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ORIGINAL ARTICLE

Capital expenditure, population growth and access to water services in South Africa

Genius Murwirapachena[1]

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Abstract
Access to sustainable and improved water services is a global concern. In South Africa, households should by law access water services within 200 m of their homes. However, many households still access water from sources more than 200 m away. This study examines the impact of capital expenditure and population growth on access to water services in South Africa. The study highlights access to water services in the country and how it is affected by capital expenditure and population growth. The fixed and random effects estimators are used to analyze panel data for 52 big municipalities during the period 2009 to 2018. Among other findings, the study reports that while capital expenditure improves access to water services, population growth is undoing municipal efforts. Thus, evidence-based planning backed by reliable population growth forecasts is essential for improved access to water services. Studies that quantify the impact of capital expenditure and population growth on access to water services are important as they aid policy formulation and implementation.

Keywords Access to water · Capital expenditure · Population growth · SDG 6 · Water services delivery

Introduction

Sustainable Development Goal (SDG 6) aims to achieve universal access to sustainable water services by 2030. Realizing this goal requires expenditure of about US$150 billion per year (McDonald et al. 2020). Such annual expenditure is too high considering that there is very little incentive for private sector involvement in water services provision, especially in developing countries. In these countries, water is generally considered a social good, making it considerably risky for private businesses to provide water services since the returns are insufficiently rewarding. Therefore, government entities carry the huge burden of providing water services while also battling socio-economic challenges like unemployment, poverty, and inequalities. Consequently, poorer populations usually have limited or even no access to improved public services (Osei et al. 2015; Sambo et al. 2021).

Population growth is also a concern on public services, with notable adverse effects observed mostly in urban areas. Achieving sustainable urban development is particularly formidable in Africa where poor planning is usually cited among the many reasons for inability to provide sustainable public services (Cohen 2006). As a result, backlogs in access to improved public services like water continue to be a key barrier to people's health and wellbeing. This challenge is more acute in slums and other low-income areas (Bisung and Elliott 2016; Chikozho et al. 2019; Mamokhere 2020). Apart from health challenges, the lack of access to improved water services is also associated with psychosocial concerns affecting the wellbeing of individuals (Bisung and Elliott 2016; Hove et al. 2019; Shola and Jijoho 2021).

In South Africa access to improved water services is a constitutionally recognized human right. However, the country has huge water service backlogs due to the legacy of the segregating policies of the apartheid era. Nevertheless, the post-democracy South Africa is also criticized for the politicization of water services, poor governance, inefficiencies, and corruption (Mamokhere 2020; Masuku and Jili 2019; Msenge and Nzewi 2021; Shola and Jijoho 2021). Consequently, South Africa is now identified as the "protesting capital of the world" because of the increased incidents of service delivery protests (Mamokhere 2020; Morudu 2017;

✉ Genius Murwirapachena
geniusm@dut.ac.za

[1] Department of Public Management and Economics, Durban University of Technology, 41 ML Sultan Road, Durban 4001, South Africa

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Msenge and Nzewi 2021). The impact of these service delivery protests is far-reaching, and usually include vandalism, arson, or even loss of life.

Nonetheless, South Africa has recorded tremendous spending in capital investment programs since 1994 (Ruch and Geyer 2017). Each year, the government spends huge amounts toward water supply infrastructure. However, it is unclear how much this investment has contributed toward improving living conditions and reducing poverty (Ruch and Geyer 2017). This phenomenon was also investigated by Kumasi (2019) in a study that examines whether capital expenditure toward water services improved access to water services in Ghana. Acknowledging improvements in budget allocations toward water services, Kumasi (2019) reports an unclear impact on improved access to water services.

This study seeks to quantify the impact of capital expenditure and population growth on access to water services in South Africa. The study is important considering that over 40% of all people who lack access to drinking water globally live in sub-Saharan Africa (Osei et al. 2015). In South Africa, the government continues to spend toward improved water service provision, but many households are still with no access to improved water services. Challenges to water services are more in urban areas due to urbanization. Rural to urban migration is creating excessive demand for water services and unmatched growth in slums as people build dwelling structures in areas with no proper infrastructure for public service delivery (Dos Santos et al. 2017; Horn 2019; Marutlulle 2017). Thus, information that quantifies the impact of capital expenditure and population growth on access to water services is important to policy makers as it aids planning, policy formulation, and implementation. Evidence-based policies are essential for improved water service delivery and addressing service delivery-related protests.

