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The impact of public spending on water, sanitation and hygiene (WASH) adoption: Governance thresholds for complementary policies

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The impact of public spending on water, sanitation and hygiene (WASH) adoption: Governance thresholds for complementary policies

Elvis D. Achuo & Simplice A. Asongu

Abstract

Despite the global resolve to ensure the availability and sustainable management of water and sanitation, several people across the world still have very limited or no access to basic drinking water, sanitation and hygiene (WASH) services. Therefore, this study primarily examined the effect of public spending on WASH adoption. The moderating role of governance quality in the nexus among public spending and WASH adoption was equally assessed. The underlying relationships for a global panel of 45 countries over the 2000-2022 period are unravelled with the help of the system Generalised Method of Moments, Driscoll-Kraay robust standard errors and the generalised least squares estimation techniques. Results from various approaches show that public spending has a statistically significant negative effect on WASH adoption. Moreover, the interactive regressions show that public spending negatively interacts with governance to produce a negative net effect of -0.319. The underlying negative effects are apparent when some governance thresholds are exceeded. These thresholds are critical points that when reached, complementary policies are needed in order to maintain the unconditional positive effect of public spending on WASH adoption. It follows that the complementarity between public spending and governance is a sufficient and necessary condition for the promotion of WASH adoption exclusively below certain governance thresholds. Contingent on the empirical results, policymakers are advised to tailor public spending to more conveniently target local-based WASH initiatives in order to limit bureaucracy and broad-based policies. Besides, the local population should be endowed with the ability to sanction elected officials when WASH measures are not effectively implemented. Beyond the economic and political governance consideration related to WASH, institutional governance should also be improved at the local level, to the extent that ensuring the respect of interactions between the citizens and the State in the promotion of WASH is also enforced at the local level.

Keywords: Public spending, Drinking water, Sanitation, Hygiene, Governance quality, WASH adoption

1. Introduction

Regardless of the venerable universal belief that water is life, a look at public investments with regard to the supply of basic water services across the globe suggests that various governments especially in developing countries seem to undermine the importance of water to the socioeconomic livelihood of the populace. It is incomprehensible that despite the global resolve to ensure the availability and sustainable management of water and sanitation, several people across the world still have very limited access to basic drinking water, sanitation and hygiene (WASH) services. These ambitions of world leaders are rooted in the Sustainable Development Goals (SDGs) adopted in 2015 to guide global development over the 2015-2030 horizon. Specifically, world leaders through SDG6 pledged to ensure universal access to safe and affordable drinking water, adequate sanitation and hygiene as well as ending open defecation and improving water quality (United Nations, 2015).

Almost a decade since the adoption of the SDGs, the lofty ambitions contained in SDG6 seem to be fast fading out in the 21 century societies where having access to basic WASH facilities has become a nightmare across rural and urban communities especially in developing countries (Asongu and Nwachukwu, 2016; Marks et al., 2018; Daniel et al., 2021; Mouteyica and Ngepah, 2023). Moreover, not only are these basic WASH services inadequately supplied, but their accessibility, affordability and quality remain far below expectations. For instance, at the global scale, while over 2.2 billion people do not have access to safe drinking water, about 3.5 billion lack access to safely managed sanitation and about 2 billion people lack access to basic hygiene (UNICEF, 2023a). The poor quality of these services has far-reaching negative consequences on human health and the socioeconomic well-being of people (Ahmed et al., 2022).

Ensuring an adequate supply of water, sanitation and hygiene services will render people healthier and more productive. Proponents of the human capital theory have demonstrated the role of health human capital in fostering economic growth. Hence, Ahmed et al. (2022) contend that the academic performance of students increases with adequate supply and adoption of WASH services within the school milieu. Consequently, increasing public spending in the provision of basic WASH services has the potential of contributing either directly or indirectly to the sustainable development drive of countries across the world (Mouteyica and Ngepah, 2023).

The role of the government in the provision of adequate and good quality water and sanitation services which guarantees the attainment of a socioeconomically industrious life for all people was particularly stressed in the 1978 Alma-Ata Declaration (WHO, 2019). Moreover, UNICEF (2023a) argues that universal access to WASH services is a fundamental human right, thereby compelling governments to increase public spending to ensure an adequate supply of WASH services. However, several academics opine that poor governance quality and inadequate financial development are major challenges with regard to the sustainable provision of WASH services especially in developing countries (Daniel et al., 2021; Marks et al., 2018). Therefore, there is urgent need for governments around the world to step up expenditures with regard to the provision of basic WASH services.

Despite the appreciable level of WASH adoption across developed European and North American countries, the situation remains pitiable especially across developing African and Asian economies. These views are corroborated by recent statistics from the United Nations Children's Fund (UNICEF) which provides highlights on the WASH adoption levels from a continental perspective (UNICEF, 2023b). The low level of WASH service provision and adoption in these developing countries could be blamed to a greater extent on the financial challenges faced by these economies in providing water and health infrastructure. While low public funding constitutes a major hinderance to the provision of adequate WASH services (Giné-Garriga et al., 2021), poor governance quality equally hampers the construction of WASH infrastructure (Daniel et al., 2022) since the funds destined for such projects are likely to be embezzled by corrupt officials.

It is against this premise that the primary aim of this study was to analyse the effects of public spending on basic drinking water, sanitation and hygiene (WASH) adoption. Besides, given the important role played by governance in infrastructure development, the moderating role of governance quality in the nexus amidst public spending and WASH adoption was equally assessed over the 2000-2022 period for a global panel of 45 developed and developing economies.

The present study is important especially at a time when the global economy is still struggling to recover from the deadly global COVID-19 pandemic that reawakened the need for basic hygiene practices both at the individual, family and public spheres. Moreover, the present study not only contributes to extant literature on the current debate regarding the nexus amidst government expenditure and WASH adoption, but also provides actionable thresholds for the

policy moderating variables to guide policymakers on the design of complementary and appropriate policies once these thresholds are attained by the moderating variables. Hence, the present article reveals that the interaction of public spending with governance leads to the establishment of negative net effects which enables the determination of actionable thresholds for the governance indicators. Further, the present paper provides a comprehensive global analysis on the link between public spending and the aggregated and disaggregated WASH adoption measures, thereby departing from the few extant studies that are largely confined to country-specific and microeconomic analysis of the underlying association between public expenditure and individual WASH indicators.

Hence, the empirical findings based on the system Generalised Method of Moments, Driscoll-Kraay robust standard errors, and generalised least squares estimation techniques reveal that public spending has a significant negative effect on WASH adoption. Moreover, the interactive regressions show that public spending negatively interacts with governance to produce a negative net effect of -0.319. The underlying negative effects are apparent when some governance thresholds are exceeded. It follows that the complementarity between public spending and governance is a sufficient and necessary condition for the promotion of WASH adoption exclusively below certain governance thresholds.

The remainder of the paper is outlined as follows. Section 2 reviews the literature. The empirical methodology presented in section 3. Section 4 presents and discusses the empirical results. Section 5 concludes and provides some policy implications of the study.

2. Synoptic Review of Literature

The theoretical foundations for the link between public spending and WASH adoption can be traced to the Integrated Behavioural Model (IBM) for Water, Sanitation and Hygiene (WASH), denoted IBM-WASH, was propounded by Dreibelbis et al. (2013). The IBM-WASH model is a combination of different behavioural theories including the FOAM (Focus, Opportunity, Ability and Motivation) and SaniFOAM (Sanitation FOAM), which are conceptual frameworks specifically designed to aid in the development, implementation, monitoring and evaluation of handwashing, sanitation and hygiene behaviours (Devine, 2009; Coombes and Devine, 2010).

The IBM-WASH model encompasses three dimensions (psychological, contextual and technical) and the interactions among various WASH determinants for each dimension are

considered at five levels (habitual, individual, interpersonal, community, and societal). To ensure a proper understanding and effective assessment of various WASH determinants and their relevance in each context, any successful intervention must consider behaviour change in these three dimensions and five levels (Hulland et al., 2013). While the contextual factors include to access to water and soap, the psychological factors relate to peoples' aversion to perceived risk of disease and contact with dirty objects. Technical factors on their part are concerned with the physical hardware storage facilities for water and soap.

Summarily, the IBM-WASH model is a conceptual model that enables the understanding of the various psychological, technical and environmental factors that influence WASH behaviour. In a recent study that attempts to identify the psychological determinants of WASH behaviour, Williams et al. (2021) emphasised the importance of the IBM-WASH model. Besides, White et al. (2020) argue that the effectiveness of hygiene interventions depends essentially on the determinants of handwashing behaviour.

Inspired by the theoretical developments of Dreibelbis et al. (2013), a few academics (Marks et al., 2018; Kabir et al., 2021; Daniel et al., 2022; Ghosh et al., 2022) have sought to provide an empirical examination of the underlying determinants of WASH adoption across the globe. In a recent study across Indian cities, Ghosh et al. (2022) argued that WASH poverty reduces with increased public spending. Specifically, the authors demonstrate that increased government expenditure through increased investment positively impacts on WASH adoption. Similarly, Giné-Garriga et al. (2021) opine that, increased government spending and financial assistance to vulnerable households is necessary to enhance access to basic WASH services. In a related study for Brazil, Ferreira et al. (2021) contend that increased public investments in water and sanitation infrastructure enhances access to WASH adoption.

