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# Does Economic Growth Drive Equitable Water and Sanitation Access? Assessing Inequality Reduction Across 64 Nations

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## ABSTRACT

This article examines whether economic growth reduces inequalities in access to water and sanitation across 64 countries over an average period of 13.5 years. Drawing on disaggregated data by income quintiles and rural–urban location, and employing ordinary least squares (OLS), two-stage least squares (2SLS), and Seemingly Unrelated Regression Estimation, the study finds that GDP per capita growth is associated with overall improvements but limited distributive gains. Disparities persist among lower-income quintiles and rural populations, and sanitation inequality shows no significant correlation with growth. The findings underscore the bidirectional relationship, as inequality in water access negatively impacts GDP per capita. Governance effectiveness, water use efficiency, and educational attainment emerge as stronger predictors of equitable access than income inequality. These results challenge growth-centric development paradigms and call for equity-oriented policy that integrates social and spatial justice into water and sanitation governance.

## 1 | Introduction

Despite numerous global commitments to improving access to water and sanitation—including their recognition as fundamental human rights and their inclusion into the Sustainable Development goals (SDGs) (Antunes and Martins 2020; Giné-Garriga and Pérez-Foguet 2019)—millions still lack safe and reliable infrastructure (Adams et al. 2016; Fuller et al. 2016). These persistent deficiencies represent not only a critical public health challenge but also a significant social justice issue, reflecting and reinforcing broader socio-economic inequalities (Sultana 2018). Recent evidence indicates that progress in expanding water and sanitation access remains uneven both across and within countries (Fuller et al. 2016; Dungumaro 2007). Persistent economic disparities, rural–urban divides, and social hierarchies

continue to shape service distribution (Adil et al. 2021; Malakar et al. 2018; Flores Baquero and Pérez Foguet 2016). Socio-demographic factors—including income level, educational attainment, household structure, gender, and geographic location—emerge as key determinants of access (Adams 2018; Sintondji et al. 2017; Chaudhuri and Roy 2017), while disparities are compounded by institutional weaknesses and limited political will (Bayu et al. 2020; de Oliveira and Saiani 2021).

Economic growth has traditionally been viewed as the primary driver of improved access to basic services, premised on the assumption that higher national wealth enables infrastructure investment and service coverage. However, GDP-centered paradigms have proven insufficient to address deep-rooted social challenges, as stagnating growth often coincides with widening

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inequality (Cetrulo et al. 2020; OECD 2020; Nicholson 2019). Achieving equitable and sustainable progress requires policy frameworks that integrate social and environmental well-being within economic objectives (Cetrulo et al. 2020; OECD 2020). Feminist and postcolonial scholarship emphasizes how intersecting dimensions of marginalization—including class, caste, gender and ethnicity—can exacerbate exclusion from essential services such as water, even when aggregate improvements in access are registered (Crenshaw 1989; Sultana 2011; Joshi and Fawcett 2005).

Although the nexus between poverty and poor access to water and sanitation has been extensively documented (Yang et al. 2013; Gazzeh and Abubakar 2018), limited comparative evidence exists on whether economic growth reduces disparities across income groups or regions. This ambiguity is consistent with broader debates on the complex, bidirectional relationship between inequality and growth, where inequality may act as both a driver and a constraint depending on institutional and policy contexts (Rahman and Alam 2021). Harada (2015) argues that sustained growth depends not only on economic specialization but also on robust intersectoral linkages; their absence risks a “growth trap,” characterized by stagnation and entrenched inequality. Consequently, social systems—including dimensions such as health resources, quality of life, rural–urban dynamics and inclusive equity—are integral to enhancing productivity and ensuring inclusive growth (Zhou et al. 2022; Hanushek 2017). Persistent regional heterogeneity reinforces the need for policy approaches that account for context-sensitive and equity-oriented policy design (Zhou et al. 2022).

Historical theorization, notably Kuznets' model, suggested that inequality rises during the shift from agrarian to industrial economies, peaking before declining through redistribution and social change. Yet empirical evidence remains inconclusive: international data compiled by López Menéndez et al. (2006) fail to consistently confirm the Kuznets curve, highlighting the contextual, methodological and institutional factors in shaping outcomes. This article examines the relationship between economic growth and inequality in access to water and sanitation across 64 countries. Moving beyond assumptions of a linear correlation between GDP per capita and equitable service delivery, it employs cross-sectional data and econometric techniques—OLS, 2SLS, SURE—to assess whether rising national incomes translate into more inclusive outcomes in urban and rural contexts. The findings suggest that the effect of growth on reducing inequality in access is marginal. Economic growth alone cannot account for a country's progress toward equitable access to water and sanitation services. By centring inequality—rather than access alone—this study advances debates on the limitations of growth-led models and highlights the need for equity-oriented policies to realize the human right to water and sanitation.

Following this introduction, this article is structured as follows. The next section outlines the conceptual framework for the study, followed by a description of the data and methodological approach. Subsequent sections present and analyse the empirical findings, discuss their broader implications, and conclude with the key insights and policy considerations.

## 2 | Literature Review

### 2.1 | Theoretical Foundations

The relationship between economic growth, inequality, and access to water, sanitation, and hygiene (WASH) services is fundamental to understanding inclusive development. Classical economic perspectives argue that economic expansion provides the fiscal and institutional basis for improving living standards, including access to essential services. In line with this, the Kuznets curve proposes that inequality initially increases during early industrialization but ultimately declines as economies mature and redistribute resources more effectively (Kuznets 1955). Applied to WASH, this implies that as countries become wealthier, increased public investment and stronger institutions should promote more equitable access to safe drinking water and sanitation (Fuller et al. 2016). Recent studies have also adapted the Kuznets hypothesis to the water sector showing that in household water security, disparities first widen and then narrow as overall water security improves in low- and middle-income contexts (Mao et al. 2022). This nonlinear relationship complements evidence at the macroeconomic level, where wealthier nations with greater institutional capacity tend to achieve broader and more equitable access to WASH (Libanio 2021).

However, empirical evidence from low- and middle-income countries (LMIC) shows that such convergence is far from automatic (Babuna et al. 2023; Bankole et al. 2023). Lee and Lee (2024) show a decoupling pattern between growth and equity, finding that economic growth worsens household income inequality despite increasing labor income share. Thus, the second half of the Kuznets curve—the downward phase, which reduces inequality—has flattened in many countries, suggesting that the relationship between macroeconomic growth and WASH inequality should not be seen as a deterministic Kuznetsian path but as a conditional process shaped by mediating variables such institutional quality, public investment strategies and social policy coherence (Libanio 2021; Babuna et al. 2023).

Endogenous growth theory offers a complementary perspective, challenging the assumption that economic expansion alone guarantees social progress. Unlike neoclassical models, which treat technological change as exogenous, this approach emphasises that long-term growth depends on deliberate investment in human capital, innovation, and institutional quality (Lucas 1988; Romer 1990). These factors not only drive productivity but also shape the distributional outcomes of development, as stronger institutions and knowledge systems enable more inclusive access to essential services. When applied to WASH services, this suggests that improvements in water and sanitation coverage are contingent on governance and capability-building rather than automatic spillovers from rising GDP. Countries that fail to invest in education and institutional capacity risk consolidating structural inequalities, even amid aggregate economic gains from the first paradigms.

