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Nexus between safe drinking water, good sanitation and sustainable development in developing countries: A system Generalized Method of Moments (GMM) approach

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Abstract
Efforts to achieve sustainable development in developing countries often go hand in hand with access to safe drinking water and good sanitation. The two facilities are essential components of most sustainable development goals leading to better health outcomes, enhanced livelihoods, and overall development. This study investigates the nexus between safe drinking water, good sanitation, and sustainable development in developing countries. System Generalized Method of Moments (GMM) estimation technique is used to estimate the relationship. The results shows that access to safe drinking water is positively related to sustainable development. Furthermore, the elasticity of access to good sanitation is statistically significant and positive. Lastly, CO_2 emissions and population were found to be important determinants of access to safe drinking water and good sanitation. The findings of this study have serious implication on the realization of achieving sustainable development goals by 2030. The study recommends governments of various developing countries prioritize policies, programs and projects that emphasize the transformative potential of reliable and equitable access to safe drinking water and proper sanitation facilities. This can be achieved through fully utilizing the market's potentials in water, sanitation and hygiene (WASH), thereby safeguarding public health and well-being of the populace.

Keywords: Safe Drinking Water, Good Sanitation, Sustainable Development, System Generalized Method of Moments (GMM)

1. Introduction

Access to safe drinking water and good sanitation are amongst the most important ingredients for achieving sustainable development, as pointed out in the United Nations 17 Sustainable Development Goals (SDGs) (United Nations, 2007). The importance of water and sanitation has been recognized by the UNDP emphasizing that every human has a water right. This implies that 100% of the global population should have access to safe drinking water and good sanitation.

Safe drinking water and sanitation are catalysts for sustainable development in developing countries. They directly impact health, education, gender equality, and economic growth while fostering environmental sustainability and reducing inequalities. By prioritizing water, sanitation and hygiene (WASH) initiatives, developing countries can unlock their full potential and achieve the 2030 Agenda for Sustainable Development.

However, about 58% of the global population does not have access to safe drinking water and good sanitation combined[1], and they are mostly from low- and lower-middle-income countries as indicated in Figure 1 below.

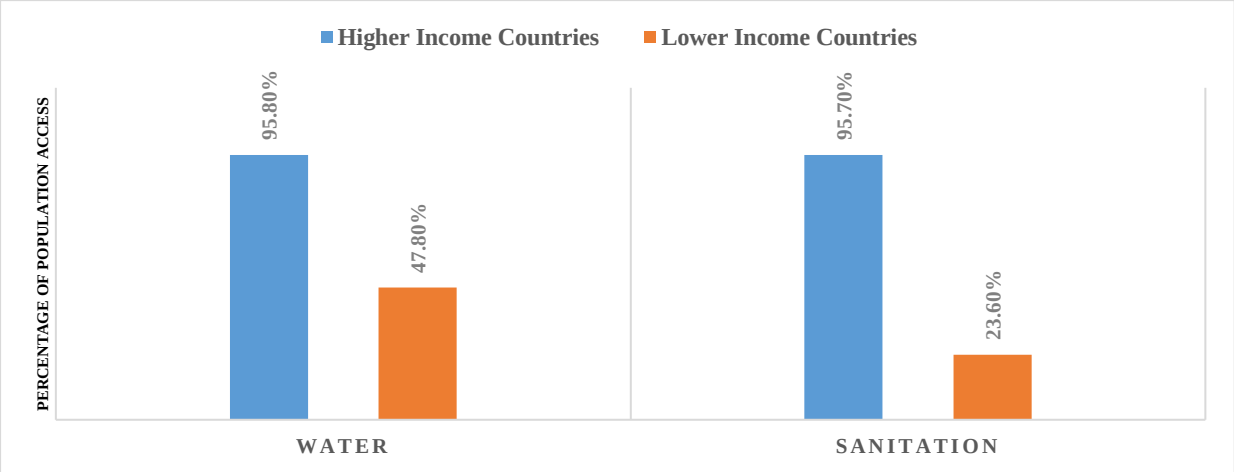

Figure 1: Percentage of Population Access to Safe Drinking Water and Good Sanitation in Higher and Lower Income Countries
Source: Authors computation from WDI (2023)

Even though, about 71% of the earth's surface is covered by water, however, almost 96% of the waters are not drinkable due to high concentration of salt. Only 4% of the global water is drinkable and 17% of the global population don't have access to safe drinking water. This implies that, they are using untreated water for their daily consumptions and mostly occur in developing countries. Thus, studies (Commission on Sustainable Development, 2005; Guzovic and Yan, 2013; United Nations, 2015) have suggested that, water is very crucial to development, and its scarcity may have an adverse effect on productivity as well as health condition.

