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Unveiling the effect of income inequality on safe drinking water, sanitation and hygiene (WASH): Does financial inclusion matter?

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ABSTRACT

Access to safe drinking water, sanitation, and hygiene (WASH) is crucial for disease prevention and improving general health outcomes. However, a significant number of people across the globe still lack access to safe drinking water and practice open defecation. Therefore, evidence-based research is needed to guide policy-makers in improving WASH adoption and practice across the globe. In this study, we add to knowledge and policy by probing the role of income inequality and financial inclusion on access to improved WASH facilities using a comprehensive panel dataset from 119 countries between 2004 and 2020. We used the heteroskedasticity-based instrumental variable regression and the Driscoll-Kraay estimator to account for endogeneity and cross-sectional dependency inherent in panel data, respectively. Our preferred endogeneity and cross-sectional dependency-corrected results show that income inequality reduces access to safe WASH facilities. Our study demonstrates that financial inclusion significantly increases access to safe WASH facilities. Income inequality and financial inclusion have heterogeneous effects on access to safe WASH facilities across rural and urban settings, income groups, and geographical regions. Through our interaction and marginal effect analysis, we document that improvement in financial inclusion reduces the adverse effect of income inequality on safe WASH adoption and practices. These findings highlight that policies that strengthen financial inclusion services and further address income inequality would improve WASH adoption and practices. Considering the inhibiting and enhancing effects of income inequality and financial inclusion, respectively, governments could adopt social welfare policies to tackle the former and also put in measures to enhance financial development and inclusion to enhance the latter.

1. Introduction

The world is racing towards the attainment of the Sustainable Development Goals (SDGs). Despite the progress made in many areas, there still exists some pertinent issues that require attention. Key among these is access to safe drinking water, sanitation, and hygiene (WASH) facilities and services. Access to safe WASH aligns with SDG number 6, which seeks to "ensure availability and sustainable management of water and sanitation for all". However, the World Health Organization (WHO) expresses concerns that the global community is not making sufficient progress towards achieving this goal (WHO, 2021). To attain these, the United Nations indicates that the speed of progress has to hasten 6 times, 5 times and 3 times for drinking water, sanitation and hygiene, respectively (UNDESA, 2023). Developing countries face the major brunt of the current WASH situation, requiring greater acceleration efforts in catching up with other countries and attaining universal WASH coverage. Many of these countries are battling with extending WASH facilities to rural areas and the poor and vulnerable. WHO (2021) reckons that, at the current pace, by 2030, a whopping 1.6 billion, 2.8 billion, and 1.9 billion people worldwide will be left without safe WASH facilities, respectively. This beckons to investigate the factors decelerating or accelerating the WASH conditions in countries across the globe.

The current WASH situation has attracted some literature; however, the major focus has been on its implications for diseases and public

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health (Augsburg & Rodríguez-Lesmes, 2018; Cairncross et al., 2010; Prüss-Ustün et al., 2019; Prüss-Ustün et al., 2014; Waddington & Snilstveit, 2009). Although nascent, another strand of the literature has looked at factors militating against the attainment of safe WASH for all. The literature has identified mainly cultural, institutional, and governance management systems as impediments to the SDG of attaining universal and equitable safe WASH coverage for all (Akpabio & Takara, 2014; WHO, 2019). Attention to economic factors is not much emphasized. Wealth inequalities are a challenge to the attainment of basic WASH services (Dangui & Jia, 2023; WHO, 2021).[1] The richest have better and quality access than the poor. Neglected tropical diseases resulting from unsafe WASH conditions are often viewed as indicators of poverty and disadvantage. These diseases are more widespread in rural areas and among the poorest, with limited access to safe WASH services (WHO, 2015). The WHO (2017) emphasizes that a tremendous financing gap remains one of the greatest impediments to achieving universal and equitable WASH (WHO, 2019). While the responsibility of WASH financing primarily falls on the state, the WHO highlights that households in many countries contribute significantly towards it (WHO, 2017, 2019). This includes investments in self-supply solutions like wells, water tanks, and household sanitation (Ikeda & Liffiton, 2019; WHO, 2019). For example, UN-Water global analysis and assessment of sanitation and drinking-water (GLAAS) surveys conducted in 2014 (for 19 countries) and 2016/2017 (for 25 countries) showed that household financing towards WASH was nearly 75 % and 66 %, respectively (WHO, 2017, 2019). This implies factors that affect the economics of households, such as income inequality, financial exclusion, and poverty, could affect households' access to WASH and contribution to the attainment of universal and equitable WASH (Ikeda & Liffiton, 2019; WHO, 2021). In this paper, we emphasize the economic determinants of WASH.

Perusing the literature, we discovered just a handful of studies examining the effect of income inequality and financial inclusion on WASH. For example, the effect of access to credit on households' investment in sanitation (Dangui and Jia, 2023; Augsburg, Caeyers, Giunti, Malde, & Smets, 2019; Augsburg, Caeyers, & Malde, 2019). These studies have focused on financial inclusion and not on income inequality; they have also focused on specific aspects of WASH and individual countries. Augsburg, Caeyers, and Malde (2019), for instance, analyse how micro-credit affects individual uptake of household toilets in India. Following the gap in the literature, this study examines the effect of income inequality and financial inclusion on access to improved WASH facilities using a comprehensive panel dataset from 119 countries between 2004 and 2020. There are at least four important differences between the present study and the previous ones, highlighting our contribution to the literature. Firstly, this study emphasizes the unconditional and conditional effect of income inequality and financial inclusion on WASH using a cross-country sample across the globe. Secondly, the present study focuses on the broader sense of WASH (which includes safe drinking water, sanitation and hygiene) relative to specifics such as drinking water only or access to toilet facilities only. In considering the previous literature, we do not get a fuller picture of the effect of income inequality or financial inclusion on WASH practices. At best, they provide a partial view of WASH and narrow policy implications, as one cap may not fit all. Policy inferences for safe drinking water may be different from those for sanitation and hygiene. In this paper, we capture a broader sense of WASH, making our conclusions and deductions more inclusive for policy analyses. Thirdly, we analyse the effect of income inequality and how it interacts with financial inclusion to affect access to WASH. To the best of our knowledge, this is the first study to provide such analyses.

Lastly, the present study, unlike previous ones, presents a sampling heterogeneity analysis by splitting the sample to ascertain the rural–urban, regional and income grouping dimensions of the effect of income inequality and financial inclusion (including their interactions). The distinction between the rural and urban settings is necessary due to the significant disparity in access to safe WASH facilities and economic conditions in rural areas. For example, in 2020, as 86 % of the urban population had access to safely managed water, only 60 % in the rural had. Regarding sanitation, 62 % used safely managed sanitation services, and 44 % did in rural areas (WHO, 2021). The regional and income groupings are also considered important as the WHO emphasizes regional and income grouping discrepancies in attaining universal safe WASH coverage. For example, in 2020, about 91 % of the population in Central and South Asia, 97 % in Latin America and the Caribbean had access to at least basic water services, just about 65 % and 57 % did in Sub-Saharan Africa and Oceania, respectively (WHO, 2021). Regarding income groupings, over 99 % of the population in high-income countries had access to at least basic water services, whereas 59 % and 88 % did in low-income and lower-middle-income countries, respectively, in the year 2020 (WHO, 2021).

Besides the contribution to literature, this study is also important for policy. The provision of safe drinking water and proper sanitation is essential for promoting human well-being. It supports good health and sustains livelihoods while also contributing to the creation of healthy environments. Drinking unsafe water can lead to health issues such as diarrhoea and neglected tropical diseases such as trachoma, schistosomiasis, and dengue (Dangui & Jia, 2023; Prüss-Ustün et al., 2019; WHO, 2015) while the absence of proper sewage treatment can pollute drinking water supplies and the environment, resulting in significant challenges for communities. For example, Augsburg and Rodríguez-Lesmes (2018) examine how important sanitation coverage is for child health (particularly height growth). Lack of safe WASH facilities affects the education of many students, especially girls, during their menstrual period (Dickin, Bisung, Nansi, & Charles, 2021; WHO, 2021). WASH is a fundamental aspect of public health and serves as a driving force for various areas of human and national development (Dangui & Jia, 2023; WHO, 2018, 2019). We believe that the results will inform policy on the ways to improve the WASH situation across countries.

Our preferred endogeneity and cross-sectional dependency-corrected results show that income inequality significantly reduces WASH adoption and practices. The study also indicates that financial inclusion significantly increases WASH adoption and practices. The study highlights that income inequality and financial inclusion affect WASH differently across rural and urban settings, income groups, and geographical regions. Through our interaction and marginal effect analysis, the results imply that improvement in financial inclusion reduces the adverse effect of income inequality on WASH adoption and practices. The remainder of the paper proceeds as follows. Section 2 provides a review of the literature on the topic. Section 3 presents the research methodology. Section 4 presents and discusses the empirical results of the study, and section 5 concludes the paper.

2. Review of related literature

2.1. Effect of income inequality on WASH

The extant literature suggests there is geographical inequality in access to safe WASH both within and across countries (de Jesus, Monteiro, & Tomasella, 2023; Pullan, Freeman, Gething, & Brooker, 2014). The developing world has witnessed an improvement in access to safe WASH since 2000, but access remains relatively low in Sub-Saharan Africa, where such facilities are mostly concentrated in urban areas (Deshpande et al., 2020). Geographical inequality in access to improved WASH poses a major challenge in rural areas where the provision of basic social services is generally poor, with significant health implications (Tseole et al., 2022). The geographical disparities in the provision of WASH are further compounded by climate change, low investment in

[1] Basic water services involves drinking from an improve source if the time taken for a round trip, including waiting in line, does not exceed 30 min (WHO, 2021).

WASH infrastructure, and low knowledge of water-borne diseases (Tseole et al., 2022). Achore and Bisung (2022), for example, showed that inequalities in access to safe water could have a detrimental effect on wellbeing. The study found that perceived water inequality significantly contributed to water-related psycho-emotional distress.

The literature so far highlights geographical inequality as a major obstacle to WASH, with limited empirical evidence on how income inequality affects access to WASH in developed and developing countries. Income is a major obstacle to safe WASH facilities for many low-income households, particularly in developing countries (Ikeda & Liffiton, 2019). The upfront cost required for securing water facilities at home is expensive and renders many households below the income ladder unequal access to water. In a very comprehensive study, Chancel and Piketty (2021) found that global income inequality had always been very large and indicative of the enduring hierarchical structure of the global economic system. They found that the share of global income held by the top 10 % had fluctuated within the range of 50 % to 60 %, while the bottom 50 % had typically held a share of only 5 % to 10 %. Moreover, the top 1 % share of global income has usually been three to four times greater than the share held by the bottom 50 %, which is typically comparable to the top 0.1 % share. The 2020 World Social Report (UN, 2020) emphasized income inequality as a global pressing concern due to the increasing inequality within and across countries. The growing disparities in income and inadequate opportunities lead to a vicious cycle of inequality, poverty, disappointment, and dissatisfaction perpetuating across generations. Income inequality can worsen the situation of poverty and also push many more into poverty (UN, 2013). This aggravates access to safe WASH facilities as the poor have inadequate and unequal access to these services. A smaller proportion of poor households have access to water networks relative to non-poor households, and even when they do, the quality of services they receive is often inferior (Ikeda & Liffiton, 2019; Pattanayak et al., 2006). Furthermore, due to unfair subsidization practices, exploitation, and a dearth of economies of scale, poor households frequently end up paying more for water services than non-poor households.

2.2. The effect of financial inclusion on WASH

Financial inclusion entails access to and the use of formal financial services (Kling, Pesqué-Cela, Tian, & Luo, 2020). The primary objective of financial inclusion is to provide everyone access to affordable and useful financial products and services, such as payments, transactions, savings, credit, and insurance (Ikeda & Liffiton, 2019; Omar & Inaba, 2020). Financial inclusion offers opportunities to augment household income by providing access to credits that could be invested in businesses, enabling individuals to have bank accounts that promote savings and allowing access to loans that can facilitate access to WASH. Therefore, financial inclusion can generate income opportunities for the poor, enabling them to afford safe WASH services. Financial inclusion is also largely found to reduce poverty (Koomson, Villano, & Hadley, 2020; Omar & Inaba, 2020; Park & Mercado, 2018). As financial inclusion is known to create an enabling environment for enhancing households' welfare, it is also widely acknowledged as a means to improved access to safe WASH for households (Augsburg, Caeyers, Giunti, et al., 2019; Dangui & Jia, 2023; Ikeda & Liffiton, 2019).

In the empirical literature, Dangui and Jia (2023) have examined the effect of financial inclusion on access to water in Togo. The study found a positive and significant effect of financial inclusion on access to safe drinking water. This effect was more pronounced among rural areas, female-headed households, and the northern part of the country. Cavoli, Gopalan, Onur, & Xenarios (2023) examined the effect of digital and traditional financial inclusion on access to sanitation across 84 low-and middle-income countries from 2000 to 2017. The results suggest that digital and traditional financial inclusion significantly enhance access to sanitation services in lower and middle-income countries, especially in rural areas. Credit constraints are noted as barriers to investment in preventive health facilities for poor households in developing countries (Augsburg, Caeyers, Giunti, et al., 2019). Using a randomised control trial in rural India, Augsburg, Caeyers, Giunti, et al. (2019) found that the provision of credit earmarked for sanitation increased the uptake and motivation of toilet construction. Augsburg, Caeyers, Giunti, et al. (2019) explained that the label of the credit, which is a credit designed for a specific investment purpose (sanitation), is significant in influencing household uptake to invest in sanitation.

While the literature on the relationship between financial inclusion and WASH is nascent with limited empirical evidence, ample evidence suggests that financial inclusion affects both poverty and income inequality. Economic theory predicts that financial exclusion can aggravate prevailing income inequality and poverty of the excluded. Financial inclusion can significantly affect income inequality by growing opportunities in education and entrepreneurship among the poor and the disadvantaged (Dangui & Jia, 2023; Kling et al., 2020; Koomson & Danquah, 2021). This is the case as financial inclusion creates opportunities to access loans and other financial facilities that can be invested in education and businesses (Ikeda & Liffiton, 2019; Koomson et al., 2020). Education improves human capital and the earning abilities of those who acquire it. Investment in businesses could lead to business expansion and increased profits, enabling business owners to climb the income ladder. However, Kling et al. (2020) reveal that as reliance on loans (formal or informal) exacerbates income inequality, access to bank accounts enhances the future income distribution of households. Therefore, Kling et al. (2020) conclude that financial inclusion may not benefit everyone. Most studies have, however, found a negative relationship between financial inclusion and income inequality (Mookerjee & Kalipioni, 2010; Neaime & Gaysset, 2018; Omar & Inaba, 2020; Park & Mercado, 2018). Hence, financial inclusion may help reduce poverty and income inequality, increasing the economic opportunities for households to be able to afford safe WASH services.