Welfare economics and the capability approach provide further grounding for this argument. Sen (1999) conceptualized development as the expansion of capabilities—defined as the

substantive freedoms that allow individuals to lead lives they have reason to value. From this perspective, equitable WASH constitutes both an outcome of human development and a catalyst for its advancement. Libanio (2021) demonstrates that human development—measured through income, education, and health dimensions—depends not on economic growth alone but on the governance mechanisms that convert economic resources into well-being. Countries with rapid GDP growth but weak institutions often fail to achieve proportional improvements in access to basic services, revealing the limits of market-driven “trickle-down” effects. The evidence that improved access to water and sanitation generates economic returns between 3 and 34 times the investment cost reinforces this interdependence (Stockholm International Water Institute (SIWI) 2005). Therefore, equitable access constitutes a productive asset rather than a welfare expenditure. Conversely, Cumming and Cairncross (2016) show that unequal WASH access perpetuates human capital deficits—malnutrition, stunting, and illness—thereby constraining long-term growth potential (Hutton and Chase 2016). Collectively, these findings suggest a bidirectional relationship: while economic performance influences the fiscal capacity for WASH provision, equitable WASH services, in turn, underpin and sustain inclusive patterns of economic growth.

Theoretical advances since the 2000s have reframed WASH access as part of a “nexus” approach linking human development, resource security, and economic performance (Libanio 2021). This perspective emphasizes interdependence: reliable water and sanitation underpin education, health, and labor productivity, while equitable social policies ensure that economic gains are transformed into inclusive outcomes. Yet, as multiple authors note, economic growth without complementary governance reforms can deepen disparities in access. Export-led or resource-intensive growth models often prioritize capital accumulation over human capital development, creating “growth without inclusion” (García-López et al. 2024; Cumming and Cairncross 2016). In this sense, the WASH sector provides a critical test of the extent to which macroeconomic gains are translated into equitable improvements in living conditions.

The recognition of water and sanitation as human rights by the United Nations (UN General Assembly 2010) institutionalized the normative and justice dimensions of WASH within the global development agenda. This recognition redefined access to these essential services not as a residual outcome of economic growth, but as a matter of justice and human dignity. By embedding legal and moral obligations within international and national governance frameworks, it shifted the policy discourse from discretionary provision to enforceable rights, thereby enhancing state accountability and empowering individuals and communities to claim equitable access. In this sense, access to water and sanitation constitutes not only a precondition for health and productivity but also a tangible expression of distributive and procedural justice. The SDGs, particularly SDG 6, embed this right within a broader framework of social inclusion and environmental sustainability, reinforcing the idea that equitable WASH access is both a precondition and an indicator of Sustainable Development. Thus, the theoretical foundations linking economic growth and

WASH inequality converge around three central principles: (1) growth can generate resources but not necessarily equity; (2) governance and public investment mediate the translation of economic resources into service delivery; and (3) equitable WASH access enhances human capital, sustaining long-term development.

## 2.2 | Determinants of Inequality in Water and Sanitation Access

### 2.2.1 | Economic and Social Determinants

Economic prosperity facilitates infrastructure investment, yet income inequality frequently determines who benefits from these investments. Income is one of the major determinants of access to water and sanitation, implying a lack of access when financial resources are limited (Yang et al. 2013; Hargrove 2020). Bankole et al. (2023) show that, across developing countries, GDP per capita correlates positively with sanitation coverage but that inequality in income distribution significantly attenuates this effect. Poorer households remain systematically excluded, even in middle-income contexts, due to affordability barriers and inadequate targeting of subsidies (Ezbakhe et al. 2019). In this line, Cumming and Cairncross (2016) highlights that poor WASH conditions perpetuate intergenerational poverty through adverse health and nutrition outcomes, particularly stunting and cognitive impairment in children. These findings underscore that economic inequality and WASH inequality are mutually reinforcing, creating self-sustaining cycles of deprivation (García-López et al. 2024).

Population dynamics play a critical role in shaping access to drinking water and sanitation. Rapid population growth, particularly in LMIC, often places significant pressure on water infrastructure, making it difficult to expand or maintain coverage at the same pace (Babuna et al. 2023; Cetrulo et al. 2020). While total population increase can drive investments and network expansion in some contexts, it frequently exacerbates inequalities, as service improvements tend to concentrate in urban centers and wealthier households, leaving marginalized populations underserved (Satterthwaite 2016; Guo et al. 2022). Additionally, education level is found to be a determinant of access to improved drinking water and sanitation, as households with higher educational attainment are more likely to secure and maintain improved services (Agbadi et al. 2019).

An intersectional perspective is needed to further reveal how interlocking systems of disadvantage—rooted in gender, socioeconomic status, ethnicity, and spatial location—mutually reinforce exclusion from water and sanitation services, thereby intensifying vulnerability among marginalized populations (Shah et al. 2023; Sultana 2011; Luh et al. 2013). These intersecting axes of inequity determine not only differential access to WASH infrastructure but also varying degrees of agency in decision-making, participation, and the capacity to claim rights. Education, gender, and household composition critically influence both the demand for and the realization of improved WASH services, reflecting broader patterns of social stratification. Women and children, in particular,

disproportionately absorb the physical, temporal, and psychosocial burdens of inadequate provision—devoting significant time to water collection and facing heightened exposure to health hazards (Cumming and Cairncross 2016; García-López et al. 2024).

### 2.2.2 | Institutional and Governance Determinants

Institutional quality has emerged as a central explanatory variable in understanding cross-national disparities in access to WASH services. Beyond the availability of physical and financial resources, transparency and accountability of governance systems fundamentally determine the extent to which such resources are equitably distributed and sustainably managed (Bromley and Anderson 2018; Cuadrado-Quesada et al. 2018; Cuadrado-Quesada and Joy 2021). Babuna et al. (2023) empirically demonstrate that adequate governance and regulatory coherence strongly predict lower water inequality and greater water security. Poorly governed systems foster corruption, inefficient allocation, and fragmented responsibilities, undermining equitable service provision. Similarly, Pinilla-Rodríguez and Torres-Sánchez (2019) find that higher levels of social public spending correlate with improved rural water coverage in Latin America, suggesting that fiscal commitment and institutional continuity are essential for inclusive outcomes.

### 2.2.3 | Spatial and Environmental Dimensions

Spatial disparities, particularly the rural–urban difference, remain among the most persistent forms of WASH inequality (Yu et al. 2014; Satterthwaite 2016). Chaudhuri and Roy (2017) document significant intra-state variation in sanitation access across Indian districts, revealing clustering patterns consistent with spatial autocorrelation. Similar spatial hierarchies are observed elsewhere, where infrastructure investments and service quality tend to concentrate in economically dynamic or densely populated urban centers, producing a geography of exclusion in peripheral and rural regions (Bravo et al. 2025; Cetrulo et al. 2020; Aleixo et al. 2019; Cole et al. 2018). Environmental pressures compound these spatial inequalities: water scarcity, climate variability, and resource degradation disproportionately affect poorer communities with limited adaptive capacity (Babuna et al. 2023; Hutton and Chase 2016). As Libanio (2021) notes, territorial inequalities in WASH provision mirror broader disparities in human development, underscoring the need for integrated spatial and environmental planning as a foundation for equitable WASH strategies.

## 2.3 | Economic Growth, WASH Inequality and Sustainable Development

The relationship between economic growth and equality in WASH access is both conceptually complex and empirically underexplored. While growth can expand fiscal capacity for investment, whether it translates into reduced inequalities depends on institutional mediation and policy design. Evidence

indicates that WASH investments stimulate growth by improving health, productivity, and employment (Stockholm International Water Institute (SIWI) 2005; Libanio 2021). Yet, the reverse relationship, whether growth fosters more equitable WASH access, remains uncertain in Sustainable Development research.

