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Water Infrastructure Performance in Sub-Saharan Africa: An Investigation of the Drivers and Impact on Economic Growth

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Abstract: There is a strong link between water infrastructure and development outcomes. As such, water infrastructure challenges could have an adverse effect on the economy at large. This study investigates the drivers of water infrastructure performance and analyzes how investment in water infrastructure affects economic growth, focusing on a panel of thirty-one Sub-Saharan African (SSA) countries. An integrative theoretical framework using panel regressions was developed. The result showed that an increase in water infrastructure performance due to a 1% increase in per-capita income growth and trade openness was 0.2% and 0.03%, respectively, and the constraint on water infrastructure performance due to a 1% increase in population density was 0.76%. The result showed that the impact is mostly driven by the effect of per-capita income growth and population density on lower- and middle-income countries. Our results also revealed that one additional increase in water infrastructure investment leads to a higher impact on economic growth. We further complement our study by investigating the policy interventions that the support water infrastructure outcome effect. We found that investment in water infrastructure along with the provision of credit to the private sector is a strong driver of economic growth; however, access to credit beyond a certain threshold—relative to the level of investment in water infrastructure in these countries—investment in water infrastructure would lead to an adverse negative macroeconomic effect. The policy implications of this study are discussed.

Keywords: water infrastructure; socioeconomic drivers; moderation and mediation model; economic growth; panel data analysis; Sub-Saharan Africa

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Citation: Dangui, K.; Jia, S. Water Infrastructure Performance in Sub-Saharan Africa: An Investigation of the Drivers and Impact on Economic Growth. *Water* **2022**, *14*, 3522. https://doi.org/10.3390/w14213522

Academic Editors: Sisira S. Withanachchi, Olcay Ünver, Hotden Leonardo Nainggolan and Sören Köpke

Received: 29 August 2022
Accepted: 1 November 2022
Published: 3 November 2022

1. Introduction

Recent scientific findings have highlighted the increasing trend in human water needs and decreasing per-capita freshwater availability for domestic, agricultural, and/or industrial needs [1,2]. Water demand is projected to increase by 55% by 2050, and about 40% of the world's population will live in areas of severe water stress [3]. There are many stressors behind these phenomena, such as population growth, increasing living standards, and climate change, among others [4,5].

In 2015, the United Nations set the 2030 Sustainable Development Goals (SDGs), of which water security and infrastructure investment are integral components. The progress made in infrastructure investment has been an essential vehicle for addressing the environmental and economic challenges imposed by water stress and water-related natural hazards [6]. As the development of water systems has been most notable in industrialized societies, it has been widely asserted that the use and availability of water infrastructure are essential factors of economic growth and development [7]. Water infrastructure services provide access, storage, regulation, circulation, and conservation of water resources; examples of water infrastructure services include: multipurpose dams for river regulation and storage, interbasin transfer systems, and drinking water and wastewater treatment facilities [8]. For emerging countries, investments in water infrastructure are regarded as the most critical investments to promote socioeconomic development, especially in developing countries characterized by high inter- and intra-annual surface water and precipitation variability [9].

Being one of the poorest and fastest-growing regions in the world, Sub-Saharan Africa remains among the most affected regions by climate variability, including periods of drought, uneven temporal and spatial rainfall distribution, and flooding globally [10]. In addition, people's access to drinking water and sanitation is limited primarily due to the lack of economic and human capacities to effectively develop and sustainably manage water resources [11]. These induce a severe threat to the region's economic, food, and water security [12,13]. Under the ambitious development goals Millennium Development Goals (MDG) and Sustainable Development Goals (SDGs) set by the United Nations, many governments in Sub-Saharan Africa have paid greater attention to the provision and investment in water infrastructures. For example, for the period 2000–2015, the region observed an annual rate of change of 57.6% of the total population with access to basic drinking water services and 28.1% for basic sanitation [14]. At the continental level, the Commission for Africa [15] in 2006 and The African Water Vision 2025 [16] advocated that infrastructure investments should be doubled, from community water retention and low-cost irrigation programs to the sustainable development of low-cost power and more efficient management of shared natural resources, to reduce poverty on the continent. Irrespective of progress made, the issue of water insecurity is still a great challenge in SSA, and is required to be more deeply analyzed in the context of the region. Indeed, all these objectives mentioned above have eloquently proven the importance and necessity of investing in water infrastructure, to pursue sustainable development. As a result, water infrastructure has attracted considerable interest from both academics and policymakers, and has raised several research questions that this study investigates. The first question is: What has been the effect of recent water infrastructure investment efforts on the region's economic development?

Globally, studies have investigated the relationship between water infrastructure and economic growth and have shown mixed results. For instance, research by Frone and Frone [17] has shown that water supply and wastewater investment are positively and significantly correlated with economic growth in Romania. A recent study by Kahsay et al. [18] uses a multisectoral computable general equilibrium (CGE) model to assess the impacts of climate change on the economy and existing irrigation development schemes in the Nile Basin. The authors show that climate-change-induced water scarcity negatively affects the entire economy, especially in areas where irrigated agriculture is still limited. The study recommends a cooperative water development strategy combined with investments in water-saving infrastructure and improved irrigation efficiency to prevent water scarcity and limit the negative effect of climate change in the region. A more recent study by Shi et al. [19] analyzed the role of large dams, primarily built for hydroelectricity, irrigation, and water supply, in promoting GDP growth at global and national scales. The authors showed that the impacts of large dams on GDP growth are more significant in countries with a higher level of socioeconomic development as compared to poorer countries, supporting large dams as a vital factor in promoting economic development. Jeuland [20] studied the effect of dam investment from an economic perspective and did not find any evidence supporting the investment in surface water storage to address the issue of water scarcity.

A first step in exploring the complex relationship between water infrastructure and the economy in SSA is to establish a closer set of relationships—namely, what are the potential drivers of water infrastructure performance, and what is the impact of water infrastructure investments on economic development in SSA?

The role of water and water infrastructure in the economic development of Sub-Saharan African countries is prominent given its representation in the multiple Sustainable Development Goals (SDGs) targets to improve energy access, sanitation and health and to end hunger and poverty. So far, a handful of studies on the impact of water infrastructure in

Sub-Saharan Africa have mainly been conducted at the national level. A study by Schreiner et al. [21] highlighted that the drought-induced water supply shortage experienced by South Africa imposes substantial constraints on the country's economic development. A study by Fuente et al. [22] illustrated that poor access to water and sanitation infrastructure and related mortality in Sub-Saharan Africa (SSA) are associated with significant economic losses in the region. Similarly, a study by Sadoff [23] has found that the water security problems due to the lack of water infrastructure facing Ethiopia are a serious impediment to the country's growth. This study found that accounting for the effects of water variability would reduce projected economic growth rates by 38% per year and increase projected poverty rates by 25% over a 12-year period, and concluded that investment in water infrastructure, such as irrigation, would reduce vulnerability to rainfall variability. Janeski et al. [24] studied the impact of U.S.-funded water and sewage infrastructure projects in Nigeria and found a significant impact on various measures of short- and long-term economic growth in communities receiving water or sewage infrastructure. Adjei et al. [25] used the case of the Chinese-financed Bui dam to assess the impact of the hydro energy project on poverty alleviation in Ghana. Their findings reveal that the presence of the Bui dam had a significant impact on the employment, energy supply, and agriculture, among others, of affected persons in the Bui community.

Although most of the above studies have provided valuable insights into the impact of water infrastructure on economic development, studies exclusively covering SSA beyond these national-level case studies are limited. Additionally, existing studies that analyzed the effect of water infrastructure on economic growth focused only on one water infrastructure variable or two that were not comprehensive, and filling these research gaps would provide a clear regional-level insight into how and under what conditions water infrastructure impacts economic growth in Sub-Saharan Africa.