Access to potable water services in the literature

Access to potable water services continues to receive considerable attention in the literature. Many theories including the Disruptive Innovation Theory (Christensen 1997) and the Innovation Diffusion Theory (Rogers 1962) are applied to explain how access to water services can be improved. These and many other social science theories generally support innovation as a critical tool for improved access to water services. Consistently, emerging studies also support innovation and technology as useful tools for improved access to water services (Enwereji and Uwizeyimana 2021; Koekemoer and von Solms 2021). A plethora of studies in the literature assess many other aspects of access to water services. Common issues investigated include the successes, challenges, opportunities, and consequences of access to water services. Considerable attention on access to water services is observed more in developing countries because they still lag with enormous challenges.

Africa has serious challenges regarding equal access to safe drinking water. More than 40% of all people globally who lacked access to drinking water in 2015 lived in sub-Saharan Africa, with only 64% of people in the region having access to improved water sources (Osei et al. 2015). A concerning reality of access to water services in Africa is that it is linked to socio-economic status and class. Wealthier people have access to improved water services and better water sources compared to uneducated, poor, and rural people (Osei et al. 2015; Sambo et al. 2021). Poorer people rely mostly on water services provided by the government, which is intermittent in most African countries. On the other hand, richer people usually have other alternatives, thus making water a commodity of privilege and not a social good (Chikozho et al. 2019).

Improving access to water services in Africa requires innovative governance and institutional arrangements that blend the strengths of public, private, and community-based water supply models (Adams et al. 2019; Dos Santos et al. 2017). The lack of prioritized civic engagement and participation of the private sector in promoting access to water services is usually cited among the many reasons why African countries still lag in citizens' access to improved water services. African literature argues that improved water services can significantly improve if civic engagement is prioritized, and the private sector takes part in local economic development. This is reinforced in many studies conducted in countries like Ethiopia, Ghana, Kenya, Nigeria, South Africa, and Tanzania (Asha and Makalela 2020; Bisung and Elliott 2016; Enwereji and Uwizeyimana 2021; Harris 2020; Hove et al. 2019; Rugeiyamu et al. 2021; Shola and Jijoho 2021; Tessema 2020).

Apart from Africa, other regions also battle with access to improved water services. Notable concerns are also observed in Bangladesh, India, Malaysia, and Viet Nam (Grant et al. 2020; Mahmuda 2020; Mishra and Attri 2020; Narayana 2020). Most studies from other parts of the world cite the lack of capacity by water utilities to provide sufficient and reliable access to water. Insufficient budgets are usually cited among the key drivers of lack of capacity which is also the case with African water utilities. In addition to genuine capacity constraints, most water utilities in developing countries are usually criticized for high levels of corruption, incompetence, political interference, and inefficiencies (De Kadt and Lieberman 2020; Mamokhere 2020; Narayana 2020; Shola and Jijoho 2021). Discussions on more institutional shortcomings of water utilities in developing countries are given in Koelble and LiPuma (2010).

Consequently, poor water service delivery leads to civil disobedience. The prevalence of service delivery protests is rife in democratic countries like South Africa (Krugell et al. 2010; Mamokhere 2020; Msenge and Nzewi 2021). In the context of South Africa, protests jeopardize public administrators' quest for effective service rendering, thus creating a cycle of poor service delivery (Msenge and Nzewi 2021). As a result, many scholars recommend water utilities to prioritize meaningful public participation in decision-making processes. Effective and sincere public participation is a commonly suggested precondition for building community trust and limiting the outbreak of service delivery protests (Mamokhere 2020; Mishra and Attri 2020; Morudu 2017; Msenge and Nzewi 2021).

Factors like rapid population growth which are outside the control of water utilities are also challenging efforts to provide improved access to water services. Population growth is a continuous concern for African water utilities, especially in the urban areas. Cohen (2006) provided an overview of the patterns and trends of urban growth, arguing that the challenges of achieving sustainable urban development are particularly formidable in Africa. Sub-Saharan Africa continues to experience one of the most rapid urbanisations in the world, with the urban population projected to be more than triple by 2050, creating more water access challenges (Dos Santos et al. 2017). The major consequence of urbanization is overpopulated urban areas where water utilities are overwhelmed and eventually underperform.