Macroeconomic expansion can enable governments to finance infrastructure and subsidies, creating opportunities to close access gaps. Stockholm International Water Institute (SIWI) (2005) estimates that achieving global WASH targets could generate USD 84 billion annually through reduced health expenditures, increased labor productivity, and time savings. Similarly, Libanio (2021) finds that countries with higher human development indices tend to achieve broader WASH coverage, illustrating how growth under inclusive governance can support equality. These dynamics align with welfare economics principles, which posit that economic progress can create fiscal space for redistributive investments. Conversely, the absence of adequate WASH access imposes substantial economic costs—up to 4% of GDP in some regions—constraining both social inclusion and growth potential (Hutton and Chase 2016).

However, growth alone does not guarantee equitable outcomes. Periods of economic stagnation have often coincided with widening inequalities and spatial disparities (Cetrulo et al. 2020; OECD 2020). In such contexts, WASH investments may concentrate in urban or industrial areas, deepening rural exclusion. Babuna et al. (2023) emphasize the central role of governance: strong institutions mitigate water inequality even at lower income levels, while weak governance can allow growth to reinforce elite capture and unequal investment patterns. Pro-poor growth frameworks offer alternative pathways by linking expansion to redistributive fiscal policies. Pinilla-Rodríguez and Torres-Sánchez (2019) show how targeted infrastructure spending improved rural access in Latin America, illustrating how policy coherence—not economic magnitude per se—shapes distributional outcomes. This aligns with inclusive growth paradigms and the integrated approach to SDG 6 advocated by World Bank (2017) and Hutton and Chase (2016).

Inequalities in WASH access, in turn, undermine Sustainable Development outcomes. Limited access to safe water and sanitation exacerbates health burdens, reduces labor capacity, and lowers income opportunities for marginalized households (Cumming and Cairncross 2016; García-López et al. 2024). These productivity losses can erode the macroeconomic gains of growth, perpetuating cycles of exclusion. At the societal level, unequal WASH provision amplifies multidimensional poverty, weakens social cohesion, and undermines resource security. Babuna et al. (2023) link water inequality to heightened social instability, while Libanio (2021) associates equitable access with higher human development scores.

These feedback loops reveal that equitable WASH systems not only reflect inclusive growth but actively sustain it. Investments in water and sanitation yield high social returns by reducing disease prevalence, boosting productivity, and strengthening human capital (Stockholm International Water Institute (SIWI) 2005; Cumming and Cairncross 2016). Improvements in early childhood WASH, for example, reduce stunting and

enhance educational outcomes, with long-term economic benefits. Thus, linking growth to equitable WASH access is not merely a distributive concern but a foundational condition for achieving the SDGs and a resilient, inclusive development trajectory.

### 3 | Data and Methodology

#### 3.1 | Data

The original database constructed for this research comprises information on a sample of 65 countries. The sampling strategy involved identifying all countries with available records on inequality in access to water and sanitation from the JMP database, amounting to 93 countries in total. However, many of these were excluded because it was not possible to obtain Gini index values or inflation rate data for the entire study period. Additionally, Angola is excluded from all calculations due to its identification as an outlier, mainly caused by an extreme increase in its price level, which would severely affect the results. The final selection of countries can be seen in Table A1 of the Appendix A.

The information employed comes from several institutions, depending on the type of data required, as summarized in Table 1. These datasets cover a wide range of countries and years, enabling an assessment of the evolution of access to water and sanitation over time. Importantly, the data measure not only overall access but also inequality in that access. The key variables used are: (i) the share of the population with basic access to water, (ii) the share of the population with basic access to sanitation and (iii) the GDP per capita (current US\$). Basic access is defined as access to improved water sources located within a 30-min round trip, including queuing time.

To capture inequality and insecurity in WASH access, data are also disaggregated by income quintiles. While the JMP database does not provide income levels associated with each quintile, this structure still allows for a distributional perspective. Quintile data are not available for all years, so we use two points in time per country, enabling at least a partial analysis of changes over time, even if not for the same years across all countries.

The Gini index, used as the primary indicator of income inequality, is mainly obtained from the World Bank. Because these data often do not coincide precisely with the years covered by other indicators, the closest available values from nearby years have been incorporated where necessary. To complement this, we also consider income redistribution through taxation, as government fiscal policies have important implications for access to basic services. Specifically, we include the percentage of income tax paid in 2024 by the lowest and highest income earners, drawing on diverse sources to provide additional insights.

Inflation is incorporated to account for rising prices, which can significantly affect inequality in access to water and sanitation, given that GDP figures are available only in nominal terms. Water Use Efficiency is introduced as a measure of economic efficiency, under the assumption that higher productivity enhances

the conditions for equitable service provision. Governance effectiveness is included as an indicator of institutional performance in ensuring water and sanitation access. Average years of schooling reflect the human capital accumulated within a society, a factor closely linked to social development. Finally, the Economic Complexity Index is incorporated on the basis that economies with more diversified and technologically complex export structures tend to be more developed and better positioned to secure equitable access to basic services.

For each country, the specific years of data depend largely on availability. Accordingly, the analysis focuses on comparing two points in time to track progress in access and inequality over the observed period.

#### 3.2 | Methodology

Based on the information described above, two types of data analysis techniques are applied. First, descriptive statistics are presented for all variables to illustrate their general evolution across the two observed periods. These statistics include measures such as means, standard deviations, ranges, and the number of countries with available information. They provide an overview of the situation in the countries under study before moving on to a more detailed analysis of the relationship between economic factors and WASH access. Standard deviation is central to the methodology, as it quantifies variation or dispersion within the data and has been widely used to study inequality (Syróvátka and Schlossarek 2019; McKenzie 2005; Kalmijn and Veenhoven 2005). Specifically, it is employed here as a measure of inequality in WASH access. This is calculated by quintiles of access to water, allowing an assessment of the average deviation across quintiles and of its interaction with economic indicators such as GDP, income levels, the Gini index, price dynamics, government effectiveness, years of schooling, and economic complexity.

After analyzing descriptive statistics for both time periods and evaluating the changes across countries, econometric estimations are carried out using ordinary least squares (OLS), two-stage least squares (2SLS), and seemingly unrelated regression equations (SURE). These estimations are based on the second period of data.

The choice of methods is conditioned by the potential simultaneous relationship between access to water or sanitation and economic growth. On one hand, insufficient access constrains growth; on the other, higher economic growth facilitates access, generating simultaneity bias (García-López et al. 2024). Addressing this bias requires appropriate econometric techniques. Although methods such as three-stage least squares (3SLS), maximum-likelihood simultaneous equation models, dynamic panel models, or bayesian/simulation approaches (MCMC) are designed for this purpose, these require larger samples than are available here (Rosales Álvarez et al. 2010; González Lara 2023). Consequently, only 2SLS and SURE are applied in this study. Both techniques have been successfully used to analyse interdependent relationships in other fields, such as the links between growth, energy use, and environmental quality (Malik 2021), or between environmental

**TABLE 1** | Description of the main variables and source.

Variable	Description	Source	Justification
Population	Total population of a country, with data available disaggregated by rural and urban areas.	AQUASTAT	The population size of a given area has a direct impact on demand for water and the infrastructure required for access to this resource. Population pressure has the potential to constrain access, provided that it is not counterbalanced by investment (Babuna et al. 2023; Cetrulo et al. 2020).
Access to water	Proportion of the population with basic access to water, providing information for national, urban, and rural populations.	JMP	Key variable
Access to sanitation	Proportion of the population with basic access to sanitation, providing information for national, urban, and rural populations.	JMP	Key variable
Inequality in water access	Proportion of the population with basic access to water, disaggregated by quintiles of income, distinguishing between national, rural, and urban areas.	JMP	Key variable
Inequality in sanitation access	Proportion of the population with basic access to sanitation, disaggregated by quintiles of income, distinguishing between national, rural, and urban areas.	JMP	Key variable
Gini index	Measure of inequality that ranges from 0 to 1, where 0 signifies perfect equality, and 1 indicates total inequality, within a population.	WB, the American Central Intelligence Agency, Islamic Republic of Afghanistan; Central Statistics Organization	The presence of elevated values is indicative of the existence of inequality, which in turn gives rise to greater disparities in access to fundamental resources such as water (Cetrulo et al. 2020; Babuna et al. 2023; WWAP 2019; UNDP 2024).