The present study endeavors to make the following contributions to the existing literature. (1) To construct an overall multidimensionality and availability of water infrastructure index using principal component analysis (PCA) methods and investigate the socioeconomic factors associated with water infrastructure performance across a wide range of countries in Sub-Saharan Africa. (2) To provide a comprehensive assessment of the effect of water infrastructure investment on the SSA region's economic growth (in terms of GDP per-capita growth). (3) To investigate the role of institutional factors in influencing the relationship between water infrastructure investment and economic growth. To this end, we employed robust econometric estimation techniques of dynamic panel ordinary least squares, which address the issue of cross-sectional dependence, heterogeneity, and heteroscedasticity in a panel data analysis.

2. Literature Review

To find ways to maximize the economic benefit of water infrastructure investments in Sub-Saharan Africa, it is particularly important to identify the drivers, as this can help to understand the factors that might challenge or improve their performance. To a large extent, studies have examined the drivers of water infrastructure; however, their total contribution to water infrastructure performance is still unclear.

Several studies have found that trade openness, a measure of a country's engagement in the global trading system, is a strong determinant of water infrastructure performance. Results from a previous analysis by Yang et al. [26] suggest that a higher level of trade openness is positively and significantly associated with a higher level of water infrastructure performance, including wastewater treatment and water supply efficiency in China. A study by Berrittella et al. [27] found a nonlinear impact of agricultural trade liberalization on water use, depending on whether the liberalization was partial or more complete. Their study also found that trade liberalization tends to reduce water use in water-scarce regions and increase water use in water-rich regions, even though water markets do not exist in most countries. Dang and Konar [28] demonstrated that globalization, in terms of trade openness, is an important determinant of water use efficiency by reducing domestic water use, especially in agriculture through the effect of the intensive margin, and by leading farmers to produce more with less water. The study further found that such a positive association between water infrastructure and openness to trade is not linear, and is related to changes in the stage of economic development.

Likewise, studies have stated that population increase is a significant driver of water infrastructure performance globally. For instance, Okello et al. [29] studied the impact of population growth induced by land use change and climate change on the future state of freshwater resources on Lamu Island in Kenya, where a major port facility is being built. They found that daily per-capita water withdrawals are projected to increase from 0.06 m^3 in 2009 to 0.1 m^3 by 2050 under the "no industrial development" population scenario. Their results also suggest that population growth, exacerbated by land use change, will be a more important factor than climate change in affecting freshwater availability. Buytaert and De Bièvre [30] evaluated current and future stressors on per-capita water availability to identify potential stressors on water availability that may lead to water use conflicts by focusing on four major cities located in, or receiving water from, the tropical Andes. Their results revealed that despite uncertainties and the distinct geospatial patterns that characterize the water supply systems of the studied cities, the effect of demographic change is the most likely to induce a challenge to water availability and thus should be the priority for local decision makers. Furthermore, Hopewell and Graham [31] investigated the trend in water and sanitation access in 31 major cities in Africa and found that the rapid increase in urban population growth and density has led to an increase in the number of people using the worst forms of sanitation or water supply, and a steady increase in the number of people using surface water and open defecation practices, with a greater impact on water and soil pollution in the region. Additionally, Josephson et al. [32] used household-level panel data on smallholder farmers in Ethiopia to estimate how rural population density affects agricultural intensification and productivity in Ethiopia. They found that population density increase was associated with a decrease in farm size and a positive association with fertilizer use, which leads to water pollution.

In contrast, Munamati et al. [33] found that high population size and densely populated countries were associated with higher access to water infrastructure. Highly densely populated countries tend to have better access to water infrastructure because they rely on economies of scale, which reduces the cost of infrastructure provision and services. Moreover, the study by Higginbottom et al. [34] evaluated the performance of large-scale irrigation projects and found no correlation between irrigation infrastructure performance and population density in SSA.

Economic outcome variables such as GDP per capita, and gross national income per capita can also have a significant influence on water infrastructure performance. For example, Rudra [35] examined international and national data to investigate the determinants of improvements or constraints in water access. He concluded that high-income countries tend to achieve better access to water than low-income countries, due to the generally more advanced technologies and stronger regulatory environments of the former. Moreover, the study by Hopewell et al. [31] found that the wealth of cities, proxied by GDP per capita, is a significant determinant of access to water and sanitation in SSA cities. The results of their analysis further indicate that GDP growth may be more critical in the provision of sanitation than other measures of access. Luh and Bartram [36], using household survey data from 73 countries from Asia, Europe, Africa, and South America, found no correlation between GDP per capita and normalized rates of change in access to water and sanitation. On the other hand, Gupta et al. [37] examined national and international drivers of demand for water resources in the context of water scarcity using indicators for China, Australia, Japan, and the UK. The results show that GDP per capita is highly significant at the 1% level in most regions, suggesting a proportional increase in water demand in response to an increase in GDP per capita. The study by Distefano and Kelly [38] further used the latest IPCC CPP projections and the OECD's Shared Socio-Economic Pathways (SSPs) for population growth and economic output to estimate the future demand for water resources in different countries around the world. They concluded that economic growth is the main driver of water scarcity.

Other socioeconomic factors could affect water infrastructure performance in developing countries. Through case studies from Turkey, India, and Sri Lanka, Shunglu et al. [39] showed that failure of community participation is strongly associated with the performance of rural water systems. The study found that this result emanates from a lack of social trust, elite capture of participatory processes, heterogeneity and power imbalances at the micro level, and a lack of inclusive participation in decision making in the implementation of water infrastructure projects. Aiyetan [40] identified the lack of competent and adequate human resources, availability of skills, institutional environment, and leadership as major obstacles to the effective performance of water projects in South Africa. Etongo et al. [41] used a shared dialogue workshop and 642 randomly selected households in 17 villages in Uganda to assess community participation and capacity development in relation to community-managed water systems. They found that training activities, particularly on operating and maintaining water points and making minor repairs, contribute significantly to the performance of community-managed water systems.

The relationship between water infrastructure investment and economic growth is less clear. As total productivity means the contribution to output growth compared to the use of new inputs, theoretically, it can be an important factor of change in economic growth [42]. We postulate that the water infrastructure investment of a country might also be a good predictor of water security and lead to long-term economic growth. This is supported by Tir et al. [43] and Musouwir [44], who directly studied the relationship between investment in water infrastructure and economic growth and found that they are highly correlated. This allows us to investigate the relationship between water infrastructure and economy in the Sub-Saharan Africa region over the period of massive infrastructure investment as the countries seek to achieve the SDGs goals by 2030.

However, we must note that an increase in water infrastructure investment is only one side of economic development prediction. The other side is the country's specific context dependency such as social and environmental factors (adequate water resource availability for example). Nevertheless, the relationship between water infrastructure investment and economic development is not straightforward and could be modulated by some contingency policy interventions (e.g., providing credit to the provider sector) along with infrastructure investment.

In summary, the literature review clearly demonstrates that the performance of water infrastructure is affected by various factors. These driven factors of water infrastructure performance remain largely unknown as shown by the lack of consensus in the existing literature. In addition, most of the highlighted studies focus either on developing countries (including SSA and other developing regions) or on the world as a whole. This paper argues that the SSA region is unique due to different socioeconomic characteristics such as low income, institutional weakness, rapid population, and urbanization growth rate. Furthermore, most previous studies on SSA have focused on the national or sub-national level. This study seeks to contribute to the literature by investigating the regional drivers and sub-regional differences by income level (according to the World Bank income classification) of water infrastructure investment across a wide range of countries in SSA.

Additionally, the few existing studies that have examined the outcome impact of water infrastructure are mainly focused on the direct channel without probing the indirect channels through which water infrastructure investment affects economic growth. Therefore, our study pursues to fill this research gap by investigating the direct and indirect effect of water infrastructure investment on economic growth in a panel of SSA countries.

To achieve the research objectives, our study employed an integrative approach to explore the drivers and outcome effect of water infrastructure investment (Figure 1). In the present study, we aim to deepen the understanding of the determinants of water infrastructure performance, including its roots, and in which condition its spending is useful for SSA countries' economies.