Exploring the key determinants of WASH adoption in rural Indonesia, Daniel et al. (2021) opine that institutional frameworks and financial development are key determinants of WASH supply and adoption. Specifically, the authors revealed that poor governance quality inhibits the supply of WASH services. Equally, inadequate financial development negatively impacts on WASH provision and adoption (Marks et al., 2018). This is consistent with the recent findings of Tamene and Afework (2021).

Exploring the gender-based challenges of WASH implementation, Anderson et al. (2021) reveal that unlike men, women are more effective in ensuring sustained improvements in water, sanitation and hygiene adoption. The authors attribute these gender inequalities as regards

WASH implementation to women's ability to use relational approaches and influence social ties in encouraging positive behaviour change. This suggests the need for women's socioeconomic empowerment in order to ensure sustainable WASH adoption. Thus, Kelly et al. (2017) opine that the active participation of women in WASH programmes improves community trust in financial management, revenue mobilisation and the delivery of WASH services.

Besides, some contemporary academics (Marks et al., 2018; Daniel et al., 2021, 2022) have shown that the quality of institutions matters for WASH adoption. For instance, in a recent study encompassing African, Asian and South American economies, Daniel et al. (2022) examined the endogeneity of psychological factors relating to water adoption and conclude that institutional quality influences water adoption.

To the best of our knowledge, despite the global resolve to provide safe and affordable drinking water, adequate sanitation and hygiene for all, as evidenced in SDG6 (United Nations, 2015), the linkage amid public spending and WASH adoption has not been given considerable attention in contemporary literature. Moreover, based on the belief that governance quality is a key determining factor for the prevailing WASH conditions across the globe and that the determinants of WASH adoption are often highly interconnected (Daniel et al., 2021; Kabir et al., 2021), the study complements and extends extant literature by verifying the interactive role of governance quality and public spending on WASH adoption from a global perspective.

Consequently, based on the theoretical and empirical foundations, this study primarily pursues a dual objective and sought to test the following hypotheses: (1) Public spending has an enhancing effect on WASH adoption. (2) The effect of public spending on WASH adoption is moderated through governance quality.

3. Research Methodology

3.1 Data Sources and Description of Variables

The data employed in this study were sourced from the 2023 World Bank database, notably the World Development Indicators and the World Governance indicators. The data covers a period of 23 years (2000-2022) for a global sample of 45 countries[1]. The adopted time period and

[1]Algeria, Angola, Armenia, Azerbaijan, Belize, Benin, Bhutan, Cambodia, Central African Republic, Chad, Colombia, Cote d'Ivoire, Cuba, Dominican Republic, Ecuador, Egypt, El Salvador, Ethiopia, Gambia, Georgia, Ghana, Guatemala, Guinea, Guinea-Bissau, India, Jamaica, Kenya, Mali, Mexico, Moldova, Mongolia, Namibia, Nepal, Pakistan, Paraguay, Philippines, Serbia, Sierra Leone, Syrian Arab Republic, Tonga, Tunisia, Turkmenistan, Uganda, Uzbekistan, Zimbabwe.

included countries were influenced by the availability of data as dictated by competent theoretical foundations and contemporary empirical studies relating to the link between public spending and WASH provision and adoption.

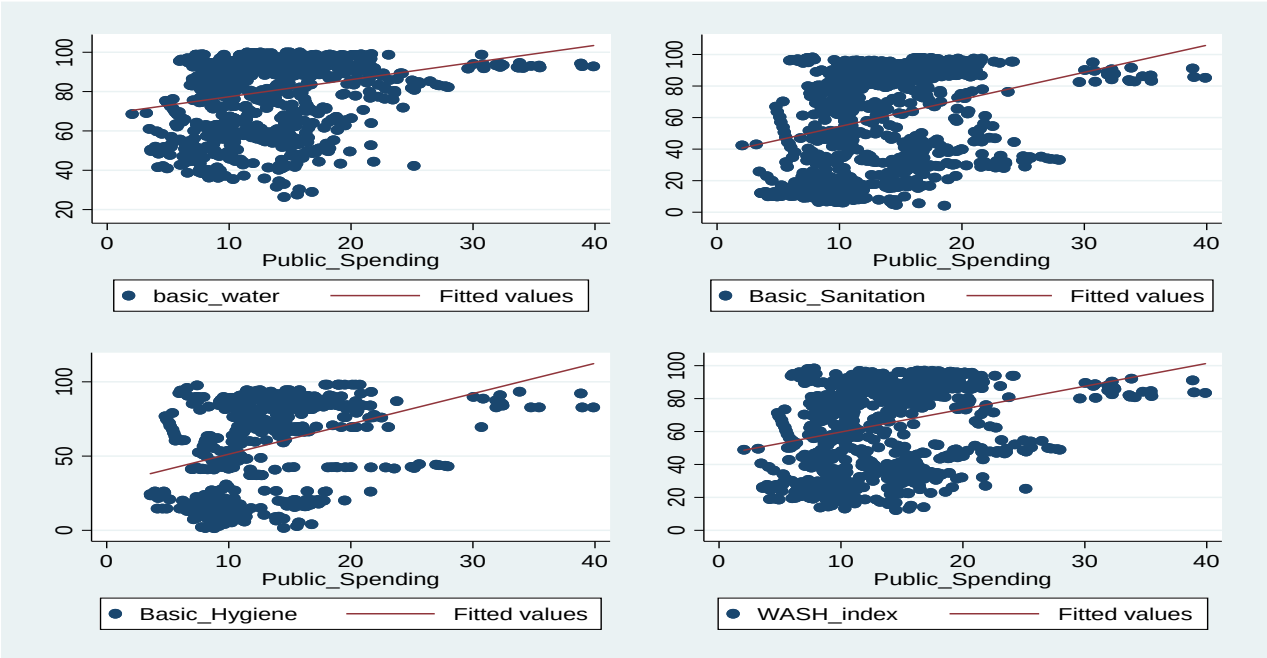
3.1.1 Dependent variable

Given that this study primarily examines the effect of public spending on water, sanitation and hygiene (WASH) adoption, the dependent variable is WASH adoption. However, various measures of WASH adoption encompassing basic drinking water, basic sanitation, and basic hygiene are adopted. Besides, the specific WASH indicators are later aggregated into a composite indicator at the rural and urban scenarios. The measurement and definitions for the various WASH indicators are provided in appendix A2.

3.1.2 Independent and Control Variables

The explanatory variable that principally explains variability in WASH adoption is public spending, proxied by general government final consumption expenditure as a percentage of Gross Domestic Product (GDP). The employment of public spending as a key determinant of WASH adoption in this study is consistent with contemporary literature (Ferreira et al., 2021; Giné-Garriga et al., 2021; Ghosh et al., 2022). Thus, in connection with Ghosh et al. (2022), public spending is likely to foster WASH adoption. The potential positive relationship between public spending and various WASH indicators is shown in Figure 1.

Figure 1. Correlation between public spending and WASH adoption



Besides the main explanatory variable, public spending, this study introduces some control variables in the the specified model. The controlled variables are credit access, population growth, development aid, Information and Communication Technology (ICT), GDP and governance. The inclusion of these variables is consistent with competent recent studies with regard to the determinants of various WASH services. Paramount among these control variables is credit access and institutional quality. This is because several researchers argue that poor governance quality and inadequate financial development are major challenges with regard to the sustainable provision of WASH services especially in developing countries (Daniel et al., 2021, Marks et al., 2018). While a comprehensive list of variables and their respective definitions and measurement is provided in appendix A2, the descriptive statistics of the modelled variables is contained in Table 1.

Table 1. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
WASH	1035	63.546	26.069	5.764	99.91
Water	1035	79.688	18.302	18.682	100
Sanitation	1032	59.251	30.829	2.794	99.819
Hygiene	620	56.977	30.973	1.464	98.13
Water (rural)	1035	71.297	21.996	8.734	100
Sanitation (rural)	1032	51.694	32.313	0	99.931
Hygiene (rural)	613	50.554	30.783	1.358	98.032
Water (urban)	1035	90.748	9.607	48.064	100
Sanitation (urban)	1035	68.28	26.834	11.472	100
Hygiene (urban)	625	64.443	30.12	1.768	98.619
Public spending	991	13.423	5.379	2.047	39.881
Credit access	937	27.338	19.482	.002	177.321
Population growth	1035	1.606	1.209	-6.852	6.336
Development aid	990	7.430e+08	1.076e+09	-74420000	1.004e+10
ICT	977	20.978	22.448	.015	86
GDP per capita	1028	2853.501	2145.364	255.1	10120.385
Corruption control	942	30.538	19.084	.481	93.75
Government effectiveness	942	34.176	18.601	1.442	75.481
Political stability	943	31.623	21.247	0	94.686
Regulatory quality	942	33.618	18.683	0	82.692
Rule of law	945	30.761	17.84	.469	79.602
Voice & accountability	945	34.276	19.545	0	76.119
Governance	945	32.556	15.441	1.524	69.635

3.2 Model and Estimation Procedure

Drawing from the theoretical foundations of the Integrated Behavioural Model (IBM) for WASH (IBM-WASH) developed by Dreibelbis et al. (2013) and contingent on recent studies with regard to the determinants of WASH adoption (Kabir et al., 2021), we specify the following model (equation 1) in which WASH adoption is essentially explained by public spending.

$$WASH_{it} = \omega_0 + \omega_1 PS_{it} + \omega_j X_{it} + \mu_{it} \qquad (1)$$

Where $WASH_{it}$ denotes water, sanitation and hygiene adoption for country *i* and period *t*. Specifically, WASH is a vector of four independent variables encompassing water, sanitation, hygiene, and an aggregated measure of the various WASH indicators. PS represents public spending. *X* is a vector of various control variables likely to impact WASH adoption. ω_s denote parameter coefficients, and μ is the stochastic error term.