(Continues)

TABLE 1 | (Continued)

Variable	Description	Source	Justification
Consumer price index	Inflation rate included to illustrate the evolution of GDP in real terms.	International Monetary Fund	Higher prices make it more difficult to access a service (Babuna et al. 2023; Cetrulo et al. 2020).
GDP	Economic indicator, representing the total monetary value of all goods and services produced within a country's borders over a year.	AQUASTAT and the WB	Key variable. A high GDP is frequently linked to superior infrastructure and expanded coverage (Babuna et al. 2023; Cetrulo et al. 2020).
GDP per capita	GDP divided by the population of a country.	AQUASTAT and the WB	See GDP justification.
Water use efficiency	Production obtained from water in \$/m <sup>3</sup>	AQUASTAT	Greater efficiency in water use is indicative of a more developed and complex economy, in which equitable access to basic services is easier to achieve (Babuna et al. 2023).
Effectiveness of Governance	Percentile Rank (0–100), which indicates the rank of a country among all countries in the world. 0 corresponds to lowest rank and 100 corresponds to highest rank.	WB–worldwide governance indicators	Effective governance is imperative for ensuring equitable water distribution, combatting corruption, avoiding the exclusion of vulnerable groups (Babuna et al. 2023; Peng and Zhang 2022; UNDP 2024).
Average years of schooling	Average number of years that adults in a country have spent in formal education	UNDP accessed through our world in data	Education and training influence the management, efficient use, and demand for water resources, facilitating equitable access (WWAP 2019; Peng and Zhang 2022).
Economic complexity index	The economic complexity index is a ranking of countries based on the diversity and complexity of their export basket.	Harvard growth lab's country rankings	Complex economies have been shown to possess greater institutional and financial capacities to ensure equitable access to public services, including water (Babuna et al. 2023).

Note: With the exception of Afghanistan, all figures are sourced from the World Bank. The details about the calculations can be found in <https://atlas.hks.harvard.edu/glossary>.

performance, R&D expenditure, and corporate performance (Wang and Chen 2021).

Nonetheless, simultaneity models are not always necessary. If simultaneity is weak, OLS estimates may not differ significantly from those of 2SLS or SURE, suggesting either an

indirect relationship or insufficient data to construct robust models. Therefore, a range of specification and diagnostic tests are conducted (see Table A5) to evaluate the validity of the models and confirm the need for simultaneity-correcting approaches. These statistical tests reveal that there is no collinearity problem between the dependent variables in any

estimate, but also that models that attempt to address simultaneity bias do not offer a significantly different result, making them unnecessary. This is consistent with the fact that the relationship between inequality in access to WASH services is not direct, but rather materialises through common elements such as access to education.

OLS serves as the baseline technique, with its results later compared against 2SLS and SURE to verify the effect of simultaneity. The dependent variables are GDP per capita (which is used instead of income due to our objective of linking economic growth and inequality in WASH access) and the standard deviation of access to basic water or sanitation. The choice of these dependent variables follows the literature, which has widely examined their interplay with development outcomes (Tangworachai et al. 2023; Adams et al. 2016; Adil et al. 2021; Cetrulo et al. 2020; Babuna et al. 2023; WWAP 2019; UNDP 2024; Peng and Zhang 2022). The independent variables comprise price level, population, the Gini index, water use efficiency, governance effectiveness, average years of schooling, and the Economic Complexity Index. Although income tax data were collected for all 65 countries, they are excluded from the model estimations because the Gini index already reflects after-tax income and the tax data are only available for the most recent period. Instead, income tax is incorporated as descriptive evidence and later used for discussion.

The hypothesised effects of these economic variables run in multiple directions. For example, higher prices or greater income inequality (higher Gini index) restrict access by raising costs or reducing resources available for consumption. By contrast, greater water use efficiency or higher economic complexity are associated with stronger economies, which are better able to finance access. Governance effectiveness and schooling improve institutional capacity and human capital, both of which support access to water and sanitation. In the 2SLS and SURE estimations, GDP per capita and the standard deviation of access (water or sanitation) are considered endogenous, as these variables are jointly determined. Exogenous variables are required as instruments to estimate the endogenous components and mitigate simultaneity bias. The estimations are carried out based on the following formulas:

$$WSD_c = X_c\beta + \epsilon_c \quad (1)$$

$$GDP_c = X_c\beta + \epsilon_c \quad (2)$$

where *WSD* represents water access standard deviation; *GDP* the Gross Domestic Product; *X* is a vector of individual explanatory variables plus a constant term;  $\beta$  is a vector of parameters and  $\epsilon$  is a random error term. The sub-index *c* refers to the unit of analysis used, the countries. These models have been run for both water access and sanitation, but given the similarity of results, only those on water access will be shown and commented on in the main text.

Twelve OLS estimations are initially performed: two per equation, across three spatial dimensions (national, urban, and rural) for both water and sanitation. For national and urban water access, the OLS results are supplemented with 2SLS

and SURE estimations, while in rural water access and all sanitation cases, OLS results indicate no simultaneity bias and therefore only OLS estimates are retained. These estimations are conducted only for the second time period. The initial OLS models include all variables as regressors when explaining GDP and the standard deviation of access. The subsequent 2SLS and SURE models are presented alongside these OLS estimates, with instruments used to address endogenous regressors.

The models are separately estimated at national, urban, and rural scales. Despite these adjustments, the core results remain consistent, reinforcing the robustness of the findings.

## 4 | Results

### 4.1 | Descriptive Evidence

As illustrated in Table 2, the descriptive statistics pertaining to the variation of the variables analysed at the two specified points in time—referred to as ‘moment A’ and ‘moment B’—are presented. The average number of years separating these two moments is 13.5 years.

The population results demonstrate a modest overall expansion, with only six out of 65 countries experiencing population declines. The majority of the sample demonstrated a clear process of urbanisation, characterised by a substantial increase in urban populations and a concurrent limitation in rural growth. This observation signifies a persistent demographic shift towards urban centres. These patterns suggest increased demand for urban services yet a relatively stable rural base, structurally favouring urban service provision.

Regarding economic indicators, widespread growth in GDP has been observed; however, it is important to note that this growth has been distributed unequally. Three countries witnessed a decline in their GDP, yet 17 recorded a drop in GDP per capita. This phenomenon is indicative of instances where aggregate gains have failed to engender an improvement in average living standards. Price levels exhibited an increase, indicating a substantial degree of inflation that potentially countervailed economic advancement in numerous instances. As demonstrated in Table A2, the fiscal evidence of these countries reveals diversity in personal income taxation. The lowest earners are subject to rates of up to 28% from a minimum of 0%, showing big differences between countries, while the highest brackets are subject to rates of up to 45%. This highlights the heterogeneity in redistributive policy approaches. It is noteworthy that the Economic Complexity Index and Water Use Efficiency exhibit significant variability and predominantly positive trends, suggesting that sectoral modernisation is progressing, albeit not uniformly.