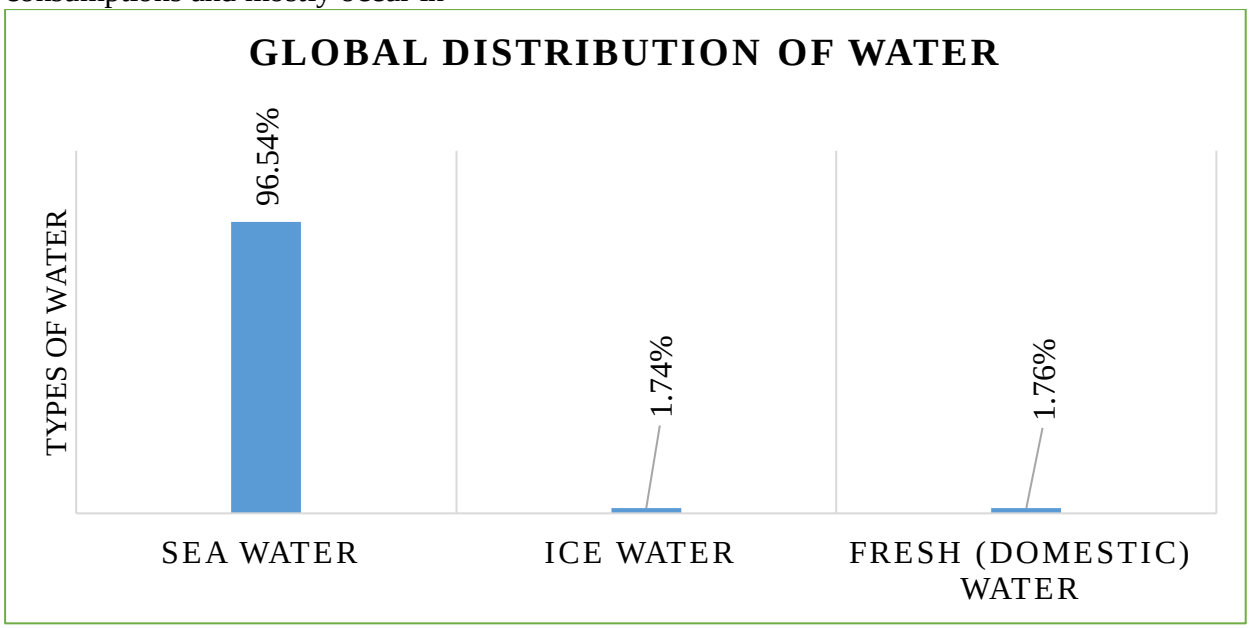

Figure 2: Global distribution of salt and fresh water in percentage (%)
Source: http://water.usgs.gov/edu/earthhowmuch.html (2023).

Fresh water is one of the significant basic necessities to quality of lives. Apart from domestic uses, it is also important for productive activities such as agricultural practices, business operations, and industrial uses for achieving economic growth and development (Appleton, 2002; Brock & Taylor, 2010). However, intensive agricultural practices coupled with rapid industrialization as recorded by many countries around the world, have contributed positively toward achieving intensive economic growth and development.

Developing countries like China, India, Nigeria, Indonesia, Pakistan and many other, have recorded remarkable increase in their GDPs over decades, due inflow and outflow of foreign direct investment (Akinlo, 2004; Alguacil, Cuadros, and Orts, 2002; Ang, 2009; Asiedu, 2002; Baharumshah and Law, 2010; Gao, 2010; Klasra, 2009; Kolstad and Villanger, 2008; Mah, 2010; Narayan, 2005; Omankhanlen, 2011; Routledge, 2011; Salim and Bloch, 2009; Vu Le and Suruga, 2005). Nonetheless, the regions accounted for the largest population that lack access to safe drinking water and good sanitation, due to largely contamination and withdrawal of fresh water.

Another challenge connected to the sustainability of water is the increasing trend in the volume of agricultural product losses and wastes. Silva (2017) affirmed that the Food and Agriculture Organization (FAO) of the United Nations reported that, food losses and waste happening across the various stages of the agricultural value chain (from the farm to the final consumption stage), which is also linked with the factors responsible for the global withdrawal of limited fresh water, hence amongst the concern of sustainable development. For example, it is estimated that about 1.3 billion tons of food are lost and wasted annually. This waste is equivalent to about 30% of agricultural products produced globally. Food loss and wastage add to existing pressures on land, water, and biodiversity and are the cause of additional Greenhouse Gases (GHG) mostly emitted from households, agricultural and industrial wastes, which affects the global environment and hence local resources such as water body like rivers, lakes, etc., hence are amongst the source of fresh waters.

For example, Figure 3 below presents the quantity of water required to produce 1 kilogram of agricultural product per liter. For instance, to produce 1 kilogram of Olives, a farmer needs about 3,025 liters of fresh water. According to IME food waste report**,** Cabbage and unit of Egg are the agricultural products that require less quantity of water in their production process, to produce a kilogram of each product, about 237 and 214 liters of fresh water is required respectively. One can imagine the quantity of water (freshwater) is needed in the production of food to feed the entire global population of about 8 billion people?