With respect to the empirical literature on the financial inclusion-income inequality nexus, Kim (2016), for example, showed that financial inclusion could offset the negative relationship between income inequality and economic growth. A study in the Middle East and North Africa by Neaime and Gaysset (2018) found significant effects of financial inclusion on income inequality and financial stability but no statistically significant effect on poverty. Khan et al. (2022) showed that financial inclusion improved financial stability and decreased poverty and income inequality in Africa. This evidence is corroborated by recent studies suggesting that digital financial inclusion influences income inequality in Africa (Atadouanla Segning, Fouopi Djiogap, Piabuo, & Ngasseu Noupie, 2023; Chinoda & Mashamba, 2021; Kebede, Naranpanawa, & Selvanathan, 2023; Soro & Senou, 2023). Similar evidence is found in Latin America (Polloni-Silva, da Costa, Moralles, & Sacomano Neto, 2021) and in Asia (Chinnakum, 2023; Huang & Zhang, 2020; Luo & Li, 2022), indicating a significant and negative relationship between financial inclusion and income inequality. Generally, the literature demonstrates that financial inclusion is instrumental in reducing poverty and income inequality in developing countries (Omar & Inaba, 2020) and in developed countries (Tsouli, 2022).

Contrary to other studies, Fomum and Aziakpono (2017) showed that financial inclusion could equally reinforce income inequality. Khoirunurrofik and Fitriatinnisa and Khoirunurrofik (2021) found that financial inclusion had a negative and significant effect on poverty on the one hand and a significant positive effect on income inequality on the other. A recent study also found a positive relationship between financial inclusion and income inequality (Wong, Badeeb, & Philip, 2023). The heterogeneity in the effect of financial inclusion is driven by the institutional context.

The literature suggests that financial inclusion can influence income inequality but fails to explore how the interaction between the former and the latter affects access to WASH. The interplay between financial inclusion and income inequality has significant implications for WASH.

We expect that financial inclusion will offset the negative effect of income inequality on WASH, given its potential to reduce income inequality by facilitating access to credit, savings, and remittances, especially among the disadvantaged segment of society, such as women and rural dwellers. Therefore, this study not only seeks to examine the direct effect of income inequality and financial inclusion on WASH but also explores their interrelationship and implications.

3. Methods and data

3.1. Model specification and estimation strategies

This research aims to unravel the effect of income inequality and financial inclusion on access to WASH. To attain this research objective, the reduced-form panel data model for estimating the effect of income inequality and financial inclusion on WASH is stated in Eq. (1).

$$WASH_{it} = \alpha_0 + \beta_1 GINI_{i,t} + \beta_2 FI_{i,t} + X_{i,t}\beta + \varepsilon_{i,t} \quad (1)$$

where $WASH_{i,t}$ represents access to safe drinking water, sanitation and hygiene of country i at time t. $GINI_{i,t}$ is income inequality of country i at time t; $FI_{i,t}$ is financial inclusion in country i at time t. $X_{i,t}$ represents a vector of control variables (GDP per capita, government spending, remittances, rule of law, foreign aid, and urbanisation) that affect WASH. α_0 is the constant parameter of the model. $\varepsilon_{i,t}$ denotes the error term. β_1 and β_2 are the unknown coefficients of interest to be estimated. Based on the literature, we expect $\beta_1 < 0$ and $\beta_2 > 0$.

From the literature, it can be inferred that the effect of income inequality on WASH can be moderated by financial inclusion. There are some reasons why financial inclusion could moderate the effect of income inequality on WASH. Imperfections in the financial system exclude most poor households from accessing financial services such as loans (Banerjee & Newman, 1993). The exclusion of the poorer households from the financial system deters their household investment and standard of living. Therefore, through financial inclusion, poor households could easily access financial services and contribute to a reduction in income inequality (Demir, Pesqué-Cela, Altunbas, & Murinde, 2022). Several studies have confirmed that financial inclusion is key to addressing income inequality (Demir et al., 2022; Park & Mercado Jr, 2018; Turegano & Herrero, 2018). This indicates that the effect of income inequality on WASH can be moderated by financial inclusion. We, therefore, extend Eq. (1) by including the interaction between income inequality and financial inclusion ($GINI \times FI$) in the empirical model. Eq. (2) is used to test if financial inclusion moderates the effect of income inequality on WASH.

$$WASH_{it} = \alpha_0 + \beta_1 GINI_{i,t} + \beta_2 FI_{i,t} + \theta_j (GINI \times FI)_{i,t} + X_{i,t}\beta + \varepsilon_{i,t} \quad (2)$$

To have a meaningful interpretation of the interaction effect, we follow the recommendation of Brambor, Clark, & Golder (2006) and use Eq. (3) to examine the marginal effect of income inequality on WASH conditioned on different values of financial inclusion.

$$\frac{\partial WASH_{i,t}}{\partial GINI_{i,t}} = \beta_1 + (\theta_j \times FI_{i,t}) \quad (3)$$

For the empirical estimation, the ordinary least squares (OLS) estimator (with robust standard errors) is used to estimate the baseline results. Despite OLS being the best linear unbiased estimator, it can generate biased estimates in the presence of endogeneity. This study's main sources of endogeneity stem from measurement error (especially in the financial inclusion data) and variable omission bias. In our empirical model, we handle the variable omission bias by controlling for the effect of potential important correlates of WASH, such as GDP per capita, government spending, remittances, rule of law, foreign aid, and urbanisation, as inferred from the literature. The financial inclusion variables used in this study are based on survey data. However, surveys are noted to be susceptible to reporting biases leading to measurement errors in the data. Self-reported data may be only as good as the respondents remember. Also, household heads mostly manage financial decisions, and other household members may not have sufficient information to respond to financial inclusion questions accurately. These discussions show that financial inclusion variables suffer from measurement errors, leading to endogeneity.

By way of methodology to account for the endogeneity issue, we use the Lewbel (2012) two-stage least squares estimator (Lewbel IV-2SLS). Unlike the conventional two-stage least squares, this econometric technique is best applied when obtaining an appropriate external instrument is difficult or when the external instrument is weak enough to identify the structural equation (Lewbel, 2012). The Lewbel IV-2SLS is capable of generating internal instruments to account for endogeneity (Lewbel, 2012). Thus, the Lewbel IV-2SLS has the capacity to construct its internal instruments, which are heteroskedasticity-based instruments. The heteroskedasticity-based instruments are constructed from the product of the auxiliary equation residuals and each of the included exogenous variables in mean-centred form (Lewbel, 2012). In using the Lewbel IV-2SLS, two main identification strategies were adopted. The first identification strategy involves using an external instrument. We used the implementation of a national financial inclusion strategy (NFIS) as the external instrument. According to the Alliance for Financial Inclusion (AFI, 2022), implementing a well-developed and coordinated NFIS facilitates the development of an inclusive financial system, which is critical for enhancing peoples' access to financial services. This indicates that countries that have implemented NFIS have a higher probability of improving inclusivity in the financial system than countries that have not. NFIS implementation directly affects financial inclusion but has no direct effect on WASH. The NFIS is a dummy variable: 1 for countries that have implemented NFIS and 0 for countries without implementation of NFIS. The second identification strategy involves using the heteroskedasticity-based instrument generated internally by the Lewbel IV-2SLS. The Lewbel IV-2SLS has been used in many empirical studies to account for endogeneity.

We further deployed the Driscoll and Kraay (1998) estimator as an alternative technique to test the robustness of the results. This econometric technique is important since it accounts for autocorrelation and heteroskedasticity. At the same time, the Driscoll–Kraay estimator generates estimates robust to both cross-sectional and temporal dependence (Hoechle, 2007). Further, the Driscoll and Kraay econometric technique can handle missing data series and works with balanced and unbalanced panels (Hoechle, 2007).

3.2. Data description and sources

This study constructs a comprehensive panel dataset from 119 countries[2] between 2004 and 2020 to estimate the effect of income inequality and financial inclusion on access to improved WASH facilities. The data in the study are extracted from World Development Indicators (WDI), the Standardized World Income Inequality Database (SWIID) and the International Monetary Fund's Financial Access Survey (FAS) database.

The outcome variable, *WASH,* is based on nine (9) different variables that measure access to safe WASH: (1) access to basic drinking water measured as natural log of people using at least basic drinking water services (% of population); (2) rural population access to basic drinking water measured as natural log of people using at least basic drinking water services, rural (% of rural population); (3) urban population access to basic drinking water measured as natural log of people using at least basic drinking water services, urban (% of urban population); (4) access to basic sanitation service measured as natural log of people using at least basic sanitation services (% of population); (5) rural population

[2] We have included the list of the countries in the Appendix Table 1.

Table 1
Descriptive Statistics.

Variable	Mean	Std. Dev.	Min	Max
Access to basic drinking water (log)	4.448	0.218	3.456	4.605
Rural population access to basic drinking water (log)	4.317	0.335	3.12	4.605
Urban population access to basic drinking water (log)	4.539	0.092	4.1	4.605
Access to basic sanitation service (log)	4.171	0.601	1.996	4.605
Rural population access to basic sanitation (log)	3.914	0.865	0.439	4.605
Urban population access to basic sanitation service (log)	4.284	0.418	2.733	4.605
Access to handwashing facilities (log)	3.529	1.061	−0.404	4.598
Rural population access to handwashing facilities (log)	3.246	1.247	−2.206	4.598
Urban population access to handwashing facilities (log)	3.824	0.812	0.566	4.597
Income inequality (log)	3.645	0.21	3.14	4.173
Financial inclusion (FI) index	0	1	−0.132	16.226
GDP per capita (log)	8.671	1.429	5.574	11.63
Government spending	16.038	5.655	2.047	56.854
Remittances (log)	0.335	1.815	−8.584	3.671
Rule of law	0.049	0.962	−1.87	2.125
Foreign aid (log)	19.558	1.492	12.429	23.993
Urbanization (log)	15.241	1.898	10.096	20.01

access to basic sanitation service measured as natural log of people using at least basic sanitation services, rural (% of rural population); (6) urban population access to basic sanitation service measured as natural log of people using at least basic sanitation services, urban (% of urban population); (7) access to handwashing facilities measured as natural log of people with basic handwashing facilities including soap and water (% of population); (8) rural population access to handwashing facilities measured as natural log of people with basic handwashing facilities including soap and water, rural (% of rural population); and (9) urban population access to handwashing facilities measured as natural log of people with basic handwashing facilities including soap and water, urban (% of urban population). These myriad WASH variables enable us to understand social and financial barriers to WASH comprehensively. All the WASH indices are extracted from WDI.

Income inequality and financial inclusion are the key explanatory variables. We use the natural log of post-tax/post-transfer Gini index from SWIID to measure income inequality. The SWIID income inequality variable is important for this study as it combines and standardises inequality data from reputable international databases, including the World Income Inequality Database, Luxembourg Income Studies, and World Income Distribution Data, among others (see, Solt, 2016).

Regarding financial inclusion, we adopted the multidimensional approach to construct the financial inclusion (FI) variables. Specifically, we apply the principal component analysis (PCA) approach to four key financial inclusion variables: Automated Teller Machines (ATMs), outstanding deposits with commercial banks, outstanding loans from commercial banks, and branches of commercial banks to generate financial inclusion index. The PCA is applied to minimise multicollinearity among the individual financial inclusion indicators. Before applying the PCA technique, we used the Z-score approach (see equation (4) to normalise these individual financial inclusion indicators due to differences in their scale and units. The data used to construct the financial inclusion variable are extracted from the International Monetary Fund's Financial Access Survey (FAS) database.

$$\mathrm{Z-score} = \frac{X_i - \overline{X}}{\alpha} \tag{4}$$

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

Following the literature, we control for the following variables: *GDP per capita*, measured as the natural log of GDP per capita (constant 2020 US$). *Government spending* is measured as general government final consumption expenditure (% of GDP). *Remittances*, measured as the natural log of personal remittances received (% of GDP). *Rule of law*, measured with the rule of law index, which captures the degree to which people have trust in and adhere to the rules of society, and especially the quality of contract enforcement, property rights, the police, and the courts, in addition to the probability of crime and violence. *Foreign aid*, measured as the natural log of net official development assistance and official aid received (constant 2020 US$). *Urbanisation*, measured as the natural log of the urban population. All the control covariates are extracted from WDI (see Appendix Table 1).

Table 1 shows the descriptive statistics of the variables. We expect

Table 2
Effect of income inequality and financial inclusion on WASH [Baseline results].

	1	2	3	4	5	6	7	8	9
	ABDWS	ABDWS_R	ABDWS_UR	ABSS	ABSS_R	ABSS_UR	HWF	HWF_R	HWF_UR
GDP per capita	0.143***	0.161***	0.046***	0.392***	0.470***	0.297***	0.737***	0.849***	0.437***
	(0.010)	(0.015)	(0.005)	(0.026)	(0.042)	(0.017)	(0.040)	(0.052)	(0.030)
Government spending	0.004***	0.004**	0.003***	0.021***	0.019***	0.017***	0.014**	0.012	0.014**
	(0.001)	(0.002)	(0.001)	(0.003)	(0.004)	(0.002)	(0.007)	(0.009)	(0.006)
Remittances	0.031***	0.059***	0.015***	0.047***	0.080***	0.039***	0.088***	0.130***	0.047***
	(0.003)	(0.007)	(0.002)	(0.008)	(0.012)	(0.005)	(0.012)	(0.017)	(0.011)
Rule of law	0.071***	0.154***	0.040***	0.034	0.129***	0.010	0.013	0.029	0.063
	(0.011)	(0.018)	(0.007)	(0.024)	(0.035)	(0.019)	(0.058)	(0.076)	(0.050)
Foreign aid	−0.018***	−0.031***	−0.008**	−0.014	−0.005	−0.015	−0.036*	−0.063**	−0.035*
	(0.005)	(0.008)	(0.003)	(0.012)	(0.019)	(0.009)	(0.021)	(0.030)	(0.019)
Urbanization	0.026***	0.032***	0.009***	0.030***	0.014	0.019***	0.090***	0.080***	0.068***
	(0.003)	(0.005)	(0.002)	(0.006)	(0.010)	(0.005)	(0.020)	(0.028)	(0.017)
Income inequality	−0.349***	−0.601***	−0.107***	−0.803***	−1.277***	−0.559***	−1.469***	−1.780***	−1.261***
	(0.031)	(0.053)	(0.019)	(0.072)	(0.116)	(0.047)	(0.152)	(0.207)	(0.131)
Financial inclusion [FI]	0.007***	0.013***	0.004***	0.030***	0.036***	0.029***	0.032***	0.047***	0.025***
	(0.002)	(0.003)	(0.001)	(0.005)	(0.007)	(0.005)	(0.009)	(0.012)	(0.007)
Constant	4.472***	5.300***	4.544***	3.438***	4.527***	3.696***	2.595***	3.340***	4.794***
	(0.179)	(0.285)	(0.116)	(0.447)	(0.734)	(0.280)	(0.748)	(1.091)	(0.643)
Observations	749	714	716	749	714	716	364	363	354
R2	0.631	0.550	0.494	0.648	0.578	0.623	0.732	0.702	0.628

Note: Robust standard errors in parentheses. (1) ABDWS: Access to basic drinking water; (2) ABDWS_R: Rural population access to basic drinking water; (3) ABDWS_UR: Urban population access to basic drinking water; (4) ABSS: Access to basic sanitation services; (5) ABSS_R: Rural population access to basic sanitation services; (6) ABSS_UR: Urban population access to basic sanitation services; (7) HWF: access to hand washing facilities; (8) HWF_R: Rural population access to hand washing facilities; (9) HWF_UR: Urban population access to hand washing facilities. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3
Effect of income inequality and financial inclusion on WASH [Lewbel IV-2SLS with an external instrument].