Governance effectiveness and educational attainment display marginal improvement. The mean increase in governance effectiveness is reduced, and considerable heterogeneity is revealed. Education, as measured by the number of years spent in school, demonstrates gradual yet uneven progress across different countries. This suggests that there is a slow but

**TABLE 2** | Descriptive statistics of the variation between A and B.

Variable	Obs.	Mean	Std. dev.	Min	Max
Consumer price index	64	1.689	1.619	0.168	7.995
Gini index	64	-0.036	0.118	-0.259	0.356
Total population	64	0.249	0.202	-0.369	0.698
Urban population	64	0.437	0.356	-0.518	1.619
Rural population	64	0.125	0.197	-0.344	0.555
GDP	64	2.022	2.101	-0.775	8.985
GDP per capita	64	1.343	1.500	-0.635	6.084
Effectiveness of governance	64	0.079	1.767	-5.441	10.473
Average years of schooling	64	0.298	0.219	-0.048	1.015
Economic complexity index	55	0.853	13.413	-34.333	92.000
Water use efficiency	53	0.638	0.770	-0.464	3.542
Basic access to water-national	64	0.204	0.297	-0.179	1.412
Basic access to water-urban	64	0.068	0.146	-0.358	0.690
Basic access to water-rural	64	0.342	0.530	-0.313	3.010
Basic access to water (National)-standard deviation	64	-0.093	0.798	-0.993	4.905
Basic access to water (Urban)-standard deviation	64	-0.103	0.672	-0.973	2.157
Basic access to water (Rural)-standard deviation	64	0.111	1.016	-0.993	6.041
Basic access to sanitation-national	64	0.355	0.515	-0.133	2.185
Basic Access to sanitation-urban	64	0.162	0.262	-0.215	1.094
Basic Access to sanitation-rural	64	0.752	1.649	-0.616	11.615
Basic access to sanitation (National)-standard Deviation	64	0.113	0.811	-0.830	3.617
Basic access to sanitation (urban)-standard deviation	64	0.221	2.465	-0.842	19.146
Basic access to sanitation (rural)-standard deviation	64	0.342	1.286	-0.911	7.488

Note: The number of Economic Complexity Index observations is 55 since eight countries did not possess the necessary data at time A and the value for Afghanistan was removed. The variation of Afghanistan from -0.01 to -1.23 demonstrates a strongly negative shift, which obscures the prevailing positive trend. However, this does not transform Afghanistan into an outlier for econometric estimations, in which only the most recent observations have been incorporated. There are only 53 Water Use Efficiency observations because 11 countries did not have this data at time A.

continuous development in institutional capacity and human capital.

Access to water was found to have improved overall at all levels, with rural areas demonstrating the most significant progress. In contrast, urban areas exhibited only marginal gains. It is important to acknowledge that, in urban areas, initial access levels are comparatively higher. Beyond these averages, the standard deviations for water access diminished at national and urban levels, but rose at rural scales, signalling increased inequality in rural areas but reduced inequality in urban ones. This issue is of particular pertinence, as it demonstrates that advances achieved in rural regions have been accompanied by an escalation in inequality. Furthermore, it has been demonstrated that the determinants of access to water vary between urban and rural areas (Chaudhuri and Roy 2017).

A similar trend can be observed in the outcomes pertaining to sanitation, with the majority of countries recording

improvements, particularly in rural settings, and higher averages being observed. However, the increasing standard deviations, particularly in the domain of rural sanitation, are indicative of a growing disparity in coverage. Variability has also been observed in national and urban sanitation coverage. Consequently, with the exception of specific declines observed in select urban areas, disparities in access to water and sanitation have become increasingly evident across the sample. The most impoverished and rural demographic groups encounter the most significant impediments. These findings are consistent with those reported by de Oliveira and Saiani (2021), who identified persistent spatial inequalities in sanitation services in Brazil, with urban areas receiving priority in infrastructure investments.

When analysed by income group, the data show a nuanced pattern. The poorest quintiles recorded the largest gains in water and sanitation access in about 66% of countries, particularly in urban areas. In rural settings, progress was more evenly

**TABLE 3** | Estimates of Equations (1) and (2) by OLS, 2SLS and SURE for water at national scale.

	BWNSD	BWNSD	BWNSD	GDP per capita	GDP per capita	GDP per capita
GDP per capita	−0.001 (0.000)**	−0.001 (0.000)***	−0.002 (0.000)***			
BWNSD				−113.657 (40.061)***	−176.308 (89.474)**	−221.825 (37.763)***
Government Effectiveness	−1.891 (2.115)			2294.170 (1091.235)**	2616.411 (810.423)***	2249.636 (596.717)***
Gini index	0.202 (0.118)*	0.183 (0.112)	0.165 (0.102)	33.353 (35.294)		
Years of schooling	−0.834 (0.344)**	−0.810 (0.348)**	−0.587 (0.292)**	114.534 (124.323)		
Water use efficiency	0.092 (0.054)*	0.104 (0.049)**	0.114 (0.049)**	35.056 (28.239)	42.890 (19.308)**	47.346 (17.933)***
Price index	0.004 (0.005)			0.183 (1.852)		
Population				−0.003 (0.001)**	−0.003 (0.002)*	−0.002 (0.002)
Economic complexity index				412.748 (445.157)		
Constant term	8.431 (6.199)	12.139 (5.007)**	12.733 (4.593)***	3755.239 (2120.458)*	6480.435 (790.184)***	6673.350 (567.325)***
R <sup>2</sup>	0.43	0.41	0.36	0.47	0.44	0.37
N	64	64	64	64	64	64

Note: The first column of each dependant variable is estimated through OLS, the second through 2SLS and the third through SURE. Estimates with GDP per capita as the dependent variable have been made with robust errors due to the presence of heteroscedasticity.

\* $p < 0.1$ .

\*\* $p < 0.05$ .

\*\*\* $p < 0.01$ .

shared, as higher-income groups also improved. Although the wealthiest groups experienced some declines, setbacks among the poorest were more severe when they occurred. Widespread regressions across all income levels were rare – observed in only five countries for water and four for sanitation– whereas comprehensive improvements were more frequent, with 26 and 17 countries showing universal gains for water and sanitation, respectively. These trends align with findings by de Oliveira and Saiani (2021), who observed an “N-shaped” relationship between economic growth and sanitation inequality, reflecting initial reductions in disparities, a mid-income resurgence, and later convergence as coverage expands. However, it also confirms the nuanced picture of the interplay between WASH and poverty pointed out by World Bank (2017, 6).

Regarding the progress of these countries according to the Kuznets model, they are in the process of consolidating their industry and continuing to advance in terms of population and production concentration in urban areas. At this juncture, the maximum level of inequality in society is attained, thereby

justifying the increasing inequality that is evident (with the exception of access to water in urban areas). As Cetrulo et al. (2020) and the OECD (2020) have previously indicated, new integrated policy frameworks are required to modify the process of economic growth so that social and environmental wellbeing objectives are pursued alongside economic ones, rather than being subordinated to economic growth.

## 4.2 | Econometric Estimates

Descriptive and econometric analysis at the national level reveals persistent disparities in access to water and sanitation across countries, shaped by a complex interplay of socioeconomic and governance factors. The results presented in Table 3 provide a comprehensive overview based on OLS, 2SLS, and SURE models, each estimating the determinants of both water inequality (BWNSD) and GDP per capita. Notably, all models with GDP per capita as dependent variable deploy robust standard errors to address detected heteroscedasticity.