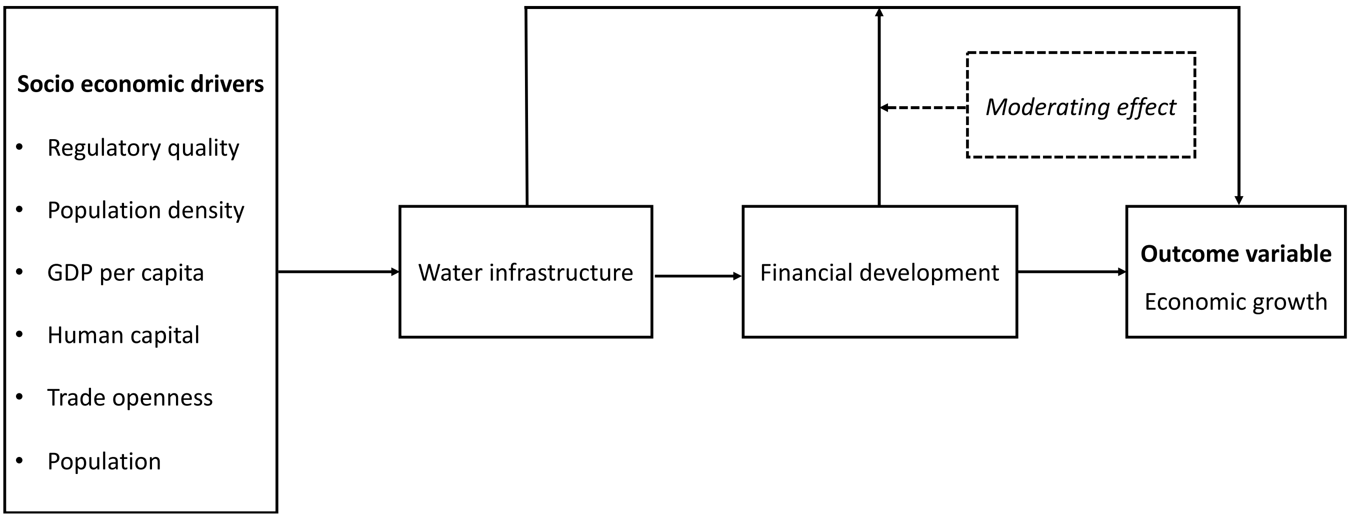

Figure 1. Research conceptual model.

3. Materials and Methods

The research design employed in this study is an exploratory empirical analysis conducted through panel regressions. Our analysis has two parts. In the first part, we use panel regressions with various specifications to identify the socioeconomic indicators that most influence water infrastructure performance at the regional scale. In the second part, we study the relationship between investment in water infrastructure and economic growth. In doing so, we provide support for the moderating effect of institutional frameworks in the relationship between water infrastructure and the economy which has not been made clear enough in existing studies.

3.1. Data

The study focuses on a panel of thirty-one Sub-Saharan African countries, as showing in Figure 2 with data covering the period 2000–2017. Data were obtained from different available sources: (a) the World Development Indicators (WDI) and World Governance Indicators (WGI) databases, published by the World Bank; (b) World Resources Institutes, published by Byers et al. [45]; (c) AQUASTAT database published by the Food and Agriculture Organization (FAO), and the WHO/UNICEF Joint Monitoring Programme (JMP) database. The description of the variables used in this study and the data sources are presented in Table 1. The first four variables in Table 1, including the number of populations connected to improved drinking water sources, share of population connected to improved sanitation, area of irrigated land, and total installed capacity of hydropower plants, were used to calculate the water infrastructure index (WI) through principal component analysis. It should be noted that the temporal and spatial scope of the study was based on data availability for both dependent and independent variables. A summary statistic of the variables used in the study is provided in Table 2. All the variables are transformed into logarithmic form. The summary statistics based on the logarithmic form show all the variables have lower levels of skewness and kurtosis, suggesting no problem regarding the normality of data [46].

Table 1. Variables definition and sources.

	Definition	Source
Data for calculation		
Access to clean water	Number of the population with access to improved drinking source	[47]
Access to sanitation	Number of the population with access to improved sanitation facilities	
Irrigated land	The total area of land equipped and provided with water exclusively for agricultural purposes.	[48]
Hydropower plants	The total capacity of hydropower plant installed	[45]
Other variables		
Logarithm of regulatory quality index (L.RQ)	Rates the ability of the governments in each country to formulate and implement sound policies and regulations to promote private sector development (logarithmic value)	
Logarithm of population density (L.PD)	Measure the total number of people per square kilometer of land area (logarithmic value)	
Logarithm of trade openness (L.TO)	Refers to a country's level of engagement in the global trading system, and is calculated as the sum of imports and exports adjusted by GDP (logarithmic value)	[49]
Logarithm of total population (L.Pop)	Expresses the total number of people of each country at a given time (logarithmic value)	
Logarithm of financial development (L.FD)	Expresses the total credit provided by banks to private sector as a percentage of GDP (logarithmic value)	
Logarithm of human capital (L.HC)	The total population of each country in the age of working between 15 and 64 (logarithmic value)	
Logarithm of GDP per capita (L.GDP)	Measure of economic outcome in constant price (logarithmic value)	
Population growth rate (PGR)	Refers to the change in population size as a factor of time	

Table 2. Summary statistics.

	Mean	sd	Min	Max	Kurtosis	Skew	Obs.
L.GDP	7.00	0.98	5.37	9.23	−0.44	0.68	558
L.TO	22.96	1.57	19.56	28.19	1.76	0.93	558
L.RQ	0.84	0.26	−0.27	1.42	1.90	−0.97	558
L.Pop	16.27	1.15	13.82	19.07	−0.15	−0.23	558
L.HC	15.90	1.21	13.17	18.47	−0.19	−0.46	558
L.PD	3.87	1.21	0.78	6.43	0.10	−0.19	558
L.FD	21.21	1.73	16.80	26.38	0.96	0.52	558
L.labor	15.32	1.18	12.58	17.87	−0.22	−0.39	558
L.WI	0.01	0.66	−0.86	2.34	1.33	1.10	558
PGR	0.81	0.58	−2.68	1.72	1.38	0.90	558

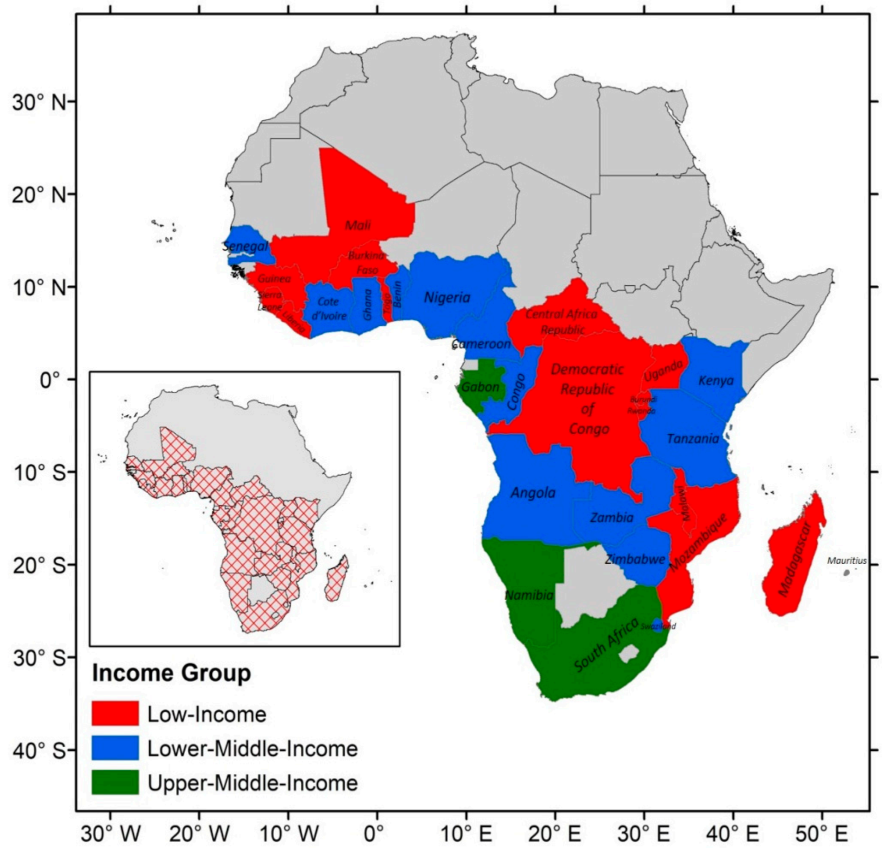

Figure 2. Map of the study area.

