issue that confronts panel data. Another important econometric issue in panel data is cross-sectional dependency. In addressing the cross-sectional and temporal dependency, we further applied the Driscoll and Kraay (1998) estimator to unravel the linkage between financial inclusion and health outcomes. In addition to addressing cross-sectional and temporal dependency, the Driscoll-Kraay estimator would generate reliable estimates (coefficients) even when applied on balance and unbalanced panel data with missing data series Hoechle (2007).

3.3 Data Description

We constructed yearly panel data for a global sample of 121 countries[2] from 2004 to 2020 to investigate the effect of income inequality on health outcomes. The study uses 2004 as the start date for analysis because the key explanatory variable of interest, financial inclusion, starts from 2004. Also, we focused only on 121 countries since these countries have data on the key variables considered in this study. The variables deployed in this study are discussed below:

Dependent variable: Regarding the dependent variable, we follow Acheampong and Opoku (2024) to proxied population health outcomes using five (5) key health indicators. These health indicators are life expectancy, neonatal mortality, under-five mortality, infant mortality, and maternal mortality. The health indicators were retrieved from the World Development Indicators (WDI).

Explanatory variable: Financial inclusion (FI) is a multidimensional concept, and therefore, we adopted a multidimensional approach consistent with the literature (Koomson et al., 2023; Said & Acheampong, 2023) to construct the FI index. We generated the FI index by applying the principal component analysis (PCA) approach to four key financial inclusion variables, namely: Automated Teller Machines (ATMs), outstanding deposits with commercial banks, outstanding loans from commercial banks, and branches of commercial banks,[3] which were obtained from the International Monetary Fund's Financial Access Survey (FAS) database. The PCA is applied to minimise multi-collinearity among the individual financial inclusion indicators. Before applying the PCA technique, we used the Z-score approach as formulated in Eq. (2) to normalise these individual financial inclusion indicators due to differences in their scale and units.

$$\text{Z-score} = \frac{X_i - \overline{X}}{\alpha} \tag{2}$$

where X_i is the variable raw score; $\overline{X}$ is the mean, and α is the standard deviation.

Control covariates: We control for nine (9) key variables in the population health outcome model to minimise omitted variable bias. First, we control for GDP per capita since it is shown to be positively related to better population health outcomes (Banerjee et al., 2023; Rustagi & Akter, 2022). All things being equal, higher GDP per capita is argued to improve health outcomes by enabling households to consume healthy food

[2] The 121 countries involved in the study are presented in Appendix Table 10.

[3] The financial inclusion indicators were measured in their absolute numbers.

and also provides the government with the financial resources to increase spending on health infrastructures and services (Lange & Vollmer, 2017; Salahuddin et al., 2020). Another important control variable in our model is trade openness. Trade openness is shown to be associated with poor health outcomes. For instance, researchers such as Huynen et al. (2005) and Timoney (2000) believe that the cross-border movement of infected animals and goods could worsen population health. In addition, trade openness could impair population health through environmental pollution. Contrarily, trade openness could enhance population health by boosting economic growth and income. For instance, Novignon et al. (2018) and Vu (2020) found that trade openness significantly improves health outcomes.

Studies have also shown that education enhances health outcomes by enabling people to make better-informed health decisions (Banerjee et al., 2023; Zajacova & Lawrence, 2018). Following these studies, we incorporated an education proxy in our model, which is expected to reduce mortality rates and improve life expectancy. We also controlled for health expenditure since it is a key input in the health production function (Acheampong & Opoku, 2024; Gallet & Doucouliagos, 2017), and it is expected to have a significant favourable effect on health outcomes. Studies such as Akinkugbe and Mohanoe (2009), Bokhari et al. (2007) and Asiskovitch (2010) found evidence that health expenditure improves health outcomes. We further accounted for income inequality as it deteriorates health outcomes by weakening social cohesion and increasing social vices such as prostitution, teenage pregnancy, crime, vandalism and others (Acheampong & Opoku, 2024; Kawachi et al., 1997; Pickett & Wilkinson, 2007; Rözer & Volker, 2016).

Urbanisation is critical to population health (Acheampong & Opoku, 2024; Banerjee et al., 2023; Vu, 2020); hence, we controlled for the effect of urbanisation on population health. Banerjee et al. (2023) argue that urbanisation represents social change, leading to economic instability and further influencing the affordability of essential goods and services. Rapid urbanisation is argued to be associated with poor housing conditions, poor sanitation, environmental pollution, and the easy spread of communicable diseases (Shao et al., 2022). Contrarily, urbanisation can improve population health outcomes by ensuring access to quality health services, better sanitation, and safe drinking water (Shao et al., 2022). Following Banerjee et al. (2023), we controlled for the rule of law to capture the effect of political institutions on population health. We further incorporated ICT variables such as mobile phone and internet penetration as a robustness check. We expect both mobile phone and internet penetration to have a significant impact on enhancing population health. ICT (mobile phone and internet penetration) can improve population health by ensuring effective and efficient access to healthcare services. ICT can also improve health outcomes by promoting patient-centred healthcare at a lower cost and enhancing the relationship between healthcare practitioners and patients (Rouleau et al., 2015).

We sourced GDP per capita, health expenditure, trade openness, urbanisation, education, mobile phone and internet penetration variables from WDI. The rule of law ranged from -2.5 to 2.5 and was obtained from World Governance Indicators. The income inequality variable, sourced from the standardised world income inequality database, ranges between zero (0) and 100, with an increasing value suggesting higher income inequality. We provide the variables' descriptive statistics in Appendix Table 9. Except for the financial inclusion and rule of law variables, we transformed the remaining variables using the natural logarithm approach. Applying the logarithm transformation minimises address skewness in these variables and enables essay

Table 1 Descriptive statistics

Variable	Proxy	Mean	Std. Dev.	Min	Max
Life expectancy	Life expectancy at birth, total (years)	4.258	0.128	3.796	4.438
Neonatal mortality	Number of neonatal deaths	7.14	2.524	0	13.911
Under-five mortality	Number of under-five deaths	7.839	2.642	0.693	14.604
Infant mortality	Number of infant deaths	7.612	2.575	0.693	14.286
Maternal mortality	Maternal mortality ratio (modeled estimate per 100,000 live births)	4.03	1.688	0.693	7.523
Financial Inclusion (FI)	Composite financial inclusion index	0	1	−0.132	16.226
GDP per capita	GDP per capita (constant 2015 US$)	8.674	1.435	5.574	11.63
Trade openness	Trade (% of GDP)	4.327	0.563	−0.279	6.081
Urbanisation	Urban population	15.185	1.933	10.096	20.01
Health expenditure	Domestic general government health expenditure (% of GDP)	0.972	0.75	−2.115	2.227
Rule of law	Rule of law index	0.051	0.967	−1.87	2.125
Education	School enrollment, secondary (% gross)	4.34	0.483	2.164	5.099
Income inequality	Post-tax/post-transfer Gini index	3.642	0.209	3.14	4.173
Internet penetration	Individuals using the internet (% of population)	3.137	1.343	−3.473	4.605
Mobile phone penetration	Mobile cellular subscriptions (per 100 people)	4.314	0.825	−0.801	5.400

Table 2 Financial Inclusion and health outcomes, IV-Lewbel 2SLS estimates

	Model 1 *Life_exp*	Model 2 *Neo_mort*	Model 3 *Under_5 mort*	Model 4 *Infant_mort*	Model 5 *Mat_mort*
Financial Inclusion (FI)	0.003*	−0.055***	−0.058***	−0.052***	0.041***
	(0.002)	(0.015)	(0.016)	(0.016)	(0.012)
GDP per capita	0.024***	−0.555***	−0.557***	−0.553***	−0.465***
	(0.004)	(0.027)	(0.028)	(0.027)	(0.035)
Trade openness	−0.001	−0.296***	−0.330***	−0.313***	−0.041
	(0.004)	(0.042)	(0.042)	(0.041)	(0.038)
Urbanisation	0.002*	0.901***	0.902***	0.897***	−0.035***
	(0.001)	(0.011)	(0.011)	(0.011)	(0.009)
Health expenditure	0.020***	−0.427***	−0.399***	−0.394***	−0.410***
	(0.005)	(0.040)	(0.040)	(0.038)	(0.042)
Rule of law	0.001	0.052	0.067*	0.037	−0.068
	(0.004)	(0.038)	(0.040)	(0.038)	(0.044)
Education	0.129***	−1.251***	−1.555***	−1.383***	−0.818***
	(0.008)	(0.061)	(0.065)	(0.062)	(0.067)
Income inequality	−0.073***	1.399***	1.626***	1.606***	2.051***
	(0.022)	(0.113)	(0.136)	(0.125)	(0.112)
Constant	3.720***	0.234	1.527**	0.601	5.178***
	(0.088)	(0.594)	(0.646)	(0.611)	(0.514)
Observations	1005	1010	1010	1010	923
R2	0.768	0.961	0.962	0.963	0.884
widstat	1789.548	1792.520	1792.520	1792.520	1702.491

Robust standard errors in parentheses. Life expectancy (Life_exp); Neo-natal mortality (Neo_mort); Under-five mortality (Under_5 mort); Infant mortality (Infant_mort); and Maternal mortality (Mat_mort)

*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$

interpretation of the coefficients to be estimated. The descriptive statistics presented in Table 1 for FI and the rule of law variables are raw values, while the descriptive statistics of the other variables are natural logarithmic values.