	1	2	3	4	5	6	7	8	9
	ABDWS	ABDWS_R	ABDWS_UR	ABSS	ABSS_R	ABSS_UR	HWF	HWF_R	HWF_UR
Financial inclusion [FI]	0.003*	0.004	0.003***	0.031***	0.036***	0.027***	0.020**	0.032***	0.013**
	(0.002)	(0.003)	(0.001)	(0.005)	(0.007)	(0.005)	(0.008)	(0.011)	(0.006)
GDP per capita	0.144***	0.162***	0.046***	0.392***	0.470***	0.297***	0.740***	0.853***	0.441***
	(0.010)	(0.015)	(0.005)	(0.026)	(0.042)	(0.017)	(0.039)	(0.051)	(0.030)
Government spending	0.004***	0.004*	0.003***	0.021***	0.019***	0.017***	0.013**	0.011	0.014**
	(0.001)	(0.002)	(0.001)	(0.003)	(0.004)	(0.002)	(0.007)	(0.008)	(0.006)
Remittances	0.031***	0.059***	0.015***	0.047***	0.080***	0.039***	0.088***	0.129***	0.047***
	(0.003)	(0.007)	(0.002)	(0.008)	(0.012)	(0.005)	(0.012)	(0.017)	(0.011)
Rule of law	0.072***	0.157***	0.040***	0.034	0.129***	0.010	0.021	0.040	0.071
	(0.011)	(0.018)	(0.007)	(0.023)	(0.034)	(0.019)	(0.057)	(0.075)	(0.049)
Foreign aid	−0.017***	−0.029***	−0.007**	−0.014	−0.005	−0.014	−0.033	−0.059**	−0.032*
	(0.005)	(0.008)	(0.003)	(0.011)	(0.019)	(0.009)	(0.021)	(0.030)	(0.018)
Urbanization	0.026***	0.033***	0.009***	0.030***	0.014	0.019***	0.091***	0.082***	0.069***
	(0.003)	(0.005)	(0.002)	(0.006)	(0.010)	(0.005)	(0.020)	(0.027)	(0.017)
Income inequality	−0.352***	−0.606***	−0.108***	−0.802***	−1.277***	−0.559***	−1.488***	−1.806***	−1.281***
	(0.031)	(0.052)	(0.019)	(0.072)	(0.115)	(0.047)	(0.151)	(0.205)	(0.130)
Constant	4.465***	5.280***	4.542***	3.439***	4.527***	3.694***	2.574***	3.319***	4.772***
	(0.178)	(0.284)	(0.115)	(0.444)	(0.729)	(0.279)	(0.740)	(1.081)	(0.639)
First-stage results. Dependent variable: Financial inclusion (FI)									
NFIS	0.178***	0.128***	0.127***	0.178***	0.128***	0.127***	0.286***	0.248***	0.266***
	(0.023)	(0.022)	(0.022)	(0.023)	(0.022)	(0.022)	(0.057)	(0.062)	(0.064)
Observations	749	714	716	749	714	716	364	363	354
R2	0.630	0.549	0.494	0.648	0.578	0.623	0.731	0.702	0.626
Kleibergen-Paap rk Wald F statistic	2813.051	1289.270	1210.392	2813.051	1289.270	1210.392	1043.191	967.832	948.048
Kleibergen-Paap rk LM statistic	23.786	24.269	24.269	23.786	24.269	24.269	27.329	26.716	26.974
Kleibergen-Paap rk LM statistic (p-value)	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001

Note: Robust standard errors in parentheses. (1) ABDWS: Access to basic drinking water; (2) ABDWS_R: Rural population access to basic drinking water; (3) ABDWS_UR: Urban population access to basic drinking water; (4) ABSS: Access to basic sanitation services; (5) ABSS_R: Rural population access to basic sanitation services; (6) ABSS_UR: Urban population access to basic sanitation services; (7) HWF: access to hand washing facilities; (8) HWF_R: Rural population access to hand washing facilities; (9) HWF_UR: Urban population access to hand washing facilities. The Kleibergen-Paap rk LM test p-value strongly rejects the null hypothesis that the structural equation is under-identified. Also, the null hypothesis that national financial inclusion strategy (NFIS) is weakly correlated with financial inclusion (endogenous variable) is strongly rejected by the Kleibergen-Paap rk Wald F statistic since their values exceed Stock-Yogo weak ID test critical values at 10 %. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

multicollinearity among the right-hand side (independent) variables to provide unreliable estimates. Appendix Table 2 shows the correlation among these independent variables, and the correlation coefficients show that the independent variables are not strongly correlated; hence, multicollinearity is not a problem. We have also presented the geographical distribution of financial inclusion, income inequality, and WASH variables in Appendix Figs. 1–5. Appendix Figs. 1–3 indicate that, on average, countries with lower access to safe drinking water, sanitation, and hygiene are largely concentrated in Sub-Saharan Africa and South Asia. However, on average, countries with relatively higher access to safe drinking water, sanitation and hygiene are in Europe & Central Asia. Specifically, Uganda, Chad, Niger, Angola, Burkina Faso, Sudan, Sierra Leone, Rwanda, and Kenya are among the Sub-Saharan African countries with less access to safe WASH, while the United Kingdom, Iceland, Norway, Switzerland, Denmark, Israel, Germany, Singapore, New Zealand, Belgium and Romania are among countries with higher access to safe WASH.

Appendix Fig. 4 shows that income inequality, on average, is relatively higher in Sub-Saharan Africa and the Caribbean and Latin America countries. On the other hand, income inequality is relatively less in Europe & Central Asia countries. Specifically, income inequality is relatively higher in countries such as Namibia, South Africa, Botswana, Zambia, Haiti, and Sudan. Also, income inequality is relatively less among Europe & Central Asia countries such as Iceland, Denmark, Norway, Finland, Sweden, Belgium, Malta, Ukraine and Austria. Appendix Fig. 5 shows that financial inclusion score, on average, is relatively higher in East Asia & Pacific, followed by Caribbean & Latin America, South Asia, Middle East & North Africa, Sub-Saharan Africa, and Europe & Central Asia. Financial inclusion scores are relatively higher in countries such as Vietnam, Indonesia, Japan, Colombia and Chile, while Tonga, Sierra Leone, Dominica, Zimbabwe, Ghana and Zambia are among the countries with lower financial inclusion scores.

4. Regression results and discussion

4.1. Baseline results (OLS)

Table 2 reports the baseline results, and they support the argument that higher income inequality could inhibit access to safe WASH. In columns 1–3, the estimated coefficient on the effect of income inequality on access to basic drinking water is significantly negative. With the estimated coefficient, a percentage rise in income inequality is associated with a decline in access to basic drinking water (*ABDWS*) by 0.349 %, all things being equal. Also, access to basic drinking water by the rural population (*ABDWS_R*) and access to basic drinking water by the urban population (*ABDWS_UR*) decline by 0.602 % and 0.107 %, all things being equal, respectively, when income inequality rises by 1 %. In columns 4–6, the estimated coefficient on the effect of income inequality on access to basic sanitation services is significantly negative. The estimated coefficients indicate that a 1 % rise in income inequality is associated with a reduction in access to basic sanitation services by the entire population (*ABSS*) by 0.803 %, access to basic sanitation services by the rural population (*ABSS_R*) by 1.277 %, and access to basic sanitation services by urban population (*ABSS_UR*) by 0.559 %, all things being equal. In columns 7–9, the estimated coefficient on the effect of income inequality on access to hand washing facilities is significantly negative. The estimated coefficients imply that a 1 % rise in income inequality is associated with a reduction in access to hand washing facilities by the entire population (*HWF*) by 1.469 %, access to hand

Table 4
Effect of income inequality and financial inclusion on WASH [Lewbel IV-2SLS without external instrument].

	1	2	3	4	5	6	7	8	9
	ABDWS	ABDWS_R	ABDWS_UR	ABSS	ABSS_R	ABSS_UR	HWF	HWF_R	HWF_UR
Financial inclusion [FI]	0.003*	0.004	0.003***	0.030***	0.035***	0.028***	0.017**	0.028***	0.009*
	(0.002)	(0.003)	(0.001)	(0.005)	(0.007)	(0.005)	(0.008)	(0.010)	(0.006)
GDP per capita	0.144***	0.162***	0.046***	0.392***	0.470***	0.297***	0.741***	0.854***	0.442***
	(0.010)	(0.015)	(0.005)	(0.026)	(0.042)	(0.017)	(0.039)	(0.051)	(0.030)
Government spending	0.004***	0.004*	0.003***	0.021***	0.019***	0.017***	0.013*	0.011	0.014**
	(0.001)	(0.002)	(0.001)	(0.003)	(0.004)	(0.002)	(0.007)	(0.008)	(0.006)
Remittances	0.031***	0.059***	0.015***	0.047***	0.080***	0.039***	0.088***	0.129***	0.046***
	(0.003)	(0.007)	(0.002)	(0.008)	(0.012)	(0.005)	(0.012)	(0.017)	(0.011)
Rule of law	0.072***	0.157***	0.040***	0.034	0.129***	0.010	0.023	0.042	0.073
	(0.011)	(0.018)	(0.007)	(0.023)	(0.034)	(0.019)	(0.057)	(0.075)	(0.049)
Foreign aid	−0.017***	−0.029***	−0.007**	−0.014	−0.005	−0.015	−0.032	−0.058*	−0.031*
	(0.005)	(0.008)	(0.003)	(0.011)	(0.019)	(0.009)	(0.021)	(0.030)	(0.019)
Urbanization	0.026***	0.033***	0.009***	0.030***	0.014	0.019***	0.092***	0.082***	0.069***
	(0.003)	(0.005)	(0.002)	(0.006)	(0.010)	(0.005)	(0.020)	(0.027)	(0.017)
Income inequality	−0.352***	−0.607***	−0.108***	−0.802***	−1.278***	−0.559***	−1.494***	−1.811***	−1.286***
	(0.031)	(0.052)	(0.019)	(0.072)	(0.115)	(0.047)	(0.151)	(0.206)	(0.130)
Constant	4.465***	5.279***	4.541***	3.439***	4.525***	3.695***	2.568***	3.314***	4.766***
	(0.178)	(0.284)	(0.115)	(0.444)	(0.729)	(0.279)	(0.741)	(1.082)	(0.640)
Observations	749	714	716	749	714	716	364	363	354
R2	0.630	0.549	0.493	0.648	0.578	0.623	0.730	0.701	0.625
Kleibergen-Paap rk Wald F statistic	2967.974	1368.959	1291.025	2967.974	1368.959	1291.025	1011.981	955.211	927.926
Kleibergen-Paap rk LM statistic	22.366	23.759	23.768	22.366	23.759	23.768	25.349	25.370	25.382
Kleibergen-Paap rk LM statistic (p-value)	0.002	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001

Note: Robust standard errors in parentheses. (1) ABDWS: Access to basic drinking water; (2) ABDWS_R: Rural population access to basic drinking water; (3) ABDWS_UR: Urban population access to basic drinking water; (4) ABSS: Access to basic sanitation services; (5) ABSS_R: Rural population access to basic sanitation services; (6) ABSS_UR: Urban population access to basic sanitation services; (7) HWF: access to hand washing facilities; (8) HWF_R: Rural population access to hand washing facilities; (9) HWF_UR: Urban population access to hand washing facilities. The Kleibergen-Paap rk LM test p-value strongly rejects the null hypothesis that the structural equation is under-identified. Also, the null hypothesis that the internally generated heteroskedasticity-based instrument by the Lewbel IV-2SLS estimator is weakly correlated with financial inclusion (endogenous variable) is strongly rejected by the Kleibergen-Paap rk Wald F statistic since their values exceed Stock-Yogo weak ID test critical values at 10 %. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 5
Effect of income inequality and financial inclusion on WASH [Driscoll-Kraay results].