Calculating Water Infrastructure Index

In contemporary data analysis, principal component analysis (PCA) is well accepted by researchers and used in different research areas. PCA is an advanced multivariate data analysis tool for extracting meaningful information from large datasets of observations that are usually represented by a set of correlated quantitative dependent variables. A principal component analysis transforms the data into a set of new, mutually independent and uncorrelated variables (P_i), called principal components, which can take the form of the following system of equations:

$$\begin{array}{c} P_1 = a_{11\ X\ 1} + \ldots + a_{1n}X_n \\ \cdot \qquad\qquad\qquad \cdot \\ \cdot \qquad\qquad\qquad \cdot \\ P_m = a_{m1\ X\ 1} + \ldots + a_{mn}X_n \end{array} \tag{1}$$

With $P = [P_1, P_2, \ldots, P_m]$ representing principal components, $A = \left[a_{hj}\right]$ for $h = (1, 2, \ldots, m)$, and $j = (1, 2 \ldots, n)$ denotes component loadings. $X = [X_1, X_2, \ldots, X_n]$ are original variables.

Each principal component is the weighted average of the underlying variables, and the eigenvalue (variance) of each principal component indicates the percentage change in the total data explained. When a PCA is performed, the output is a matrix of factor scores or loadings for each variable. Kaiser [50] proposes that the factor with eigenvalues greater than 1 should be retained for PCA. Jolliffe [51] further suggests that factors with eigenvalues >0.70 should be retained. Equation (2) is used to compute the composite index:

$$WI_{it} = \sum\nolimits_{k=1}^{4} a_k \frac{X_{it}}{Sd(X_i)} \tag{2}$$

where WI_{it} is the composite index of the water infrastructure, S_d is the standard deviation, X_{it} is the ith variable in year t; a_k is factor load as derived by the PCA.

3.2. Econometric Analysis of Socioeconomic Drivers of Water Infrastructure Performance

We used the panel regression data set to identify possible socioeconomic variables that have a significant impact on water infrastructure performance. The advantage of using this approach is that it allows compounding the effects of each cross-section through time, and also accounts for changes both within a country as well as between countries [52]. We use individual country fixed effects to model the possible heterogeneity of the individual group (in our case, countries), by adding in the fixed effects in the standard ordinary least square (OLS) model.

The specification of the panel model is as follow:

$$Y_{it} = \sum_{i=k}^{k} \beta X_{it} + \alpha_i + \gamma_{it} \tag{3}$$

where Y_{it} represents the dependent variable (water infrastructure) for the country i during the year t, $\sum_{i=t}^{k} \beta$ represents the coefficients for the independent variables, X_{it} represents the independent variables in the country i and year t, α_i represents the fixed effect, and γ_{it} is the error term.

We conducted several specification models using stepwise regression with different criteria to help identify the socioeconomic variables that are significantly associated with water infrastructure in SSA and are most critical in describing the performance of water infrastructure in the region. We started by running a regression model that included all the potential determinants of water infrastructure that were available to us. In the second specification, we removed population growth and the human capital variables to avoid any confounding effects in the regression estimation. We then proceeded to create additional models by essentially excluding all the determinants that were not statistically significant from the analysis.

We performed the Breusch–Pagan diagnostic test [53] to check whether or not individual country effects exist in each model, which was found to be the case. Therefore, individual effect regressions were used. Nevertheless, the tests for nonstationarity of the data were assumed unnecessary, as we have large sample countries and a short time series dataset. To deal with potential heterogeneity, serial correlation, and cross-sectional dependence in the panel data, we performed robust covariance matrix estimation for the fixed-effect models following [54]

Besides the fixed-effect models, there are also random-effect models, which are generally used to estimate effects on a population from a random sample of data. We performed both fixed-effect and random-effect regressions in each case. To decide between the fixed effect and random effect, we performed the Haussmann test [55], and the fixed-effect regression models were more appropriate in each case.

3.3. Impact of Water Infrastructure Investment on Economic Growth

We first use panel regressions [56] based on a stepwise removal process to help identify the socioeconomic indicators related to water infrastructure performance in the preceding analysis, while we expect the relationship between water infrastructure and socioeconomic drivers to vary according to the countries' economic structure. Next, we seek to investigate the outcome impact of the ongoing investments in water infrastructure. We postulate that investments in water infrastructure within a comprehensive policy setting would lead to substantial economic benefits in the region. We use GDP per-capita growth as the measure of economic outcome in our study.

To investigate the relationship between water infrastructure and economic growth, we used the countries' individual fixed effects from the panel model described above, and GDP per capita was used as the dependent variable in this second regression.

We performed three different regression models to explore the possible effect of water infrastructure investments and their modulating factors on economic growth. The first model included all the variables in the study except for credit by banks to the private sector. Under the second model, we included the institutional variable (credit provided by banks to the private sector) to determine the overall effect of additional policy variables. In the third and last model, we control for the moderating effect of water infrastructure investment and financial development.

4. Results and Discussion

This section presents and discusses the empirical results from the fixed-effect and random-effect estimation methods of the drivers of water infrastructure performance for the total sample and the subsample. The direct and indirect channels through which water infrastructure investments affect economic growth are also presented and discussed.

4.1. Key Determinants of Water Infrastructure Performance in SSA

To show how drivers are related to water infrastructure performance in SSA, we estimated three differently specified models based on the backward stepwise removal process. The study performed both the fixed-effect and random-effect estimations in each case to robustly estimate the regressions coefficient.

As presented in Table 3, Model 1 shows the results for all drivers included. The results show a positive statistically significant relationship between water infrastructure, GDP per capita, and population growth, and a negative statistically significant relationship between human capital and regulatory quality. They also show a statistically positive but not significant difference between trade openness and water infrastructure, and a statistically negative and not significant difference between population density and water infrastructure. The positive relationship between water infrastructure performance and population is especially surprising. Intuitions suggest population increase would have a negative instead of a positive impact on water infrastructure, as it would put much pressure on resource availability. Indeed, this is seen in the coefficient associated with the increase in population density. The population growth and population density variables are expected to be strongly correlated with the inclusion of a country's population data in the calculation of its population density, and the population growth and the human capital variables are strongly correlated [correlation coefficient, $r = 0.99$]. It is possible that including both variables concurrently confounds estimation results due to collinearity, which may be the reason behind the unexpected sign of population growth. In Model 2, we remove the population and the human capital variable to avoid any confounding effects of collinearity in parameter estimation. With this model specification, the population density variable is now statistically significant. This indicates a form of overlap between the total population, human capital, and population density variables, which could be explained by the inclusion of a country's population in its population density calculation. Model 3 was generated by removing all drivers that did not show statistical significance in Model 2. Model 3's regression results show consistent signs and statistical significance of per-capita GDP, trade openness, and population density for both estimation methods. This is our preferred model specification since it includes all drivers that have a statistically significant relationship with our dependent variables.

The consistent positive association between water infrastructure and per-capita GDP implies that the richer the country is getting, the more successful its water infrastructure performance. This is mainly because countries have more economic resources to invest in water infrastructure and management expertise as they become richer. Additionally, developing countries, such as those of SSA, have significant access to their water infrastructure from privately financed and self-supplied sources. Therefore, an increase in income would provide more economic means to households and private sectors to supply themselves with water infrastructure, which may explain the significant impact of per-capita income growth. These results are consistent with our expectations and are in line with previous studies of Cazcarro et al. [57] and Li et al. [58]. From these results, it can be inferred that countries with higher per-capita GDP are more likely to have better water infrastructure such as adequate access to drinking water and sanitation facilities, as well as irrigation and hydropower development. This suggests that targeting policies that promote sustainable economic development would significantly contribute to improving water infrastructure performance and improving water security in the SSA region.