4 Results and Discussion

Table 2 reports the Lewbel IV-2SLS results on the impact of financial inclusion (FI) on population health outcomes while accounting for other determinants of health. Before interpreting the Lewbel IV-2SLS results, we used the OLS to estimate the baseline results (see Appendix Table 10). We must state that the OLS estimates are largely consistent with the Lewbel IV-2SLS results. In alignment with our expectation, Table 2 shows that financial inclusion (FI) significantly predicts population health outcomes. Our Lewbel IV-2SLS regression shows that FI significantly improves life expectancy (Life_exp), neonatal mortality (Neo_mort), under-five mortality (Under_5 mort), and infant mortality (Infant_mort) while negatively impacting maternal mortality (Mat_mort). Our estimate suggests a unit increase in FI improves Life_exp by 0.3%. Also, a unit increase in FI reduces Neo_mort by 5.5%, Under_5 mort by 5.8%, and Infant_mort by 5.2%. Conversely,

a unit increase in FI rises Mat_mort by 4.1%. These estimated effects show that financial inclusion significantly improves life expectancy and child health outcomes. Contrarily, the estimated effects imply that financial inclusion is not associated with improvement in maternal health. The role of financial inclusion in improving child health outcomes while not improving maternal health outcomes signifies that parents and, for that matter, women have a higher propensity to borrow or use their financial resources to invest in the health of their children rather than investing in themselves since children are seen as the security that parents would rely on in the future. Also, financial inclusion improves life expectancy and child health by increasing out-of-pocket expenditure, enabling people to afford nutritious foods, better sanitation, and enhanced access to better healthcare services. Financial inclusion could help people to manage their medical expenses (Koomson et al., 2021a, 2021b). Limited empirical studies have documented that financial inclusion improves health outcomes using different health proxies. For instance, Koomson et al., (2021a, 2021b) documented financial inclusion to increase out-of-pocket health expenditure in Ghana; Banerjee et al. (2023) found a favourable effect of financial inclusion on life expectancy and infant mortality in 61 developing countries, and Ajefu et al. (2020) found financial inclusion to improve mental health in Nigeria.

The impact of control variables on population health outcomes is largely consistent with the literature and theory. For instance, the results indicate that GDP per capita significantly improves population health outcomes by showing that a percentage increase in GDP per capita increases Life_exp by 0.024% while curtailing Neo_mort by 0.555%, Under_5 mort by 0.557%, Infant_mort by 0.553% and Mat_mort by 0.465%. This finding highlights that, on average, increasing GDP per capita improves health outcomes by enabling households to consume healthy food and also provides the government with the financial resources to increase spending on health infrastructures and services (Lange & Vollmer, 2017; Salahuddin et al., 2020).

The estimates indicate that trade openness significantly improves child health outcomes while having a neutral on life expectancy and maternal mortality. The estimated effect of trade openness denotes that a percentage increase in trade openness is associated with a 0.296% decrease in Neo_mort, 0.330% reduction in Under_5 mort, and 0.313% decrease in Infant_mort. The implication is that trade openness is crucial for reducing child mortality. Consistent with Novignon et al. (2018) and Vu (2020), our finding suggests that trade openness could enhance household income and enable the transfer of health-related technologies that could improve child health outcomes. Our results diverge from Huynen et al.'s (2005) and Timoney's (2000) conjecture that trade openness could penalise population health outcomes.

Consistent with the findings of Acheampong and Opoku (2024), our analysis also suggests that urbanisation's effect on population health depends on population health measurement. For instance, the estimated effect suggests that urbanisation improves life expectancy and maternal mortality but significantly worsens child health outcomes. The estimated elasticity implies that a percentage increase in urbanisation is associated with a 0.002% increase in Life_exp and a 0.035% reduction in Mat_mort. Regarding child health outcomes, a percentage increase in urbanisation is associated with 0.901%, 0.902%, and 0.897% rises in Neo_mort, Under_5 mort, and Infant_mort, respectively. The role of urbanisation in improving access to quality health services facilitates better sanitation and safe drinking water (Shao et al., 2022), which could explain the favourable effect of urbanisation on life expectancy and maternal health. Contrarily, our estimates suggest that urbanisation worsens child health outcomes, which could be attributed to the role of urbanisation

in contributing to poor housing conditions, poor sanitation, environmental pollution, and the easy spread of communicable diseases (Shao et al., 2022).

Consistent with the findings of Akinkugbe and Mohanoe (2009), Bokhari et al. (2007) and Asiskovitch (2010), our results also suggest that health expenditure is significantly associated with improvement in life expectancy, child health and maternal health outcomes. The estimated impact shows that a percentage increase in health expenditure is associated with a 0.020% increase in Life_exp. Also, Neo_mort, Under_5 mort, Infant_mort and Mat_mort decrease by 0.427, 0.399, 0.394 and 0.410%, respectively, when health expenditure increases by 1%. Education significantly enhances life expectancy, child health, and maternal health outcomes. Health expenditure is a key input in health production (Gallet & Doucouliagos, 2017); therefore, higher expenditure on healthcare goods and services could lead to better population health outcomes.

Also, our estimate shows that a percentage increase in education increases Life_exp by 0.129%. In addition, Neo_mort, Under_5 mort, Infant_mort and Mat_mort decrease by 1.251, 1.555, 1.383 and 0.818%, respectively, when there is a percentage increase in education. Generally, this finding suggests that improvement in education leads to better health outcomes. Education enables people to make better-informed health decisions, supporting the findings of Banerjee et al., (2023) and Zajacova and Lawrence (2018).

Our analysis shows that income inequality significantly hinders life expectancy, child health and maternal health outcomes. The estimated coefficients suggest that a percentage increase in income inequality declines Life_exp by 0.073%. At the same time, a percentage increase in income inequality is associated with 1.251, 1.555, 1.383 and 2.051% rise in Neo_mort, Under_5 mort, Infant_mort and Mat_mort, respectively. The role of income inequality in deteriorating health outcomes can be attributed to its role in weakening social cohesion and increasing social vices such as prostitution, teenage pregnancy, crime, vandalism and among others (Acheampong & Opoku, 2024; Kawachi et al., 1997; Pickett & Wilkinson, 2007; Rözer & Volker, 2016).

Unlike the results of Banerjee et al. (2023), our findings suggest that the rule of law is an insignificant predictor of life expectancy and neonatal, infant, and maternal mortality but significantly increases under-five mortality.

4.1 Robustness Checks and Further Analysis

4.1.1 Using the Driscol–Kraay Technique as an Alternative Econometric Estimator

We test the consistency and robustness of the Lewbel IV-2SLS estimates. Table 3 shows that the Driscol–Kraay estimator[4] results are consistent with Lewbel IV-2SLS results. The Driscol–Kraay results show that FI significantly improves life expectancy, neonatal mortality, under-five mortality, and infant mortality while increasing maternal mortality. The size of the estimated coefficients from the Driscol–Kraay estimator is similar to that of the Lewbel IV-2SLS estimates. For instance, a unit increase in FI improves Life_exp by 0.3%. Also, a unit increase in FI reduces Neo_mort by 4.7%, Under_5 mort by 4.8%, and Infant_mort by 4.1%. Also, a unit increase in FI is associated with a 6.4% increase in Mat_mort. The Driscol–Kraay estimator confirms that financial inclusion plays a significant role in population health and that increasing financial inclusion improves life expectancy and child health outcomes but worsens maternal health.

[4] As presented in Appendix Table 11, we also test the robustness of the results by including time-fixed effect in the analysis the results are qualitatively consistent.

Table 3 Financial Inclusion and health outcomes, Driscol–Kraay estimator estimates

	Model 1 *Life_exp*	Model 2 *Neo_mort*	Model 3 *Under_5 mort*	Model 4 *Infant_mort*	Model 5 *Mat_mort*
Financial Inclusion (FI)	0.003**	−0.047***	−0.048***	−0.041***	0.064***
	(0.001)	(0.005)	(0.008)	(0.006)	(0.016)
GDP per capita	0.024***	−0.555***	−0.556***	−0.552***	−0.465***
	(0.003)	(0.012)	(0.016)	(0.013)	(0.036)
Trade openness	−0.001	−0.296***	−0.329***	−0.312***	−0.040
	(0.002)	(0.040)	(0.023)	(0.024)	(0.038)
Urbanisation	0.002***	0.900***	0.901***	0.896***	−0.036***
	(0.001)	(0.003)	(0.003)	(0.004)	(0.003)
Health expenditure	0.020***	−0.425***	−0.397***	−0.392***	−0.405***
	(0.006)	(0.030)	(0.034)	(0.033)	(0.023)
Rule of law	0.001	0.051***	0.066***	0.037**	−0.070***
	(0.002)	(0.013)	(0.012)	(0.013)	(0.019)
Education	0.129***	−1.254***	−1.559***	−1.386***	−0.825***
	(0.011)	(0.077)	(0.047)	(0.054)	(0.063)
Income inequality	−0.073**	1.397***	1.623***	1.603***	2.044***
	(0.026)	(0.101)	(0.121)	(0.085)	(0.018)
Constant	3.720***	0.257	1.555**	0.630	5.234***
	(0.084)	(0.729)	(0.725)	(0.586)	(0.238)
Observations	1005	1010	1010	1010	923
R2	0.768	0.961	0.962	0.963	0.884

Standard errors in parentheses. Life expectancy (Life_exp); Neo-natal mortality (Neo_mort); Under-five mortality (Under_5 mort); Infant mortality (Infant_mort); and Maternal mortality (Mat_mort).