	1	2	3	4	5	6	7	8	9
	ABDWS	ABDWS_R	ABDWS_UR	ABSS	ABSS_R	ABSS_UR	HWF	HWF_R	HWF_UR
GDP per capita	0.143***	0.161***	0.046***	0.392***	0.470***	0.297***	0.737***	0.849***	0.437***
	(0.010)	(0.018)	(0.010)	(0.023)	(0.037)	(0.021)	(0.052)	(0.080)	(0.027)
Government spending	0.004***	0.004*	0.003***	0.021***	0.019***	0.017***	0.014**	0.012	0.014**
	(0.001)	(0.002)	(0.000)	(0.001)	(0.004)	(0.001)	(0.006)	(0.009)	(0.006)
Remittances	0.031***	0.059***	0.015***	0.047***	0.080***	0.039***	0.088***	0.130***	0.047**
	(0.005)	(0.012)	(0.003)	(0.007)	(0.015)	(0.003)	(0.015)	(0.029)	(0.020)
Rule of law	0.071***	0.154***	0.040***	0.034***	0.129***	0.010	0.013	0.029	0.063
	(0.006)	(0.012)	(0.007)	(0.005)	(0.023)	(0.013)	(0.050)	(0.069)	(0.042)
Foreign aid	−0.018**	−0.031***	−0.008	−0.014*	−0.005	−0.015**	−0.036	−0.063	−0.035
	(0.007)	(0.010)	(0.005)	(0.008)	(0.013)	(0.007)	(0.027)	(0.046)	(0.020)
Urbanization	0.026***	0.032***	0.009***	0.030***	0.014	0.019***	0.090***	0.080***	0.068***
	(0.002)	(0.006)	(0.001)	(0.004)	(0.012)	(0.003)	(0.012)	(0.023)	(0.012)
Income inequality	−0.349***	−0.601***	−0.107***	−0.803***	−1.277***	−0.559***	−1.469***	−1.780***	−1.261***
	(0.027)	(0.056)	(0.024)	(0.055)	(0.125)	(0.034)	(0.112)	(0.105)	(0.131)
Financial inclusion [FI]	0.007**	0.013**	0.004***	0.030***	0.036***	0.029***	0.032**	0.047**	0.025**
	(0.003)	(0.006)	(0.001)	(0.007)	(0.011)	(0.008)	(0.012)	(0.016)	(0.009)
Constant	4.472***	5.300***	4.544***	3.438***	4.527***	3.696***	2.595***	3.340***	4.794***
	(0.315)	(0.634)	(0.237)	(0.378)	(0.859)	(0.297)	(0.516)	(1.131)	(0.463)
Observations	749	714	716	749	714	716	364	363	354
R2	0.631	0.550	0.494	0.648	0.578	0.623	0.732	0.702	0.628

Note: Standard errors in parentheses. (1) ABDWS: Access to basic drinking water; (2) ABDWS_R: Rural population access to basic drinking water; (3) ABDWS_UR: Urban population access to basic drinking water; (4) ABSS: Access to basic sanitation services; (5) ABSS_R: Rural population access to basic sanitation services; (6) ABSS_UR: Urban population access to basic sanitation services; (7) HWF: access to hand washing facilities; (8) HWF_R: Rural population access to hand washing facilities; (9) HWF_UR: Urban population access to hand washing facilities. * p < 0.10, ** p < 0.05, *** p < 0.01.

washing facilities by the rural population (*HWF_R*) by 1.780 %, and access to hand washing facilities by urban population (*HWF_UR*) by 1.261 %, all things being equal.

The results also indicate that financial inclusion is key to accessing WASH. As presented in columns 1–3, the estimated coefficient on the effect of financial inclusion (FI) on access to basic drinking water is significantly positive. With the estimated coefficient, a unit increase in FI is associated with an increase in *ABDWS* by 0.7 %, all things being equal. At the same time, the associated increase in *ABDWS_R* is 1.3 %, and *ABDWS_UR* is 0.4 % when FI rises by 1 %, all things being equal. Also, in columns 4–6, the estimated coefficient on the effect of FI on access to basic sanitation services is significantly positive. The estimated coefficients indicate that a unit increase in FI is associated with an increase in *ABSS* by 3%, *ABSS_R* by 3.6 %, and *ABSS_UR* by 2.9 %, all

Table 6A
Effect of income inequality and financial inclusion on access to drinking water across income groups [Driscoll-Kraay results].

	1	2	3	4	5	6	7	8	9	10	11	12
	Low-income countries			Lower-middle income countries			Upper-middle income countries			High-income countries		
	ABDWS	ABDWS_R	ABDWS_UR	ABDWS	ABDWS_R	ABDWS_UR	ABDWS	ABDWS_R	ABDWS_UR	ABDWS	ABDWS_R	ABDWS_UR
GDP per capita	0.705***	0.929***	0.053	0.017	−0.087**	−0.003	0.069***	0.143***	0.018***	0.037***	0.105***	0.007***
	(0.138)	(0.114)	(0.066)	(0.014)	(0.032)	(0.017)	(0.009)	(0.019)	(0.005)	(0.005)	(0.022)	(0.001)
Government spending	0.021***	0.028***	0.011***	0.003	0.002	0.002*	−0.001*	−0.001	−0.000	−0.000	0.011**	0.000
	(0.003)	(0.002)	(0.001)	(0.002)	(0.006)	(0.001)	(0.000)	(0.001)	(0.000)	(0.000)	(0.004)	(0.000)
Remittances	−0.016***	−0.013**	−0.017***	0.054***	0.104***	0.034***	0.009***	0.035***	0.001**	−0.007***	−0.020	−0.004***
	(0.002)	(0.005)	(0.002)	(0.003)	(0.014)	(0.003)	(0.001)	(0.004)	(0.000)	(0.001)	(0.020)	(0.001)
Rule of law	0.282***	0.246***	0.150***	0.121***	0.221***	0.048***	0.039***	0.104***	0.019***	0.027***	−0.045	0.007***
	(0.027)	(0.033)	(0.021)	(0.011)	(0.021)	(0.005)	(0.009)	(0.027)	(0.005)	(0.002)	(0.039)	(0.002)
Foreign aid	−0.171***	−0.102	−0.079***	−0.079***	−0.134***	−0.021**	0.006***	0.010**	0.003***	−0.003***	−0.001	−0.000
	(0.049)	(0.066)	(0.019)	(0.014)	(0.021)	(0.010)	(0.001)	(0.005)	(0.000)	(0.001)	(0.004)	(0.001)
Urbanization	−0.156***	−0.339***	0.040	0.038***	0.069***	0.004	0.005***	0.003***	0.002***	−0.000	−0.030	−0.001
	(0.051)	(0.034)	(0.023)	(0.002)	(0.006)	(0.003)	(0.001)	(0.001)	(0.001)	(0.001)	(0.023)	(0.001)
Income inequality	−1.886***	−2.340***	−0.543**	−0.399***	−0.756***	−0.085*	−0.225***	−0.470***	−0.036***	−0.079***	−0.186***	−0.030***
	(0.333)	(0.367)	(0.192)	(0.045)	(0.080)	(0.043)	(0.020)	(0.058)	(0.011)	(0.006)	(0.052)	(0.004)
Financial inclusion [FI]	−4.219	2.760	−1.571	0.010**	0.022**	0.006**	0.075***	0.082**	0.034***	0.013	0.676***	0.006
	(4.708)	(4.676)	(1.574)	(0.004)	(0.008)	(0.002)	(0.016)	(0.030)	(0.006)	(0.015)	(0.133)	(0.008)
Constant	11.726***	13.924***	6.880***	6.696***	9.271***	5.191***	4.634***	4.754***	4.467***	4.547***	4.558***	4.645***
	(2.152)	(2.242)	(0.979)	(0.509)	(0.844)	(0.426)	(0.136)	(0.381)	(0.068)	(0.073)	(0.752)	(0.017)
Observations	77	77	77	301	292	292	319	311	313	52	34	34
R2	0.567	0.554	0.720	0.598	0.584	0.599	0.603	0.419	0.342	0.849	0.868	0.932

Note: Standard errors in parentheses. ABDWS: Access to basic drinking water; ABDWS_R: Rural population access to basic drinking water; ABDWS_UR: Urban population access to basic drinking water; ABSS: Access to basic sanitation services; ABSS_R: Rural population access to basic sanitation services; ABSS_UR: Urban population access to basic sanitation services; HWF: access to hand washing facilities; HWF_R: Rural population access to hand washing facilities; HWF_UR: Urban population access to hand washing facilities. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 6B
Effect of income inequality and financial inclusion on sanitation across income groups [Driscoll-Kraay results].

	1	2	3	4	5	6	7	8	9	10	11	12
	Low-income countries			Lower-middle income countries			Upper-middle income countries			High-income countries		
	ABSS	ABSS_R	ABSS_UR	ABSS	ABSS_R	ABSS_UR	ABSS	ABSS_R	ABSS_UR	ABSS	ABSS_R	ABSS_UR
GDP per capita	0.898***	0.582	0.586***	0.326***	0.393***	0.156***	0.162***	0.264***	0.098***	0.086***	0.188***	0.057*
	(0.267)	(0.490)	(0.125)	(0.024)	(0.051)	(0.024)	(0.025)	(0.020)	(0.019)	(0.027)	(0.043)	(0.032)
Government spending	0.063***	0.077***	0.040***	0.037***	0.034***	0.027***	−0.004***	−0.013***	−0.001	0.002*	−0.013	−0.002
	(0.004)	(0.003)	(0.003)	(0.003)	(0.005)	(0.005)	(0.001)	(0.001)	(0.001)	(0.001)	(0.008)	(0.003)
Remittances	−0.051***	−0.090***	−0.027***	0.072***	0.139***	0.049***	0.041***	0.064***	0.031***	−0.050***	−0.057*	−0.008
	(0.013)	(0.016)	(0.008)	(0.009)	(0.007)	(0.010)	(0.005)	(0.008)	(0.005)	(0.002)	(0.029)	(0.010)
Rule of law	0.365***	0.381**	0.172***	−0.019	0.068	−0.020	0.091***	0.137***	0.076***	0.049***	0.125**	0.054***
	(0.087)	(0.151)	(0.046)	(0.031)	(0.057)	(0.024)	(0.022)	(0.033)	(0.024)	(0.008)	(0.056)	(0.016)
Foreign aid	0.335***	0.625***	0.161**	−0.127***	−0.119***	−0.132***	−0.002	0.003	0.002	−0.010***	0.001	0.000
	(0.105)	(0.154)	(0.065)	(0.013)	(0.015)	(0.014)	(0.006)	(0.008)	(0.006)	(0.003)	(0.007)	(0.006)
Urbanization	−0.625***	−0.670**	−0.235***	0.078***	0.088**	0.068***	0.028***	0.006	0.015***	−0.025***	0.014	0.014
	(0.135)	(0.277)	(0.062)	(0.015)	(0.033)	(0.013)	(0.002)	(0.006)	(0.002)	(0.003)	(0.039)	(0.020)
Income inequality	−1.396	−1.054	−0.836	−0.710***	−1.013***	−0.650***	−0.911***	−1.468***	−0.536***	−0.358***	−1.085***	−0.215***
	(0.868)	(1.264)	(0.510)	(0.100)	(0.144)	(0.077)	(0.044)	(0.096)	(0.029)	(0.019)	(0.035)	(0.039)
Financial inclusion [FI]	−3.209	8.076	−13.017***	0.040***	0.046***	0.038***	0.233***	0.416***	0.153***	0.111***	0.299	0.054
	(5.758)	(5.637)	(4.092)	(0.013)	(0.015)	(0.013)	(0.032)	(0.071)	(0.016)	(0.034)	(0.249)	(0.059)
Constant	4.266	0.775	1.124	4.858***	4.912***	6.548***	6.132***	7.618***	5.411***	5.457***	6.446***	4.579***
	(3.044)	(4.248)	(1.434)	(0.743)	(0.970)	(0.753)	(0.204)	(0.348)	(0.171)	(0.316)	(1.043)	(0.428)
Observations	77	77	77	301	292	292	319	311	313	52	34	34
R2	0.665	0.693	0.664	0.662	0.582	0.497	0.558	0.602	0.424	0.887	0.936	0.894

Note: Standard errors in parentheses. ABDWS: Access to basic drinking water; ABDWS_R: Rural population access to basic drinking water; ABDWS_UR: Urban population access to basic drinking water; ABSS: Access to basic sanitation services; ABSS_R: Rural population access to basic sanitation services; ABSS_UR: Urban population access to basic sanitation services; HWF: access to hand washing facilities; HWF_R: Rural population access to hand washing facilities; HWF_UR: Urban population access to hand washing facilities. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 6C
Effect of income inequality and financial inclusion on handwashing facilities across income groups [Driscoll-Kraay results].

	1	2	3	4	5	6	7	8	9
	Low-income countries			Lower-middle income countries			Upper-middle income countries		
	HWF	HWF_R	HWF_UR	HWF	HWF_R	HWF_UR	HWF	HWF_R	HWF_UR
GDP per capita	0.305	0.119	−0.221	0.185***	0.209**	−0.049	0.239***	0.376***	0.141***
	(0.631)	(0.741)	(0.526)	(0.062)	(0.083)	(0.042)	(0.018)	(0.040)	(0.011)
Government spending	0.012**	0.037***	0.037***	0.033***	0.039***	0.028**	−0.010***	−0.013***	−0.003*
	(0.004)	(0.011)	(0.005)	(0.011)	(0.011)	(0.011)	(0.002)	(0.004)	(0.002)
Remittances	−0.093***	−0.126***	−0.129***	0.103***	0.157***	0.083***	0.020***	0.044***	0.009**
	(0.008)	(0.018)	(0.012)	(0.024)	(0.044)	(0.016)	(0.004)	(0.009)	(0.004)
Rule of law	−0.220	0.030	0.090	0.300***	0.377***	0.265***	−0.031***	−0.052*	−0.032***
	(0.167)	(0.350)	(0.206)	(0.086)	(0.114)	(0.068)	(0.010)	(0.026)	(0.009)
Foreign aid	−0.283***	−0.235	−0.210**	−0.148***	−0.154***	−0.156***	0.006	−0.028***	0.015***
	(0.076)	(0.207)	(0.083)	(0.027)	(0.037)	(0.018)	(0.004)	(0.009)	(0.004)
Urbanization	0.744**	0.777**	0.562**	0.101***	0.099***	0.103***	−0.017*	−0.031*	−0.016***
	(0.269)	(0.328)	(0.213)	(0.021)	(0.027)	(0.019)	(0.009)	(0.017)	(0.003)
Income inequality	−1.071	−1.042	−0.550	−0.772**	−0.482	−1.083***	−1.129***	−1.720***	−0.757***
	(1.329)	(1.532)	(1.116)	(0.306)	(0.366)	(0.279)	(0.035)	(0.051)	(0.033)
Financial inclusion [FI]	17.362**	49.512***	22.101***	0.039**	0.055**	0.034**	−0.059***	−0.761***	−0.024**
	(7.227)	(5.536)	(7.046)	(0.017)	(0.022)	(0.013)	(0.019)	(0.091)	(0.008)
Constant	0.930	3.991	4.859	6.419***	5.015**	9.757***	6.830***	8.564***	6.049***
	(5.686)	(6.166)	(6.014)	(1.537)	(2.073)	(1.013)	(0.225)	(0.440)	(0.233)
Observations	60	53	53	178	178	178	123	132	123
R2	0.886	0.761	0.737	0.449	0.443	0.404	0.839	0.875	0.731

Note: Standard errors in parentheses. ABDWS: Access to basic drinking water; ABDWS_R: Rural population access to basic drinking water; ABDWS_UR: Urban population access to basic drinking water; ABSS: Access to basic sanitation services; ABSS_R: Rural population access to basic sanitation services; ABSS_UR: Urban population access to basic sanitation services; HWF: access to hand washing facilities; HWF_R: Rural population access to hand washing facilities; HWF_UR: Urban population access to hand washing facilities. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