As mentioned earlier, Agricultural sector alone, is responsible for the consumption of about 70% of global fresh water, which is followed by the industrial sector with 22% and the remaining 8% is used for domestic consumption (mainly for drinking, cooking washing amongst others). More ever, the United Nations recommend about 50-100 liters of water for domestic consumption per day such as drinking, washing, cooking etc. per individual.

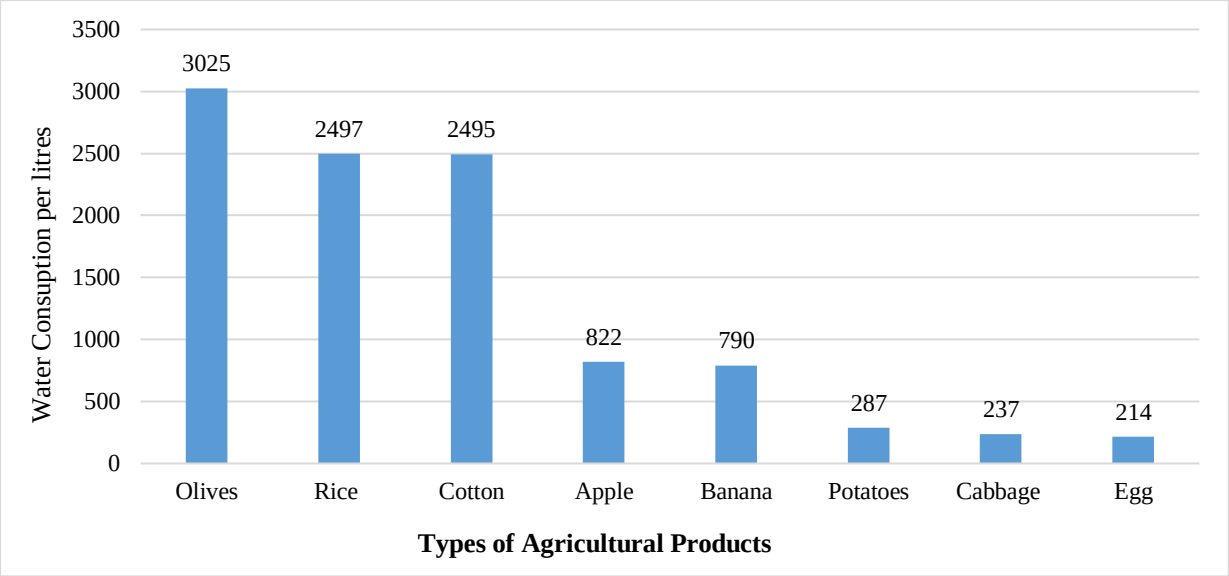

Figure 3: Volume of Water required for the production of 1kg of Agricultural Products.
Sources: Authors computation from IME food waste report (2023).

Water pollution is also another global developmental issues due to high rate of dumping agricultural, household, and industrial wastes into main sources of fresh water, such as rivers, lakes etc. For example, Zhang et al. (2014) reveal that many communities do not have access to safe drinking water in rural communities in China, thus it is amongst the major causes of under-five mortality.

More so, countries like Nigeria, Niger Republic, Chad and Cameroun Republic are also faced with similar problem of withdrawal of fresh water due to shrinking of Lake Chad[2]. Commission on Sustainable Development (2005) has reported that, in addition to the major source of their drinking water to those confluents, Lake Chad generates almost 100,000 tons of fish and generate $20 to 25 million income per annum to the region. Indonesia is also facing with the problem of contaminations of its five biggest Rivers due excessive dumping of refuse, making these waters undrinkable (A. Markandya, 2001; Bosch et al., 2001; and López, 2010).

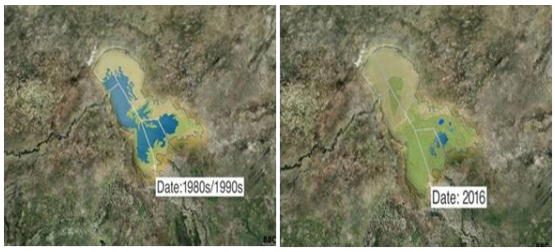

Figure 4 Aerial view of Lake Chad between 1980 and 2016
Source: (NASA/BBC Africa 2016).

It is worthy explanation that, if greater proportion of people living in a decent environment with accessibility to portable drinking water, good sanitation and hygiene, then, this can be translated into better income, schooling, and better health due to the low prevalence of water communicable diseases (Commission on Sustainable et al., 2005).

It is against this background that this study investigates the nexus between Safe Drinking Water and good Sanitation and Sustainable Development in Developing Countries.

2. Literature Review

The theoretical framework of sustainable development was discussed by previous studies such as (Bossel, 1999) and is classified into six categories; "environmental, economic, technological, social, political and psychological" aspects.