Across all specifications, GDP per capita displays a consistently negative and statistically significant association with water access inequality, with OLS, 2SLS, and SURE point estimates centred around  $-0.001$  to  $-0.002$  ( $p < 0.01$ ). This reinforces the established link between economic growth and reduced disparities in water and sanitation, although the magnitude remains modest. Complementarily, BWNSD is negatively associated with GDP per capita, with effect sizes from  $-113.657$  to  $-221.825$  depending on the specification (all significant at the 5% or 1% level). This bidirectional relationship highlights the interconnected nature of income and distributional outcomes in the water sector, but the explanatory power ( $R^2$ ) of these models, while somewhat improved relative to previous estimates, remains moderate, ranging from 0.36 to 0.47 for national scale models. Actually, despite the data showing a positive correlation between increases in GDP per capita and overall coverage rates, they also reveal persistent gaps for low-income quintiles and rural populations. These results are consistent with previous research, as Deshpande et al. (2020) and de Oliveira and Saiani (2021) expressed, economic growth is not sufficient to achieve equality in water and sanitation access and inequalities persist after economic growth processes, and there are many other drivers (Adams et al. 2016; Adams 2018; Dungumaro 2007; Sintondji et al. 2017; Adil et al. 2021).

Government effectiveness emerges as a salient factor: its coefficient, though somewhat imprecisely estimated in the water inequality equations, is robustly positive in GDP per capita regressions, reaching significance at the 5% or 1% level in all specifications. This supports the hypothesis that institutional quality is a key driver of economic performance and, indirectly, of water sector outcomes, as indicated by Bayu et al. (2020) and Victoria (2018). The role of social variables is partly mixed—the Gini index and years of schooling show consistently positive effects on GDP per capita, though coefficients occasionally fall just short of conventional significance thresholds, suggesting room for further inquiry into the impact of distributional and educational reforms. In contrast to previous studies that identify a direct and significant effect of income inequality, measured by the Gini index, on disparities in access to safe water and sanitation (Acheampong 2024; Hasan and Alam 2020; Shadabi and Ward 2022), our results show that the Gini index is not statistically significant. This finding highlights the limited relevance of income inequality as captured by the Gini coefficient for explaining access disparities in our sample, suggesting other factors play more substantive roles.

Water use efficiency exerts a statistically significant and positive influence on both water inequality and GDP per capita, with its coefficient size and significance increasing in SURE estimations. This result points to the importance of technical and managerial improvements in promoting both sector equity and economic development, echoing findings from recent sectoral studies (Jiang 2023; Adams et al. 2016; Victoria 2018).

Price index and population variables, while included to capture economic context, show modest or non-significant effects throughout. Similarly, economic complexity index, albeit positive, is not significant in the main regressions, indicating that macro-level structural factors may only exert indirect or longer-term impacts.

A key statistical insight that emerges from the utilisation of 2SLS and SURE methods is that statistical tests for endogeneity do not necessitate the correction of any simultaneity bias between the primary variables of interest. This revelation indicates that while the correlation between water access inequality and economic growth is evident, the preponderance of this correlation is attributable to indirect effects, such as the inability to acquire an education or to perform a job.

It is important to mention that these results apply to inequality in access at the national and urban levels (see Table A3), but not at the rural level, where estimates (see Table A4) show a lack of correlation between the two main variables from the outset. In line with Bankole et al. (2023), this indicates that the determinants of access differ depending on the context, as well as the urban sphere (industry and services) and not the rural sphere (agriculture) that is driving economic growth. Thus, economic growth is concentrated in the urban sphere without resulting in a reduction in inequality in the rural sphere.

Sanitation outcomes, as reported in Table 4, do not exhibit a significant empirical linkage with income levels or inequality indicators in the sample countries. Across national, urban, and rural scales, GDP per capita demonstrates a negligible and statistically insignificant association with sanitation access inequality, indicating that economic growth alone does not address disparities in sanitation coverage, in line again with de Deshpande et al. (2020) findings. Other explanatory variables such as education, Gini Index, population, and water use efficiency show sporadic significance in explaining sanitation access inequality, but do not alter the overall pattern of weak or absent relationships between sanitation inequality and the main socioeconomic drivers under study.

These findings confirm that, within the analytic framework, sanitation dynamics lack a robust connection to the income-based drivers that characterize water access outcomes, reinforcing the limited relevance of sanitation results for the central research focus. Nevertheless, a correlation exists between inequality in sanitation access and GDP, as variables such as education and the Gini index, which are relevant in elucidating inequality in access to sanitation, can be altered by economic growth. In other words, although the relationship between GDP and inequality in access to sanitation is not direct, there is an indirect link that renders GDP a key variable in the quest to guarantee universal access to this service.

## 5 | Discussion

The bidirectional and asymmetrical relationship between economic growth and inequality in water and sanitation access challenges core assumptions of traditional development models. Our findings—showing only a modest negative effect of GDP per capita on water inequality—contradict the “growth-first” and trickle-down paradigms, which assume that aggregate income expansion automatically benefits marginalized groups. These results also question the Kuznets hypothesis, as improvements in service delivery do not follow a predictable convergence pattern, leaving vulnerable populations behind even when coverage rises (de Oliveira and Saiani 2021). This evidence reinforces critiques

**TABLE 4** | Estimates of Equations (1) and (2) by OLS for sanitation at national, urban and rural scale.

	BSNSD	BSUSD	BSRSD	GDP per capita	GDP per capita	GDP per capita
GDP per capita	−0.000 (0.000)	−0.000 (0.000)	−0.000 (0.000)			
BSSD				−21.242 (44.262)	−66.944 (49.346)	−21.564 (39.348)
Government effectiveness	−2.433 (2.701)	−2.220 (2.273)	1.645 (2.624)	2645.357 (1189.622)**	2449.516 (1172.908)**	2739.577 (1268.873)**
Gini index	0.200 (0.145)	0.349 (0.122)***	0.154 (0.142)	18.129 (38.033)	40.678 (44.704)	15.409 (36.058)
Years of schooling	−0.940 (0.423)**	−1.071 (0.355)***	−0.648 (0.413)	220.577 (129.773)*	180.901 (133.973)	218.094 (124.982)*
Water use efficiency	0.078 (0.065)	0.133 (0.055)**	0.006 (0.064)	28.156 (29.405)	34.252 (30.414)	26.745 (29.401)
Price index	−0.001 (0.007)	0.008 (0.006)	0.004 (0.006)	−0.365 (1.787)	0.105 (1.901)	−0.220 (1.829)
Population	0.000 (0.000)**	0.000 (0.000)	0.000 (0.000)**	−0.002 (0.001)**	−0.003 (0.004)	−0.004 (0.001)**
Economic complexity index				398.378 (503.770)	325.509 (455.020)	413.950 (473.506)
Constant term	11.641 (7.841)	3.846 (6.555)	10.363 (7.644)	3053.216 (2276.812)	2675.920 (2152.471)	3157.009 (2274.870)
R <sup>2</sup>	0.32	0.50	0.18	0.42	0.43	0.42
N	64	64	64	64	64	64

Note: The first column of each dependant variable is estimated at national scale, the second at urban scale and the third at rural scale. Estimates with GDP per capita as the dependent variable have been made with robust errors due to the presence of heteroscedasticity.

\* $p < 0.1$ .

\*\* $p < 0.05$ .

\*\*\* $p < 0.01$ .

of linear growth models and highlights the conditional nature of distributive outcomes. Rather than income growth alone, our analysis points to institutional quality and human capital as decisive factors, aligning with endogenous growth theory, which emphasizes knowledge, governance, and technical capacity as engines of inclusive development (Lustig et al. 2002; Fane and Warr 2002; Škare and Družeta 2016). In this sense, the study underscores that economic expansion without complementary governance and capability-building measures risks perpetuating structural inequalities in essential services.