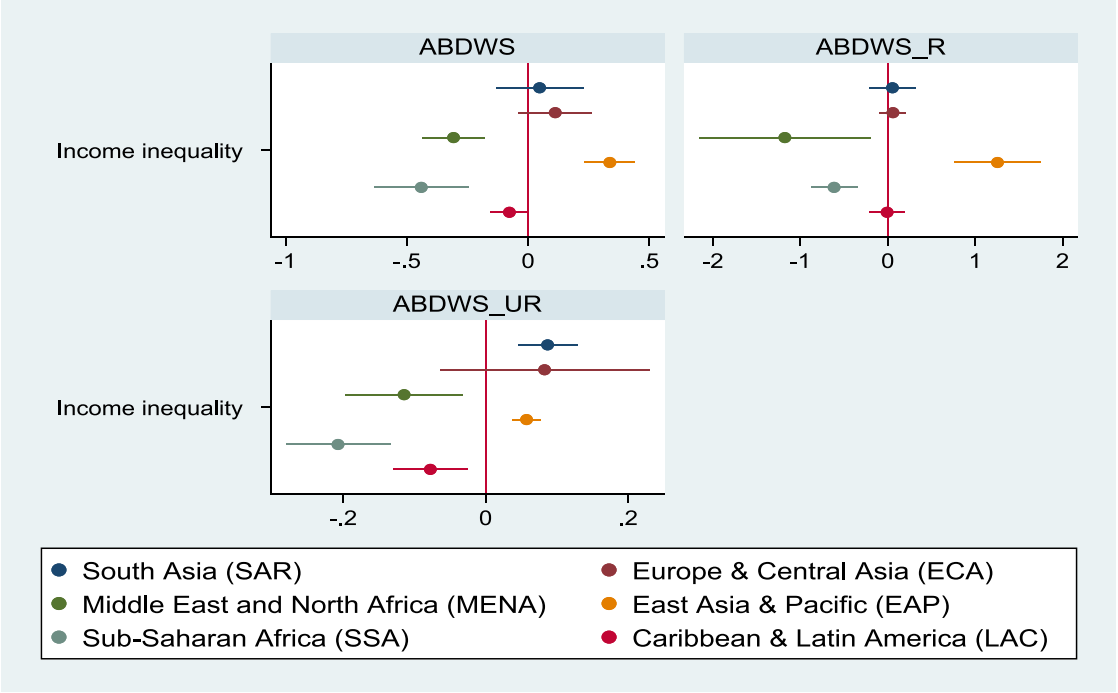


Fig. 1A. Driscoll-Kraay estimator coefficients of the effect of income inequality on access to basic drinking water services (Driscoll-Kraay estimator coefficients and 90% confidence interval) across geographical regions. All regression models include control variables (GDP per capita, government spending, remittances, rule of law, foreign aid and urbanisation). ABDWS: Access to basic drinking water; ABDWS_R: Rural population access to basic drinking water; ABDWS_UR: Urban population access to basic drinking water.

things being equal. Similarly, the estimates in columns 7–9 imply that the estimated coefficient on the effect of FI on access to hand-washing facilities is significantly positive. The estimated coefficients imply that a unit increase in FI is associated with an increase in *HWF* by 3.2 %, *HWF_R* by 4.7 %, and *HWF_UR* by 2.5 %, all things being equal.

Besides the key explanatory variables, most of the control covariates support an increase in access to WASH. For instance, in Columns 1–9, the coefficients on GDP per capita are significantly positive, suggesting that increasing per capita GDP is associated with an increase in access to WASH. Also, except in Column 9, the coefficient on government spending is significantly positive, implying that increasing government spending is important for hastening access to WASH. In Columns 1–9, the coefficients on the effect of remittances are positive and significant, supporting the idea that international remittances are crucial for

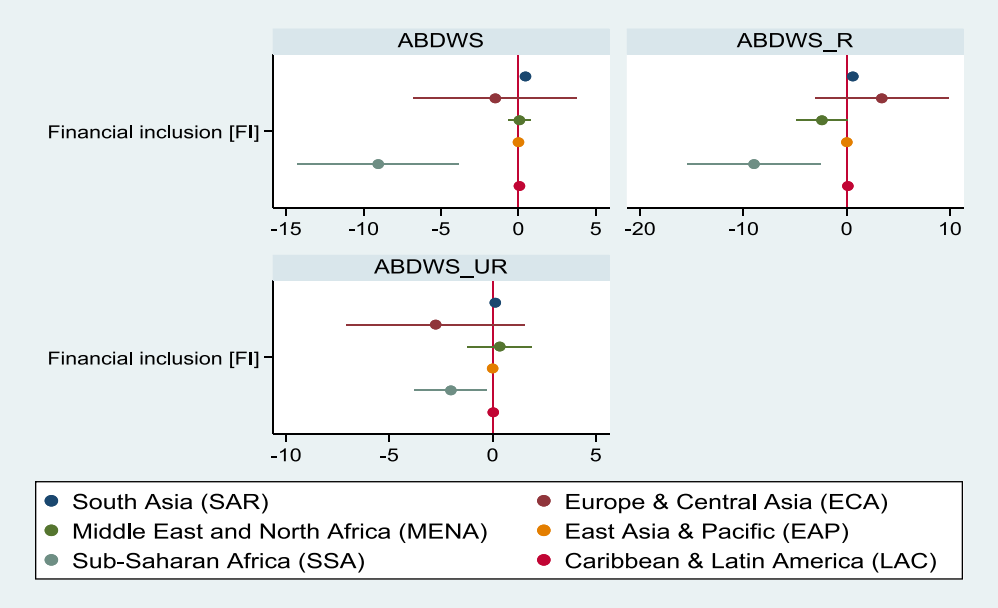


Fig. 1B. Driscoll-Kraay estimator coefficients of the effect of financial inclusion on access to basic drinking water services (Driscoll-Kraay estimator coefficients and 90% confidence interval) across geographical regions. All regression models include control variables (GDP per capita, government spending, remittances, rule of law, foreign aid and urbanisation). ABDWS: Access to basic drinking water; ABDWS_R: Rural population access to basic drinking water; ABDWS_UR: Urban population access to basic drinking water.

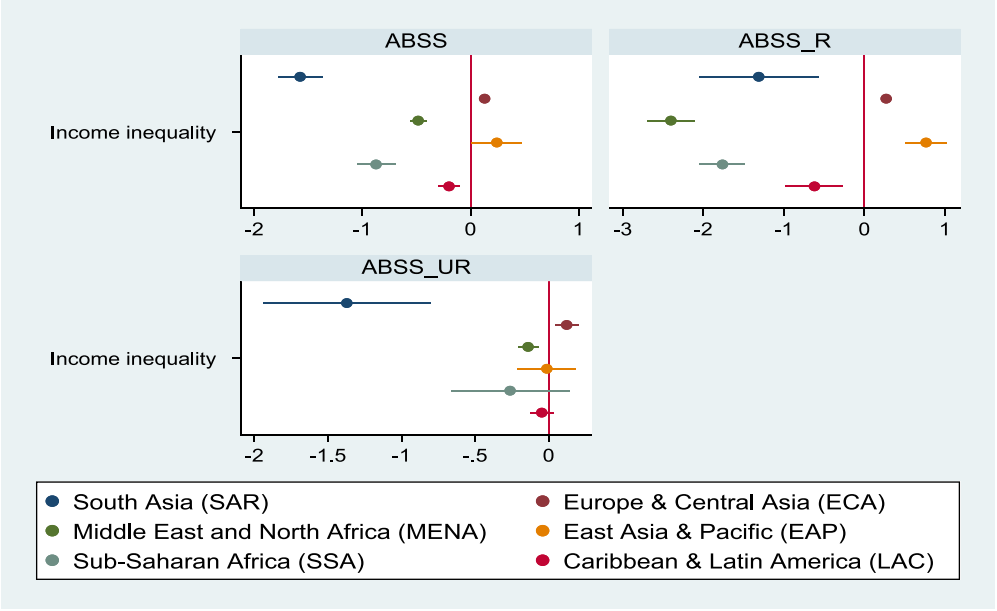


Fig. 2A. Driscoll-Kraay estimator coefficients of the effect of income inequality on access to basic sanitation services (Driscoll-Kraay estimator coefficients and 90% confidence interval) across geographical regions. All regression models include control variables (GDP per capita, government spending, remittances, rule of law, foreign aid and urbanisation). ABSS: Access to basic sanitation services; ABSS_R: Rural population access to basic sanitation services; ABSS_UR: Urban population access to basic sanitation services.

facilitating access to WASH by the general population as well as residents in rural and urban areas. The findings indicate that access to basic drinking water by the entire population and access to basic drinking water by rural and urban residents are positively and significantly related to the rule of law. Also, rule of law is insignificantly related to access to basic sanitation services by the general population, access to basic sanitation services by urban residents, and access to hand washing facilities, including rural and urban residents' access. Access to basic drinking water, including rural and urban residents' access, and access to hand washing facilities, including rural and urban residents' access, is negatively and significantly related to foreign aid. At the same time, access to basic sanitation services, including rural and urban residents' access, is not statistically related to foreign aid. Except in Column 5, the coefficients on the effect of urbanisation are significantly positive, suggesting that urbanisation is important for improving access to WASH.

4.2. *Lewbel IV-2SLS results*

This section reports the Lewbel IV-2SLS results with (see Table 3) and without (see Table 4) an external instrument. In Table 3, the first-stage

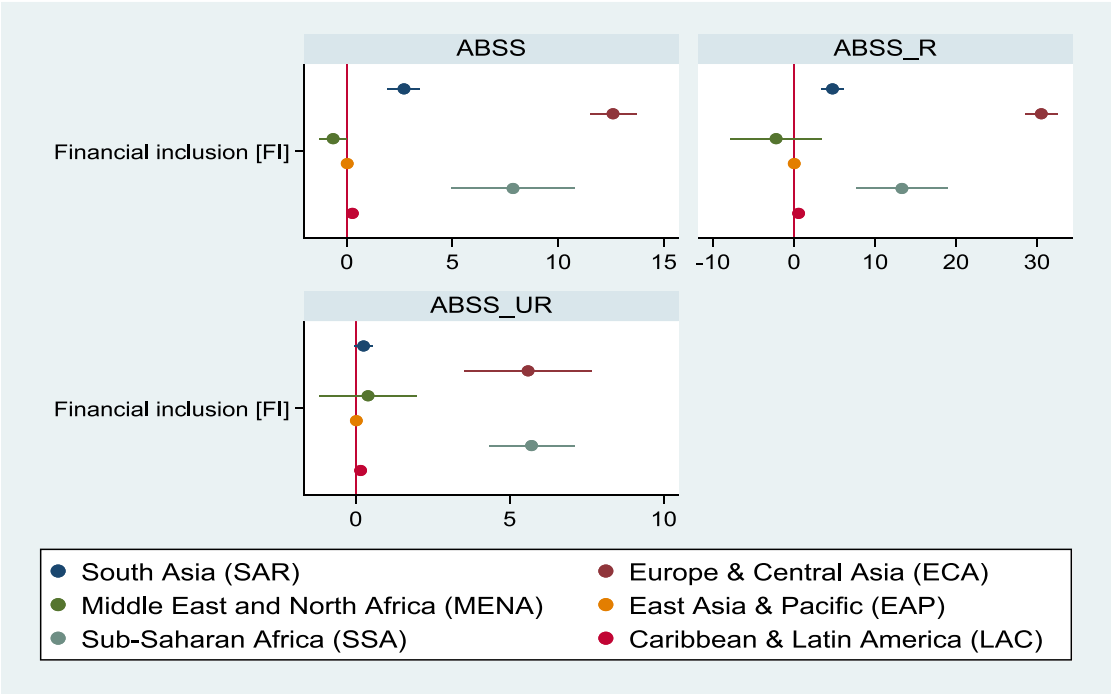


Fig. 2B. Driscoll-Kraay estimator coefficients of the effect of financial inclusion on access to basic sanitation services (Driscoll-Kraay estimator coefficients and 90% confidence interval) across geographical regions. All regression models include control variables (GDP per capita, government spending, remittances, rule of law, foreign aid and urbanisation). ABSS: Access to basic sanitation services; ABSS_R: Rural population access to basic sanitation services; ABSS_UR: Urban population access to basic sanitation services.

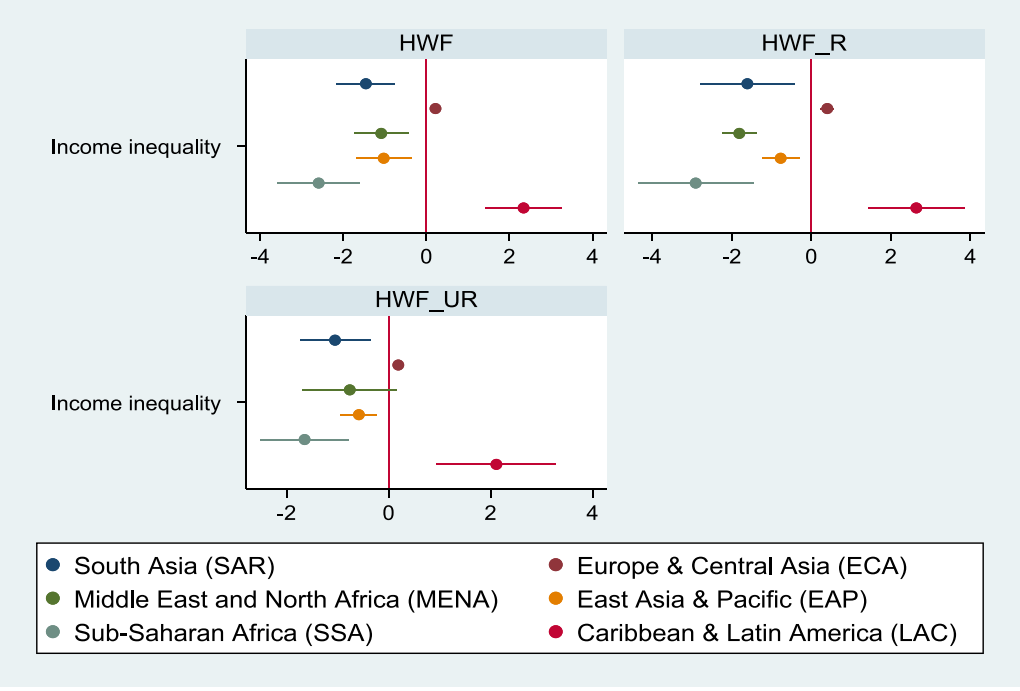


Fig. 3A. Driscoll-Kraay estimator coefficients of the effect of income inequality on access to basic handwashing facilities (Driscoll-Kraay estimator coefficients and 90% confidence interval) across geographical regions. All regression models include control variables (GDP per capita, government spending, remittances, rule of law, foreign aid and urbanisation). Access to hand washing facilities; HWF_R: Rural population access to hand washing facilities; HWF_UR: Urban population access to hand washing facilities.