2.1 Safe Drinking Water and Sustainable Development

Sustainable Development Goal (SDG) targets 6.1 and 6.2 were analyzed by Shehu and Nazim, (2022) concerning the state strategy and mediations in Nigeria. They examine the frameworks that have failed to contribute to achieving equitable access to safe and protected drinking water for all, ignoring the vulnerabilities faced by women and children. Nigeria has a high incidence of intestinal and diarrheal disorders, which has been linked to a lack of access to sufficient water, sanitation, and hygiene (WASH). Their findings indicate that inadequate policy formulation in Nigeria is exacerbating the challenges related to sanitation, water scarcity, health, and safety, hence giving rise to possible problems such as malnourishment, sickness, incompetence, and violence.

The worldwide water situation is predicted to get worse if immediate action is not taken to make lasting changes, according to (Qamar et al., 2022). This is relevant to Pakistan because the nation as a whole greatly suffers from inadequate water sanitation. In many of Pakistan's water bodies, the growth in drug toxicity, trace element contamination, and microbial infestations is to blame for the exponential rise in waterborne infections. Individuals as well as national agencies must undertake treatment and preventative programs. Emphasis must be placed on the usage of clean water, and appropriate administration of water management regulations must be put into place. Pakistan can have a safer future if water resources are immediately and actively sustained.

Fotio and Nguea, (2022) examine the effect of globalization on access to clean water and improved sanitation in Africa over the 1990–2015 period. Based on the panel corrected standard errors estimator, the results show that overall globalization improves access to water and improved sanitation while increasing disparities between urban and rural areas in access to improved sanitation. Among the sub-indexes of globalization, social globalization enhances access to drinkable water and improved sanitation for the total, urban and rural population. However, social globalization widens the urban-rural gap in access to improved sanitation while its effect on disparities in access to drinkable water is not significant. Economic globalization reduces the share of the population with access to improved sanitation while its effects on access to drinkable water and the urban-rural disparities in access in both social services are not statistically significant. Their paper suggest that African countries should pursue their integration policies by prioritizing the social dimension towards improving policies to increase information flows between citizens of different countries. Thus, policies to promote international migration, increase the flows of information and ideas (through technology transfer) should be considered as a priority. However, their paper couldn't cover additional control variables such as economic and political uncertainty, the level of education, and ICT development.

The reduction of poverty disparities by increased involvement in education, and access to clean water, and sanitary water is examined by Budiono & Purba, (2022). In 2018, 501 Indonesian districts and cities' worth of data were examined for this study. An econometric approach using multiple regression equation models with robustness provisions was the methodology employed. The computation results demonstrate the robustness of the model and the considerable impact of each

variable chosen on the degree of freedom of 5% for every district and city in Indonesia. According to this research, to close the poverty gap, the priority for education policy should include access to clean water and its proper distribution, as well as sanitary facilities.

Imam et al., (2023) provide a thorough analysis of the water sources used for human consumption in northern Nigeria during the previous ten years. Based on the quality of the region's water sources, their report intends to provide a point of reference for determining whether or not Sustainable Development Goal 6 (clean water and sanitation) can be achieved by 2030. The study discovered that, in northern Nigeria, well and borehole water continue to be the predominant sources of drinking water, with little to no existing pipe-borne water networks in the area. Notably, inadequate portability was cited as the reason why 55.74% of these sources were deemed inappropriate for eating. Furthermore, 31.14% of the water sources were classified as fair, indicating that further treatment was necessary. Furthermore, because of some amount of contamination that did not meet WHO requirements, 31.14% of the water sources were classified as fair, requiring extra treatment to prevent disease outbreaks and health implications. According to the research, just 13.11% of the people in northern Nigeria have access to clean water, which makes it challenging to meet SDG goal six by 2030 unless all stakeholders take significant action. Since all of the SDGs are either directly or indirectly related to SDG objective six, failing to meet it could also hinder Nigeria's progress toward attaining the other SDGs.

Sahoo and Goswami, (2024) examined the connection between sustainable development and water contamination. One major environmental issue that endangers human health, economic growth, and ecological sustainability is water pollution. A thorough analysis of pertinent research on water pollution and sustainable development, including empirical studies, theoretical frameworks, and policy papers, is part of their study technique. The impact of water pollution on sustainable development, the causes of water pollution, and the legislative and policy frameworks supporting sustainable water management were all further examined in this study. Their research has deepened our understanding of the intricate connection between water pollution and sustainable development and has given rise to useful tactics and laws that support sustainable water management. Their study also emphasized the value of educating and raising public understanding of sustainable practices and behaviors that can be used to avoid and lessen water pollution.

2.2 Good Sanitation and Sustainable Development

Abdulkareem et al., (2022) investigate the socioeconomic contributions of social inclusion and poverty reduction to Nigeria's achievement of sustainable development (SD) between 1970 and 2019. VECM, is used as the analytical method. According to their findings, SD is positively impacted by the economic factors (GDP per capita and the ratio of FDI to GDP) and two social determinants (life expectancy and school enrollment); however, during the study period, SD in Nigeria was negatively impacted by the remaining two social determinants (the poverty gap and the percentage of women in parliament) and the environmental determinants (CO2 emissions and endowment of natural resources).