The interrelationship between public spending and WASH adoption is empirically assessed with the help of the system Generalised Method of Moments (GMM) technique. The system GMM approach propounded by Roodman (2009) is believed to outperform other classical econometric approaches for several reasons. For instance, this approach is suitable when the cross sections (N) surpass the time periods (T) in the panel dataset, which is the case in this study where T=23 and N=45. Besides, recent studies (Achuo, 2023; Nchofoung et al., 2022) applaud the system GMM approach for its ability to yield consistent estimates while controlling for simultaneity bias, heterogeneity, and cross-section dependence. Moreover, the system GMM modelling framework ensures the simultaneous integration of the level and difference equations.

Consistent with the system GMM literature (Achuo et al., 2023a,b), equation 1 is transformed into the following level (equation 2) and difference (equation 3) equations.

$$WASH_{it} = \omega_0 + \omega_1 WASH_{i(t-1)} + \omega_1 PS_{it} + \sum_{j=1}^{m} \omega_j X_{j,i(t-1)} + \beta_i + \zeta_t + \mu_{it} \qquad (2)$$

$$WASH_{it} - WASH_{i(t-1)} = \omega_1 \left(WASH_{i(t-1)} - WASH_{i(t-2)}\right) + \omega_2 \left(PS_{it} - PS_{i(t-1)}\right) + \sum_{j=1}^{m} \omega_j \left(X_{j,i(t-1)} - X_{j,i(t-2)}\right)(\zeta_t - \zeta_{t-1}) + (\mu_{it} - \mu_{i(t-1)}) \qquad (3)$$

Where $WASH$, PS, X, ω_s and μ are all defined as above, β_i and ζ_t are the respective country and period fixed effects.

In addition to the examination of the direct effects of public spending on WASH adoption, this study conducts interactive regressions[2] with regard to the potential conditional effect of public spending on WASH adoption through various institutional quality measures. Based on the

[2] Please consult Achuo and Ojong (2023) and Achuo (2023) for details on interactive regressions as well as the mathematical formulations for the net effects and thresholds.

interactive regressions and where applicable, net effects and policy thresholds are calculated for the moderating variables.

Despite the ability of the system GMM technique to yield consistent estimates in the presence of cross-section dependence, the study conducted several preliminary tests. First, the study tested for cross-sectional dependence following Pesaran (2015). Second, the study tested for unit root following Pesaran (2007), before employing the Kao (1999) panel cointegration test.

Besides, the system GMM approach was complemented by other robust estimation techniques, notably the Driscoll-Kraay robust standard errors (Driscoll and Kraay, 1998), as well as the generalised least squares estimators. This is because of the ability of these approaches to control for cross-section dependence and endogeneity (Nchofoung et al., 2023), thus yielding consistent estimates.

4. Empirical Results and Discussions

4.1 Preliminary Results

Before employing contemporary econometric estimation techniques on our specified model, we first tested for cross-section dependence with the help of the Pesaran CD test. Having confirmed the presence of cross-section dependence for our series, we employed the Pesaran CADF second generation unit root test to ascertain the level of stationarity of the series. Consequently, the results (see appendix A3) reveal that some variables are stationary at levels whereas others attain stationarity at first difference, thereby suggesting that the series is cointegrated. In this respect, we verified for possible cointegration among the series with the help of the Kao (1999) panel cointegration test. The significant p-values for all the tests statistics associated with the Kao test (see appendix A4) implies we cannot fail to reject the null hypothesis of the absence of cointegration in favour of the alternative that the series is cointegrated. The confirmation of cointegration therefore requires the verification of the direction of causality, which was ascertained with the help of the pairwise Granger causality test. The ensuing causality test results reveal the existence of both unidirectional causality and feedback effects. Specifically, there exists a feedback effect between public spending and WASH adoption. Appendix A5 provides a comprehensive analysis of the causality results for all the modelled variables.

4.2 Baseline Results

The baseline results present the empirical estimates of the direct effects of public spending on basic WASH adoption.

Table 2. Baseline estimates of the implications of public spending on basic WASH adoption

	(Model 1)	(Model 2)	(Model 3)
	GLS	Driscoll-Kraay	System GMM
Variables	Dependent Variable: Basic WASH adoption		
L.WASH			0.936***
			(0.0142)
Public spending	-0.461***	-0.0260	-0.0900**
	(0.106)	(0.0465)	(0.0347)
Credit access	0.178***	0.110***	0.0290***
	(0.0279)	(0.00861)	(0.00628)
Population growth	-7.178***	-1.641***	-0.252**
	(0.437)	(0.323)	(0.121)
Development aid	-1.342***	-0.396***	0.297
	(0.405)	(0.136)	(0.231)
ICT	0.0555**	0.0290*	-0.00958**
	(0.0250)	(0.0150)	(0.00380)
GDP (log)	16.53***	15.30***	1.358***
	(0.722)	(1.003)	(0.324)
Constant	-24.80**	-46.42***	-10.73*
	(10.83)	(8.129)	(5.358)
Observations	860	860	824
Number of Countries	45	45	45
Number of Instruments			22
AR(2)_proba.			0.461
Hansen_proba.			0.160
chi2	2657***		
R-squared		0.589	
Fisher		324.4***	58957***

Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

The results in Table 2 show that public spending negatively affects WASH adoption. The negative association between public spending and basic WASH adoption is consistent for various estimation techniques. Although these findings contradict the findings of Ferreira et al. (2021) who argue that increased public investments in water and sanitation infrastructure enhances WASH adoption, they corroborate the results of Razakamanana et al. (2023). Razakamanana et al. (2023) argued that public spending alone does not improve health outcomes, since the efficiency of health spending depends on the quality of institutions. Besides public spending that hampers WASH adoption, access to credit facilities has a significant

positive impact on WASH adoption. These findings suggest that either public spending destined for WASH infrastructure is largely insufficient to provide adequate and sustainable WASH services or that the WASH services provided are not readily affordable to the population. This corroborates extant studies (Giné-Garriga et al., 2021) stressing the need for the provision of good quality and affordable WASH services for all.

4.2 Robustness Checks

The consistency and pertinence of the baseline findings were verified on several grounds, encompassing the disaggregation of the outcome variable (WASH adoption index) into its different components, area of residence, level of development, regional and income categories of the countries under consideration.

The results in Table 3 reveal that the baseline findings remain robust when the different WASH indicators are considered with the exception of hygiene adoption which is positively impacted by public spending though the effect is non-significant. When the area of residence is taken into consideration, the results in Table 4 show that the effects of public spending on WASH adoption are divergent depending on the measure of WASH adoption and area of residence. Specifically, while the effect of public spending on the aggregate WASH index is negative both in the rural and urban setting, a significant negative and positive effect is observed for basic drinking water in the rural and urban milieu respectively. However, although public spending positively impacts on sanitation and hygiene in the rural areas, the effect is non-significant. These findings suggest that the problem of access to basic drinking water is very critical in rural areas than in urban areas, while access to basic sanitation appears to be a major preoccupation in urban areas. This could be due to the high population density that characterises urban centres.

Nevertheless, access to WASH adoption remains a major challenge both in rural and urban centres as evidenced by the negative correlation between public spending and the aggregate WASH index. Likewise, the effect of public spending on WASH adoption is divergent across geographical regions and income groups (Table 5) as well as level of development (Table 6). Specifically, although Table 6 reveals that the effect of public spending on WASH adoption is positive but non-significant across developed and developing countries, a significant negative relationship is observed among the urban population in develop countries, thus indicating that

developed countries are more concerned with access to safely managed WASH adoption and not just access basic WASH services.

Overall, the established negative effect of public spending on WASH adoption corroborates the findings of Razakamanana et al. (2023) who argued that public spending alone does not improve health outcomes. Besides, the authors argue that a proper understanding of the implications of public expenditures on health outcomes requires the consideration of governance dynamics. Thus, the authors reiterate the role of governance quality as a key determinant of health outcomes as well as the efficiency of public spending.