*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$

The signs of the estimated coefficients and significance levels of the control covariate from the Driscol–Kraay estimator are consistent with the Lewbel IV-2SLS results. For instance, GDP per capita significantly improves life expectancy, child health (neonatal, under-five, and infant mortality) and maternal health. Also, trade openness significantly improves child health outcomes neonatal mortality, under-five mortality, and infant mortality) while having a neutral effect on life expectancy and maternal mortality. Consistently, urbanisation improves life expectancy and maternal mortality but significantly worsens child health outcomes (neonatal mortality, under-five mortality, and infant mortality). Health expenditure is significantly associated with improvement in life expectancy, child health (neonatal mortality, under-five mortality, and infant mortality) and maternal health outcomes. Also, education consistently improves life expectancy, child health (neonatal, under-five, and infant mortality) and maternal health outcomes. Income inequality significantly worsens life expectancy, child health (neonatal, under-five, and infant mortality) and maternal health outcomes. Driscol–Kraay estimator yields that rule of law has an insignificant effect on life expectancy. At the same time, rule of law improves maternal health while significantly deteriorating child health outcomes (neonatal, infant and under-five mortality).

The agreement of the Lewbel IV-2SLS and the Driscol–Kraay results suggest that our findings are reliable and could contribute significantly to the formulation of financial inclusion and health policies across the globe. In other words, the consistency of the findings across different econometric estimators suggests that techniques do not drive our findings and conclusions.

4.1.2 Using Two-Stages Least Square (IV-2SLS) as Alternative Estimator

In using a two-stage least square to estimate the effect of financial inclusion on life expectancy and infant mortality, Banerjee et al. (2023) use the one-period and two-period lags of financial inclusion as the instrument for financial inclusion. In addition to the Lewbel IV-2SLS and Driscol–Kraay techniques, we follow Banerjee et al. (2023) and use the one-period and two-period lagged financial inclusion as the instrument for financial inclusion. The traditional two-stage least square results are presented in Table 4. From Table 4, Models 1–5 present the estimates using the first lag of FI as an instrument and Models 6–10 present the estimates using the first two lags of FI as an instrument. In Table 4, the findings from the conventional two-stages (IV-2SLS) least square estimator are consistent with Lewbel IV-2SLS and Driscol–Kraay's results.

The traditional IV-2SLS results show that FI significantly improves life expectancy, neonatal mortality, under-five mortality, and infant mortality while increasing maternal mortality. When the first lag of financial inclusion is used as an instrument, the size of the estimated coefficients shows that a unit increase in FI increases Life_exp by 0.3%. Also, a unit increase in FI reduces Neo_mort by 4.8%, Under_5 mort by 4.8%, and Infant_mort by 4.1%, while a unit increase in FI is associated with a 6.2% increase in Mat_mort. Also, when the first two lags of financial inclusion are used as an instrument, the size of the estimated coefficients shows that a unit increase in FI increases Life_exp by 0.3%. Also, a unit increase in FI reduces Neo_mort by 4.4%, Under_5 mort by 4.4%, and Infant_mort by 3.8%, while a unit increase in FI is associated with a 6.1% increase in Mat_mort. In conclusion, the size of the estimated coefficient from IV-2SLS is fairly similar to Lewbel IV-2SLS and Driscol–Kraay's estimates. These findings further support our earlier evidence that financial inclusion enhances life expectancy and child health outcomes but worsens maternal health outcomes.

4.1.3 Effect of Financial Inclusion on Health Outcomes Across Geographical Regions

The study by Barajas et al. (2020) showed that the extent of financial inclusion differs among geographical regions. Given this, we expect financial inclusion to impact population health outcomes across geographical regions differently. We followed World Bank regional classification to categorise our sample into six (6) main geographical regions: Middle East and North Africa, Europe and Central Asia, East Asia and Pacific, sub-Saharan Africa, Latin America and the Caribbean and South Asia. We estimated the regional results using the Driscol–Kraay estimator, and the results are presented in Fig. 1.[5] Figure 1 shows the effect of financial inclusion on population health outcome variables across different

[5] We presented the coefficients for financial inclusion using graphs in other to conserve space and provide a pictorial presentation of the regions across regions. However, the extensive tables containing the estimates for the financial inclusion variables and the control variables on the population health variables across the regions can be available upon request.

Table 4 Financial Inclusion and health outcomes, IV-2SLS estimates

	Financial inclusion index instrumented by its 1-year lag value					Financial inclusion index instrumented by its 2-year lag value				
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
	Life_exp	*Neo_mort*	*Under_5 mort*	*Infant_mort*	*Mat_mort*	*Life_exp*	*Neo_mort*	*Under_5 mort*	*Infant_mort*	*Mat_mort*
Financial Inclusion (FI)	0.003*	−0.048***	−0.048***	−0.041***	0.062***	0.003*	−0.044***	−0.044***	−0.038***	0.061***
	(0.001)	(0.015)	(0.014)	(0.014)	(0.010)	(0.001)	(0.015)	(0.014)	(0.013)	(0.010)
GDP per capita	0.023***	−0.555***	−0.554***	−0.552***	−0.468***	0.022***	−0.557***	−0.553***	−0.553***	−0.468***
	(0.004)	(0.028)	(0.030)	(0.029)	(0.038)	(0.004)	(0.030)	(0.031)	(0.030)	(0.041)
Trade openness	−0.001	−0.300***	−0.332***	−0.314***	−0.048	0.000	−0.315***	−0.345***	−0.325***	−0.066
	(0.004)	(0.043)	(0.043)	(0.043)	(0.039)	(0.004)	(0.045)	(0.045)	(0.045)	(0.041)
Urbanisation	0.002*	0.900***	0.902***	0.897***	−0.038***	0.002*	0.901***	0.903***	0.898***	−0.040***
	(0.001)	(0.011)	(0.012)	(0.012)	(0.010)	(0.001)	(0.012)	(0.013)	(0.013)	(0.010)
Health expenditure	0.022***	−0.422***	−0.395***	−0.389***	−0.409***	0.023***	−0.415***	−0.387***	−0.381***	−0.418***
	(0.006)	(0.042)	(0.042)	(0.040)	(0.045)	(0.006)	(0.045)	(0.045)	(0.043)	(0.049)
Rule of law	0.003	0.050	0.058	0.033	−0.073	0.005	0.054	0.057	0.034	−0.074
	(0.004)	(0.040)	(0.041)	(0.040)	(0.047)	(0.004)	(0.042)	(0.043)	(0.042)	(0.051)
Education	0.127***	−1.285***	−1.582***	−1.413***	−0.818***	0.126***	−1.323***	−1.615***	−1.445***	−0.809***
	(0.008)	(0.067)	(0.070)	(0.067)	(0.072)	(0.009)	(0.071)	(0.074)	(0.071)	(0.077)
Income inequality	−0.064***	1.386***	1.595***	1.588***	2.029***	−0.054**	1.362***	1.555***	1.563***	2.011***
	(0.022)	(0.119)	(0.143)	(0.132)	(0.117)	(0.022)	(0.126)	(0.151)	(0.141)	(0.126)
Constant	3.700***	0.448	1.728**	0.778	5.357***	3.674***	0.761	2.038***	1.043	5.496***
	(0.092)	(0.636)	(0.689)	(0.654)	(0.542)	(0.095)	(0.670)	(0.727)	(0.693)	(0.573)
Observations	922	927	927	927	841	840	845	845	845	759
R2	0.771	0.960	0.962	0.963	0.881	0.778	0.961	0.962	0.963	0.877
Kleibergen–Paap rk Wald F statistic	6748.607	6748.872	6748.872	6748.872	3940.627	6488.684	6489.091	6489.091	6489.091	10,070.430
Kleibergen–Paap rk LM statistic	8.320	8.319	8.319	8.319	7.700	10.656	10.655	10.655	10.655	9.427

Table 4 (continued)

	Financial inclusion index instrumented by its 1-year lag value					Financial inclusion index instrumented by its 2-year lag value				
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
	Life_exp	*Neo_mort*	*Under_5 mort*	*Infant_mort*	*Mat_mort*	*Life_exp*	*Neo_mort*	*Under_5 mort*	*Infant_mort*	*Mat_mort*
Kleibergen–Paap rk LM statistic p-value	0.004	0.004	0.004	0.004	0.006	0.005	0.005	0.005	0.005	0.009

Robust standard errors in parentheses. Life expectancy (Life_exp); Neo-natal mortality (Neo_mort); Under-five mortality (Under_5 mort); Infant mortality (Infant_mort); and Maternal mortality (Mat_mort). Across all the models, the null hypothesis of Kleibergen–Paap rk LM test is that the structural equation is under-identified. The null hypothesis of Kleibergen–Paap rk Wald F statistic is that the instrument is weakly correlated with the endogenous variable. Across all the models, the Kleibergen–Paap rk LM test p-value rejects the null hypothesis that the structural equation is under-identified. The Kleibergen–Paap rk Wald F statistics reject the null hypothesis that instruments are weakly correlated with the endogenous variable since their values are greater than the Stock-Yogo weak ID test critical values at 10%.