The study by Gaffan et al., (2022) aims to provide an overview of household access to basic WASH services based on nationally representative data in Benin. Secondary analyses were run using the ‘HOUSEHOLD’ dataset of the fifth Demographic and Health Survey 2017–2018 by employing multivariate logistic regression to identify predictors of

outcome variables. The result revealed that 63.98%, 13.28%, and 10.11% had access to individual basic water, sanitation, and hygiene facilities, respectively. Also, 3% of households had access to combined basic WASH services. Overall, the richest households and few, and those headed by people aged 30 and over, female and with higher levels of education, were the most likely to have access to individual and combined basic WASH services. In addition, disparities based on the department of residence were observed. Their study found that the proportion of households with access to individual and combined basic WASH services was higher in urban than in rural areas.

Azeez et al., (2023) examine the socioeconomic variables connected to the availability of WASH using binary logistic regression, the findings indicated that Nigerians residing in rural regions had lower odds of having access to better sanitation facilities (p, 0.001, OR ¼ 0.79 [0.77, 0.81]) and improved water sources (p, 0.001, OR ¼ 0.42 [0.41, 0.44]). According to a sub-group regression analysis conducted on respondents who did not have access to improved WASH, living in a rural area (OR ¼ 0.84 [0.76, 0.93]) and having less money and education were linked to not treating their unimproved drinking water. According to this report, initiatives are required to enhance home water treatment in places lacking access to better water and sanitation as well as to expand WASH access in rural regions.

Celeste, (2023) found that in the Philippines, the kind of toilet facilities and the availability of safe water were related to household characteristics. The investigation comprised 39,771 respondents' data from the Department of Science and Technology Food and Nutrition Research Institute. To ascertain the relationship between the availability of a toilet and factors such as water supply, sharing of toilets, and access to safe water, Cramer's V was employed as a statistical technique. The kind of toilet facilities was also predicted using multinomial logistic regression together with other household factors. In the meanwhile, the kind of lavatory facilities was categorized using a Classification and Regression Tree according to a wealth quintile, water sources, and availability of safe water. Based on statistical analysis, the outcome indicated a strong correlation between the factors provided. The study concludes that having access to safe water and water sources is strongly correlated with having access to sanitation, including the kind of toilet facility each home has. In addition, the poorest families need to have access to sanitary facilities. The decision rule described in this study can serve as a basis for delivering such an intervention to lessen the disparities in these services.

Dubik et al., (2024) examine the status and factors driving access to basic WASH services in Ghana. This survey involved an analysis of routine health service data submitted to the District Information Management System 2 (DHIMS 2). Complete data were available for 1,646 HCFs across Ghana for analysis, secondary data utilized in this study were cross-sectional. Coverage of basic WASH services was 69, 58, and 64%, respectively. About 50% had a WASH-infection prevention and control (IPC) action plan, and 67% had a WASH-IPC manager who is responsible for the day-to-day WASH management. Regional inequities in access to basic WASH services exist, with the newly established regions and those in Northern Ghana being disadvantaged

2.3 Novelty and Gaps in the Research

The sustainability of natural resources is a pressing worldwide issue, and three key research areas—sustainable development, water pollution, and adequate sanitation—have drawn a lot of attention lately. However, there is still a lot to learn about the relationship between good sanitation, sustainable development, and water pollution despite the abundance of studies

on these topics. Thus, a novel aspect of this research might be analyzing the relationship between sustainable development, good sanitation, and safe drinking water in developing nations and coming up with workable solutions to this issue. Even while water pollution, proper sanitation, and sustainable development have all been the focus of much research, little is still known about the relationships between these crucial areas. Few researches has looked at how access to safe drinking water and good sanitation affect sustainable development; instead, most have concentrated on how it affects the environment and public health. Furthermore, little study has been done on the best ways to incorporate the objectives of sustainable development into practices and policies for reducing water pollution. For policymakers and practitioners looking to create solutions that effectively manage water pollution while advancing sustainable development, this information gap poses a serious problem. Thus, more investigation is required to examine these problems and provide answers that can help achieve the sustainability objectives.