Table 3. Effect of public spending on various basic WASH adoption indicators (System GMM estimators)

	(Model 1)	(Model 2)	(Model 3)	(Model 4)
		Dependent Variable:		
Variables	Water	Sanitation	Hygiene	WASH
L.Water	0.993***			
	(0.00163)			
Public spending	-0.00436*	-0.0306***	0.00612	-0.0900**
	(0.00231)	(0.00691)	(0.00559)	(0.0347)
Credit access	0.00156***	0.0190***	0.00791***	0.0290***
	(0.000347)	(0.00146)	(0.00167)	(0.00628)
Population growth	0.0675***	-0.0354**	0.714***	-0.252**
	(0.0158)	(0.0141)	(0.0321)	(0.121)
Development aid	0.0578***	0.109***	0.264***	0.297
	(0.00771)	(0.0322)	(0.0358)	(0.231)
ICT	-0.00249***	-0.00749***	-0.0137***	-0.00958**
	(0.000495)	(0.000665)	(0.00104)	(0.00380)
GDP (log)	0.142***	0.0615	-1.128***	1.358***
	(0.0273)	(0.0488)	(0.0923)	(0.324)
L.Sanitation		0.997***		
		(0.00162)		
L.Hygiene			1.057***	
			(0.00279)	
L.WASH				0.936***
				(0.0142)
Constant	-1.250***	-1.679**	-0.377	-10.73*
	(0.336)	(0.775)	(1.085)	(5.358)
Observations	729	727	476	824
Number of countries	45	45	45	45
Number of Instruments	36	36	43	22
AR(2)_proba.	0.959	0.189	0.142	0.461
Hansen_proba.	0.701	0.545	0.522	0.160
Fisher	2.160e+07***	5.570e+06***	4.600e+07***	58957***

Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 4. Effect of public spending on basic WASH adoption considering the area of residence (System GMM estimators)

	(Model 1)	(Model 2)	(Model 3)	(Model 4)	(Model 5)	(Model 6)	(Model 7)	(Model 8)
	Rural Areas				Urban Areas			
	Dependent Variable:							
VARIABLES	Water	Sanitation	Hygiene	WASH	Water	Sanitation	Hygiene	WASH
L.Water (rural)	0.957***							
	(0.00349)							
Public spending	-0.0534***	0.00366	0.00682	-0.125***	0.0104***	-0.101***	0.0276**	-0.0606***
	(0.00973)	(0.0143)	(0.108)	(0.0327)	(0.000745)	(0.0126)	(0.0108)	(0.00720)
Credit access	0.0109***	0.00511*	0.0223**	0.0307***	-0.00208***	0.00756**	0.00179	0.0149***
	(0.00195)	(0.00265)	(0.0106)	(0.00945)	(0.000187)	(0.00316)	(0.00178)	(0.00174)
Population growth	0.237***	0.0830	0.0747	-0.303**	0.0359***	0.0949**	0.178***	-0.295***
	(0.0319)	(0.109)	(0.350)	(0.144)	(0.00742)	(0.0351)	(0.0533)	(0.0802)
Development aid	0.149***	0.136	1.297*	0.465*	0.0131***	0.0960***	0.0347	-0.128***
	(0.0303)	(0.144)	(0.654)	(0.259)	(0.00319)	(0.0324)	(0.0332)	(0.0276)
ICT	-0.00674***	-0.00656***	-0.0241***	-0.0107**	-0.00176***	0.00275*	0.00119	0.00442***
	(0.00245)	(0.00139)	(0.00699)	(0.00437)	(0.000147)	(0.00141)	(0.00135)	(0.00128)
GDP (log)	1.459***	0.336*	0.641	1.281***	0.263***	-0.591***	-0.330***	0.194
	(0.160)	(0.177)	(0.625)	(0.343)	(0.0270)	(0.198)	(0.0924)	(0.246)
L.Sanitation (rural)		1.003***						
		(0.00362)						
L.Hygiene (rural)			1.000***					
			(0.0185)					
L.WASH (rural)				0.950***				
				(0.0130)				
L.Water (urban)					0.993***			
					(0.00112)			
L.Sanitation (urban)						1.010***		
						(0.00765)		
L.Hygiene (urban)							0.992***	
							(0.00269)	
L.WASH (urban)								0.831***
								(0.00627)
Constant	-10.29***	-4.776	-30.57*	-13.80**	-1.579***	3.384**	1.936**	15.24***
	(1.595)	(3.298)	(15.48)	(5.764)	(0.223)	(1.383)	(0.949)	(2.193)
Observations	824	822	469	824	824	824	481	824
Number of countries	45	45	45	45	45	45	45	45
Number of instruments	36	15	15	22	36	29	29	36

AR(2)_proba.	0.674	0.224	0.154	0.308	0.106	0.338	0.954	0.870
Hansen_proba.	0.294	0.352	0.278	0.114	0.231	0.175	0.557	0.399
Fisher	345177***	70624***	7090***	41115***	3.305e+06***	220262***	405373***	28297***

Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 5. Effect of public spending on basic WASH adoption taking into consideration regional and income categories (Driscoll-Kraay estimators)

	(Model 1)	(Model 2)	(Model 3)	(Model 4)	(Model 5)	(Model 6)	(Model 7)	(Model 8)	(Model 9)
	Regional Groupings						Income category		
	SSA	MENA	EAP	ECA	LAC	South Asia	LIC	LMIC	UMIC
VARIABLES	Dependent Variable: Basic WASH adoption								
Public spending	-0.0164	0.0456	-0.235	0.282	1.239***	0.978***	0.285***	-0.0476	0.0791
	(0.0741)	(0.145)	(0.226)	(0.289)	(0.357)	(0.309)	(0.0731)	(0.0895)	(0.113)
Credit access	0.116***	-0.0215	0.138***	-0.267***	0.196**	-0.0217	0.364***	0.0911***	0.0199
	(0.0378)	(0.0244)	(0.0277)	(0.0494)	(0.0692)	(0.0441)	(0.0976)	(0.00837)	(0.0235)
Population growth	-0.380	0.138	0.0558	0.350	-3.220*	2.179*	0.554*	-1.416**	-2.006**
	(0.693)	(0.232)	(1.782)	(0.857)	(1.599)	(1.091)	(0.281)	(0.510)	(0.794)
Development aid	-1.022***	1.105**	-0.674	-1.671***	-0.683	1.017	-0.708	0.103	-1.588***
	(0.264)	(0.412)	(0.411)	(0.467)	(0.645)	(0.901)	(0.752)	(0.366)	(0.442)
ICT	0.0534**	0.0670***	-0.0688	0.151***	-0.00215	0.0320	-0.0505	0.0284	0.0913***
	(0.0197)	(0.0106)	(0.0529)	(0.0318)	(0.0576)	(0.0279)	(0.0298)	(0.0168)	(0.0106)
GDP (log)	14.67***	16.06***	27.11***	10.20***	7.975	34.96***	20.11***	22.98***	5.471*
	(2.384)	(1.471)	(2.359)	(1.734)	(5.699)	(3.542)	(2.739)	(1.470)	(2.733)
Constant	-48.19***	-65.56***	-127.2***	35.91***	7.888	-217.6***	-89.69***	-114.2***	63.01***
	(15.11)	(16.55)	(21.97)	(10.18)	(53.14)	(25.67)	(12.51)	(15.48)	(18.15)
Observations	306	78	82	112	195	87	162	356	342
R-squared	0.451	0.833	0.897	0.712	0.502	0.945	0.410	0.861	0.427
Fisher	23.55***	1393***	316.5***	156.8***	73.80***	193.3***	28.98***	1077***	340.6***

Notes: Standard errors in parentheses; *** p<0.01; ** p<0.05; * p<0.1; SSA=sub-Saharan Africa; MENA=Middle East and North Africa; EAP=East Asia and Pacific; ECA=Europe and Central Asia; LAC=Latin America and the Caribbean; South Asia; LIC=Low-income; LMIC=Lower-middle-income; UMIC=Upper-middle-income

Table 6. Effect of public spending on basic WASH adoption considering the level of development (Driscoll-Kraay estimators)

	(1)	(2)	(3)	(4)	(5)	(6)
	Developing countries			Developed countries		
	Total	Rural Areas	Urban Areas	Total	Rural Areas	Urban Areas
VARIABLES	Dependent Variable: Basic WASH adoption					
Public spending	0.0419	0.0525	0.190	0.0791	0.0654	-0.204***
	(0.0794)	(0.0804)	(0.124)	(0.113)	(0.106)	(0.0601)
Credit access	0.105***	0.1000***	0.0545***	0.0199	0.0323	0.0723***
	(0.00675)	(0.00657)	(0.00855)	(0.0235)	(0.0280)	(0.0179)
Population growth	-0.374	-0.281	0.145	-2.006**	-2.711***	-1.315*
	(0.418)	(0.404)	(0.371)	(0.794)	(0.956)	(0.737)
Development aid	-0.268	-0.645*	-1.267***	-1.588***	-1.814***	-1.065***
	(0.258)	(0.326)	(0.337)	(0.442)	(0.516)	(0.192)
ICT	0.0344*	0.0656***	-0.0523*	0.0913***	0.0986***	0.00814
	(0.0174)	(0.0208)	(0.0257)	(0.0106)	(0.0127)	(0.00778)
GDP (log)	21.91***	21.82***	13.73***	5.471*	5.083	0.176
	(1.644)	(1.835)	(1.652)	(2.733)	(3.530)	(1.679)
Constant	-102.6***	-99.39***	-8.693	63.01***	65.88**	110.9***
	(10.99)	(10.21)	(9.014)	(18.15)	(23.89)	(11.60)
Observations	518	518	518	342	342	342
R-sqaured	0.769	0.698	0.398	0.427	0.343	0.152
Fisher	274.8	492.0	43.20	340.6	235.8	42.61

Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

4.3 Interactive Regressions

This section presents the indirect effects of public spending on WASH adoption. Owing to vital role played by governance in infrastructure development as evidenced by several contemporary academics (Giné-Garriga et al., 2021; Daniel et al., 2022; Razakamanana et al., 2023; Malah Kuete and Asongu, 2023), this study explores the moderating role of various governance indicators on the nexus amidst public spending and WASH adoption. Specifically, Table 7 reveals that public spending negatively interacts with governance to produce a negative net effect of -0.319, which is up to a governance threshold of 19.34. Given that there is a positive unconditional effect from public spending, it implies that at the attendant threshold, in the light of the negative interactive or conditional effect, the positive unconditional effect of public spending on WASH adoption changes from positive to negative.