*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$

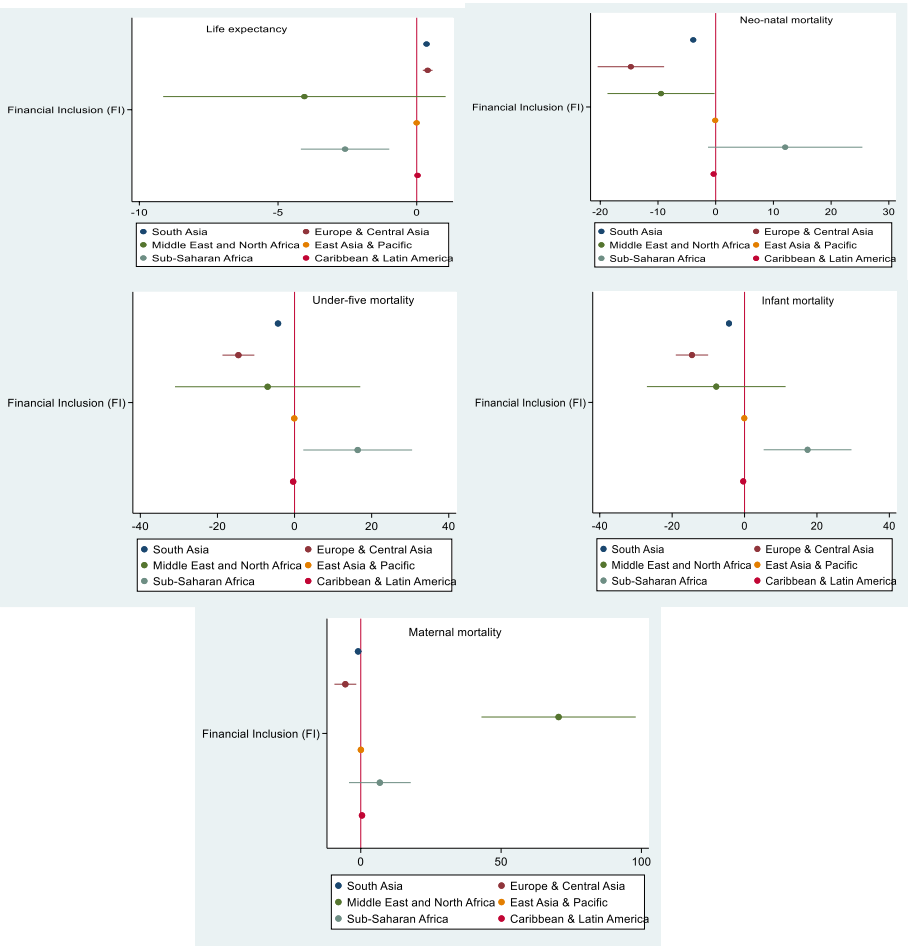

Fig. 1 Driscoll and Kraay regression coefficients of the effect of financial inclusion on population health outcome variables (Driscoll and Kraay estimates and 90% confidence interval) across different regions. All regression models include control variables (GDP per capita, health expenditure, trade openness, urbanisation, education, income inequality, and rule of law)

geographical regions while accounting for GDP per capita, health expenditure, trade openness, urbanisation, education, income inequality, and rule of law.

For life expectancy, Fig. 1 shows that across the regions, FI significantly increases Life_exp in South Asia, Europe and Central Asia and Latin America and the Caribbean. On the contrary, FI significantly reduces Life_exp in East Asia and the Pacific and sub-Saharan Africa while having an insignificant negative effect in the Middle East and North Africa. For child health outcomes, Fig. 1 reveals that FI significantly reduces in Neo_mort in South Asia, Europe and Central Asia, Middle East and North Africa, East Asia and Pacific and Latin America and the Caribbean but has an insignificant positive effect on Neo_mort in sub-Saharan Africa. Similarly, Fig. 1 shows that FI significantly reduces Under_5 mort in South Asia, Europe and Central Asia, East Asia and the Pacific and Latin America and the Caribbean but has an insignificant negative effect in the Middle East and North Africa.

In sub-Saharan Africa, FI significantly increases Under_5 mort. Consistently, FI significantly reduces Infant_mort in South Asia, Europe and Central Asia, Middle East and North Africa, East Asia and Pacific and Latin America and the Caribbean but has an insignificant positive effect on Infant_mort in sub-Saharan Africa. Finally, for maternal health outcome, Fig. 1 also shows that FI significantly reduces Mat_mort in Europe and Central Asia while significantly increasing Mat_mort in the Middle East and North Africa, East Asia and Pacific and Latin America, and the Caribbean. For South Asia, FI has an insignificant negative effect on Mat_mort, while in sub-Saharan Africa, it has an insignificant positive effect on Mat_mort.

The regional effect analysis highlighted that the impact of financial inclusion differs among regions. For instance, in South Asia, financial inclusion enhances health outcomes by increasing life expectancy and reducing child health outcomes (neonatal, under-five and infant mortality), while financial inclusion does not significantly determine maternal health. This result for South Asia is not surprising because countries in South Asia have implemented a number of financial inclusion strategies to enhance easy access to financial services and products by the population. Also, for Europe and Central Asia, financial inclusion is important for improving population health by increasing life expectancy and reducing both child and maternal mortalities, underscoring the importance of the robust financial system in these regions in promoting better health outcomes.

In Latin America and the Caribbean, financial inclusion significantly improves life expectancy and child health outcomes but is not associated with better maternal health outcomes. Similarly, financial inclusion in East Asia and the Pacific reduces child health outcomes (neonatal, under-five and infant mortality) but has not been associated with better improvement in life expectancy and maternal mortality. Also, in the Middle East and North Africa, financial inclusion significantly enhances child health, especially neonatal and infant mortality, but is associated with a negative effect on maternal health outcomes. In these regions, where financial inclusion improves child health but is not associated with improvement in maternal health, it supports our earlier argument that parents and, for that matter, women have a higher propensity to borrow or use their financial resources to invest in the health of their children rather than investing in themselves since children are seen as the security that parents would rely on in the future. In sub-Saharan Africa, financial inclusion has not been associated with significant improvement in health outcomes. This result for sub-Saharan Africa could reflect the under-development of their financial system, which is constrained by the high cost of accessing financial services, especially credit. The high cost associated with borrowing would prevent the majority of the population from borrowing to invest in their own and children's health.

4.1.4 Effect of Financial Inclusion on Health Outcomes Across Income Groups

Similar to the regional results, the Driscol–Kraay estimator was used to estimate the effect of financial inclusion on the population health variables across income groups while controlling for the effect of GDP per capita, health expenditure, trade openness, urbanisation, education, income inequality, and rule of law and the estimated coefficients are presented in Fig. 2.[6] From Fig. 2, FI significantly increases life expectancy across all

[6] We presented the coefficients for financial inclusion using graphs in other to conserve space and provide a pictorial presentation of the regions across different income groups. However, the extensive tables containing the estimates for the financial inclusion variables and the control variables on the population health variables across the different income groups can be available upon request.

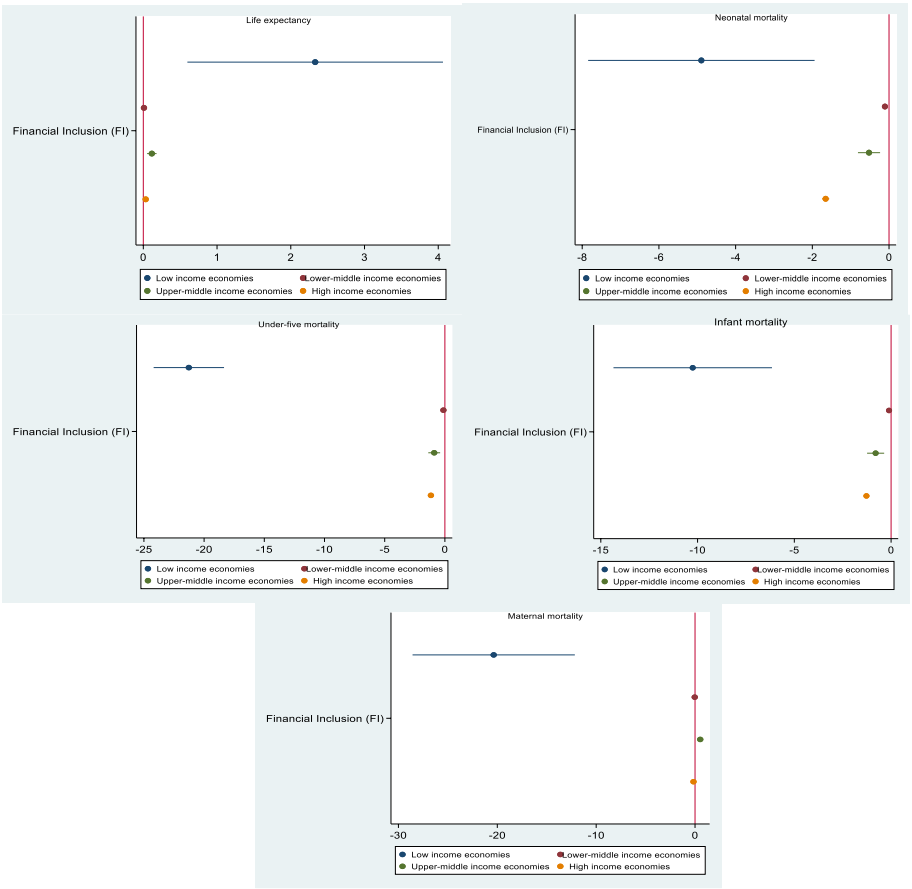

Fig. 2 Driscoll and Kraay regression coefficients of the effect of financial inclusion on population health outcome variables (Driscoll and Kraay estimates and 90% confidence interval) across different income groups. All regression models include control variables (GDP per capita, health expenditure, trade openness, urbanisation, education, income inequality, and rule of law)

income groups. The estimated effect shows that FI significantly increases Life_exp in low-income economies, lower-middle income economies, upper-middle income economies, and high-income economies. Similarly, FI significantly contributes to a reduction in neonatal mortality across all income groups. FI significantly reduces Neo_mort in low-income economies, lower-middle middle-income economies, upper-middle income economies and high-income economies. Also, FI significantly reduces Under_5 mort in low-income economies, lower-middle income economies, upper-middle income economies and high-income economies. Similarly, FI significantly reduces Infant_mort mort in low-income economies, lower-middle middle-income economies, upper-middle income economies and high-income economies. Also, FI significantly reduces Mat_mort in low-income economies, lower-middle income economies, and high-income economies. Contrarily, FI significantly increases Mat_mort in upper-middle income economies.