3. Methodology

3.1 Empirical Framework and Model Specification

The empirical framework and model specification of the sustainable development index are derived, following the empirical work of Costantini and Martini (2006) and Brock and Taylor (2010) for the derivation of the modified EKC for sustainable development model and the linear green Solow model as specified below:

$$\frac{1}{V} log\left(\frac{sd_{it}}{sd_{it}-V}\right) = \alpha_0 + \beta_n\, log(sd_{it} - V) + \vartheta_{it} \ldots\ldots\ldots (1)$$

From equation (1) above, $\frac{1}{V} log\left(\frac{sd_{it}}{sd_{it}-V}\right)$ is the green Solow model and dependent variable capturing index of sustainable development. While $\alpha_0$is an intercept of the equation, and $\beta_n\, log(sd_{it} - V)$ is the vector matrix of independent variables that determines sustainable development in countries (i) at time (t). Their variation will explain the degree of responsiveness of the dependent variable $\frac{1}{V} log\left(\frac{sd_{it}}{sd_{it}-V}\right)$through their respective level form coefficients (β_n). Similarly, Costantini and Martini (2006) on the other hand have explained sustainable development in different passion but emphasizing the same with Green Solow model of Brock and Taylor (2010). The modified human development model (MHDI) that captures indicators of health, education, income is further derived from equation (1) above following the work of Costantini and Martini (2006). Hence a new version of the model is specified as:

$$MHD_{it} = \alpha_0 + \beta_n\, ln\, X_{it} + \ell_{it} \qquad (2)$$

The dependent variable; sustainable development is the modified form of HDI that captures indicators of health, education, income and environment as well. Therefore, MHDI model is also a sustainable development model and can be further be specified with some modification in the choice of variables as:

$$SD_{it} = \alpha_0 + \beta_n\, ln\, X_{it} + \ell_{it} \qquad (3)$$

The connection between equation (2) and (3) is that both the two models are explaining sustainable development indicators in different passion. For example (2) is referred as modified human development indicators, which is sustainable development. While on the other hand, equation (3) is the new form of modified human development index which is also referred to sustainable development. Therefore, SD represents sustainable development and dependent variable as well, which according to WCED (1987) is defined as *"any development that meet the need of present generation without compromising the ability of future generation to meets their own need"*. Therefore, in this study, components of sustainable development comprised of

health, education, income and environmental indicators. Hence are generated from the work of Bravo, (2014) and Bravo (2015). In order to specify the final model in achieving objective of this study, the choice of the independent variables with little modification from the green Solow model by Brock and Taylor, (2010) is specified as follows:

$$SD_{it} = \alpha_0 + \beta_1 \ln WAT_{it} + \beta_2 \ln SAN_{it} + \beta_3 \ln POP_{it} + \beta_4 \ln CO2_{it} + \beta_5 \ln POV_{it} + \Omega_i + \xi_t + \ell_{it} \quad (4)$$

Where ℓ_{it} is the time variant disturbance variable, and ξ_t is time invariant country specific effect such as location of the country. Then Ω_i stand for time variant country specific effect like shocks. In order to avoid possibility of endogeneity between water and sanitation, equation (4) is specified into (5) and (6) (Waziri *et al.*, 2015b) as:

$$SD_{it} = \alpha_0 + \lambda SD_{it-1} + \beta_1 \ln WAT_{it} + \beta_2 \ln POP_{it} + \beta_3 \ln CO_{2it} + \beta_4 \ln POV_{it} + \Omega_i + \xi_t + \ell_{it} \quad (5)$$

The dependent variable, sustainable development (SD) is dynamic in the sense that, the present development defends on the fast development. Therefore, it is consistent with the dynamic panel model; generalized method of moments (GMM). The model was proposed by Arellano and Bond (1991); and Arellano and Bover (1995) . It is dynamic and powerful in overcoming the weaknesses of fixed OLS model in which the dependent variable depends on its lag and other independent variables. Hence the GMM model for achieving this objective is hereby specified as:

$$SD_{it} = \alpha_0 + \lambda SD_{it-1} + \beta_1 \ln SAN_{it} + \beta_2 \ln POP_{it} + \beta_3 \ln CO_{2it} + \beta_4 \ln U5Mit + \Omega_i + \xi_t + \ell_{it} \quad (6)$$

A panel sample of 49 low- and lower-middle-income countries were taken, based on WDI income classification. The period (t) covers 9 years from 2015 to 2023 based on the availability of data.

4. Result and Discussion

In order to determine the degree of relationship amongst the variables, Table 1 presents the correlation matrix below. According Prodan (2013); and Sulaiman et al. (2017) have suggested that, though all economic variables are in one way or the other interrelated to one another. However, estimating variables that are highly correlated in one model may lead to spurious result.

Therefore, correlation matrix reveals such relationship, and independent variables with correlation of less than 80% can be specified and estimated in the same model.

Table 1: Correlation Matrix

	WAT_{it}	**POV_{it}**	**SAN_{it}**	**CO_{2it}**	**POP_{it}**
WAT_{it}	1				
POV_{it}	-0.097	1			
SAN_{it}	0.723	-0.166	1		
CO_{2it}	0.103	0.040	-0.013	1	
POP_{it}	-0.708	0.056	0.774	-0.03	1

Note that WAT_{it} is representing access to safe drinking water, POV_{it} stand for poverty, CO_{2it} is the Carbon dioxide in metric tons per capita. POP_{it} stands for annual population growth.