The results also found a strong association between population density and water infrastructure. Population density has a negative and significant influence on water infrastructure. The implication is that higher population density constrains water infrastructure performance in SSA. Indeed, with the fast-growing population in this region of Africa, urban and rural areas of the countries are becoming more and more densely populated, and this may intensify pressure on water and land resources such as pollution and increased competition between irrigation land use and population settlement, for example, leading to system performance failure. Our results are in line with those of Chen et al. [59] and Zhang et al. [60].

Table 3. Estimation results of the drivers of water infrastructure performance.

	Dependent Variable: L.WI					
	Model 1		**Model 2**		**Model 3**	
Method	**Fixed Effect**	**Random Effect**	**Fixed Effect**	**Random Effect**	**Fixed Effect**	**Random Effect**
L.GDP	0.20 *** (0.070)	0.22 *** (0.043)	0.23 ** (0.079)	0.24 *** (0.074)	0.20 *** (0.073)	0.22 *** (0.070)
L.RQ	−0.14 ** (0.063)	−0.15 *** (0.062)	−0.11 ** (0.073)	−0.11 (0.067)		
L.PD	−0.21 (0.104)	−0.005 (0.010)	−0.74 *** (0.073)	−0.64 *** (0.057)	−0.76 *** (0.076)	−0.66 *** (0.062)
L.TO	0.02 (0.015)	0.02 ** (0.014)	0.03 * (0.016)	0.05 *** (0.021)	0.03 * (0.02)	0.05 * (0.019)
L.HC	−0.63 * (0.259)	−0.67 *** (0.196)				
L.Pop	1.15 *** (0.253)	1.34 (0.198)				
PGR	−0.01 (0.16)	−0.02 (0.02)	−0.01 (0.01)	−0.02 (0.15)		
Constant	−9.81 (2.34)	−13.06 (0.782)	0.68 (0.900)	−0.25 *** (0.751)	0.93 (0.889)	−0.01 (0.768)
R squared	0.871	0.870	0.857	0.854	0.852	0.858
Number of obs.	558	558	558	558	558	558

Note: *, **, *** are the levels of significance; robust standard errors are in parentheses; logarithm of water infrastructure (L.WI) is the dependent variable.

Trade openness is found by our analysis to be positively and significantly associated with the water infrastructure variable. This positive association suggests that an increase in trade openness in SSA supports water infrastructure performance in the region and may be a significant reason behind its performance in the region. This is because openness to trade facilitates adaptation of more water-saving and self-supply water technologies such as rope pumps, leading to water use efficiency and infrastructure performance, in line with Dang and Konar [28] and Maltha and Veldman [61].

4.2. Impact of the Determinants of Water Infrastructure Performance across Countries' Economic Structure in SSA

The preceding analyses reveal the most significant factors associated with water infrastructure performance in Sub-Saharan Africa. Subsequently, we investigate the various characteristics of countries' economic structures that make them less or more sensitive to the drivers of water infrastructure performance. The level of economic development of a country, which determines the quality of its infrastructure and institutions, could be a factor that influences how determinants affect the performance of water infrastructure in the region. To test this concern, we categorized our sample into three subgroups according to income level. The country categorization was performed following the World Bank's country classification based on gross national income (GNI) per capita. Results from the panel regressions are reported in Table 4. The findings showed that the concern of investigating water infrastructure determinants according to economic development level is sensible. The socioeconomic determinants have different effects on water infrastructure performance when panels are delineated by income level.

Table 4. Estimation results of the drivers of water infrastructure performance by income levels.

	Dependent Variable: L.WI		
Variables	**Low Income**	**Lower-Middle Income**	**Upper-Middle Income**
L.GDP	0.21 ** (0.094)	0.20 * (0.092)	0.05 (0.101)
L.TO	0.01 (0.029)	0.08 (0.095)	0.08 (0.081)
L.PD	−0.79 *** (0.130)	−0.78 *** (0.124)	−0.25 * (0.097)
Constant	1.04 (0.692)	−0.03 (2.686)	−0.12 (0.873)
R squared	0.905	0.852	0.555
Obs.	252	234	72

Note: *, **, *** are the levels of significance, robust standard errors are in parentheses; logarithm of water infrastructure (L.WI) is the dependent variable.

As shown in Table 4, the per-capita GDP has a positive and significant effect on lower income levels; however, the impact is insignificant in higher income levels. This implies that per-capita income increase has a more pronounced impact on water infrastructure performance in lower-income countries than in higher-income countries. Lower- and middle-income countries have significant access to their water infrastructure from privately financed and self-supplied sources, which may explain the significant impact of per-capita income growth, in line with previous findings of Oluwasanya et al. [62] and Foster et al. [63]. Further, the consistent negative and significant impact of population density across all income groups supports that the fast increase in the population density is the strongest determinant of water infrastructure underperformance in the SSA region. Indeed, the impact of population density is lowest in higher-income countries compared to lower-and middle-income groups. These results support the hypothesis that countries with stronger economies may be associated with greater governance effectiveness [64], allowing for sustainable planning of the increase in population density.

4.3. Impact of Water Infrastructure on Economic Development

Water infrastructure is an important factor in economic development. We have inferred that the investments in water infrastructure in SSA, along with appropriate policies, would lead to a significant economic development effect. Results of the panel regressions of water infrastructure and economic development from three differently specified models are presented in Table 5. To ensure the robustness of the estimation results, the study applied both the fixed-effect and random-effect methods. The results of the panel regression models show that the signs and significance of the estimated coefficients remain consistent for both estimators. This implies that the estimation results are robust. Reading through the fixed-effect estimation, the results show that water infrastructure has a positive and significant association with economic growth, implying that we would expect economic growth to increase by 0.71% if investment in water infrastructure increased by 1%. These results are justifiable since the economy of SSA countries is primarily dependent on agriculture, and the majority of the population is rural and farmers. Therefore, increasing water infrastructure investment such as drinking water infrastructure will help reduce the time intensity of domestic activities such as time spent collecting water over long distances and caring for children affected by water-borne diseases. As a result, more time can be allocated to leisure activities and in the marketplace, especially work on farm activities, leading to increased productivity. Another explanation is that hydroelectricity generation provides clean and renewable energy, including carbon-neutral emissions and reduced air pollution, which has important environmental and socioeconomic benefits in Sub-Saharan African countries, while irrigation infrastructure help alleviates the adverse effects of climate-induced stress associated with drought and extreme heat, ensures reliable water supply, and enables year-round agricultural production, leading to increased productivity. These results agree with the findings of Meeks [65], Maji [66], and Burney et al. [67].

Indeed, we found a much higher variation in economic growth to water infrastructure investment when the policy intervention variable (credit to the private sector by banks) is added to the regression of Model 2 as a mediation variable. This relationship can be seen by looking at the value of the R-squared value of Model 2, meaning that investment in water infrastructure, together with access to credit, explains more the economic development within each country. The results validate the positive relationship between water infrastructure and economic development, and allow policymakers to understand that by targeting water infrastructure investment, together with providing credit to the private sector, they could have the potential to strengthen economic development in the region.

However, the interaction of water infrastructure investment and financial development further shows a negative and significant association with economic growth, as reported in Model 5. This result is quite surprising and does not meet our primary expectation to observe a negative and significant interaction effect between water infrastructure and financial development (WI*FD) when investigated within the context of SSA. A possible explanation is the higher level of access to credit by the private sector relative to the level of investment in water infrastructure in the region. Consistent with the recent threshold literature of Asongu and Odhiambo [68] and Asongu and Odhiambo [69], increasing policy intervention beyond critical masses or thresholds generates adverse macroeconomic effects. This suggests that increased investment in water infrastructure in SSA should be matched with increased access to credit by the private sector to facilitate desired or favorable outcomes on growth.