These findings suggest that financial inclusion plays a significant role in population health outcomes across countries at different stages of economic development.

Interestingly, the estimated coefficients show that financial inclusion's impact on population health outcomes is significantly higher than in low-income countries relative to middle-income and high-income countries. Historically, low-income economies have suffered from an anaemic financial system, which has excluded most of their population from accessing financial services. However, recent campaigns and national policy support, such as the national financial inclusion strategy, have significantly boosted financial services in low-income countries. The current improvement in financial inclusion services in developing countries has significantly improved health outcomes in low-income countries. The higher estimated effect of financial inclusion on health outcomes in low-income countries could also suggest that financial inclusion has higher returns on health in countries with poor economic development relative to countries with higher economic development.

4.1.5 Accounting for the Effect of ICT Variables

We also tested the robustness of the impact of FI on population health outcomes by including ICT variables in the models; the results are displayed in Table 5. In Table 5, we consistently observe that FI significantly improves life expectancy and child health (neonatal, under-five, and infant mortality) while increasing maternal mortality even after controlling for mobile phone and internet penetration. At the same time, the size of the estimated coefficients of FI on population health outcomes is largely stable after controlling for mobile phone and internet penetration. For instance, in models with internet penetration, the estimates suggest that a unit increase in FI raises Life_exp by 0.3%. Also, a unit increase in FI reduces Neo_mort by 4.4%, Under_5 mort by 4.5%, and Infant_mort by 3.9%, while Mat_mort increases by 6.4%. Also, in models with mobile phone penetration, the estimates show that FI has an insignificant positive effect on Life_exp. However, a unit increase in FI reduces Neo_mort by 4.1%, Under_5 mort by 4.1%, and Infant_mort by 3.4%, while Mat_mort increases by 6.8%. These findings suggest that the effect of financial inclusion on population health outcomes is robust to ICT variables.

Regarding the ICT variables, mobile phone and internet penetration significantly enhance life expectancy, child health (neonatal, under-five, and infant mortality) and maternal health. The estimated effect suggests that a percentage increase in internet penetration increases Life_exp by 0.021%. Also, a percentage increase in internet penetration reduces Neo_mort by 0.210%, Under_5 mort by 0.274%, Infant_mort by 0.252%, and Mat_mort by 0.094%. At the same, a percentage increase in mobile phone penetration increases Life_exp by 0.012%. Also, a percentage increase in mobile phone penetration reduces Neo_mort by 0.127%, Under_5 mort by 0.165%, Infant_mort by 0.157%, and Mat_mort by 0.077%. These findings imply that mobile phone and internet penetration enhance population health outcomes. ICT (mobile phone and internet penetration) can improve population health by ensuring effective and efficient access to healthcare services and facilitating patient-centred healthcare at a lower cost (Rouleau et al., 2015).

4.2 Exploring the Conditional Effect of Financial Inclusion

4.2.1 Synergistic Effect of Financial Inclusion and Income Inequality on Health Outcomes

Theoretically, income inequality is a significant barrier to financial inclusion. Therefore, we expect income inequality to condition the effect of financial inclusion on health

Table 5 Financial Inclusion and health outcomes, accounting for ICT variables, Driscol–Kraay estimator estimates

	Life_exp		*Neo_mort*		*Under_5 mort*		*Infant_mort*		*Mat_mort*	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Financial Inclusion (FI)	0.003*	0.002	−0.044***	−0.041***	−0.045***	−0.041***	−0.039***	−0.034***	0.064***	0.068***
	(0.002)	(0.001)	(0.007)	(0.007)	(0.011)	(0.008)	(0.009)	(0.007)	(0.019)	(0.016)
GDP per capita	0.016***	0.023***	−0.483***	−0.532***	−0.456***	−0.527***	−0.458***	−0.524***	−0.433***	−0.455***
	(0.005)	(0.003)	(0.007)	(0.012)	(0.018)	(0.018)	(0.012)	(0.014)	(0.040)	(0.038)
Trade openness	−0.002	−0.003	−0.281***	−0.274***	−0.315***	−0.299***	−0.302***	−0.284***	−0.033	−0.029
	(0.003)	(0.003)	(0.045)	(0.044)	(0.028)	(0.029)	(0.028)	(0.030)	(0.046)	(0.043)
Urbanisation	0.001	0.001*	0.909***	0.907***	0.912***	0.911***	0.906***	0.906***	−0.032***	−0.033***
	(0.001)	(0.001)	(0.003)	(0.004)	(0.003)	(0.003)	(0.002)	(0.003)	(0.006)	(0.004)
Healthexpenditure	0.017*	0.020**	−0.393***	−0.432***	−0.356***	−0.404***	−0.354***	−0.399***	−0.389***	−0.406***
	(0.008)	(0.007)	(0.037)	(0.032)	(0.050)	(0.039)	(0.046)	(0.036)	(0.029)	(0.025)
Rule of law	0.001	0.002	0.066***	0.034**	0.079***	0.044**	0.047***	0.015	−0.059***	−0.077***
	(0.003)	(0.002)	(0.012)	(0.014)	(0.018)	(0.017)	(0.015)	(0.016)	(0.013)	(0.022)
Education	0.107***	0.116***	−1.004***	−1.125***	−1.241***	−1.391***	−1.096***	−1.227***	−0.724***	−0.741***
	(0.012)	(0.014)	(0.029)	(0.069)	(0.033)	(0.039)	(0.020)	(0.042)	(0.081)	(0.073)
Income inequality	−0.077**	−0.074**	1.414***	1.394***	1.654***	1.623***	1.633***	1.602***	2.055***	2.047***
	(0.026)	(0.025)	(0.100)	(0.095)	(0.119)	(0.112)	(0.085)	(0.078)	(0.018)	(0.020)
Internet penetration	0.021***		−0.210***		−0.274***		−0.252***		−0.094***	
	(0.003)		(0.037)		(0.040)		(0.039)		(0.026)	
Mobile phone penetration		0.012**		−0.127**		−0.165***		−0.157***		−0.077**
		(0.004)		(0.045)		(0.050)		(0.049)		(0.027)
Constant	3.860***	3.756***	−1.098*	−0.147	−0.229	1.006	−1.002*	0.111	4.657***	5.021***
	(0.106)	(0.091)	(0.620)	(0.782)	(0.670)	(0.851)	(0.517)	(0.688)	(0.327)	(0.288)
Observations	995	1002	1000	1007	1000	1007	1000	1007	913	920
R2	0.776	0.769	0.963	0.962	0.965	0.963	0.966	0.964	0.883	0.884

Standard errors in parentheses. Life expectancy (Life_exp); Neo-natal mortality (Neo_mort); Under-five mortality (Under_5 mort); Infant mortality (Infant_mort); and Maternal mortality (Mat_mort)

*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$

Table 6 Synergistic effect of financial inclusion and income inequality on population health, Driscol–Kraay estimator estimates

	Model 1 *Life_exp*	Model 2 *Neo_mort*	Model 3 *Under_5 mort*	Model 4 *Infant_mort*	Model 5 *Mat_mort*
Financial Inclusion (FI)	0.397***	− 14.763***	− 10.105***	− 11.009***	− 1.643
	(0.034)	(2.301)	(1.560)	(1.748)	(1.215)
Income inequality × Financial Inclusion (FI)	− 0.102***	3.825***	2.614***	2.851***	0.444
	(0.009)	(0.595)	(0.404)	(0.452)	(0.311)
Income inequality	− 0.086***	1.881***	1.954***	1.964***	2.100***
	(0.027)	(0.055)	(0.074)	(0.038)	(0.050)
GDP per capita	0.024***	− 0.555***	− 0.557***	− 0.553***	− 0.465***
	(0.003)	(0.012)	(0.016)	(0.013)	(0.036)
Trade openness	− 0.000	− 0.313***	− 0.341***	− 0.325***	− 0.041
	(0.003)	(0.051)	(0.030)	(0.031)	(0.040)
Urbanisation	0.002***	0.907***	0.906***	0.902***	− 0.035***
	(0.000)	(0.005)	(0.006)	(0.006)	(0.002)
Health expenditure	0.020***	− 0.414***	− 0.390***	− 0.384***	− 0.404***
	(0.006)	(0.022)	(0.023)	(0.022)	(0.021)
Rule of law	0.000	0.065**	0.076***	0.047**	− 0.069***
	(0.002)	(0.023)	(0.019)	(0.020)	(0.021)
Education	0.130***	− 1.278***	− 1.575***	− 1.404***	− 0.827***
	(0.011)	(0.101)	(0.061)	(0.073)	(0.058)
Constant	3.768***	− 1.542**	0.326	− 0.710	5.024***
	(0.089)	(0.568)	(0.631)	(0.475)	(0.139)
Marginal effects of FI conditioned on different values of income inequality					
Minimum value of income inequality (3.140)	0.075***	-2.753***	− 1.897***	-2.057***	− 0.249
	(0.006)	(0.433)	(0.291)	(0.327)	(0.237)
Mean value of income inequality (3.642)	0.024***	− 0.832***	− 0.585***	− 0.626***	− 0.027
	(0.001)	(0.135)	(0.088)	(0.101)	(0.081)
Maximum value of income inequality (4.173)	− 0.030***	1.199***	0.803***	0.887***	0.209**
	(0.004)	(0.181)	(0.126)	(0.139)	(0.084)
Observations	1005	1010	1010	1010	923
R2	0.768	0.963	0.963	0.964	0.884

Standard errors in parentheses. Life expectancy (Life_exp); Neo-natal mortality (Neo_mort); Under-five mortality (Under_5 mort); Infant mortality (Infant_mort); and Maternal mortality (Mat_mort).