4.1 Safe Drinking Water, Good Sanitation, and Sustainable Development in Developing Countries

Investigating the relationship between Safe drinking water, good sanitation, and sustainable development in developing countries, the dependent variable sustainable development is dynamic and consistent with theoretical provision because the coefficient of its lagged dependent variable was positive and significant. This implies that present development is dependent on the past. Interestingly, it is applied to models for difference and system GMM is positive and significant at 1% respectively.

The estimated coefficients of access to safe drinking water (WAT_{it}) produce mixed result under difference GMM for one- and two-steps but, they are not significant. However, the system GMM produces significant result that is consistent with theory. This condition is applied to both of the estimated coefficients of WAT_{it} for system GMM is roughly 0.12 and significant by 10%. An improvement in the provision of safe drinking water to the population by 1% has a corresponding effect toward achieving sustainable development by 0.12%.

Table 2: Nexus between Safe Drinking Water Sustainable Development in Developing Countries

Variables	Difference GMM		System GMM
	One-Step	Two-Step	
SD_{it-1}	.876(.055)***	.859(.0519)***	.931(.009)***
$lnWAT_{it}$	-.006(.046)	.005(.0211)	.125(.068)*
$lnCO_{2it}$	-.031(.004)***	-.033(.008)***	-.051(.013)***
POP_{it}	-.026(.009)**	-.014(.005)*	. 004(.012)
Const.	.036(.213)	-.004(.092)	-.571(.325)*
AR(1)	-	0.145	0.197
AR(2)	-	0.064	0.156
Hansen test of ORR	-	-	0.379
Difference-in-Hansen		-	0.232
Number of observation	164	164	162
Number of groups	42	42	42
Number of instruments	16	16	19

Note that WAT_{it} is representing access to safe drinking water, $CO2_{it}$ is the Carbon dioxide in metric tons per capita. POP_{it} stand for annual population growth, Figures in the parenthesis () represents standard error, while * ** *** represents significance level at 1%, 5% and 10%.

Similarly, for system GMM in Table 2 also indicated that, WAT_{it} found to be positively correlated to sustainable development SD_{it} with estimated coefficient of roughly 0.12, which means that, an increase in access to safe drinking water by 1% would lead to increase in sustainable development by 0.12%. The findings of Corvalán et al. (1999) have also suggested the need of focusing on the long-term action toward reducing environmental health threats which can help achieving sustained health benefits and environmental protection in accordance with the principles of sustainable development goals (SDGs). Because poor access to safe drinking is amongst the risk that ignites the prevalence of diseases like diarrhea, malaria which triggers under-five mortality rate especially in developing countries.

Similarly, carbon dioxide (CO_{2it}) emission variable also produced an expected sign. Carbon dioxide emission was found to be negatively related to sustainable

development. Also, for the purpose of getting a result that is more robust, both the difference and system GMM produces similar and results that are significant and consistent to theory. For example, similar coefficient was produced in one-step and two-step difference GMM with roughly -0.31 and -0.33 all significance at 1%. The result is supported by the system GMM with also negative coefficient of -0.51 and significant by 1% respectively. Impliedly, this result means that, CO_2 emission is amongst the factors that may deter the achievement of sustainable development in low- and lower-middle income countries. Based on its coefficient we can see that an increase in CO_2 emission by 1%, draw away the low- and lower-middle income countries from attaining sustainable development by roughly 0.3% and 0.5% respectively. This result have confirmed the findings of some previous literature such as (Beckerman, 1992; Gaffney and Marley 2009; and Gill *et al.,* 2017).

Other control variables include population growth (POP_{it}) which measures the annual rate of increase in the total population. The coefficient of POP_{it} is negatively related to sustainable development SD_{it} in difference GMM with -0.26 and -0.14 respectively. This negative sign is impliedly interpreted as a trade-off relationship between population growth and sustainable development, which suggest that, an increase in annual population by 1% in the low- and lower-middle income countries, has a corresponding decrease in sustainable development by -0.26% and -0.14%. More ever, the result of system GMM coefficient found to be positively correlated with sustainable development, with an estimated coefficient of 0.004 though is not significant.

Table 3: Relationship between Sanitation, and Sustainable Development in Developing Countries

Variables	**Difference GMM**		**System GMM**
	One-Step	Two-Step	
SD_{it-1}			
	.873(.055)***	.844(.046)***	.932(.008)***
$lnSAN_{it}$	-.007(.047)	.004(.020)	.166 (.054)**
$lnU5M_{it}$	-.009(.002)***	-.006(.002)***	-.001(.005)**
$lnCO_{2it}$	-.031(.004)***	-.032(.002)***	-.051(.012)***
POP_{it}	-.027(.008)***	-.014(.005)***	.007(.012)
Const.			
	.0464(.216)	.006(.091)	-.752(.242)**
AR(1)	-	0.145	0.195
AR(2)	-	0.042	0.218
Hansen test of ORR	-	-	0.490
Difference-in-Hansen	-	-	0.329
Number of observation	164	164	164
Number of groups	42	42	42
Number of instruments	16	16	19

Note that SAN_{it} is representing access to good sanitation, $U5M_{it}$ is the prevalence of under-five mortality. $lnCO_{2it}$ is the Carbon dioxide in metric tons per capita. POP_{it} stand for annual population growth. Figures in the parenthesis () represents standard error, while * ** *** represents significance level at 1%, 5% and 10%.