The absence of a significant correlation between GDP per capita and sanitation inequality underscores these dynamics. Sanitation systems, being more capital-intensive and institutionally complex, do not respond directly to income growth, especially in rural or marginalized areas (World Bank 2017; Hutton and Chase 2016; Sarker and Khan 2016). Infrastructure expansion often perpetuates existing social and spatial inequalities rather than addressing them (Chaudhuri and Roy 2017; Aleixo et al. 2019). These patterns empirically challenge trickle-down

models, which overstate growth's distributive power and highlight the need for proactive equity-oriented policies (Škare and Družeta 2016; Cetrulo et al. 2020; OECD 2020).

The reverse causal pathway is equally critical. Water access inequality exerts a strong negative effect on GDP per capita. This positions WASH disparities as active constraints on growth, increasing health burdens, reducing productivity (and even labour force), and deepening territorial gaps (Cumming and Cairncross 2016; Hutton and Chase 2016). These mechanisms are consistent with classic and contemporary analyses of the negative impact of inequality on economic performance (Alesina and Rodrik 1994; Persson and Tabellini 1994; Chong and Gradstein 2017; Motahar and Mamipour 2025). Persistent service stratification traps the poorest in low-growth equilibria (García-López et al. 2024).

Governance and technical capacity emerge as decisive mediators. Government effectiveness shows a significant positive association with GDP per capita, confirming that institutional

quality amplifies growth's developmental impact through better resource allocation and service delivery (Kouadio and Gakpa 2022; Pinilla-Rodríguez and Torres-Sánchez 2019; Zhang and Borja-Vega 2024). Similarly, water-use efficiency correlates strongly with both equity and growth, highlighting the importance of technical and managerial improvements (Oduro-Kwarteng et al. 2015). These findings support the capabilities approach: growth matters only when converted into expanded freedoms and equitable access (Sen 1999).

These outcomes are strongly influenced by spatial asymmetries. Our results reveal entrenched territorial biases in infrastructure provision, showing that GDP per capita reduces water inequality in urban areas but has no effect in rural contexts. Urban regions benefit from economic expansion through higher initial coverage, lower unit costs, and stronger institutions, while rural areas remain structurally disconnected (Chaudhuri and Roy 2017; World Bank 2017). This divide mirrors documented patterns of spatial inequality, whereby growth consolidates urban advantages and leaves rural regions lagging (Zhang and Borja-Vega 2024). Such fragmentation limits rural contributions to national growth and weakens the distributive potential of economic expansion. Evidence from Kumar et al. (2008) and Abdou et al. (2024) confirms that targeted investments and institutional strengthening in rural and low-income areas can enhance human development even under modest GDP growth. Therefore, our findings indicate that WASH equity depends less on aggregate growth and more on resource allocation and governance effectiveness. Equity must be embedded as a core policy principle, not treated as a residual outcome of economic expansion.

Recent advances in development economics, highlighted by the 2024 Nobel Prize awarded to Acemoglu, Johnson, and Robinson, provide compelling evidence that inclusive institutions, rather than extractive ones, are fundamental for long-run prosperity and inequality reduction. Their work (Colonial Origins of Comparative Development, Institutions as the Fundamental Cause of Long-Run Growth) demonstrates that political and economic institutions shape incentives, resource allocation, and ultimately development trajectories (Acemoglu et al. 2001, 2005). Our findings support this perspective as effective governance strongly predicts GDP per capita, while unequal access to water significantly constrains growth, and income expansion alone fails to reduce sanitation disparities, particularly in rural areas.

These insights yield several timely and practical policy implications. First, reducing inequality in WASH services requires deliberate, equity-oriented interventions, as the marginal equalizing effects of economic growth are insufficient to overcome entrenched disparities. The contrasting outcomes observed for water and sanitation underscore the need for sector-specific policy frameworks, rather than uniform strategies. Accordingly, policy efforts should prioritize strengthening institutional capacity and improving water-use efficiency, alongside expanding educational opportunities, particularly in underserved rural areas (Agbadi et al. 2019). Government effectiveness and water-use efficiency are consistently associated with both economic performance and more equitable water access, highlighting institutional capacity and technical efficiency as central mechanisms for achieving inclusive outcomes. Importantly, our results

point out that higher educational attainment is associated with lower inequality in water access, suggesting that integrating education and WASH strategies can reinforce long-term equity and sustainability and, therefore, education complements WASH policy by addressing structural drivers of inequality. Additionally, targeted rural investment, decentralized governance arrangements, and stable financing mechanisms are essential to prevent the entrenchment of a dual-track development model in which urban areas benefit disproportionately from economic growth (Abdou et al. 2024; Zhang and Borja-Vega 2024). Strengthening governance and regulatory capacity emerges as a high-return strategy, confirming that institutional effectiveness is central to achieving equitable outcomes, while further gains can be achieved by enhancing water-use efficiency and broadening access to education.

## 6 | Conclusions

This study provides novel empirical evidence on the reciprocal relationship between economic development and inequality in access to water and sanitation, showing that reducing inequality in access is a driver, not merely a by-product, of Sustainable Development. The results reveal an asymmetric bidirectional relationship between economic growth and water access inequality: higher GDP per capita is associated with only modest reduction in inequality; disparities in access exert a sizeable negative impact on growth. In contrast, no systematic relationship emerges between economic growth and sanitation inequality, reflecting the distinct institutional, financial, and infrastructural challenges that characterize this sector. This underscores a central policy insight: growth alone is insufficient to close WASH access gaps, particularly for sanitation and rural water services.

These relationships are mediated by governance quality, technical efficiency, and educational attainment, with stronger effects in urban areas and no significant association in rural settings. Overall, these factors function as enabling mechanisms for equitable and sustainable service provision and economic growth. Higher levels of government effectiveness foster economic performance and support more inclusive patterns of service expansion, consistent with adequate governance and regulatory capacity noted in comparable studies of water sustainability and adaptation (Bromley and Anderson 2018; Babuna et al. 2023). Improvements in water use efficiency also contribute to both economic and distributional outcomes, reflecting the importance of resource productivity for long-term water security (Jiang 2023). Similarly, higher educational attainment is associated with lower inequality in water access, echoing evidence on the links between WASH conditions, child health, time use, and human capital formation (Ortiz-Correa et al. 2016). At the same time, persistent territorial disparities reveal that growth disproportionately benefits urban populations, while rural areas remain structurally disconnected from the mechanisms that reduce inequality, amplifying these territorial asymmetries.

Overall, this study demonstrates that reducing inequalities in water and sanitation access is essential for advancing sustainable and inclusive development. Aligning economic expansion with redistributive policies, sector-specific strategies, and territorial

equity measures is necessary to break the cycle in which WASH disparities reinforce socioeconomic disadvantages. Embedding equity at the core of water and sanitation policy is therefore crucial for ensuring that progress toward SDG 6 also supports broader objectives related to poverty reduction, health, human capital, and inclusive growth.

## 6.1 | Limitations of the Study

These findings should be interpreted in light of several limitations. The analysis is constrained by incomplete data coverage, which reduces the sample size and leads to the use of non-coincident observation years. Inequality is measured at only two points in time, restricting the ability to capture dynamic processes or nonlinear evolution. In addition, several structural determinants—such as affordability constraints, subnational governance arrangements, environmental pressures, and fiscal capacity—could not be incorporated due to data limitations. Finally, the econometric strategy relies on a cross-sectional model for the most recent year, limiting causal inference (Wooldridge 2010). While these constraints do not undermine the substantive insights, they highlight the need for more systematic, granular, and longitudinal data on WASH inequality to inform future research and policy design.