The control variables denoted by labor force and regulatory quality reveal a significant and positive relationship with economic growth, as suggested by the fixed-effect estimator across models. This suggests an improvement in the quality of institutional regulations and labor force facilitates economic growth in SSA. Meanwhile, the human capital variable consistently reveals a significant and negative relationship association with economic growth across SSA. The significant negative effects of human capital on economic growth in SSA can be explained by the low level of education and unskilled nature of the human capital in SSA countries, and is consistent with previous findings of Kargbo et al. [70] and Akinola et al. [71], which should appeal to policymakers in the region.

Table 5. Regression results of the economic impact of water infrastructure investment.

	Dependent Variable: L.GDP					
	Model 1		**Model 2**		**Model 3**	
	Fixed Effect	**Random Effect**	**Fixed Effect**	**Random Effect**	**Fixed Effect**	**Random Effect**
L.WI	0.71 ** (0.151)	0.80 *** (0.142)	0.53 *** (0.144)	0.56 *** (0.138)	0.55 ** (0.550)	0.57 *** (0.139)
L.RQ	0.40 *** (0.131)	0.42 *** (0.122)	0.21 * (0.122)	0.20 * (0.114)	0.21 *** (0.121)	0.20 * (0.114)
L.Labor	1.84 ** (0.940)	2.32 *** (0.926)	2.26 ** (0.816)	2.48 *** (0.718)	2.19 ** (0.798)	2.42 *** (0.710)
L.HC	−1.93 ** (0.992)	−2.57 *** (0.960)	−2.74 ** (0.889)	−3.04 *** (0.733)	−2.66 ** (0.868)	−2.98 (0.726)
L.FD			0.13 *** (0.0.03)	0.14 *** (0.023)	0.13 *** (0.025)	0.13 *** (0.023)
L.FD*WI					−0.01 ** (0.002)	−0.009 *** (0.002)
Constant	9.24 ** (2.947)	12.03 *** (2.5)	12.93 *** (2.84)	14.27 *** (1.8)	13.11 *** (2.82)	14.48 *** (1.89)
Obs.						558
R squared	0.640		0.714	0.713	0.718	0.717

Note: *, **, *** are the levels of significance; robust standard errors are in parentheses; logarithm of GDP per capita (L.GDP) is the dependent variable.

5. Conclusions and Recommendation

It has been argued that adequate and reliable access to water infrastructure is an important asset for socioeconomic sustainability. Despite the considerable efforts made by African countries in the water sector, the challenge of water insecurity remains persistent in Sub-Saharan Africa. Hence, the need to formulate policies to maximize the economic benefit associated with the massive investment in water made in recent years in the region has also led to the need to understand the factors that influence the performance of water infrastructure in the region. This study therefore provided a comprehensive insight to date and covered a large number of countries about the socioeconomic determinants and analyzed the direct and indirect impacts of water infrastructure in Sub-Saharan Africa. The findings of this study established that an increase in per-capita income and openness in trade have a positive significant impact on enhancing the performance of water infrastructure performance, while increasing population density has a significant negative impact on water infrastructure performance. Comparative analysis suggests that the impact of factors associated with water infrastructure performance is driven by the effect of per-capita income growth and population density in low- and lower-middle-income economies for the selected countries considered. Further analysis revealed that the recent massive water infrastructure investment in SSA has a significant positive impact on economic growth in these countries. Moreover, the positive impact of water infrastructure on economic growth is fully mediated by the policy intervention of increasing access to credit to the private sector. Nevertheless, the moderating term of investment in water infrastructure and access to credit by the private sector induces negative coefficients.

The above findings have implications for the national, sub-regional, and regional policymakers in the Sub-Saharan African region. Most importantly, there is a need to update trade liberalization and globalization policies in these countries to include key issues related to sustainable water infrastructure. This can be achieved by encouraging the import of advanced water-saving technologies for irrigation and innovative low-cost wastewater reuse and water treatment through fiscal incentives on imports such as those proposed by Sorlini et al. [72] and Sorlini et al. [73]. These policies are necessary and might also help to reduce the massive challenges of pollution and water resource depletion posed by the rapid population growth. Policies to improve economic growth are also required in efforts to improve the performance of water infrastructure. This could be achieved through an effort to improve the quality of institutions and intensification of fixed capital investment. Moreover, sustainable urban development solutions are required in these countries to cope with the expansion of African cities due to rapid population growth and to mitigate its negative effect on water infrastructure. To achieve this, decision makers in these countries should pay attention to education and raising awareness about the environmental consequences of individual actions and the responsibility of the population for water resource protection. In addition, policies aimed at demographic transition, such as birth spacing and control are needed.

Furthermore, investments in the water sector are needed to increase the stock and operational management of infrastructures in these countries. Because raising funds to finance public infrastructure is challenging in developing countries such as those of SSA, policy options available such as public–private partnerships and the need to move from a “supply-side management” to a “demand-side management paradigm” should be prioritized so as to mobilize additional funds and make better use of scarce water resources, as discussed by [74]. The study emphasizes that investment in water infrastructure, along with policy intervention to improve access to credit by the private sector, is necessary to make investment more productive and attractive in Sub-Saharan Africa. However, increased investment in water infrastructure in Sub-Saharan Africa should be matched with increased access to credit by the private sector to facilitate desired or favorable outcomes on growth, though access to credit beyond a level—relative to the level of investment in water infrastructure in the region—would lead to adverse macroeconomic effects, as indicated by the negative correlation of the term representing the interaction between water infrastructure and access to credit and economic growth.

Author Contributions: Conceptualization, K.D. and S.J.; methodology, K.D. and S.J.; software, K.D. and S.J.; validation, S.J.; formal analysis, K.D. and S.J.; investigation, K.D.; resources, S.J.; data curation, K.D.; writing—original draft preparation, K.D.; writing—review and editing, K.D. and S.J.; visualization, K.D. and S.J.; supervision, S.J.; project administration, S.J.; funding acquisition, S.J. All authors have read and agreed to the published version of the manuscript.