*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$

outcomes. In this section, we test empirically if income inequality moderates the effect of financial inclusion on health outcomes. The moderating or interaction effect of financial inclusion and income inequality are presented in Table 6. In Table 6, the unconditional effect of FI shows that FI significantly improves life expectancy

and child health (neonatal, under-five, and infant mortality) while exerting an insignificant negative effect on maternal mortality. At the same time, income inequality unconditionally impairs life expectancy, child health and maternal health outcomes. However, the interactive effect of FI and income inequality significantly reduces life expectancy and increases child health outcomes while having a statistically insignificant positive effect on maternal health. We evaluated the marginal effect of financial inclusion on health outcomes conditioned on income inequality using Eq. (3):

$$\frac{\partial lnPHO}{\partial FI} = \beta_1 + \delta_1 \times Income\ inequality \tag{3}$$

where β_1 is the financial inclusion (FI) coefficients, δ_1 is the coefficient of the interaction term [Income inequality × Financial Inclusion (FI)]. We evaluated the marginal effect of FI at the minimum (3.140), mean (3.642) and maximum (4.173) values of income inequality.

The marginal effect of financial inclusion suggests that financial inclusion significantly worsens population health outcomes when income inequality is higher. The estimated marginal effects coefficient shows that at the minimum and mean values of income inequality, FI significantly increases Life_exp by 0.075 and 0.024%, respectively. At the same time, at maximum values of income inequality, FI significantly deteriorates Life_exp by 0.030%. At the minimum and mean values of income inequality, FI significantly improves child and maternal health outcomes but worsens child and maternal health outcomes when income inequality is at maximum. At the minimum value of income inequality, the estimated coefficients show that FI significantly reduces Neo_mort by 2.753%, Under_5 mort by 1.897%, and Infant_mort by 2.057% but has a neutral effect on Mat_mort. Similarly, at the mean value of income inequality, the estimated coefficients show that FI significantly reduces Neo_mort by 0.832%, Under_5 mort by 0.585% and Infant_mort by 0.626% but has a neutral effect on Mat_mort. Contrarily, at the maximum value of income inequality, the estimated coefficients show that FI significantly increases Neo_mort by 1.199%, Under_5 mort by 0.803%, Infant_mort by 0.887%, and Mat_mort by 0.209%. These estimates suggest that higher income inequality conditions financial inclusion to worsen population health outcomes.

The moderation and marginal effect analysis suggest that financial inclusion could worsen population health outcomes with higher income inequality by reducing the life expectancy and increasing child and maternal mortalities. Higher-income inequality acts as a significant barrier to financial inclusion. In countries with higher income inequality, low-income people face many challenges in accessing financial services such as loans because these people have low savings and even lack assets to be used as collateral. In addition, higher income inequality increases distrust in the financial system and further increases the risk of default. Increasing distrust and default risk lead to higher borrowing costs and exclude low-income people from the financial system. These justifications show that higher income inequality could render financial inclusion ineffective in improving population health outcomes. The policy suggestion is that for financial inclusion to improve life expectancy, child and maternal health outcomes significantly, policymakers should carefully address income inequality.

4.2.2 Synergistic Effect of Financial Inclusion and GDP per Capita on Health Outcomes

The "demand-following" hypothesis argues that increasing GDP per capita increases the demand for financial services, thereby improving financial development (Khalifa Al-Yousif, 2002). This suggests that expansion in GDP per capita could increase access

Table 7 Synergistic effect of financial inclusion and GDP per capita on population health, Driscol–Kraay estimator estimates

	Model 1 *Life_exp*	Model 2 *Neo_mort*	Model 3 *Under_5 mort*	Model 4 *Infant_mort*	Model 5 *Mat_mort*
Financial Inclusion (FI)	−0.160***	5.592***	4.242***	4.560***	1.446***
	(0.023)	(0.358)	(0.078)	(0.097)	(0.413)
GDP per capita × Financial Inclusion (FI)	0.020***	−0.692***	−0.527***	−0.565***	−0.170***
	(0.003)	(0.041)	(0.008)	(0.010)	(0.050)
GDP per capita	0.027***	−0.649***	−0.628***	−0.630***	−0.488***
	(0.003)	(0.017)	(0.017)	(0.014)	(0.030)
Trade openness	−0.000	−0.324***	−0.351***	−0.335***	−0.046
	(0.003)	(0.048)	(0.028)	(0.029)	(0.039)
Urbanisation	0.002***	0.904***	0.904***	0.899***	−0.035***
	(0.000)	(0.006)	(0.006)	(0.007)	(0.002)
Health expenditure	0.019***	−0.370***	−0.355***	−0.347***	−0.393***
	(0.006)	(0.022)	(0.021)	(0.020)	(0.023)
Rule of law	0.000	0.070**	0.080***	0.052**	−0.066***
	(0.002)	(0.024)	(0.019)	(0.021)	(0.020)
Education	0.130***	−1.300***	−1.594***	−1.424***	−0.834***
	(0.011)	(0.104)	(0.064)	(0.076)	(0.059)
Income inequality	−0.074**	1.433***	1.651***	1.633***	2.052***
	(0.026)	(0.087)	(0.109)	(0.074)	(0.018)
Constant	3.695***	1.103	2.199**	1.321*	5.440***
	(0.083)	(0.819)	(0.761)	(0.629)	(0.210)
Marginal effects of FI conditioned on different values of GDP per capita					
Minimum value of GDP per capita (5.574)	−0.049***	1.734***	1.307***	1.413***	0.497***
	(0.008)	(0.132)	(0.040)	(0.047)	(0.137)
Mean value of GDP per capita (8.674)	0.014***	−0.411***	−0.325***	−0.338***	−0.031***
	(0.003)	(0.027)	(0.031)	(0.029)	(0.017)
Maximum value of GDP per capita (11.630)	0.073***	-2.457***	−1.881***	-2.007***	−0.534***
	(0.010)	(0.120)	(0.039)	(0.036)	(0.163)
Observations	1005	1010	1010	1010	923
R2	0.769	0.963	0.963	0.965	0.884

Standard errors in parentheses. Life expectancy (Life_exp); Neo-natal mortality (Neo_mort); Under-five mortality (Under_5 mort); Infant mortality (Infant_mort); and Maternal mortality (Mat_mort).

*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$

to and availability of financial services. We, therefore, test if GDP per capita moderates the effect of financial inclusion on population health outcomes. The moderating effect of financial inclusion and GDP per capita are presented in Table 7. In Table 7, the unconditional effect of FI shows that FI significantly improves life expectancy and child health (neonatal, under-five, and infant mortality) and significantly increases maternal mortality. At the same time, GDP per capita unconditionally enhances life expectancy,

child health and maternal health outcomes. Also, the interactive effect of FI and GDP per capita significantly increases life expectancy and reduces child and maternal health outcomes. We evaluated the marginal effect of financial inclusion on health outcomes conditioned on GDP per capita using Eq. (4):

$$\frac{\partial lnPHO}{\partial FI} = \beta_1 + \delta_2 \times GDP\ per\ capita \tag{4}$$

where β_1 is the financial inclusion (FI) coefficients, δ_2 is the coefficient of the interaction term [GDP per capita × Financial Inclusion (FI)]. We evaluated the marginal effect of FI at the minimum (5.574), mean (8.674) and maximum (11.630) values of GDP per capita.

It can be observed from the marginal analysis that as the value of GDP per capita rises, financial inclusion significantly enhances population health outcomes. For instance, at the minimum value of GDP per capita, FI significantly reduces Life_exp by 0.049%. However, at the mean and maximum values of GDP per capita, FI significantly increases Life_exp by 0.014 and 0.073%, respectively. At the minimum value of GDP per capita, FI worsens child and maternal health outcomes but significantly improves child and maternal health outcomes at the mean and maximum values of GDP per capita. From the estimated coefficients, FI significantly increases Neo_mort by 1.734%, Under_5 mort by 1.307%, Infant_mort by 1.413%, and Mat_mort by 0.497% at the minimum value of GDP per capita. Contrarily, at the mean value of GDP per capita, FI significantly reduces Neo_mort by 0.411%, Under_5 mort by 0.325%, Infant_mort by 0.338%, and Mat_mort by 0.031%. Consistently, at the maximum value of GDP per capita, FI significantly reduces Neo_mort by 2.457%, Under_5 mort by 1.881%, Infant_mort by 2.007%, and Mat_mort by 0.534%. These results suggest that the impact of financial inclusion on population health outcomes depends on GDP per capita. The policy relevance is that increasing GDP per capita could boost financial inclusion by enabling households, especially poor ones, to access and use financial services such as borrowing to finance their health needs.

4.2.3 Synergistic Effect of Financial Inclusion and ICT Penetration on Health Outcomes

ICT could boost financial inclusion by enabling underserved communities with limited access to traditional banking services to access financial services easily. Also, ICT could enhance financial inclusion through financial literacy. Internet and mobile phone penetration could give people easy access to information to make decisions regarding savings, financial management and investment. ICT facilitates financial services transactions through information transformation and rapid flow of financial transactions in the financial system (Kouladoum et al., 2022). Contrarily, ICT has greater exposure to fraud and privacy risks, which can hinder financial inclusion. Also, vulnerable groups such as the ICT illiterate group, people with disabilities, and older people who face significant challenges in using digital platforms can be excluded from accessing financial services. These discussions show that ICT in the form of internet and mobile phone penetration could moderate the effect of financial inclusion on population health outcomes. Therefore, we test if ICT moderates the effect of financial inclusion on population health outcomes. The interaction effect of financial inclusion and ICT (mobile phone and internet penetration) are presented in Table 8.