Table 7. Interaction between governance and public spending on basic WASH adoption in rural and urban areas (Thresholds for complementary policies)

	(Model 1)	(Model 2)	(Model 3)
	Total	Rural Areas	Urban Areas
VARIABLES	Dependent Variable: Basic WASH adoption		
Public spending (**PS**)	0.466**	0.488**	0.412**
	(0.222)	(0.215)	(0.196)
Credit access	0.220***	0.203***	0.0696***
	(0.0271)	(0.0276)	(0.0109)
Population growth	-7.389***	-7.730***	-0.612*
	(0.553)	(0.722)	(0.295)
Development aid	-1.739**	-2.527***	-0.920***
	(0.612)	(0.729)	(0.239)
ICT	0.0507**	0.0983***	-0.0241
	(0.0220)	(0.0274)	(0.0183)
GDP (log)	16.53***	14.27***	7.795***
	(0.559)	(0.641)	(0.933)
Governance (**Gov**)	0.237***	0.325***	0.108*
	(0.0748)	(0.0951)	(0.0527)
PSxGov	-0.0241***	-0.0273***	-0.0144***
	(0.00494)	(0.00501)	(0.00444)
Constant	-26.45*	-0.109	32.36***
	(14.05)	(16.06)	(6.396)
Net effect	-0.319	-0.401	-0.057
Threshold	19.34	17.88	28.61
Observations	822	822	822
R-squared	0.766	0.719	0.684
Fisher	3826***	3550***	117.0***

Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Likewise, the positive unconditional effects from public spending on WASH adoption, observed for rural and urban settings are related to respective governance thresholds of 17.88 and 28.61. This implies that in the light of the corresponding negative or conditional effects, governance constitutes a relevant complement to public spending in the promotion of WASH adoption exclusively below the underlying governance thresholds. In other words, the governance thresholds are thresholds for complementary policies.

Similar results are obtained when the basic WASH adoption index is disaggregated into various basic WASH indicators and controlled for area of residence (see Tables 8, 9, 10, and 11).

Table 8. Interaction between public spending and governance on various Basic WASH adoption indicators (Threshold for complementary policy and negative synergy)

	(Model 1)	(Model 2)	(Model 3)	(Model 4)	(Model 5)	(Model 6)	(Model 7)	(Model 8)	(Model 9)
		Total			Rural Areas			Urban Areas	
	Dependent variable:								
Variables	Water	Sanitation	Hyygiene	Water	Sanitation	Hyygiene	Water	Sanitation	Hyygiene
Public spending (**PS**)	0.207**	1.150***	0.0274	0.433***	0.264	-0.110	0.0331	0.326*	-0.843**
	(0.0987)	(0.246)	(0.208)	(0.152)	(0.172)	(0.138)	(0.180)	(0.167)	(0.337)
Credit access	0.0235***	0.213***	0.358***	0.0170	0.168***	-0.0321	0.0865***	0.111***	0.456***
	(0.00571)	(0.0308)	(0.0310)	(0.0109)	(0.0133)	(0.0363)	(0.0239)	(0.0113)	(0.0653)
Population growth	-1.015***	-7.613***	-10.95***	-1.171***	-2.231***	0.502	-2.110***	-1.321***	-11.54***
	(0.278)	(0.541)	(0.391)	(0.349)	(0.580)	(0.445)	(0.325)	(0.310)	(0.451)
Development aid	-0.204	-2.653***	0.442	-0.133	0.863***	0.882*	0.326	0.384	3.152***
	(0.206)	(0.569)	(0.485)	(0.315)	(0.239)	(0.430)	(0.269)	(0.229)	(0.372)
ICT	0.0582***	0.109***	-0.121***	0.116***	0.0980***	0.117***	-0.0156	0.0229*	-0.267***
	(0.0105)	(0.0336)	(0.0356)	(0.00985)	(0.0143)	(0.0288)	(0.0107)	(0.0132)	(0.0451)
GDP (log)	12.31***	22.25***	23.65***	13.65***	19.35***	22.14***	6.036***	12.39***	24.58***
	(0.809)	(0.498)	(0.638)	(0.974)	(1.709)	(2.761)	(0.488)	(0.815)	(0.817)
Governance (**Gov**)	-0.0498	0.236***	-0.279*	-0.0607	-0.189***	-0.135	0.114**	-0.00703	-0.765***
	(0.0551)	(0.0796)	(0.139)	(0.0696)	(0.0600)	(0.0939)	(0.0415)	(0.0702)	(0.143)
PSxGov	-0.00920**	-0.0402***	-0.00366	-0.0124**	-0.00720	0.000648	-0.00366	-0.0134**	0.0221*
	(0.00381)	(0.00554)	(0.0101)	(0.00498)	(0.00604)	(0.00466)	(0.00307)	(0.00477)	(0.0112)
Constant	-6.937	-58.82***	-110.9***	-28.87***	-110.8***	-134.0***	36.87***	-33.25***	-146.0***
	(7.573)	(9.476)	(9.512)	(9.666)	(14.25)	(26.55)	(10.65)	(8.590)	(7.797)
Net effect	n.p	-0.159	n.p	n.p	n.a	n.a	n.a	n.p	-0.124
Threshold	n.p	28.61	n.p	n.p	n.a	n.a	n.a	n.p	n.s.a
Observations	822	820	510	822	820	504	822	822	515
R-squared	0.534	0.790	0.816	0.580	0.579	0.502	0.624	0.291	0.794
Fisher	550.9	5776	6174	1570	1459	248.3	14033	361.6	3346

Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1, n.a=not applicable. n.s.a: not specifically applicable because there is a negative synergy.

Table 9. Interaction between public spending and various governance indicators on basic WASH adoption (Thresholds for complementary policies)

	(Model 1)	(Model 2)	(Model 3)	(Model 4)	(Model 5)	(Model 6)	(Model 7)
Variables	Dependent Variable: Basic WASH adoption						
Public spending (**PS**)	0.466**	0.138*	0.333**	0.284***	0.668**	0.185*	0.207
	(0.222)	(0.0709)	(0.137)	(0.0477)	(0.251)	(0.0900)	(0.188)
Credit access	0.220***	0.104***	0.103***	0.0941***	0.219***	0.117***	0.242***
	(0.0271)	(0.00920)	(0.00819)	(0.00893)	(0.0243)	(0.00910)	(0.0290)
Population growth	-7.389***	-1.540***	-1.441***	-1.526***	-7.803***	-1.326***	-7.456***
	(0.553)	(0.292)	(0.250)	(0.331)	(0.683)	(0.208)	(0.540)
Development aid	-1.739**	-0.373**	-0.489***	-0.308*	-1.041	-0.568***	-1.583**
	(0.612)	(0.154)	(0.168)	(0.156)	(0.700)	(0.153)	(0.589)
ICT	0.0507**	0.0368**	0.0405**	0.0406**	0.0473*	0.0409**	0.0421*
	(0.0220)	(0.0161)	(0.0163)	(0.0177)	(0.0268)	(0.0177)	(0.0221)
GDP (log)	16.53***	15.56***	15.50***	14.91***	17.42***	15.57***	17.94***
	(0.559)	(1.311)	(1.174)	(1.346)	(0.891)	(1.269)	(0.377)
Governance (**Gov**)	0.237***						
	(0.0748)						
PSxGov	-0.0241***						
	(0.00494)						
Corruption control (**CC**)		-0.000907					
		(0.0305)					
PSxCC		-0.00603**					
		(0.00238)					
Government effectiveness (**GE**)			0.0768*				
			(0.0443)				
PSxGE			-0.0122***				
			(0.00416)				
Political stability (**PolS**)				0.123***			
				(0.0289)			
PSxPolS				-0.0114***			
				(0.00153)			
Regulatory quality (**RQ**)					0.302***		
					(0.102)		
PSxRQ					-0.0340***		
					(0.00605)		
Rule of law (**RL**)						-0.00168	
						(0.0290)	
PSxRL						-0.0108***	
						(0.00280)	
Voice & accountability (**VA**)							-0.0417
							(0.0401)
PSxVA							-0.0157***
							(0.00375)
Constant	-26.45*	-48.50***	-47.91***	-48.03***	-46.72***	-43.77***	-31.02**
	(14.05)	(9.765)	(9.423)	(8.883)	(16.40)	(9.679)	(12.96)
Net effect	-0.319	n.p	-0.084	-0.171	-0.475	n.p	n.p
Threshold	19.34	n.p	27.30	24.91	19.65	n.p	n.p
Observations	822	819	819	820	819	822	822
R-squared	0.766	0.590	0.598	0.596	0.777	0.612	0.786
Fisher	3826***	697.4***	446.3***	221.8***	4960***	747.1***	3189***

Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 10. Interaction among public spending and various governance indicators on basic WASH adoption in rural areas (Thresholds for complementary policies)

	(Model 1)	(Model 2)	(Model 3)	(Model 4)	(Model 5)	(Model 6)	(Model 7)
Variables	Dependent Variable: Rural basic WASH adoption						
Public spending (**PS**)	0.488**	0.138	0.401**	0.376***	0.731**	0.174	0.0750
	(0.215)	(0.0979)	(0.169)	(0.0753)	(0.287)	(0.109)	(0.189)
Credit access	0.203***	0.103***	0.1000***	0.0883***	0.210***	0.116***	0.225***
	(0.0276)	(0.0118)	(0.0102)	(0.0113)	(0.0257)	(0.0103)	(0.0274)
Population growth	-7.730***	-1.567***	-1.433***	-1.512***	-8.173***	-1.355***	-7.839***
	(0.722)	(0.393)	(0.338)	(0.453)	(0.928)	(0.305)	(0.708)
Development aid	-2.527***	-0.623**	-0.725**	-0.538*	-1.830**	-0.826***	-2.316***
	(0.729)	(0.285)	(0.284)	(0.267)	(0.826)	(0.278)	(0.689)
ICT	0.0983***	0.0573***	0.0620***	0.0640***	0.0946***	0.0611***	0.0892***
	(0.0274)	(0.0174)	(0.0189)	(0.0195)	(0.0321)	(0.0194)	(0.0273)
GDP (log)	14.27***	15.19***	15.11***	14.43***	15.30***	15.20***	15.83***
	(0.641)	(1.364)	(1.250)	(1.370)	(1.024)	(1.296)	(0.430)
Governance (**Gov**)	0.325***						
	(0.0951)						
PSxGov	-0.0273***						
	(0.00501)						
Corruption control (**CC**)		0.00472					
		(0.0542)					
PSxCC		-0.00677*					
		(0.00337)					
Government effectiveness (**GE**)			0.120*				
			(0.0637)				
PSxGE			-0.0152***				
			(0.00534)				
Political stability (**PolS**)				0.170***			
				(0.0349)			
PSxPolS				-0.0155***			
				(0.00237)			
Regulatory quality (**RQ**)					0.361***		
					(0.111)		
PSxRQ					-0.0375***		
					(0.00643)		
Rule of law (**RL**)						9.84e-05	
						(0.0456)	
PSxRL						-0.0112**	
						(0.00401)	
Voice & accountability (**VA**)							-0.0324
							(0.0489)
PSxVA							-0.0141***
							(0.00377)
Constant	-0.109	-45.53***	-46.15***	-45.62***	-20.95	-40.52***	-4.458
	(16.06)	(10.52)	(10.82)	(9.752)	(19.21)	(10.43)	(15.10)
Net effect	-0.401	n.p	-0.118	-0.114	-0.530	n.p	n.p
Threshold	16.41	n.p	26.38	24.26	19.49	n.p	n.p
Observations	822	819	819	820	819	822	822
R-squared	0.719	0.504	0.514	0.518	0.731	0.522	0.732
Fisher	3550***	2457***	228.1***	234.2***	3818***	320.4***	2992***

Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 11. Interaction between public spending and various governance indicators on WASH adoption in urban areas (Thresholds for complementary policies)

Variables	(Model 1)	(Model 2)	(Model 3)	(Model 4)	(Model 5)	(Model 6)	(Model 7)
	Dependent Variable: Urban Basic WASH adoption						
Public spending (**PS**)	0.412**	0.237*	0.340*	0.221	0.332**	0.340*	0.298*
	(0.196)	(0.131)	(0.197)	(0.133)	(0.131)	(0.172)	(0.148)
Credit access	0.0696***	0.0691***	0.0674***	0.0632***	0.231***	0.0760***	0.0702***
	(0.0109)	(0.0101)	(0.0104)	(0.0103)	(0.0235)	(0.0109)	(0.00987)
Population growth	-0.612*	-0.768**	-0.693**	-0.815**	-6.347***	-0.574*	-0.829***
	(0.295)	(0.314)	(0.315)	(0.317)	(0.508)	(0.290)	(0.280)
Development aid	-0.920***	-0.874***	-0.961***	-0.879***	0.171	-1.008***	-0.808***
	(0.239)	(0.231)	(0.237)	(0.230)	(0.439)	(0.205)	(0.223)
ICT	-0.0241	-0.0303	-0.0290	-0.0301	-0.111***	-0.0251	-0.0242
	(0.0183)	(0.0188)	(0.0185)	(0.0183)	(0.0214)	(0.0191)	(0.0172)
GDP (log)	7.795***	7.599***	7.846***	7.414***	15.78***	7.568***	7.660***
	(0.933)	(1.041)	(0.945)	(0.954)	(0.892)	(0.873)	(0.919)
Governance (**Gov**)	0.108*						
	(0.0527)						
PSxGov	-0.0144***						
	(0.00444)						
Corruption control (**CC**)		0.0868***					
		(0.0268)					
PSxCC		-0.00831***					
		(0.00252)					
Government effectiveness (**GE**)			0.101*				
			(0.0485)				
PSxGE			-0.0106**				
			(0.00400)				
Political stability (**PolS**)				0.0942***			
				(0.0249)			
PSxPolS				-0.00690***			
				(0.00228)			
Regulatory quality (**RQ**)					0.0982		
					(0.0604)		
PSxRQ					-0.0190***		
					(0.00350)		
Rule of law (**RL**)						0.107*	
						(0.0518)	
PSxRL						-0.0137***	
						(0.00383)	
Voice & accountability (**VA**)							0.0756
							(0.0526)
PSxVA							-0.00887***
							(0.00285)
Constant	32.36***	33.45***	32.50***	34.54***	-39.69***	36.17***	31.57***
	(6.396)	(6.278)	(6.800)	(5.931)	(13.54)	(6.174)	(6.325)
Net effect	-0.057	-0.017	-0.022	n.p	n.p	-0.081	n.p
Threshold	28.61	28.52	32.08	n.p	n.p	24.82	n.p
Observations	822	819	819	820	819	822	822
R-squared	0.284	0.259	0.273	0.260	0.761	0.304	0.271
Fisher	117.0***	199.2***	125.0***	103.9***	8451***	140.9***	126.8***

Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Contingent on the interactive regressions, the findings suggest the need for policymakers to consider complementary policy measures to complement public spending beyond governance, when the corresponding thresholds are exceeded. The complementary governance considerations are worthwhile from a comparative standpoint especially with regard to the construction of WASH infrastructure in order to improve access to WASH services within the urban milieu where the effect of corruption seems to be higher. While Daniel et al. (2022) contend that poor governance quality hampers the construction of WASH infrastructure since the funds destined for such projects are likely to be embezzled by corrupt officials, the findings in this study show that the relevance of public spending in promoting WASH adoption is below a specific governance threshold.

Indeed, the interactive regression results are consistent with the baseline findings in terms of public spending displaying positive unconditional effects while the corresponding conditional or interactive effects are consistently negative for the most part. Accordingly, the corresponding negative net effects are apparent when some governance thresholds are exceeded. These thresholds are critical points that when reached, complementary policies are needed in order to maintain the unconditional positive effect of public spending on WASH adoption. It follows that the complementarity between public spending and governance is a sufficient and necessary condition for the promotion of WASH adoption exclusively below certain governance thresholds. Beyond the relevant governance thresholds, the interaction between public spending and governance become a necessary but not a sufficient condition for WASH adoption.

5. Conclusion and Policy Recommendations

Despite the global resolve to ensure the availability and sustainable management of water and sanitation, several people across the world still have very limited or no access to basic drinking water, sanitation and hygiene (WASH) services. Therefore, this study primarily examined the effects of public spending on WASH adoption for a global panel of 45 economies over the 2000-2022 period. The moderating role of governance quality in the nexus between public spending and WASH adoption was also assessed. To control for cross-section dependence and endogeneity, the study adopts the system Generalised Method of Moments (GMM) estimation technique, as well as other dynamic econometric approaches like the Driscoll-Kraay robust standard errors and the generalised least squares.