results presented in Panel A imply that the implementation of a national financial inclusion strategy (NFIS) has a statistically significant positive effect on FI. We validated the reliability and usefulness using the Kleibergen-Paap rk LM Kleibergen-Paap rk Wald F statistic. The Kleibergen-Paap rk LM test p-value supported that the structural equation is not under-identified. At the same time, Kleibergen-Paap rk Wald F statistic proves that NFIS strongly correlates with financial inclusion (FI), the endogenous variable. Also, in Table 4, the null hypothesis that

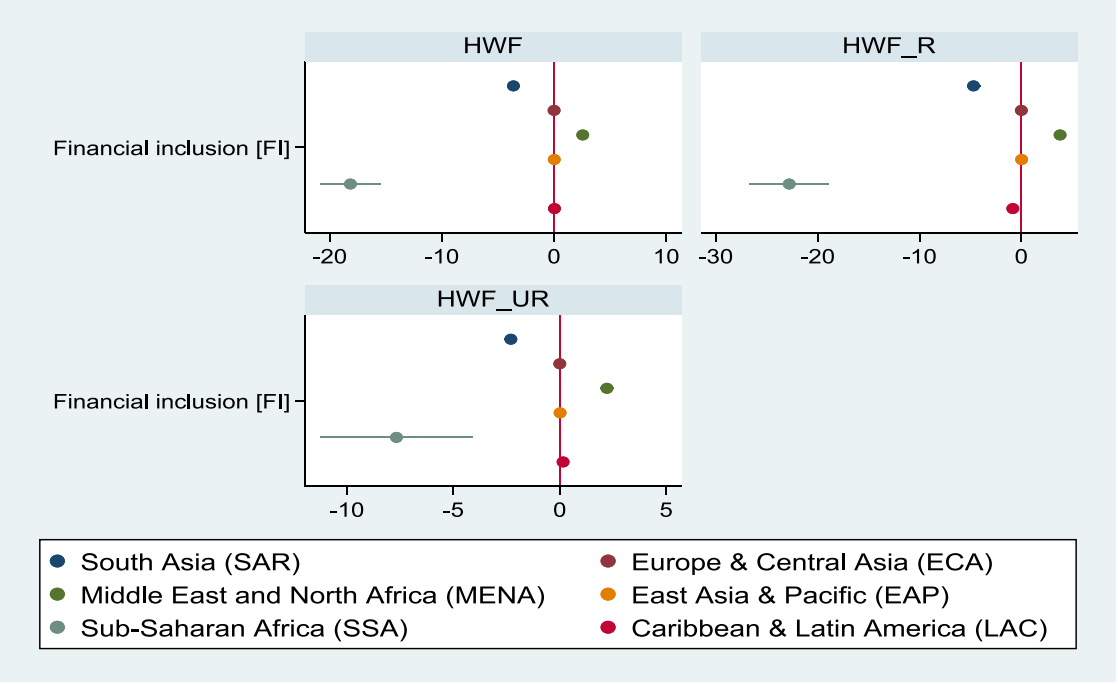


Fig. 3B. Driscoll-Kraay estimator coefficients of the effect of financial inclusion on access to basic handwashing facilities (Driscoll-Kraay estimator coefficients and 90% confidence interval) across geographical regions. All regression models include control variables (GDP per capita, government spending, remittances, rule of law, foreign aid and urbanisation). HWF: Access to hand washing facilities; HWF_R: Rural population access to hand washing facilities; HWF_UR: Urban population access to hand washing facilities.

Table 7
Conditional effect of income inequality and financial inclusion on WASH [Driscoll-Kraay **results**].

	1	2	3	4	5	6	7	8	9
	ABDWS	ABDWS_R	ABDWS_UR	ABSS	ABSS_R	ABSS_UR	HWF	HWF_R	HWF_UR
GDP per capita	0.144***	0.162***	0.046***	0.393***	0.473***	0.298***	0.742***	0.854***	0.441***
	(0.010)	(0.018)	(0.010)	(0.023)	(0.038)	(0.022)	(0.053)	(0.081)	(0.028)
Government spending	0.004***	0.004*	0.003***	0.021***	0.019***	0.017***	0.014**	0.012	0.015**
	(0.001)	(0.002)	(0.000)	(0.001)	(0.004)	(0.001)	(0.006)	(0.009)	(0.006)
Remittances	0.031***	0.059***	0.015***	0.047***	0.080***	0.039***	0.090***	0.131***	0.048**
	(0.005)	(0.012)	(0.003)	(0.007)	(0.015)	(0.003)	(0.015)	(0.028)	(0.020)
Rule of law	0.071***	0.154***	0.040***	0.034***	0.129***	0.010	0.015	0.032	0.065
	(0.006)	(0.012)	(0.007)	(0.005)	(0.023)	(0.013)	(0.050)	(0.069)	(0.043)
Foreign aid	−0.018**	−0.030**	−0.007	−0.012	−0.001	−0.013*	−0.028	−0.053	−0.027
	(0.007)	(0.010)	(0.005)	(0.008)	(0.014)	(0.007)	(0.027)	(0.046)	(0.021)
Urbanization	0.025***	0.031***	0.008***	0.028***	0.011	0.018***	0.083***	0.073***	0.062***
	(0.002)	(0.006)	(0.001)	(0.004)	(0.011)	(0.003)	(0.013)	(0.024)	(0.013)
Income inequality	−0.348***	−0.600***	−0.107***	−0.801***	−1.274***	−0.558***	−1.488***	−1.802***	−1.279***
	(0.025)	(0.052)	(0.023)	(0.051)	(0.114)	(0.032)	(0.102)	(0.092)	(0.125)
Financial inclusion [FI]	−0.108***	−0.221***	−0.050***	−0.376***	−0.693***	−0.241***	−0.573***	−0.645***	−0.511***
	(0.026)	(0.055)	(0.011)	(0.074)	(0.142)	(0.059)	(0.150)	(0.155)	(0.153)
Income inequality × Financial inclusion [FI]	0.032***	0.064***	0.015***	0.111***	0.200***	0.074***	0.166***	0.190***	0.147***
	(0.008)	(0.017)	(0.003)	(0.022)	(0.041)	(0.018)	(0.044)	(0.046)	(0.044)
Constant	4.463***	5.279***	4.539***	3.407***	4.461***	3.672***	2.556***	3.301**	4.769***
	(0.313)	(0.628)	(0.236)	(0.370)	(0.839)	(0.293)	(0.552)	(1.169)	(0.497)
Marginal effects of income inequality at:									
FI threshold value (*0.000*)	−0.348***	−0.600***	−0.107***	−0.801***	−1.274***	−0.558***	−1.488***	−1.802***	−1.279***
	(0.025)	(0.052)	(0.023)	(0.051)	(0.114)	(0.032)	(0.102)	(0.092)	(0.125)
FI threshold value (*16.226*)	0.163	0.439*	0.132***	1.003***	1.967***	0.641**	1.204*	1.277*	1.1061*
	(0.107)	(0.236)	(0.049)	(0.315)	(0.566)	(0.267)	(0.623)	(0.699)	(0.613)
FI threshold value (*20.226*)	0.289***	0.695**	0.191***	1.448***	2.767***	0.937***	1.867**	2.036**	1.694**
	(0.137)	(0.302)	(0.061)	(0.403)	(0.731)	(0.337)	(0.798)	(0.881)	(0.790)
Observations	749	714	716	749	714	716	364	363	354
R2	0.631	0.551	0.494	0.649	0.581	0.624	0.733	0.704	0.631

Note: Standard errors in parentheses. ABDWS: Access to basic drinking water; ABDWS_R: Rural population access to basic drinking water; ABDWS_UR: Urban population access to basic drinking water; ABSS: Access to basic sanitation services; ABSS_R: Rural population access to basic sanitation services; ABSS_UR: Urban population access to basic sanitation services; HWF: Access to hand washing facilities; HWF_R: Rural population access to hand washing facilities; HWF_UR: Urban population access to hand washing facilities. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Appendix Table 1
. List of countries.

Albania, Algeria, 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, Togo, Tonga, Trinidad and Tobago, Tunisia, Uganda, Ukraine, United Arab Emirates, United Kingdom, Uruguay, Vanuatu, Vietnam, Zambia, Zimbabwe.

the structural equation is under-identified is strongly rejected by the Kleibergen-Paap rk LM test p-value. Also, the null hypothesis that the internally generated heteroskedasticity-based instrument by the Lewbel IV-2SLS estimator is weakly correlated with the endogenous variable is strongly rejected by the Kleibergen-Paap rk Wald F statistic.

In both Tables 3 and 4, the second-stage results presented in their respective Panel B are similar to the baseline regressions results. The endogeneity-corrected results in Tables 3-4 indicate that *ABDWS*, *ABDWS_R*, and *ABDWS_UR* are significant and negatively related to income inequality. Similarly, income inequality is significantly and negatively related to *ABSS*, *ABSS_R*, and *ABSS_UR*. Income inequality has a significant negative effect on *HWF*, HWF_R, and *HWF_UR*. These findings highlight that income inequality impedes WASH adoption and practices across the globe. Intuitively, higher income inequality perpetuates income poverty and hinders access to safe WASH facilities, as the poor have inadequate and unequal access to these services. Relative to the rich, only a small fraction of poor households have access to water networks, and the poor also tend to consume inferior-quality water (Ikeda & Liffiton, 2019; Pattanayak et al., 2006).

Also, in both Tables 3 and 4, the results presented in their respective Panel B show that FI has a significantly positive effect on *ABDWS* and *ABDWS_UR* while it has a statistically insignificant impact on *ABDWS_R*. The results further proved that FI is significant and positively related to *ABSS*, *ABSS_R*, and *ABSS_UR*. FI consistently has a significant positive effect on *HWF*, HWF_R, and *HWF_UR*. These results suggest that financial inclusion is an important policy tool for enhancing impediments to access to WASH across the globe. These findings substantiate our claim that financial inclusion could offer opportunities for households, especially poorer households, to access credits or loans that facilitate access to WASH. This result is important in light of the recent study by Augsburg, Caeyers, and Malde (2019) and Lipscomb and Schechter (2018). Augsburg, Caeyers, and Malde (2019) argue that financial support is key to overcoming liquidity constraints that hamper investment in sanitation. Using randomised control trials in India, the authors demonstrated that micro-credit supports investment in the sanitation (toilet) of poor households. Also, Lipscomb and Schechter (2018) documented that mobile money payments, which ensure financial inclusion, increase sanitation adoption among urban residents in Dakar, Senegal. The results also align with those of Dangui and Jia (2023).

4.3. Robustness check and further analysis

4.3.1. Alternative econometric technique

In this section, we test the robustness of the baseline and the Lewbel IV-2SLS results using the Driscoll-Kraay estimator. The Driscoll-Kraay estimator results are displayed in Table 5. The results are congruent with the Lewbel IV-2SLS and the baseline results. The estimated coefficients indicate that income inequality has a significantly inverse relationship with *ABDWS*, access to basic *ABDWS_R*, and *ABDWS_UR*. Also, the results in Table 5 confirmed that income inequality has a significant negative effect on *ABSS*, *ABSS_R*, and *ABSS_UR*. Also, *HWF*, HWF_R, and *HWF_UR* are inversely and significantly related to income inequality. These outcomes confirmed our earlier results that rising income inequality is one of the key social barriers to WASH adoption and practices. We also confirmed from Table 5 that FI is significantly and positively related to *ABDWS, ABDWS_R* and *ABDWS_UR*. Consistently, the Driscoll-Kraay estimator yields that financial inclusion (FI) has a significant positive effect on *ABSS*, *ABSS_R* and *ABSS_UR*. Consistently, FI has a significant positive effect on *HWF*, HWF_R, and *HWF_UR*. These results from the Driscoll-Kraay estimator support that financial inclusion is key for enhancing WASH adoption and practices. The consistency of the results across different econometric estimators based on different assumptions indicates our results' validity and reliability.

4.3.2. Accounting for heterogeneity in results based on income groups

This section examines the impact of FI and income inequality on WASH across different income groups. Following the World Bank income group classification, we subdivided our study sample into low (LIC), lower-middle (LMIC), upper-middle (UMIC) and high-income economies (HIC). The results for the income groups are presented in Tables 6A–6C.

In Table 6A, income inequality has a significant inverse effect on ABDWS, ABDWS_R, and ABDWS_UR in low (LIC), lower-middle (LMIC), upper-middle (UMIC) and high-income economies (HIC). Based on the estimated coefficients, the effect of income inequality on access to basic drinking water is highest in LIC, followed by LMIC, UMIC and HIC, respectively. This evidence showcases that irrespective of the stage of economic development, financial inclusion acts as a significant barrier to WASH adoption and practice. Table 6A also shows that in LIC, financial inclusion (FI) has a neutral effect on ABDWS, ABDWS_R and ABDWS_UR. However, for the middle-income groups (LMIC and UMIC), financial inclusion (FI) has a significant and direct relationship with ABDWS, ABDWS_R, and ABDWS_UR. In HIC, financial inclusion only has a significant positive effect on access to ABDWS_R. These results highlight that the role of financial inclusion in enhancing access to safe drinking water is limited in middle-income economies and, to a limited extent, in high-income economies. However, financial inclusion has no role in WASH adoption and practices in low-income economies due to their underdeveloped and fragile financial system.

Also, the results in Table 6B suggest that in LIC, income inequality has an insignificant effect on ABSS, ABSS_R, and ABSS_UR. However, for the rest of the income groups, income inequality significantly and negatively affects ABSS, ABSS_R, and ABSS_UR. These results imply that the role of income inequality hindering access to sanitation services pertains to middle-income and high-income economies. Also, Table 6B shows that in LIC, financial inclusion (FI) plays a neutral role in ABSS and ABSS_R; however, it significantly reduces ABSS_UR. However, for the middle-income groups (LMIC and UMIC), financial inclusion (FI) has a statistically significant and positive effect on ABSS), ABSS_R, and ABSS_UR. In HIC, FI has a statistically significant and positive effect on ABSS but has an insignificant effect on ABSS_R and ABSS_UR. These results indicate that the role of financial inclusion in enhancing access to sanitation services is important in middle-income and high-income economies and not low-income economies due to their underdeveloped and fragile financial system.

The results in Table 6C show that income inequality does not significantly affect HWF, HWF_R and HWF_UR in LIC.[3] On the other hand, in LMIC, UMIC, and HIC, income inequality significantly reduces

[3] In Table 6C, we did not report the results for high-income economies because they have very limited observations for sanitation variable.