In Table 8, the unconditional effect of FI shows that FI significantly improves life expectancy and child health (neonatal, under-five, and infant mortality) while it significantly increases maternal mortality. At the same time, internet and phone

Table 8 Synergistic effect of financial inclusion and ICT on population health, Driscol–Kraay estimator estimates, Driscol–Kraay estimator estimates

	Life_exp		*Neo_mort*		*Under_5 mort*		*Infant_mort*		*Mat_mort*	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Financial Inclusion (FI)	0.014	0.068***	0.209	−0.282**	0.065	−0.414**	0.124	−0.326**	0.193*	0.385**
	(0.008)	(0.018)	(0.136)	(0.101)	(0.089)	(0.148)	(0.093)	(0.137)	(0.101)	(0.170)
Internet penetration × Financial Inclusion (FI)	−0.003		−0.080*		−0.035		−0.051*		−0.043	
	(0.002)		(0.042)		(0.028)		(0.029)		(0.028)	
Internet penetration	0.021***		−0.215***		−0.276***		−0.256***		−0.097***	
	(0.003)		(0.036)		(0.039)		(0.038)		(0.025)	
Mobile Phone penetration		0.011**		−0.122**		−0.159***		−0.152***		−0.083***
		(0.004)		(0.044)		(0.048)		(0.047)		(0.025)
Mobile Phone penetration × Financial Inclusion (FI)		−0.013***		0.050**		0.077**		0.060**		−0.065*
		(0.004)		(0.021)		(0.030)		(0.028)		(0.033)
GDP per capita	0.016***	0.022***	−0.486***	−0.531***	−0.457***	−0.527***	−0.460***	−0.524***	−0.435***	−0.455***
	(0.005)	(0.003)	(0.008)	(0.012)	(0.019)	(0.018)	(0.013)	(0.014)	(0.039)	(0.038)
Trade openness	−0.002	−0.003	−0.285***	−0.273***	−0.317***	−0.298***	−0.305***	−0.283***	−0.035	−0.031
	(0.003)	(0.003)	(0.046)	(0.044)	(0.029)	(0.030)	(0.029)	(0.030)	(0.045)	(0.041)
Urbanisation	0.001	0.001*	0.908***	0.908***	0.912***	0.912***	0.905***	0.906***	−0.032***	−0.034***
	(0.001)	(0.001)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)	(0.005)	(0.003)
Health expenditure	0.017**	0.021***	−0.383***	−0.435***	−0.352***	−0.408***	−0.348***	−0.402***	−0.385***	−0.402***
	(0.008)	(0.007)	(0.032)	(0.032)	(0.046)	(0.039)	(0.042)	(0.037)	(0.031)	(0.028)
Rule of law	0.001	0.002	0.067***	0.034**	0.079***	0.044**	0.048***	0.015	−0.058***	−0.077***
	(0.004)	(0.002)	(0.011)	(0.014)	(0.017)	(0.017)	(0.014)	(0.016)	(0.013)	(0.022)
Education	0.106***	0.115***	−1.018***	−1.121***	−1.247***	−1.384***	−1.105***	−1.222***	−0.730***	−0.747***
	(0.012)	(0.014)	(0.032)	(0.069)	(0.027)	(0.039)	(0.015)	(0.041)	(0.082)	(0.077)
Income inequality	−0.077**	−0.074**	1.417***	1.395***	1.655***	1.623***	1.635***	1.602***	2.057***	2.047***
	(0.026)	(0.025)	(0.098)	(0.095)	(0.118)	(0.112)	(0.083)	(0.078)	(0.017)	(0.020)

Table 8 (continued)

	Life_exp		*Neo_mort*		*Under_5 mort*		*Infant_mort*		*Mat_mort*	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Constant	3.865***	3.771***	−0.987	−0.200	−0.181	0.923	−0.931	0.046	4.711***	5.096***
	(0.108)	(0.091)	(0.671)	(0.771)	(0.705)	(0.834)	(0.552)	(0.671)	(0.324)	(0.253)
Marginal effects of FI conditioned on different values of ICT (internet and mobile phone penetration)										
Minimum value of ICT	0.026	0.078***	0.486*	−0.322***	0.186	−0.476***	0.301	−0.374***	0.341*	0.437**
	(0.016)	(0.021)	(0.280)	(0.117)	(0.183)	(0.172)	(0.193)	(0.159)	(0.200)	(0.196)
Mean value of ICT	0.003***	0.009***	−0.041*	−0.068***	−0.044***	−0.081***	−0.037**	−0.066***	0.059***	0.103***
	(0.001)	(0.003)	(0.021)	(0.012)	(0.016)	(0.018)	(0.017)	(0.016)	(0.012)	(0.029)
Maximum value of ICT	−0.002	−0.005***	−0.159**	−0.014***	−0.095***	0.003	−0.112**	−0.0004	−0.003	0.032**
	(0.003)	(0.001)	(0.061)	(0.012)	(0.043)	(0.016)	(0.045)	(0.015)	(0.031)	(0.008)
Observations	995	1002	1000	1007	1000	1007	1000	1007	913	920
R2	0.776	0.769	0.963	0.962	0.965	0.963	0.966	0.964	0.883	0.884

Standard errors in parentheses. Life expectancy (Life_exp); Neo-natal mortality (Neo_mort); Under-five mortality (Under_5 mort); Infant mortality (Infant_mort); and Maternal mortality (Mat_mort)

*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$

penetration unconditionally enhance life expectancy, child health and maternal health outcomes. Also, the interactive effect of FI and internet penetration has a statistically significantly reducing effect on neonatal and infant mortality, while the impact of life expectancy, under-five and maternal mortality is statistically insignificant. Additionally, the interactive effect of FI and mobile phone penetration has a statistically significantly reducing effect on life expectancy and maternal mortality. At the same time, the interactive effect of FI and mobile phone penetration significantly increases child mortalities (neonatal, under-five, and infant mortality). We evaluated the marginal effect of financial inclusion on health outcomes conditioned on ICT variables (mobile phone and internet penetration) using Eq. (5):

$$\frac{\partial lnPHO}{\partial FI} = \beta_1 + \delta_3 \times ICT \tag{5}$$

where β_1 is the financial inclusion (FI) coefficients, δ_3 is the coefficient of the interaction term [ICT × Financial Inclusion (FI)]. We evaluated the marginal effect of FI at the minimum, mean and maximum values of internet and mobile phone penetrations. Internet penetration has a mean, minimum and maximum value of −3.473, 3.137 and 4.605, respectively. Also, mobile phone penetration has mean, minimum and maximum values of −0.801, 4.314 and 5.400, respectively.

The marginal analysis shows that the minimum and maximum value of internet penetration, FI, has an insignificant effect on Life_exp; however, at the mean value of internet penetration, FI significantly increases Life_exp by 0.003%. Regarding child health outcomes, FI increases Neo_mort by 0.486% at the minimum value of internet penetration. However, at the mean and maximum values of internet penetration, FI significantly reduces Neo_mort by 0.041% and 0.159%, respectively. Also, at the minimum value of internet penetration, FI has an insignificant effect on Under_5 mort. However, at the mean and maximum values of internet penetration, FI significantly reduces Under_5 mort by 0.044 and 0.095%, respectively. Similarly, at the minimum value of internet penetration, FI has an insignificant effect on Infant_mort. However, at the mean and maximum values of internet penetration, FI significantly reduces Infant_mort by 0.037 and 0.112%, respectively. It is also observed that FI increases Mat_mort by 0.341 and 0.059% at the minimum, mean and maximum value of internet penetration but insignificantly reduces Mat_mort at the maximum value of internet penetration.

The marginal analysis shows that the minimum and maximum value of mobile phone penetration, FI, has significantly increased Life_exp by 0.078 and 0.009%, respectively; however, at the mean mobile phone penetration, FI significantly reduces Life_exp by 0.005%. Regarding child health outcomes, FI significantly reduces Neo_mort by 0.322, 0.068 and 0.014% at the minimum, mean and maximum values of mobile phone penetration. Also, at the minimum and mean value of mobile phone penetration, FI significantly reduces Under_5 mort by 0.476 and 0.081%, respectively, while at the maximum mobile phone penetration, FI has an insignificant effect on Under_5 mort. Similarly, at the minimum and mean value of mobile phone penetration, FI significantly reduces Infant_mort by 0.374 and 0.066%, respectively, but at the maximum value of mobile phone penetration, FI insignificantly reduces Infant_mort. It is also observed that FI increases Mat_mort by 0.437, 0.103, and 0.032% at the minimum, mean, and maximum values of mobile phone penetration. Generally, these findings support that higher ICT penetration (mobile and internet penetration) could support financial inclusion to improve population health outcomes significantly. Therefore, policy

measures to expand access and usage of ICT tools could be beneficial in conditioning financial inclusion to enhance health outcomes.

5 Conclusion and Policy Implications

Currently, extensive empirical studies exist on the impact of financial inclusion on socio-economic outcomes such as economic growth, inequality, and poverty. However, research on financial inclusion and population health is limited and still at the infant stage. Therefore, this article adds to knowledge by inquiring into the health implications of financial inclusion using a global panel dataset for 121 countries between 2004 and 2020. To achieve this paper's objective, our study seeks to provide evidence-based answers to the following policy-relevant questions: (i) Does financial inclusion improve global population health? (ii) Do socio-economic conditions (income inequality and GDP per capita) influence the effect of financial inclusion on population health? (iii) Does ICT (mobile phone and internet penetration) influence the effect of financial inclusion on population health? and (iv) Does financial inclusion's effect on population health differ across geographical regions and income groups? After accounting for endogeneity with heteroskedasticity-based instrumental variable regression and cross-sectional dependency with the Driscol–Kraay estimator, five (5) key findings emerged from this study, which are summarised below:

First, the aggregated sample results showed that financial inclusion improves population health by increasing life expectancy and reducing neonatal, under-five and infant mortality. At the same time, financial inclusion worsened maternal health outcomes. Second, our findings revealed that financial inclusion significantly improves health outcomes by increasing life expectancy and reducing child and maternal mortalities across all income groups. However, financial inclusion has the largest impact on improving population health outcomes in low-income countries than in lower-middle, upper-middle and high-income countries.