## 6.2 | Policy Recommendations

In order to translate the insights generated by our results into actionable policy, inclusion must be embedded into WASH governance. Firstly, universal service obligations and equity-based performance standards should be enforced and monitored by independent regulators with tariff oversight and sanctioning powers (World Bank 2017; GLAAS 2022). Secondly, targeted affordability measures such as lifeline tariffs, connection subsidies and output-based aid should be implemented to protect low-income and rural households where market incentives are weakest (Hutton and Chase 2016). Thirdly, secure ring-fenced rural financing through formula-based transfers and performance-linked grants, alongside local capacity building for planning and post-construction support (Jiménez and Pérez-Foguet 2010). Finally, polycentric governance and participatory monitoring should be adopted to strengthen accountability and reduce information asymmetries (Ostrom 2010), alongside technical programmes to improve water use efficiency and resilience (GLAAS 2022). Together, these measures implement the institutional changes recommended by Nobel laureates, aligning sector rules and incentives to ensure that growth translates into equitable access and breaks the cycle of WASH inequality and its negative impact on the economy.

Addressing the data gaps identified as limitations of this study is critical for enhancing diagnostic capacity and informing evidence-based policy design. Strengthening national and subnational monitoring systems, expanding the collection of granular and longitudinal WASH indicators, and improving data interoperability would facilitate precise assessments of territorial disparities and support the more effective targeting of interventions.

## Author Contributions

**Marcos García-López:** conceptualization, methodology, formal analysis, investigation, writing – original draft, visualisation, funding acquisition. **Gabriela Cuadrado-Quesada:** conceptualization, formal analysis, investigation, writing – original draft, writing – review and editing, visualisation, funding acquisition. **Samara López-Ruiz:** conceptualization, methodology, formal analysis, investigation, writing – original draft, writing – review and editing, funding acquisition.

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## Conflicts of Interest

The authors declare no conflicts of interest.

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## Appendix A

**TABLE A1** | List of countries analysed.

<b>List of countries included in the analysis using descriptive statistics and econometric estimations.</b>			
Afghanistan	Dominican REPUBLIC	Kenya	Rwanda
Albania	Egypt	Kyrgyzstan	Sao Tome and Principe
Algeria	Eswatini	Lao People's Democratic Republic	Senegal
Armenia	Ethiopia	Lesotho	South Africa
Bangladesh	Gabon	Mali	Sudan
Belarus	Gambia	Mauritania	Tajikistan
Benin	Georgia	Mexico	Thailand
Bolivia	Ghana	Mongolia	Tunisia
Burkina Faso	Guatemala	Nicaragua	Turkey
Burundi	Guinea-Bissau	Niger	Uganda
Chad	Guyana	Nigeria	Ukraine
Colombia	Honduras	Pakistan	United Republic of Tanzania
Comoros	India	Paraguay	Uruguay
Congo	Indonesia	Peru	Viet Nam
Costa Rica	Iraq	Philippines	Yemen
Côte d'Ivoire	Kazakhstan	Republic of Moldova	Zambia

**TABLE A2** | Statistics on income distribution.

Variable	Obs	Mean	Std. dev.	Min	Max
Tax bracket 1	64	4.624	7.043	0.000	28.000
Tax bracket 2	64	12.656	7.186	1.500	40.000
Highest tax bracket	64	27.702	9.729	6.000	45.000
Difference between bracket 1 and highest bracket	64	23.079	12.826	0.000	43.000

**TABLE A3** | Estimates of Equations (1) and (2) by OLS, 2-Stage Least Squares and SURE for water at urban scale.

	BWUSD	BWUSD	BWUSD	GDP per capita	GDP per capita	GDP per capita
GDP per capita	-0.001 (0.000)**	-0.001 (0.000)**	-0.001 (0.000)***			
BWUSD				-134.297 (58.585)**	-339.694 (148.949)**	-281.079 (54.270)***
Government Effectiveness	1.791 (1.653)			2733.392 (1246.634)**	2593.819 (757.179)***	2547.480 (587.788)***
Gini index	-0.055 (0.089)			9.132 (34.857)		
Years of schooling	-0.789 (0.258)***	-0.601 (0.251)**	-0.497 (0.220)**	135.981 (137.840)		
Water use efficiency	0.107 (0.040)***	0.095 (0.036)***	0.100 (0.035)***	38.855 (32.084)	56.613 (22.287)**	51.396 (18.531)***
Price index	0.004 (0.004)			0.112 (1.902)		
Population	-0.000 (0.000)			-0.006 (0.004)		
Economic complexity index	-0.001 (0.000)**			321.295 (469.916)		
Constant term	13.606 (4.767)***	10.260 (1.626)***	10.400 (1.581)***	4160.331 (2388.605)*	5940.331 (668.777)***	5670.498 (512.491)***
R <sup>2</sup>	0.35	0.32	0.28	0.45	0.33	0.38
N	64	64	64	64	64	64

Note: The first column of each dependent variable is estimated through OLS, the second through 2SLS and the third through SURE. Estimates with GDP per capita as the dependent variable have been made with robust errors due to the presence of heteroscedasticity.

\* $p < 0.1$ .

\*\* $p < 0.05$ .

\*\*\* $p < 0.01$ .

**TABLE A4** | Estimates of Equations (1) and (2) by OLS, for water at rural scale.

	<b>BWRSD</b>	<b>GDP per capita</b>
GDP per capita	−0.000 (0.000)	
BWRSD		−28.743 (50.414)
Government Effectiveness	−1.378 (2.005)	2645.154 (1187.480)**
Gini index	0.241 (0.108)**	18.512 (39.763)
Years of schooling	−0.352 (0.315)	217.667 (121.415)*
Water use efficiency	0.039 (0.049)	28.200 (29.009)
Price index	0.006 (0.005)	−0.100 (1.790)
Population	−0.000 (0.000)	−0.004 (0.002)**
Economic complexity index		461.328 (439.206)
Constant term	−0.896 (5.840)	2960.060 (2142.267)
$R^2$	0.21	0.42
$N$	64	64

Note: Estimate with GDP per capita as the dependent variable has been made with robust errors due to the presence of heteroscedasticity.

\* $p < 0.1$ .

\*\* $p < 0.05$ .

**TABLE A5** | Statistical tests of the models shown in Tables 4 and 5, A2 and A3.

Table	Model	Dependant variable	VIF	Minimum eigenvalue statistic	Tests of overidentifying restrictions		
					Sargan (score) chi2 (1)	Basmann chi2 (1)	Hausman test
4	OLS	BWNSD	1.40	—	—	—	—
4	2SLS	BWNSD	—	29.201	0.734	0.673	0.53
4	OLS	GDP per capita	1.50	—	—	—	—
4	2SLS	GDP per capita	—	7.508	1.459	1.353	0.37
5	OLS	BSNSD	1.40	—	—	—	—
5	OLS	BSUSD	1.40	—	—	—	—
5	OLS	BSRSD	1.40	—	—	—	—
5	OLS	GDP per capita	1.50	—	—	—	—
5	OLS	GDP per capita	1.50	—	—	—	—
5	OLS	GDP per capita	1.50	—	—	—	—
A.2	OLS	BWUSD	1.40	—	—	—	—
A.2	2SLS	BWUSD	—	29.201	0.921	0.847	0.30
A.2	OLS	GDP per capita	1.50	—	—	—	—
A.2	2SLS	GDP per capita	—	6.347	0.003	0.003	1.18
A.3	OLS	BWRSD	1.53	—	—	—	—
A.3	OLS	GDP per capita	1.49	—	—	—	—