Appendix Table 2
. Matrix of correlations.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1) Access to basic drinking water	1.000																
(2) Rural population access to basic drinking water	0.938	1.000															
(3) Urban population access to basic drinking water	0.911	0.887	1.000														
(4) Access to basic sanitation service	0.767	0.723	0.712	1.000													
(5) Rural population access to basic sanitation	0.702	0.726	0.692	0.966	1.000												
(6) Urban population access to basic sanitation service	0.783	0.724	0.722	0.959	0.892	1.000											
(7) Access to handwashing facilities	0.790	0.691	0.735	0.688	0.630	0.766	1.000										
(8) Rural population access to handwashing facilities	0.762	0.699	0.728	0.684	0.650	0.748	0.983	1.000									
(9) Urban population access to handwashing facilities	0.778	0.712	0.752	0.706	0.669	0.783	0.971	0.953	1.000								
(10) Income inequality	−0.145	−0.166	−0.114	−0.090	−0.124	−0.096	−0.123	−0.142	−0.184	1.000							
(11) Financial inclusion (FI) index	0.125	0.143	0.120	0.147	0.146	0.173	0.162	0.167	0.171	−0.105	1.000						
(12) GDP per capita	0.704	0.570	0.617	0.724	0.633	0.737	0.774	0.746	0.689	0.203	0.043	1.000					
(13) Government spending	0.126	0.095	0.209	0.275	0.220	0.251	0.078	0.072	0.090	0.227	−0.219	0.252	1.000				
(14) Remittances	0.238	0.312	0.304	0.042	0.101	0.059	0.212	0.252	0.181	−0.211	0.034	−0.005	−0.203	1.000			
(15) Rule of law	0.288	0.324	0.244	0.233	0.242	0.228	0.258	0.257	0.251	0.241	0.091	0.394	0.187	0.018	1.000		
(16) Foreign aid	−0.285	−0.255	−0.229	−0.369	−0.315	−0.362	−0.280	−0.295	−0.252	−0.152	0.194	−0.487	−0.401	0.099	−0.318	1.000	
(17) Urbanization	0.113	0.077	0.038	−0.006	−0.007	0.019	0.131	0.095	0.119	−0.027	0.243	−0.013	−0.535	0.037	−0.220	0.622	1.000

HWF, HWF_R, and *HWF_UR*. Similar to the earlier results, these outcomes show that it is only in middle and high-income economies that income inequality is found to inhibit access to handwashing facilities. Further, the results in Table 6C show that in LIC and LMIC, financial inclusion has a positive and significant effect on HWF, *HWF_R*, and *HWF_UR*, while it significantly reduces *HWF*, *HWF_R* and *HWF_UR* in UMIC. These results indicate that financial inclusion boosts access to handwashing facilities in low and lower-middle-income economies and not upper-middle-income economies.

4.3.3. Accounting for heterogeneity in the results based on regions

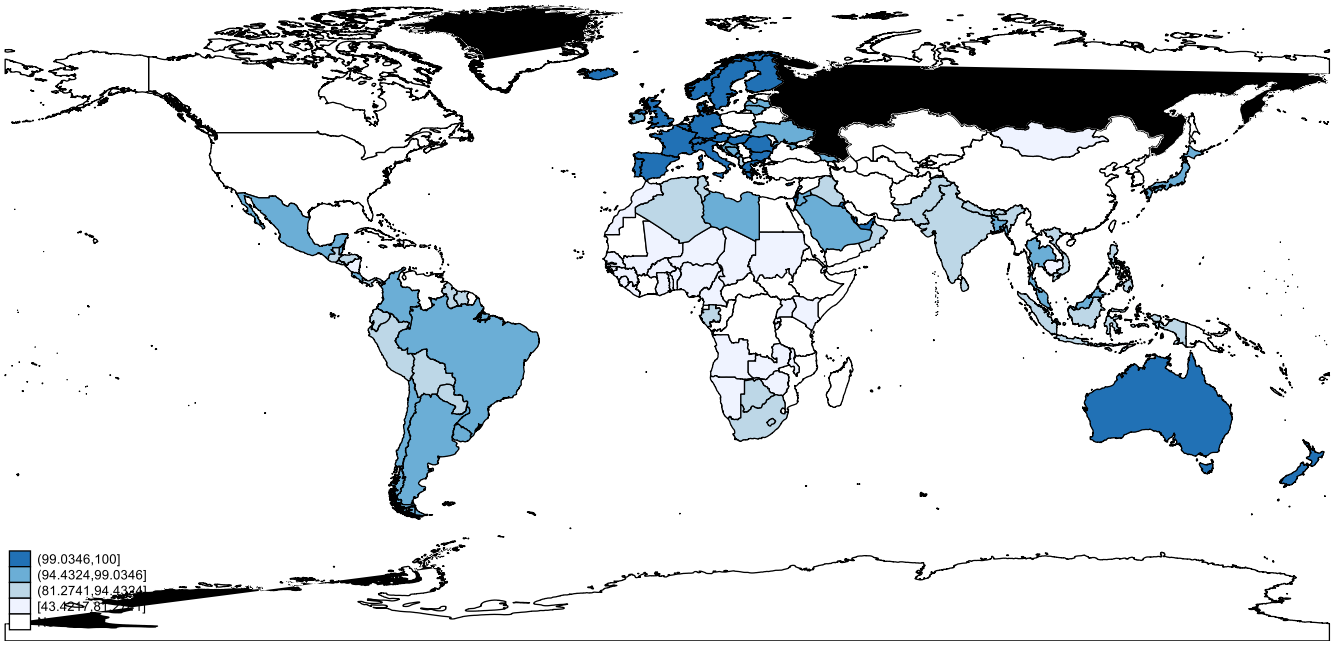
In this section, we presented the effect of FI and income inequality on WASH across six geographical regions. We follow the World Bank regional groups to categorise our sampled countries into South Asia (SAR), Europe & Central Asia (ECA), Middle East & North Africa (MENA), East Asia and the Pacific (EAP), Sub-Saharan Africa (SSA) and Latin America & Caribbean (LAC). The regional results are presented graphically to preserve space.[4]

4.3.3.1. Effects of income inequality and financial inclusion on access to basic drinking water services across geographical regions. The results displayed in Fig. 1A indicate that income inequality negatively and significantly affects ABDWS in MENA and SSA countries. Although income inequality negatively affects ABDWS in LAC, the impact is statistically insignificant. Contrarily, income inequality is positively related to ABDWS in SAR, ECA, and EAP; the impact is only statistically significant in EAP. As shown in Fig. 1A, income inequality has a significant inverse effect on ABDWS_R in MENA and SSA, with a significant positive effect in EAP. However, income inequality has an insignificant positive relationship with ABDWS_R in SAR and ECA and an insignificant negative effect in LAC. The impact of income inequality on ABDWS_UR in SAR and, EAP is significantly positive, while the impact of income inequality in the MENA, SSA and LAC are significantly negative. Also, income inequality has an insignificant effect on ABDWS_UR in ECA. The significant positive relationship between income inequality and safe drinking water in ECA may be due to their relatively lower income inequality. However, the higher income inequality in the SSA and MENA region contributes to reducing access to safe drinking water in these regions.

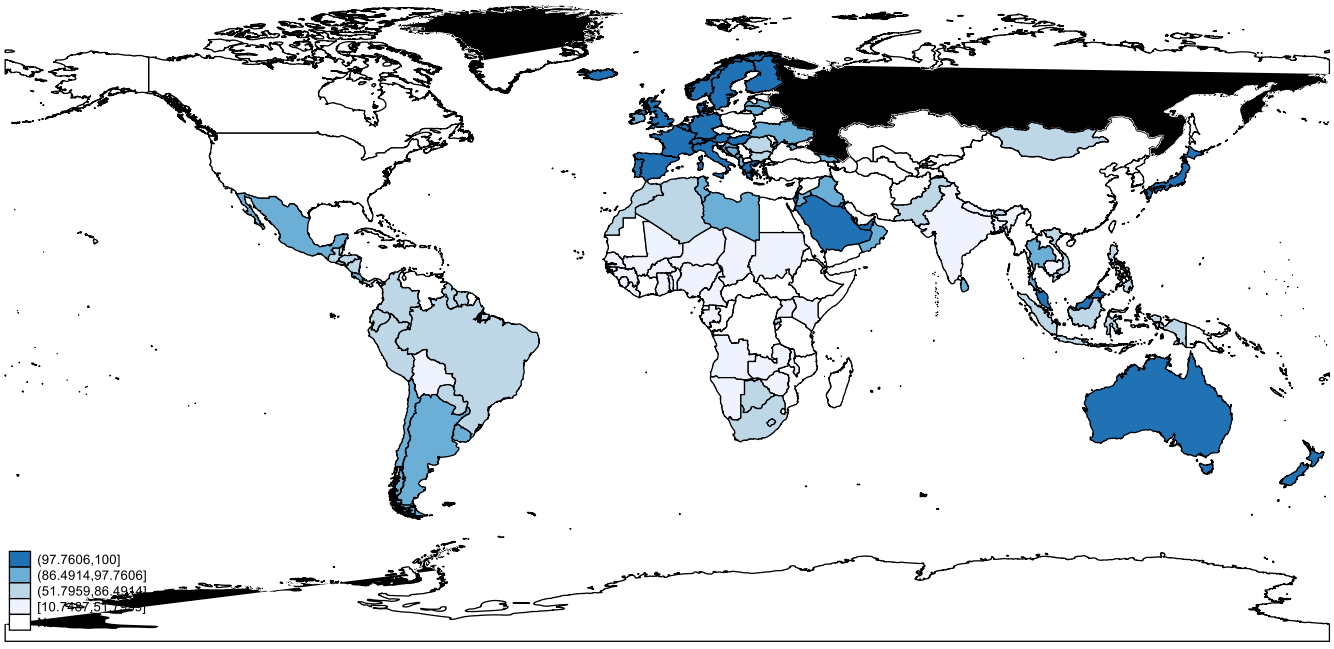
Also, from Fig. 1B, financial inclusion has a positive and significant effect on ABDWS in SAR, EAP, and LAC, while its impact in SSA is negative and significant. On the other hand, financial inclusion has an insignificant effect on ABDWS in ECA and MENA. Fig. 1B further indicates that financial inclusion has a significant and positive impact on ABDWS_R in SAR, EAP, and LAC, while it is significantly negative in SSA. In ECA, financial inclusion has an insignificant positive effect on ABDWS_R. In SAR, EAP, and LAC, the impact of financial inclusion on ABDWS_UR is significantly positive, while the impact of financial inclusion on ABDWS_UR is significantly negative in SSA. In ECA, financial inclusion has an insignificant negative effect on ABDWS_UR and an insignificant positive effect on ABDWS_UR in the MENA. These results generally imply that financial inclusion plays an important role in driving access to safe drinking water in SAR, EAP, and LAC since these regions have relatively higher financial inclusion. On the other hand, SSA has a weak or low financial inclusion, thereby hindering the region's access to safe drinking water.

4.3.3.2. Effects of income inequality and financial inclusion on access to basic sanitation services across geographical regions. Fig. 2A highlights that the impact of income inequality on ABSS is significantly negative in SAR, the MENA, SSA, and LAC. On the contrary, income inequality

[4] The detailed Tables containing the results for the regions are available upon request.



Appendix Fig. 1. . Geographical distribution of access to basic drinking water.

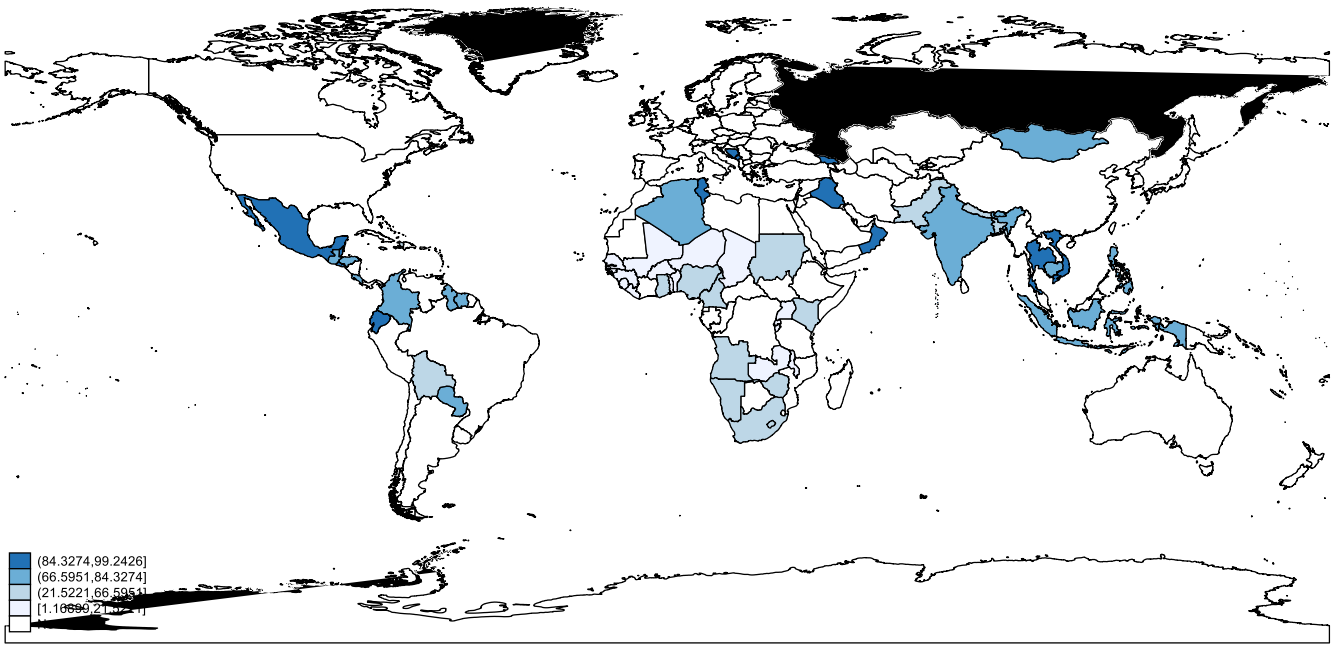


Appendix Fig. 2. . Geographical distribution of access to basic sanitation services.

impacts ABSS positively and significantly in ECA and EAP. Similarly, the results indicate that the impact of income inequality on ABSS_R is significantly negative in SAR, MENA, SSA, and LAC. On the contrary, income inequality impacts ABSS_R positively and significantly in ECA. Also, income inequality has a negative effect on ABSS_UR in SAR, MENA, SSA and LAC, but the impact is only significant for SAR and MENA. Contrarily, income inequality has a significant positive effect on ABSS_UR) in ECA. Generally, these results indicate that the relatively higher income inequality in SAR, the MENA, SSA, and LAC has been a significant barrier to access to basic sanitation services. However, EAP and ECA are the regions with relatively lower income inequality, thereby boosting access to basic sanitation services in these regions.