Third, the regional effect analysis highlighted that the impact of financial inclusion differs among regions. In South Asia, financial inclusion enhances health outcomes by increasing life expectancy and reducing child health outcomes (neonatal, under-five and infant mortality), while financial inclusion does not significantly determine maternal health. Also, for Europe and Central Asia, financial inclusion is important for improving population health by increasing life expectancy and reducing both child and maternal mortalities. In Latin America and the Caribbean, financial inclusion significantly improves life expectancy and child health outcomes but is not associated with better maternal health outcomes. Similarly, financial inclusion in East Asia and the Pacific reduces child health outcomes (neonatal, under-five and infant mortality) but has not been associated with better improvement in life expectancy and maternal mortality. Also, in the Middle East and North Africa, financial inclusion significantly enhances child health, especially neonatal and infant mortality, but is associated with a negative effect on maternal health outcomes. In sub-Saharan Africa, financial inclusion has not been associated with significant improvement in health outcomes.

Fourth, our results also show that income inequality, GDP per capita, and ICT condition the impact of financial inclusion on population health. Financial inclusion substantially improves population health outcomes at higher GDP per capita and increases mobile phone and internet penetration. At the same time, financial inclusion worsens population health outcomes at higher income inequality. Finally, our analysis indicated that other factors such

as GDP per capita, health expenditure, education, and trade openness increase life expectancy while reducing child and maternal mortality. However, income inequality and urbanisation reduced life expectancy while increasing child and maternal mortality.

Apart from the knowledge contributions, the findings established in this study are key for improving global health outcomes. The findings suggest that financial inclusion could serve as an instrument for enhancing population health outcomes. This study, therefore, calls for policies and strategies that could boost financial inclusion to improve global health outcomes. Enhancing financial inclusion requires policymakers, financial regulators and financial institutions to address structural barriers that limit the effectiveness and efficiency of the financial system. Specific policies and strategies that could promote competition in the financial system, financial literacy, financial innovation, cost-effective delivery of financial services, and minimising financial access barriers such as collateral security are fundamental for enhancing financial inclusion. Our findings highlight that the effectiveness of financial inclusion depends on economic output, ICT penetration and income inequality. Therefore, structural policies could boost economic performance and improve access to and usage of ICT, which could supplement financial inclusion to enhance population health outcomes. Addressing income inequality through redistributive policies could also strengthen the favourable effect on population health outcomes.

This study makes a significant contribution to knowledge and policies to improve health outcomes. However, this study is not free from limitations, which present some avenues for future studies. This study examines the effect of financial inclusion on health outcomes such as life expectancy, child mortality and maternal mortality while not considering health-seeking behaviour such as immunisation and out-of-pocket expenditure. Therefore, future studies can extend our study by investigating the effect of financial inclusion on immunisation and out-of-pocket expenditure in developing countries. Also, future studies can contribute to the literature by examining the factors that mediate the impact of health outcomes and health-seeking behaviour across the globe, especially in developing countries. Finally, improving financial inclusion depends on the effectiveness of countries' financial inclusion policies and strategies. However, the effectiveness of financial inclusion policies and strategies is dictated by the quality of countries' governance. While this study did not investigate if the impact of financial inclusion on health outcomes depends on political institutions, future studies can contribute to knowledge by probing the role of political institutions (governance) on the effect of financial inclusion on health outcomes and health-seeking behaviours across the globe.

Appendix

See Tables 9, 10 and 11.

Table 9 List of countries used for the analysis

Albania, Algeria, Andorra, Angola, Argentina, Australia, Austria, Bangladesh, Barbados, Belgium, Belize, Benin, Bhutan, Bolivia, Bosnia and Herzegovina, Botswana, Brazil, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Chad, Chile, Colombia, Costa Rica, Croatia, Cyprus, Denmark, Djibouti, Dominica, Ecuador, El Salvador, Finland, France, Gabon, Georgia, Germany, Ghana, Greece, Grenada, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, Hungary, Iceland, India, Indonesia, Iraq, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kenya, Kuwait, Latvia, Lebanon, Liberia, Libya, Lithuania, Luxembourg, Malawi, Malaysia, Maldives, Mali, Malta, Mauritius, Mexico, Mongolia, Montenegro, Morocco, Namibia, Nepal, New Zealand, Nicaragua, Niger, Nigeria, Norway, Oman, Pakistan, Panama, Paraguay, Peru, Philippines, Portugal, Qatar, Romania, Rwanda, Samoa, Saudi Arabia, Senegal, Seychelles, Sierra Leone, Singapore, South Africa, Spain, Sri Lanka, Sudan, Suriname, Sweden, Switzerland, Thailand, Timor-Leste, Togo, Tonga, Trinidad and Tobago, Tunisia, Uganda, Ukraine, United Arab Emirates, United Kingdom, Uruguay, Vanuatu, Vietnam, Zambia and Zimbabwe

Table 10 Effect of financial inclusion on health outcomes, OLS estimates

	Model 1 *Life_exp*	Model 2 *Neo_mort*	Model 3 *Under_5 mort*	Model 4 *Infant_mort*	Model 5 *Mat_mort*
Financial Inclusion (FI)	0.003**	−0.047***	−0.048***	−0.041***	0.064***
	(0.001)	(0.014)	(0.013)	(0.013)	(0.010)
GDP per capita	0.024***	−0.555***	−0.556***	−0.552***	−0.465***
	(0.004)	(0.027)	(0.029)	(0.028)	(0.035)
Trade openness	−0.001	−0.296***	−0.329***	−0.312***	−0.040
	(0.004)	(0.042)	(0.042)	(0.041)	(0.038)
Urbanisation	0.002*	0.900***	0.901***	0.896***	−0.036***
	(0.001)	(0.011)	(0.012)	(0.012)	(0.009)
Health expenditure	0.020***	−0.425***	−0.397***	−0.392***	−0.405***
	(0.005)	(0.041)	(0.040)	(0.039)	(0.042)
Rule of law	0.001	0.051	0.066*	0.037	−0.070
	(0.004)	(0.038)	(0.040)	(0.038)	(0.044)
Education	0.129***	−1.254***	−1.559***	−1.386***	−0.825***
	(0.008)	(0.062)	(0.065)	(0.063)	(0.067)
Income inequality	−0.073***	1.397***	1.623***	1.603***	2.044***
	(0.022)	(0.114)	(0.137)	(0.125)	(0.112)
Constant	3.720***	0.257	1.555**	0.630	5.234***
	(0.088)	(0.599)	(0.651)	(0.616)	(0.516)
Observations	1005	1010	1010	1010	923
R2	0.768	0.961	0.962	0.963	0.884

Robust standard errors in parentheses. Life expectancy (Life_exp); Neo-natal mortality (Neo_mort); Under-five mortality (Under_5 mort); Infant mortality (Infant_mort); and Maternal mortality (Mat_mort)

*p < 0.10, **p < 0.05, ***p < 0.01

Table 11 Financial Inclusion and health outcomes, Driscol–Kraay estimator estimates with time fixed effect

	Model 1 *Life_exp*	Model 2 *Neo_mort*	Model 3 *Under_5 mort*	Model 4 *Infant_mort*	Model 5 *Mat_mort*
Financial Inclusion (FI)	0.002*	− 0.039***	− 0.040***	− 0.033***	0.066***
	(0.001)	(0.005)	(0.007)	(0.006)	(0.016)
GDP per capita	0.024***	− 0.549***	− 0.551***	− 0.547***	− 0.462***
	(0.003)	(0.010)	(0.014)	(0.012)	(0.034)
Trade openness	− 0.001	− 0.294***	− 0.326***	− 0.309***	− 0.042
	(0.002)	(0.032)	(0.015)	(0.016)	(0.038)
Urbanization	0.001***	0.904***	0.906***	0.901***	− 0.036***
	(0.000)	(0.004)	(0.006)	(0.006)	(0.003)
Health expenditure	0.020**	− 0.425***	− 0.396***	− 0.391***	− 0.408***
	(0.007)	(0.033)	(0.040)	(0.038)	(0.024)
Rule of law	0.001	0.040**	0.056***	0.026**	− 0.071***
	(0.002)	(0.014)	(0.009)	(0.010)	(0.018)
Education	0.125***	− 1.204***	− 1.510***	− 1.334***	− 0.816***
	(0.012)	(0.071)	(0.044)	(0.045)	(0.071)
Income inequality	− 0.072**	1.370***	1.599***	1.577***	2.042***
	(0.027)	(0.107)	(0.125)	(0.091)	(0.019)
Time-fixed effect	Yes	Yes	Yes	Yes	Yes
Constant	3.725***	0.018	1.325**	0.391	5.167***
	(0.083)	(0.558)	(0.596)	(0.440)	(0.186)
Observations	1005	1010	1010	1010	923
R2	0.771	0.962	0.963	0.964	0.884

Standard errors in parentheses. Life expectancy (Life_exp); Neo-natal mortality (Neo_mort); Under-five mortality (Under_5 mort); Infant mortality (Infant_mort); and Maternal mortality (Mat_mort)

*p < 0.10, **p < 0.05, ***p < 0.01

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