Results from the different econometric approaches reveal that public spending negatively affects WASH adoption. Although these findings are consistent for different measures of WASH adoption, they are divergent across geographical regions and level of development. Moreover, the causality results revealed the existence of a feedback effect between public spending and WASH adoption. The results further reveal the importance of good governance in moderating the effects of public spending on WASH adoption. Specifically, the interactive regressions show that public spending negatively interacts with governance to produce a negative net effect of -0.319. The underlying negative effects are apparent when some governance thresholds are exceeded. These thresholds are critical points that when reached, complementary policies are needed in order to maintain the unconditional positive effect of public spending on WASH adoption. It follows that the complementarity between public spending and governance is a sufficient and necessary condition for the promotion of WASH adoption exclusively below certain governance thresholds. Beyond the relevant governance thresholds, the interaction between public spending and governance become a necessary but not a sufficient condition for WASH adoption. Contingent on the foregoing results, there is need for various governments to increase investments in the construction of WASH infrastructure and ensure that these infrastructures are of high quality, readily available and affordable to all citizens. This recommendation is consistent with the unconditional positive effects of public spending on WASH adoption. Besides, various governments especially in developing countries should step up measures aimed at complementing good governance policies with other policy initiatives when some critical levels of governance have been reached. The complementary policy initiatives may be consistent of other determinants of WASH which are indispensable when the complementary between public spending and good governance have reached some critical thresholds. An example of a complementary policy initiative that could be designed to further improve the interaction between public spending and governance could be the recruitment of more qualified staff or training existing staff to acquire more relevant skills, in order to improve the underlying complementarity. While this is just a policy suggestion based on intuition, the attendant complementary policy measures should be based on robust empirical evidence in the sampled countries. Moreover, policymakers must equally take into consideration some specificities with regard to the area of residence in designing policies relating to the provision of WASH services.

It is relevant to note that policy recommendations from interactive regressions in which thresholds are computed are directly relevant to policy makers because the computed

thresholds are actionable levels of the moderating or policy variables that policy makers can act upon in order to influence how the main channel (i.e., public spending) influences that outcome variable (i.e., WASH). Hence, in principle, thresholds are already policy implications because they provide specific levels of the policy variables that policy makers should act upon.

Within the remit of this study, thresholds for complementary policies are provided which are an indication that policy makers must improve the interaction between public spending and governance in order to boost WASH when the corresponding thresholds of governance have been reached. This can be considered as new because it shows that the interaction between public spending and governance is a necessary and not a sufficient condition for the improvement of WASH. Accordingly, policy makers might have previously thought that such interaction is a necessary and sufficient condition for the promotion of WASH. What complementary policies can be considered should be subject to empirical validity. We do not want to provide policy implications that do not directly result from the findings of the study, not least, because the thresholds for complementary policies are already actionable policy thresholds that policy makers should act upon.

Notwithstanding the above, some capacity-building initiatives that could be taken to improve WASH include, *inter alia*: (i) tailoring public spending to more conveniently target local-based WASH initiatives in order to limit bureaucracy and broad-based policies. This is essentially because, with centralized governments implementation measures, WASH requirements may not be the same in all local communities in terms of need and urgency and thus broad-based policies for the central government may not be the most optimal at local levels (i.e., improvement of economic governance). (ii) The local population should be endowed with the ability to sanction elected officials when WASH measures are not effectively implemented. In this vein, WASH officials should be directly accountable to the local population and not appointed by the central government (i.e., enhancement of political governance). (iii) Beyond the economic and political governance consideration related to WASH, institutional governance should also be improved at the local level, to the extent that ensuring the respect of interactions between the citizens and the State in the promotion of WASH is also enforced at the local level. Such local enforcement will ensure that in situations where government officials capture and/or mismanage WASH funds, they should be aware that they will be accountable for such mismanagement through effective institutions such as independent local courts.

Despite the inclusiveness of this study, it is however limited to the nexus between public spending and WASH adoption. There is therefore need for future studies to explore the underlying relationships between public investments and various WASH provision and adoption indicators from a country- or region-specific perspective in order to design practical policies targeting country-or regional-specificities. Further research could as well explore other moderating channels through which public spending affect WASH adoption. The first step to this last but not the least future research direction could be the examination of complementary moderators that can help to maintain the positive relevance of the interaction between public spending and governance beyond certain governance thresholds.

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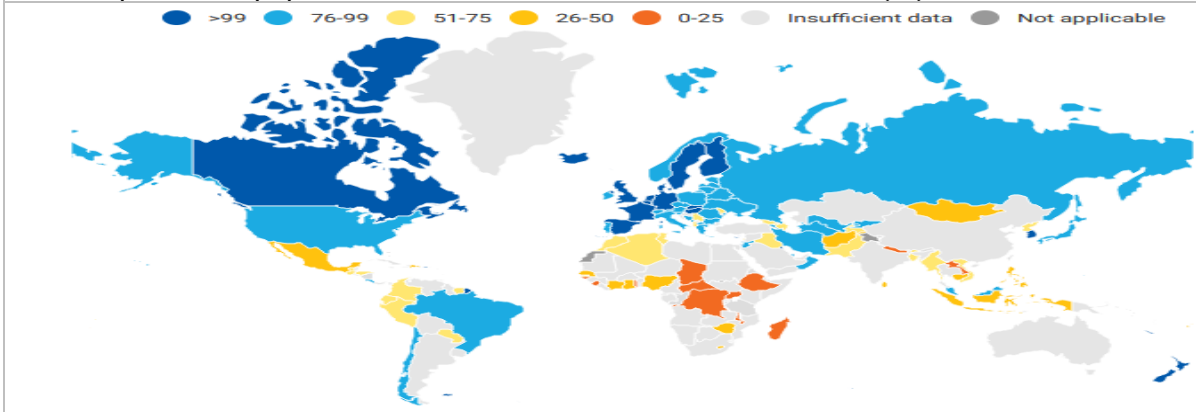
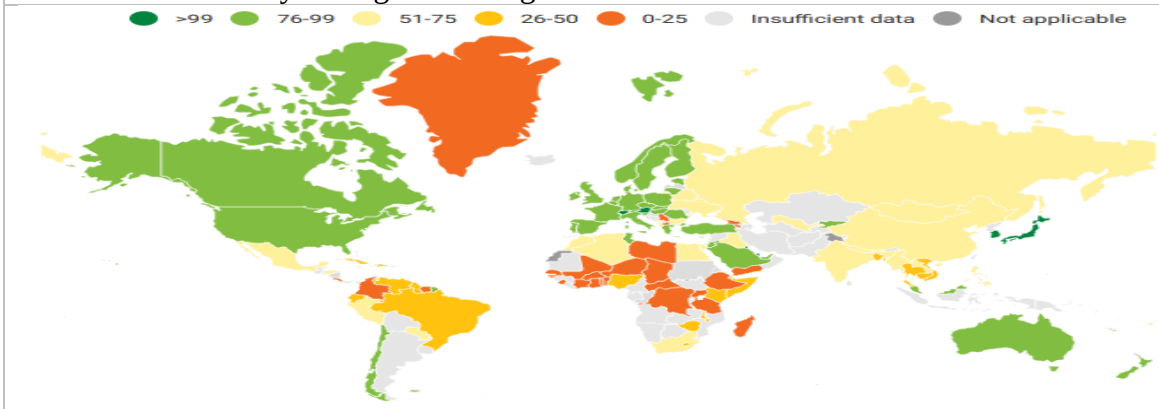
Appendices

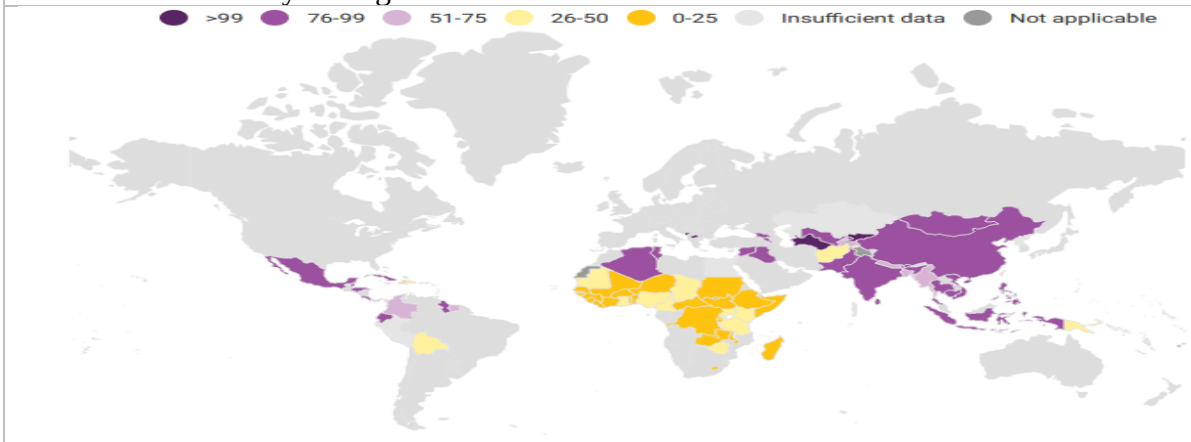
A1: Proportion of population with access to WASH services, 2022 (%)