Funding: This study was financially sponsored by the Strategic Priority Research Program of the Chinese Academy of Sciences (XDA 20010201).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data used in this study can be found online at: https://www.fao.org/aquastat/statistics/query/ (accessed on 1 June 2022); https://datasets.wri.org/dataset/globalpowerplantdatabase (accessed on 7 June 2022); https://data.unicef.org/dv_index/?q= (accessed on 1 June 2022); https://databank.worldbank.org/source/worldwide-governance-indicators (accessed on 1 June 2022).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Ogou, F.K.; Ojeh, V.N.; Naabil, E.; Mbah, C.I. Hydro-climatic and Water Availability Changes and its Relationship with NDVI in Northern Sub-Saharan Africa. *Earth Syst. Environ.* **2022**, *6*, 681–696. [CrossRef]
2. Huang, Z.; Yuan, X.; Liu, X. The key drivers for the changes in global water scarcity: Water withdrawal versus water availability. *J. Hydrol.* **2021**, *601*, 126658. [CrossRef]
3. Boretti, A.; Rosa, L. Reassessing the projections of the World Water Development Report. *NPJ Clean Water* **2019**, *2*, 15. [CrossRef]
4. Valipour, M.; Bateni, S.M.; Gholami Sefidkouhi, M.A.; Raeini-Sarjaz, M.; Singh, V.P. Complexity of Forces Driving Trend of Reference Evapotranspiration and Signals of Climate Change. *Atmosphere* **2020**, *11*, 1081. [CrossRef]
5. Tuyishimire, A.; Liu, Y.; Yin, J.; Kou, L.; Lin, S.; Lin, J.; Kubwimana, J.J.; Moharrami, K.; Simbi, C.H. Drivers of the increasing water footprint in Africa: The food consumption perspective. *Sci. Total Environ.* **2022**, *809*, 152196. [CrossRef]
6. Ochoa-Tocachi, B.F.; Bardales, J.D.; Antiporta, J.; Pérez, K.; Acosta, L.; Mao, F.; Zulkafli, Z.; Gil-Ríos, J.; Angulo, O.; Grainger, S.; et al. Potential contributions of pre-Inca infiltration infrastructure to Andean water security. *Nat. Sustain.* **2019**, *2*, 584–593. [CrossRef]
7. Tortajada, C. Water infrastructure as an essential element for human development. *Int. J. Water Resour. Dev.* **2014**, *30*, 8–19. [CrossRef]
8. Grey, D.; Sadoff, C.W. Sink or swim? Water security for growth and development. *Water Policy* **2007**, *9*, 545–571. [CrossRef]
9. Dadson, S.; Hall, J.W.; Garrick, D.; Sadoff, C.; Grey, D.; Whittington, D. Water security, risk, and economic growth: Insights from a dynamical systems model. *Water Resour. Res.* **2017**, *53*, 6425–6438. [CrossRef]
10. Adelekan, I.O.; Simpson, N.P.; Totin, E.; Trisos, C.H. *Climate Change 2022-Impacts, Adaptation and Vulnerability: Regional Factsheet Africa*; IPCC Sixth Assessment Report (AR6): Geneva, Switzerland, 2022. Available online: https://policycommons.net/artifacts/2264240/ipcc_ar6_wgii_factsheet_africa/3023294/ (accessed on 28 August 2022).
11. World Health Organization. *Global Progress Report on Water, Sanitation and Hygiene in Health Care Facilities: Fundamentals First*; 9240017542; UNICEF: New York, NY, USA, 2020.
12. Affoh, R.; Zheng, H.; Dangui, K.; Dissani, B.M. The Impact of Climate Variability and Change on Food Security in Sub-Saharan Africa: Perspective from Panel Data Analysis. *Sustainability* **2022**, *14*, 759. [CrossRef]
13. Conway, D.; Van Garderen, E.A.; Deryng, D.; Dorling, S.; Krueger, T.; Landman, W.; Lankford, B.; Lebek, K.; Osborn, T.; Ringler, C. Climate and southern Africa's water–energy–food nexus. *Nat. Clim. Chang.* **2015**, *5*, 837–846. [CrossRef]
14. Bain, R.; Johnston, R.; Mitis, F.; Chatterley, C.; Slaymaker, T. Establishing sustainable development goal baselines for household drinking water, sanitation and hygiene services. *Water* **2018**, *10*, 1711. [CrossRef]
15. Donkor, S.M. *Water in Africa: Management Options to Enhance Survival and Growth*; Economic Commission for Africa; United Nations: Addis Abeba, Ethiopia, 2006.
16. La Banque Africaine, D.D.P.; Bankgroup, A. *The Africa Water Vision for 2025: Equitable and Sustainable Use of Water for Socioeconomic Development*; Economic Commission for Africa: Addis Ababa, Ethiopia, 2000. Available online: https://hdl.handle.net/10855/5488 (accessed on 25 August 2022).
17. Frone, S.; Frone, D.F. Challenges in Analyzing Correlation between Water Infrastructure and Economic Development. *Procedia Econ. Financ.* **2014**, *10*, 197–206. [CrossRef]
18. Kahsay, T.N.; Kuik, O.; Brouwer, R.; Van Der Zaag, P. The economy-wide impacts of climate change and irrigation development in the Nile Basin: A computable general equilibrium approach. *Clim. Chang. Econ.* **2017**, *8*, 1750004. [CrossRef]
19. Shi, H.; Chen, J.; Liu, S.; Sivakumar, B. The Role of Large Dams in Promoting Economic Development under the Pressure of Population Growth. *Sustainability* **2019**, *11*, 2965. [CrossRef]
20. Jeuland, M. The economics of dams. *Oxf. Rev. Econ. Policy* **2020**, *36*, 45–68. [CrossRef]
21. Schreiner, B.G.; Mungatana, E.D.; Baleta, H. Impacts of drought induced water shortages in South Africa: Economic analysis. In *WRC Report No. 2604/1/18*; Report Commissioned by the Water Research Commission; Pegasys Institute: Pretoria, South Africa, 2018.
22. Fuente, D.; Allaire, M.; Jeuland, M.; Whittington, D. Forecasts of mortality and economic losses from poor water and sanitation in sub-Saharan Africa. *PLoS ONE* **2020**, *15*, e0227611. [CrossRef]

23. Sadoff, C. *Can Water Undermine Growth? Evidence from Ethiopia*; The World Bank: Washington, DC, USA, 2006.
24. Janeski, I.; Whitacre, B.C. Long-term economic impacts of USDA water and sewer infrastructure investments in Oklahoma. *J. Agric. Appl. Econ. Asssoc.* **2014**, *46*, 21–39. [CrossRef]
25. Adjei, E.A.; Amoabeng, K.O.; Ayetor, G.K.K.; Obeng, G.Y.; Quansah, D.A.; Adusei, J.S. Assessing the impact of hydro energy project on poverty alleviation: The case of Bui Dam in Ghana. *Energy Policy* **2022**, *170*, 113227. [CrossRef]
26. Yang, J.; Liu, X.; Ying, L.; Chen, X.; Li, M. Correlation analysis of environmental treatment, sewage treatment and water supply efficiency in China. *Sci. Total Environ.* **2020**, *708*, 135128. [CrossRef]
27. Berrittella, M.; Rehdanz, K.; Tol, R.S.J.; Zhang, J. The impact of trade liberalization on water use: A computable general equilibrium analysis. *J. Econ. Integr.* **2008**, *23*, 631–655. [CrossRef]
28. Dang, Q.; Konar, M. Trade openness and domestic water use. *Water Resour. Res.* **2018**, *54*, 4–18. [CrossRef]
29. Okello, C.; Tomasello, B.; Greggio, N.; Wambiji, N.; Antonellini, M. Impact of Population Growth and Climate Change on the Freshwater Resources of Lamu Island, Kenya. *Water* **2015**, *7*, 1264–1290. [CrossRef]
30. Buytaert, W.; De Bièvre, B. Water for cities: The impact of climate change and demographic growth in the tropical Andes. *Water Resour. Res.* **2012**, *48*, W08503. [CrossRef]
31. Hopewell, M.R.; Graham, J.P. Trends in access to water supply and sanitation in 31 major sub-Saharan African cities: An analysis of DHS data from 2000 to 2012. *BMC Public Health* **2014**, *14*, 208. [CrossRef]
32. Josephson, A.L.; Ricker-Gilbert, J.; Florax, R.J.G.M. How does population density influence agricultural intensification and pro ductivity? Evidence from Ethiopia. *Food Policy* **2014**, *48*, 142–152. [CrossRef]
33. Munamati, M.; Nhapi, I.; Misi, S. Exploring the determinants of sanitation success in Sub-Saharan Africa. *Water Res.* **2016**, *103*, 435–443. [CrossRef]
34. Higginbottom, T.P.; Adhikari, R.; Dimova, R.; Redicker, S.; Foster, T. Performance of large-scale irrigation projects in sub-Saharan Africa. *Nat. Sustain.* **2021**, *4*, 501–508. [CrossRef]
35. Rudra, N. Openness and the politics of potable water. *Comp. Polit. Stud.* **2011**, *44*, 771–803. [CrossRef]
36. Luh, J.; Bartram, J. Drinking water and sanitation: Progress in 73 countries in relation to socioeconomic indicators. *Bull. World Health Organ.* **2016**, *94*, 111. [CrossRef]
37. Gupta, R.; Yan, K.; Singh, T.; Mo, D. Domestic and International Drivers of the Demand for Water Resources in the Context of Water Scarcity: A Cross-Country Study. *J. Risk Financ. Manag.* **2020**, *13*, 255. [CrossRef]
38. Distefano, T.; Kelly, S. Are we in deep water? Water scarcity and its limits to economic growth. *Ecol Econ.* **2017**, *142*, 130–147.
39. Shunglu, R.; Köpke, S.; Kanoi, L.; Nissanka, T.S.; Withanachchi, C.R.; Gamage, D.U.; Dissanayake, H.R.; Kibaroglu, A.; Ünver, O.; Withanachchi, S.S. Barriers in Participative Water Governance: A Critical Analysis of Community Development Approaches. *Water* **2022**, *14*, 762. [CrossRef]
40. Aiyetan, A.O.; Das, D.K. Evaluation of the Factors and Strategies for Water Infrastructure Project Delivery in South Africa. *Infrastructures* **2021**, *6*, 65. [CrossRef]
41. Etongo, D.; Fagan, G.H.; Kabonesa, C.; Asaba, B.R. Community-Managed Water Supply Systems in Rural Uganda: The Role of Participation and Capacity Development. *Water* **2018**, *10*, 1271. [CrossRef]
42. Jones, C.I. Chapter 1: The Facts of economic growth. In *Handbook of Macroeconomics*; Elsevier: Amsterdam, The Netherlands, 2016; Volume 2A, pp. 3–69, ISSN 1574-0048. [CrossRef]
43. Tir, N.A.; Momeni, F.; Boboevich, G.T. Exploring the Effects of Water Sector Investment in Economic Development in Iran. *Procedia Soc. Behav. Sci.* **2014**, *131*, 396–405. [CrossRef]
44. Musouwir, T. Water and Economic Development: Correlation between Investment in the Water Sector and Economic Growth in Developing Countries. UNESCO-IHE. 2010. Available online: http://www.rid.go.th/thaicid/_6_activity/YPF-INACID/YPF_01_Tesar_H_M.pdf (accessed on 25 August 2022).
45. Byers, L.; Friedrich, J.; Hennig, R.; Kressig, A.; Li, X.; McCormick, C.; Valeri, L.M. *A Global Database of Power Plants*; World Resources Institute: Washington, DC, USA, 2018; Volume 18. Available online: https://datasets.wri.org/dataset/globalpowerplantdatabase (accessed on 7 June 2022).
46. Kim, H.-Y. Statistical notes for clinical researchers: Assessing normal distribution (2) using skewness and kurtosis. *Restor. Dent. Endod.* **2013**, *38*, 52–54. [CrossRef]
47. WHO/UNICEF. Joint Monitoring Programme Database (JMP). 2022. Available online: https://data.unicef.org/dv_index/?q= (accessed on 1 June 2022).
48. FAO. Aquastata, Area Equiped for Irrigation. 2022. Available online: https://www.fao.org/aquastat/statistics/query/ (accessed on 1 June 2022).
49. World Bank. World Development Indicators. 2022. Available online: https://databank.worldbank.org/source/worldwide-governance-indicators (accessed on 1 June 2022).
50. Kaiser, H.F. A note on Guttman's lower bound for the number of common factors. *Br. J. Stat. Psychol.* **1961**, *14*, 1–2. [CrossRef]
51. Jolliffe, I. Principal Component Analysis. *Technometrics* **2005**, *3*, 1580–1584. [CrossRef]
52. Allison, P.D. *Fixed Effect Regression Models*; Sage Publications: Thousand Oaks, CA, USA, 2009.
53. Breusch, T.S.; Pagan, A.R. A Simple Test for Heteroscedasticity and Random Coefficient Variation. *Econometrica* **1979**, *47*, 1287. [CrossRef]