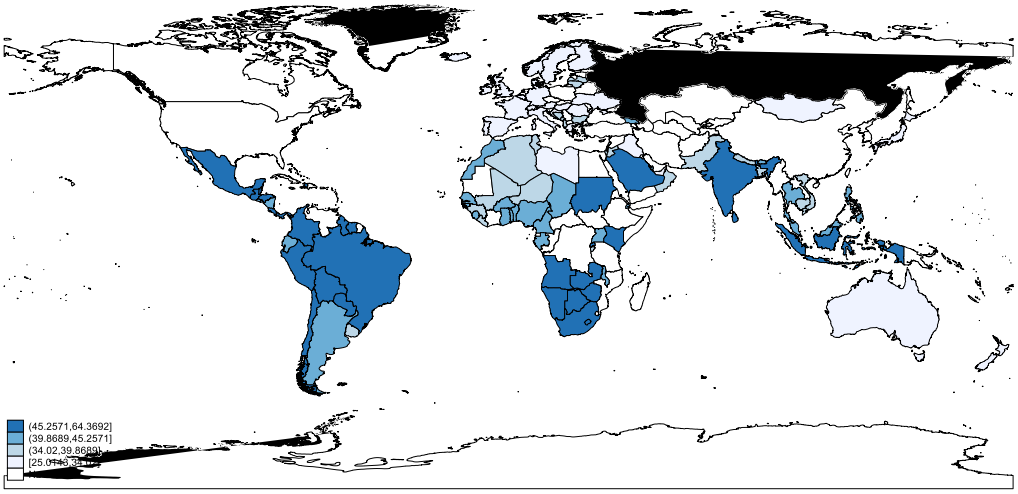
From Fig. 2B, FI impacts ABSS positively and significantly in SAR, ECA, EAP, SSA, and LAC. In MENA, financial inclusion has an insignificant negative effect on ABSS. Similarly, financial inclusion impacts ABSS_R positively and significantly in SAR, ECA, EAP, SSA, and LAC. In MENA, FI has an insignificant negative effect on ABSS_R. Also, FI has a significant positive effect on ABSS_UR in ECA, EAP, SSA and LAC but has an insignificant positive effect on ABSS_UR in SAR and MENA. Again, these generally highlight that FI spurs access to sanitation services in SAR, ECA, EAP, SSA, and LAC but plays no role in access to sanitation services in the MENA region.

4.3.3.3. Effects of income inequality and financial inclusion on access to basic handwashing facilities across geographical regions. As presented in Fig. 3A, income inequality significantly and negatively affects HWF in



Appendix Fig. 3. . Geographical distribution of access to basic handwashing facilities.

Appendix Figure 3: Geographical distribution of access to basic handwashing facilities



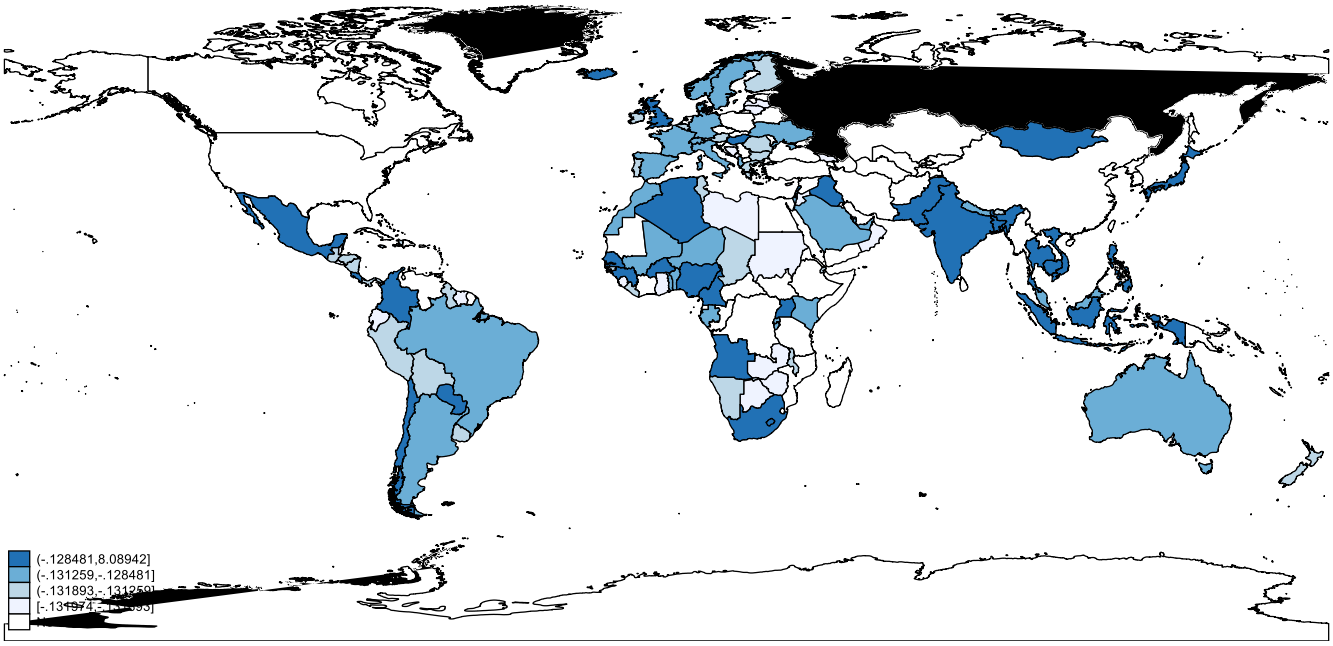
Appendix Fig. 4. . Geographical distribution of income inequality.

SAR, MENA, EAP and SSA. Also, income inequality has a significant positive effect on HWF in ECA and LAC. In SAR, MENA, EAP and SSA, income inequality has a significant negative effect on HWF_R. Also, income inequality has a significant positive effect on HWF_R in ECA and LAC. Also, in SAR, the MENA, EAP, and SSA, income inequality has a significant negative effect on HWF_UR. Also, income inequality has a significant positive effect on HWF_UR in ECA and LAC. We can derive from these results that access to handwashing facilities is hindered by relatively higher income inequality in SAR, MENA, EAP and SSA.

Fig. 3B shows that FI significantly and negatively affects HWF in SAR and SSA. In MENA and EAP, FI significantly has a significant and positive effect on HWF; however, the effect of FI on HWF in ECA and the LAC is statistically insignificant. Fig. 3B demonstrates that FI significantly reduces HWF_R in SAR, SSA and LAC. However, in MENA and EAP, FI significantly increases HWF_R, while its impact on HWF_R in ECA is statistically insignificant. We also noted from Fig. 3B that the FI impact on HWF_UR is significantly negative in SAR and SSA. Meanwhile, Fig. 3B highlights that in MENA and EAP, FI significantly increases HWF_UR, while in ECA and LAC, the effect of FI on HWF_UR is statistically insignificant. These results denote that FI plays a crucial role in accessing handwashing facilities in MENA and EAP, while it does not promote access in SAR and SSA due to probably the relatively low FI in these regions.

4.4. The moderation (conditional) effect of income inequality and financial inclusion on WASH

The moderating effects of income inequality and FI on WASH are presented in Table 7. After accounting for the interactions between financial inclusion and income inequality, the coefficients of financial inclusion are significantly negative. Similarly, the coefficients of income inequality are significantly negative across all the columns. At the same time, the estimated coefficients of the interaction between financial inclusion and income inequality are significantly positive across the



Appendix Fig. 5. . Geographical distribution of financial inclusion.

columns. Because the interactive effect of financial inclusion and income inequality are conditioned effect estimates, they cannot be interpreted as unconditioned effects. To have a meaningful interpretation of the interaction effect, we follow the recommendation of (Brambor et al., 2006); we use Eq. (3) to examine the marginal effect of income inequality on WASH conditioned on different values of financial inclusion.

The marginal effect shows that the role of income inequality on WASH is contingent on FI. The conditional effect results generally support the idea that increasing FI would reduce the role of income inequality in access to safe drinking water, sanitation and hygiene. For instance, at an FI threshold value of zero(0), indicating no FI, the marginal effects of income inequality are significantly negative. Thus, with no FI, income inequality significantly reduces access to basic drinking water (*ABDWS*), access to basic drinking water by the rural population (*ABDWS_R*), access to basic drinking water by the urban population (*ABDWS_UR*), access to basic sanitation services by the entire population (*ABSS*), access to basic sanitation services by the rural population (*ABSS_R*) access to basic sanitation services by the urban population (*ABSS_UR*), access to handwashing facilities by the entire population (*HWF*), access to handwashing facilities by the rural population (HWF_R) and access to handwashing facilities by the urban population (*HWF_UR*).

Contrarily, at the FI threshold values of 16.266 and 20.266, indicating increasing financial inclusion, the marginal effects of income inequality are significantly positive, and the estimated marginal effects coefficients of income inequality rise as the FI threshold increases. Thus, with increasing financial inclusion, income inequality enhances access to basic drinking water (*ABDWS*), access to basic drinking water by the rural population (*ABDWS_R*), access to basic drinking water by the urban population (*ABDWS_UR*), access to basic sanitation services by the entire population (*ABSS*), access to basic sanitation services by the rural population (*ABSS_R*) access to basic sanitation services by the urban population (*ABSS_UR*), access to handwashing facilities by the entire population (*HWF*), access to handwashing facilities by the rural population (HWF_R) and access to handwashing facilities by the urban population (*HWF_UR*).

5. Conclusion and policy implication

This paper investigates the effect of income inequality and financial inclusion on WASH using a comprehensive panel dataset from 119 countries between 2004 and 2020. Heteroskedasticity-based instrumental variable regression and the Driscoll-Kraay estimator are used to account for endogeneity and cross-sectional dependency inherent in panel data, respectively. We infer five key findings from the results:

The first finding is that income inequality is associated with a reduction in WASH adoption and practices. In addition, the findings highlight that although income inequality could be a barrier to WASH adoption and practices among rural and urban residents, the negative effect is more pronounced for rural residents than for the urban population. The second result is that financial inclusion significantly facilitates WASH adoption and practices. As financial inclusion promotes WASH among rural and urban populations, the role of financial inclusion in enhancing WASH adoption and practices is more pronounced among the rural than the urban. Third, the findings highlight heterogeneity in the effect of income inequality and financial inclusion on WASH across income groups. For instance, the evidence shows that income inequality adversely affects WASH adoption and practices across all income groups. On the other hand, the findings suggest that financial inclusion facilitates WASH adoption and practices in lower-middle, upper-middle and high-income countries and not in low-income countries.

The fourth finding is that the impact of income inequality and financial inclusion differ across regions. For instance, the results indicate that income inequality hinders access to safe drinking water and sanitation services in SAR, MENA, SSA, and LAC but facilitates access to safe drinking water, sanitation and handwashing facilities in EAC and EAP. At the same time, income inequality minimises access to handwashing facilities in SAR, MENA, EAP, and SSA but contributes to access to handwashing facilities in ECA and LAC. Also, the findings highlight that financial inclusion spurs access to safe drinking water in SAR, EAP and LAC but inhibits access to safe drinking water in SSA. Similarly, financial inclusion also facilitates access to basic sanitation services in SAR, ECA, EAP, SSA and LAC. Financial inclusion reduces access to handwashing facilities in SAR and SSA but enhances access to handwashing facilities in the MENA and EAP. The fifth finding is that the effect of income inequality is conditional on financial inclusion. Thus, through our

interaction and marginal effect analysis, we documented that the adverse effect of income inequality on WASH is reduced when financial inclusion increases. For the control variables, GDP per capita, remittance, government spending, urbanisation and the rule of law are enablers of access to safe WASH, but foreign aid is found not to enhance access to safe WASH.

The findings of the study have implications for SDG Goal 6, which, among others, aims to ensure the availability and sustainable management of water and sanitation for all. Targets 6.1 and 6.2 of the Goal specifically seek to, by 2030, attain universal and equitable access to safe and affordable WASH for all. This study highlights some of the pertinent challenges to these targets. The findings indicate that income inequality impedes the adoption and practices of WASH. Income inequality affects affordability for the people at the bottom of the income ladder. Deduction from the results hence indicates that in achieving SDG6, countries have to consider the income inequality situation. The findings also highlight that financial inclusion is key for engendering access to safe WASH facilities and, to a large extent, minimising the negative effect of income inequality on WASH adoption. This is the case as financial inclusion enhances the affordability aspect of WASH.

Given that income inequality is a barrier to WASH, governments could address income inequality using redistribution and social welfare policies. Pro-poor policies that support an inclusive economy and society and build the human capital of the marginalised or vulnerable households are key for improving and facilitating access to safe drinking water, sanitation and handwashing facilities. Also, given that poorer households and communities incur significant costs in constructing WASH facilities, the government could support them by subsidizing the cost of materials used to construct WASH facilities to cover some of the initial costs of adoption. Regarding financial inclusion, governments could incentivise financial institutions such as banks, credit unions, savings and loan companies, and other microfinance institutions to provide loans or credit with low interest rates to support the development, access, and adoption of WASH practices. To ensure that loans or credits are used to finance the construction of WASH facilities, the government could collaborate with financial institutions to set up a task force to monitor and assess if these loans are utilized to construct WASH facilities. Along this line, governments could provide financial rebates to poorer households that use loans or credit access from financial institutions to construct WASH facilities. Also, rural communities are largely excluded from financial services; therefore, promoting financial inclusion in rural and distant communities through mobile banking, financial literacy, and microfinance is key for driving accessibility to safe drinking water, sanitation and handwashing facilities in these underserved communities.

Despite the contributions of this study, there are some limitations that warrant further studies. First, this study is limited as it only examines the conditional and unconditional effect of income inequality and financial inclusion on access to WASH. However, it does not test for the potential transmission channels through which income inequality and financial inclusion affect WASH. Therefore, future studies can extend this study by conceptualising and examining the potential transmission channels through which income inequality and financial inclusion affect WASH. Second, this study is also limited as it did not consider the role of institutions and policies on access to WASH. Better institutions and policies are crucial for improving access to WASH. Therefore, future studies can extend this study by investigating the effect of countries' institutions and policies on access to WASH. Finally, while this study is focused on the macro level, future studies can extend and complement our study by deploying a household survey dataset to investigate the social and financial barriers to WASH.

CRediT authorship contribution statement

Alex O. Acheampong: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft. **Eric Evans Osei Opoku:** Conceptualization, Formal analysis, Methodology, Writing – original draft. **Godsway Korku Tetteh:** Conceptualization, Methodology, Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix

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