A1a: Access to safely managed drinking water services



A1b: Access to safely managed sanitation services



A1c: Access to basic hygiene services

Source: Adapted from UNICEF (2023b)

A2: Sources and measurement of variables

Variable	Definition/measurement	Source
Water	People using at least basic drinking water services (% of population)	WDI, 2023
Sanitation	People using at least basic sanitation services (% of population)	WDI, 2023
Hygiene	People with basic handwashing facilities including soap and water (% of population)	WDI, 2023
Water (rural)	People using at least basic drinking water services, rural (% of rural population)	WDI, 2023
Sanitation (rural)	People using at least basic sanitation services, rural (% of rural population)	WDI, 2023
Hygiene (rural)	People with basic handwashing facilities including soap and water, rural (% of rural population)	WDI, 2023
Water (urban)	People using at least basic drinking water services, urban (% of urban population)	WDI, 2023
Sanitation (urban)	People using at least basic sanitation services, urban (% of urban population)	WDI, 2023
Hygiene (urban)	People with basic handwashing facilities including soap and water, urban (% of urban population)	WDI, 2023
WASH	Basic water, sanitation and hygiene (WASH) adoption Index, computed by authors from various basic WASH indicators (% of population)	WDI, 2023
Public spending	General government final consumption expenditure (% of GDP)	WDI, 2023
Credit access	Monetary Sector credit to private sector (% GDP)	WDI, 2023
Population growth	Population growth (annual %)	WDI, 2023
Development aid (log)	Net official development assistance and official aid received (constant 2020 US$)	WDI, 2023
ICT	Individuals using the Internet (% of population)	WDI, 2023
GDP (log)	GDP per capita (constant 2015 US$)	WDI, 2023
Corruption control	Control of Corruption: Percentile Rank	WGI, 2023
Government effectiveness	Government Effectiveness: Percentile Rank	WGI, 2023
Political stability	Political Stability and Absence of Violence/Terrorism: Percentile Rank	WGI, 2023
Regulatory quality	Regulatory Quality: Percentile Rank	WGI, 2023
Rule of law	Rule of Law: Percentile Rank	WGI, 2023
Voice & accountability	Voice and Accountability: Percentile Rank	WGI, 2023
Governance	Governance quality index, computed by authors from various governance indicators	WGI, 2023

Notes: WDI=World Development Indicators; WGI=World Governance Indicators

A3: Cross-section dependence and unit root tests

	Cross-section dependence	Pesaran CADF unit root test	
Variable	CD-test	Z[t-bar] statistic	Decision
Water	104.126*** (0.000)	-1.663* (0.048)	I(0)
Sanitation	100.581*** (0.000)	-6.431*** (0.000)	I(0)
Hygiene	57.061*** (0.000)	-7.982*** (0.000)	I(1)
WASH	67.997*** (0.000)	-2.837*** (0.002)	I(1)
Public spending	8.404*** (0.000)	-9.549*** (0.000)	I(1)
Credit access	47.338*** (0.000)	-6.061*** (0.000)	I(1)
Population growth	14.184*** (0.000)	-1.486* (0.069)	I(0)
Development aid (log)	30.818*** (0.000)	-4.675*** (0.000)	I(0)
ICT	135.553*** (0.000)	-5.248*** (0.000)	I(1)
GDP per capita (log)	86.226*** (0.000)	-3.196*** (0.001)	I(1)
Corruption control	1.331 (0.183)	-5.980*** (0.000)	I(1)
Government effectiveness	.084 (0.933)	-2.214** (0.013)	I(0)

Political stability	3.276*** (0.001)	-1.862** (0.031)	I(0)
Regulatory quality	-.262 (0.793)	-5.318*** (0.000)	I(1)
Rule of law	4.364*** (0.000)	-3.038*** (0.001)	I(0)
Voice & accountability	2.7*** (0.007)	-2.263** (0.012)	I(0)
Governance	4.622*** (0.000)	-3.304*** (0.000)	I(0)

Notes: P-values in parentheses, *** p<0.01, ** p<0.05, * p<0.1, I(0)=series stationary at levels, I(1)=series stationary at first difference

A4: Kao test for cointegration

	Statistic	p-value
Modified Dickey-Fuller t	2.7027	0.0034
Dickey-Fuller t	1.9691	0.0245
Augmented Dickey-Fuller t	1.5205	0.0642
Unadjusted modified Dickey-Fuller t	2.4782	0.0066
Unadjusted Dickey-Fuller t	1.7215	0.0426

A5: Summary Results of the Pairwise Granger Causality Tests

Variables	WASH adoption	Public spending	Credit access	Population growth	Development aid	ICT	GDP per capita	Governance
WASH adoption	…	3.64988** (0.0264)	1.50362 (0.2229)	17.6918*** (3.E-08)	0.03643 (0.9642)	8.55469*** (0.0002)	3.88464** (0.0209)	0.86148 (0.4229)
Public spending	2.40101* (0.0912)	…	5.49681*** (0.0043)	4.00276** (0.0186)	0.26468 (0.7675)	1.15289 (0.3162)	4.17975** (0.0156)	1.07991 (0.3401)
Credit access	6.90506*** (0.0011)	4.69793** (0.0094)	…	4.33648** (0.0134)	0.13790 (0.8712)	4.69017** (0.0094)	0.24129 (0.7857)	2.24836 (0.1063)
Population growth	0.31714 (0.7283)	3.78931** (0.0230)	1.79193 (0.1673)	…	4.81121** (0.0083)	1.87923 (0.1533)	6.67108*** (0.0013)	4.58336** (0.0105)
Development aid	0.74266 (0.4761)	3.14918 (0.0434)	0.38379 (0.6814)	4.88633** (0.0078)	…	2.96110* (0.0523)	0.13505 (0.8737)	0.21329 (0.8080)
ICT	0.95919 (0.3836)	2.87237* (0.0571)	1.07161 (0.3430)	6.23171*** (0.0021)	0.83384 (0.4347)	…	2.22924 (0.1082)	3.00971* (0.0499)
GDP per capita	7.91496*** (0.0004)	4.37442** (0.0129)	20.5441*** (2.E-09)	17.5159*** (3.E-08)	2.64294* (0.0717)	8.55767*** (0.0002)	…	4.32580** (0.0135)
Governance	1.11454 (0.3286)	4.91571** (0.0076)	2.84892** (0.0586)	7.04837*** (0.0009)	3.00566* (0.0501)	4.77474** (0.0087)	4.28914** (0.0140)	…

Notes: P-values of the F-statistic in parentheses ( ), ***p<0.01, **p<0.05, *p<0.1

A6: Matrix of correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
(1) L.WASH	1.000																	
(2) WASH	0.998	1.000																
(3) Water	0.935	0.935	1.000															
(4) Sanitation	0.973	0.971	0.886	1.000														
(5) Hygiene	0.956	0.961	0.842	0.910	1.000													
(6) Water (rural)	0.919	0.919	0.965	0.849	0.813	1.000												
(7) Sanitation (rural)	0.968	0.966	0.869	0.985	0.899	0.864	1.000											
(8) Hygiene (rural)	0.928	0.933	0.802	0.867	0.975	0.806	0.877	1.000										
(9) Water (urban)	0.865	0.866	0.914	0.812	0.812	0.863	0.804	0.766	1.000									
(10) Sanitation (urban)	0.963	0.964	0.875	0.980	0.916	0.839	0.950	0.866	0.814	1.000								
(11) Hygiene (urban)	0.916	0.923	0.809	0.855	0.974	0.788	0.846	0.931	0.808	0.887	1.000							
(12) Public spending	0.369	0.363	0.351	0.369	0.356	0.302	0.352	0.320	0.356	0.349	0.319	1.000						
(13) Credit access	0.568	0.577	0.536	0.539	0.588	0.517	0.534	0.551	0.525	0.564	0.613	0.264	1.000					
(14) Population growth	-0.693	-0.693	-0.631	-0.647	-0.693	-0.637	-0.644	-0.671	-0.559	-0.652	-0.687	-0.293	-0.455	1.000				
(15) Development aid (log)	-0.124	-0.117	-0.106	-0.150	-0.119	-0.047	-0.108	-0.135	-0.031	-0.150	-0.039	-0.223	0.031	0.167	1.000			
(16) ICT	0.667	0.665	0.638	0.698	0.602	0.591	0.693	0.579	0.594	0.648	0.514	0.282	0.478	-0.424	-0.150	1.000		
(17) GDP per capita (log)	0.723	0.719	0.671	0.757	0.677	0.599	0.724	0.638	0.625	0.718	0.590	0.355	0.314	-0.402	-0.289	0.687	1.000	
(18) Governance	0.519	0.521	0.589	0.470	0.495	0.535	0.455	0.471	0.559	0.431	0.434	0.455	0.482	-0.462	-0.131	0.412	0.487	1.000

A7: VIF test for multicollinearity

Variable	VIF	1/VIF
GDP (log)	2.29	0.436932
ICT	1.79	0.557557
Governance	1.70	0.587223
Credit access	1.66	0.601572
Population growth	1.46	0.687107
Public spending	1.30	0.771903
Development aid (log)	1.18	0.845907
Mean VIF	1.63	