54. Baltagi, B.H. Heteroskedasticity and Serial Correlation in the Error Component Model. In *Econometric Analysis of Panel Data*; Book Series; Springer: Berlin/Heidelberg, Germany, 2021; pp. 109–147. [CrossRef]
55. Hausman, J.A. Specification tests in econometrics. *Econometrica* **1978**, *46*, 1251–1271. [CrossRef]
56. Wooldridge, J.M. *Econometric Analysis of Cross Section and Panel Data*; MIT Press: Cambridge, MA, USA, 2010.
57. Cazcarro, I.; Duarte, R.; Sánchez-Chóliz, J. Economic growth and the evolution of water consumption in Spain: A structural decomposition analysis. *Ecol Econ.* **2013**, *96*, 51–61. [CrossRef]
58. Li, H.; Cohen, A.; Li, Z.; Zhang, M. The Impacts of Socioeconomic Development on Rural Drinking Water Safety in China: A Provincial-Level Comparative Analysis. *Sustainability* **2019**, *11*, 85. [CrossRef]
59. Chen, W.; Wu, S.; Lei, Y.; Li, S. China's water footprint by province, and inter-provincial transfer of virtual water. *Ecol Indic.* **2017**, *74*, 321–333. [CrossRef]
60. Zhang, P.; Zou, Z.; Liu, G.; Feng, C.; Liang, S.; Xu, M. Socioeconomic drivers of water use in China during 2002–2017. *Resour. Conserv. Recycl.* **2020**, *154*, 104636. [CrossRef]
61. Maltha, A.; Veldman, R. A market-based approach to scale up sustainable rural water supply: Experiences from Tanzania. In Proceedings of the 39th WEDC International Conference, Kumasi, Ghana, 11–15 July 2016.
62. Oluwasanya, G.; Smith, J.; Carter, R. Self supply systems: Urban dug wells in Abeokuta, Nigeria. *Water Supply* **2011**, *11*, 172–178. [CrossRef]
63. Foster, T.; Priadi, C.; Kotra, K.K.; Odagiri, M.; Rand, E.C.; Willetts, J. Self-supplied drinking water in low- and middle-income countries in the Asia-Pacific. *NPJ Clean Water* **2021**, *4*, 37. [CrossRef]
64. Doeffinger, T.; Hall, J.W. Water stress and productivity: An empirical analysis of trends and drivers. *Water Resour. Res.* **2020**, *56*, e2019WR025925. [CrossRef]
65. Meeks, R. Water Works: The Economic Impact of Water Infrastructure. *J. Hum. Resour.* **2017**, *52*, 1119–1153. [CrossRef]
66. Maji, I.K. Does clean energy contribute to economic growth? Evidence from Nigeria. *Energy Rep.* **2015**, *1*, 145–150. [CrossRef]
67. Burney, J.A.; Naylor, R.L.; Postel, S.L. The case for distributed irrigation as a development priority in sub-Saharan Africa. *Proc. Natl. Acad. Sci.* **2013**, *110*, 12513. [CrossRef] [PubMed]
68. Asongu, S.A.; Odhiambo, N.M. Insurance Policy Thresholds for Economic Growth in Africa. *Eur. J. Dev. Res.* **2020**, *32*, 672–689. [CrossRef]
69. Asongu, S.A.; Odhiambo, N.M. Foreign direct investment, information technology and economic growth dynamics in Sub-Saharan Africa. *Telecommun. Policy* **2020**, *44*, 101838. [CrossRef]
70. Kargbo, A.A.; Ding, Y.; Kargbo, M. Financial development, human capital and economic growth: New evidence from Sierra Leone. *J. Financ. Bank Manag.* **2016**, *4*, 49–67. [CrossRef]
71. Akinola, G.W.; Bokana, K.G. Human capital, higher education enrolment and economic growth in the SSA countries (panel model approach). *J. Econ. Behav. Stud.* **2017**, *9*, 215–226. [CrossRef]
72. Sorlini, S.; Collivignarelli, M.C.; Miino, M.C. Technologies for the control of emerging contaminants in drinking water treatment plants. *Environ. Eng. Manag. J.* **2019**, *18*, 2203–2213. Available online: http://www.eemj.icpm.tuiasi.ro/pdfs/vol18/no10/11_85_Sorlini_19.pdf (accessed on 28 August 2022).
73. Sorlini, S.; Collivignarelli, C.; Miino, M.C.; Caccamo, F.M.; Collivignarelli, M.C. Kinetics of microcystin-LR removal in a real lake water by UV/H_2O_2 treatment and analysis of specific energy consumption. *Toxin* **2020**, *12*, 810. [CrossRef]
74. Narzetti, D.A.; Marques, R.C. Policies and incentives for developing universal access to water and sanitation for vulnerable families. *Water Policy* **2022**, *24*, 485–499. [CrossRef]