The estimated System GMM in Table 3 shows that the elasticity of access to good sanitation (SAN_{it}) is .166, which indicates that if the proportion of the population who had access to good sanitation rises by 10%, sustainable development will be achieved by approximately 0.17%. This demonstrates a strong and positive association between access to good sanitation and sustainable development index in developing countries. For robustness, two-step difference GMM further confirmed a positive association between access to good sanitation and sustainable development. The estimated coefficients of SAN_{it} in the two-step difference GMM is .004, implying that an improvement in the provision of good sanitation to the population by 1% has a corresponding impact toward achieving sustainable development by 0.004%. This study supports the theory and empirical investigations on some specific SDGs. For instance, the result of this study validates the findings of Joshi and Amadi (2013), Waziri et al. (2018) Andrés and Rana (2021), Parikh et al (2021), Carbonell et al (2023) and Balza et al (2025) on SDG 3 that access to good sanitation is positively related to health outcomes such as reduced child and maternal mortality, diarrhea incidence, and waterborne diseases, and improved mental health. This supports the idea that improved sanitation leads to better health outcomes and sustainable development. The result of this study is also in consonance with the findings of Devnarain and Matthias (2011), Ortiz-Correa et al. (2016), Adukia (2017), Crankshaw et al (2020), Scriptore and Azzoni (2020), Gibbs et al (2021) and Sharma et al (2024) on SDG 4 (quality education) that good sanitation in schools reduces absenteeism and ensures equal learning opportunities for both girls and boys. Furthermore, the result of this study is in agreement with the findings that good sanitation is linked to reducing hunger and malnutrition (SDG 2) and achieving food security (Villalba et al., 2024; Sharif et al., 2024) and improved work and economic growth, as outlined in SDG 8 (Tehupeiory et al., 2024; Nguea, 2024).

Other control variables, such as U5Mit, yield an expected result with a negative coefficient. With the coefficient of -.001, it indicates that under-five mortality reduces SD by .001%. This shows a negative and strong association, which is in line with theoretical and empirical investigations. Furthermore, the elasticity of CO_{2it} also yielded results that are consistent with the theory and other empirical findings. The coefficient of CO_{2it} is -0.051, indicating a negative association that is statistically significant at 10%. This implies that an increase in CO_2 would deter SD by .051%. This is further confirmed by both one-step and two-step difference GMM with the coefficients of -0.031% and -0.032%, respectively. This validates the finding of Zaman and Abd-el Moemen (2017) that CO_2 emission is found to reduce sustainable development. This shows that CO_2 emission is an important factor that deter sustainable development in low- and middle-income countries.

The coefficient of POP_{it} produces mixed results that are statistically significant at 10%. The estimated POP_{it} coefficient in the system GMM shows a positive sign (.007). This implies that an increase in POP_{it} would lead to an increase in SD by .007%. The result of this study is in line with the finding of Vo and Vo (2021) that moderate population growth is vital to achieving sustainable development. However, POP_{it} for difference GMM both the one-step and two-step shows a negative sign. The coefficients of -.027 and -.014 for one-step and two-step difference GMM implied that increase in population 10% would deter the achievement of sustainable development by .027 and .014 respectively. Thus, increase in population can put a strain on the environment, transportation, and natural resources like water, food, and energy if governments do not think

strategically or make adaptable changes. Ineffective management can lead to resource scarcity and environmental degradation, impeding efforts for sustainable development.

5. Conclusion and Policy Recommendations

The nexus between safe drinking water, good sanitation and sustainable development have been empirically investigated. The impact of safe drinking water and sanitation on sustainable development is multifaceted and have a wide-ranging impact. Therefore, based on the finding of this study, it can be concluding that access to reliable safe drinking water and good sanitation is essential for achieving sustainable development goals. Based on this, the following recommendations were offered:

1. Developing countries are encouraged to prioritize policies that prioritize reliable and equitable access to safe drinking water and proper sanitation facilities, thereby safeguarding public health and well-being. This can be achieved by investing in water and sanitation and hygiene (WASH) infrastructure for universal access.
2. The study indicates a significant association between CO_2 emissions and sustainable development, urging for concerted efforts to decrease CO_2 emissions in the studied countries by implementing energy efficiency appliances and replacing traditional energy sources.
3. Since the finding of the study indicates a significant relationship between population and sustainable development, governments in studied countries are encouraged to make concerted efforts to control population growth through population-friendly policies like skills acquisitions, entrepreneurships development, education, and economic empowerment, addressing population growth.

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