Considering several water service delivery challenges, capital expenditure toward water infrastructure development has been improving in most developing countries. Attention toward the management of water resources and the efficient provision of water services is gaining commendable momentum in most developing countries. However, Kumasi (2019) examined how the size of budget and expenditure on water services changed over time in Ghana and observed marginal improvements in allocations toward water delivery. In South Africa, Ruch and Geyer (2017) examined the relationship between public-sector capital investment and poverty reduction at a municipal level and found that increases in capital investments are yielding very small results in terms of poverty reduction. This is usually the case with most urban areas due to urbanization, corruption, and political interferences (De Kadt and Lieberman 2020; Dos Santos et al. 2017; Krugell et al. 2010; Mamokhere 2020; Masuku and Jili 2019). Considering these challenges, many possible solutions to improve access to water services are proposed (Asha and Makalela 2020; Hove et al. 2019; Moriarty et al. 2013; Narayana 2020; Shola and Jijoho 2021).

Water service provision and access in South Africa

In South Africa, water service provision is within the competence of municipalities. Thus, municipalities are natural monopolies in water service provision. The country has 9 provinces and 278 municipalities which are grouped into 8 metropolitans (category A), 44 districts (category C) and 226 locals (category B). Metropolitans are highly urbanized municipalities, while districts are very large municipalities consisting of between 3 and 6 local municipalities. Local municipalities are further grouped into 4 sub-categories, namely, B1, B2, B3 and B4. Category B1 refers to local municipalities with a large town or city, while B2 refers to those with a medium town. Category B3 refers to local municipalities with a small town, while B4 are those without an urban core.

Although the country has 278 municipalities, only 152 municipalities are authorized by the national government to provide water services. Municipalities authorized to provide water services are called Water Services Authorities (WSAs). When a district is authorized, local municipalities in that district will not have such authority. On the other hand, when local municipalities within a district are authorized, the district will not be authorized. Local municipalities are authorized ahead of the district if they have a large budget, and this is usually the case with category B1 municipalities which are also called secondary cities. Apart from districts and secondary cities, all metropolitan municipalities are WSAs. Figure 1 shows the district and metropolitan municipalities across the 9 South African provinces.

The municipalities shown in Fig. 1 operate in different environments. Variations are due to factors like differences in the levels of industrialisation, population statistics, and socio-economic standards. Metropolitan municipalities are the richest due to the high concentration of industries and the availability of larger tax bases (Chauke et al. 2017). Nevertheless, they experience huge challenges in terms of water service delivery because of massive urbanization and rapid population growth. They commonly experience rural-to-urban migration because they offer better opportunities (Marutlulle 2017).

In most urban areas, population growth has seen a rise in slums as people build shelter in unsanctioned areas and still expect public service delivery (Kovacic et al. 2019; Marutlulle 2017). Hence, most utilities in urban areas fail to meet the legally required minimum water service standards. In South Africa, each household should by law get at least 25 L of potable water per person per day within 200 m (Yates and Harris 2018). However, many households still access potable water from sources more than

Fig. 1 Map of South Africa showing some of the big municipalities. 2021 Source: Lesniewski (n.d.)

200 m away. Figure 2 shows the trends in household access to water services for the period 2003 to 2018.

Figure 2 shows the number of household connections accessing water in the yard, within 200 m, and more than 200 m away for the period 2003 to 2018. The number of households accessing water services in the yard increased progressively over the period from about 6.3 million in 2003 to about 9.5 million households by 2018. While the government's goal is to have most households access water services in the yard, regulations permit access within 200 m. For the period, the number of connections accessing water services within 200 m increased from about 1 million in 2003 to about 2.7 million by 2018. The figure has constantly been above 2 million from 2008 to 2018. Then again, the number of households accessing water services more than 200 m away has been consistently below 1 million during the period, except in 2006 when a peak of about 1.3 million was reached. More precisely, the figure increased from 508,509 households in 2003 to 704,255 by 2018. Although these statistics are relatively low, they are still a cause for concern because they go against the minimum expected standards of access to water services[1].

Methodology and empirical model specification

This study uses panel regression models to examine the impact of capital expenditure and population growth on access to water services in South Africa. These models are preferred because they can clarify complex issues that may not be sufficiently answered using either time-series or cross-sectional data alone. They are credited for considering variables that differ between entities, while remaining unchanged over time and those that change over time but are similar for all entities in each period (Park 2011; Reed and Ye 2011). Commonly, the fixed effects (FE) and random effects (RE) estimators are used

[1] Statistics were obtained from the Municipal Non-Financial Census Data published by Statistics South Africa.

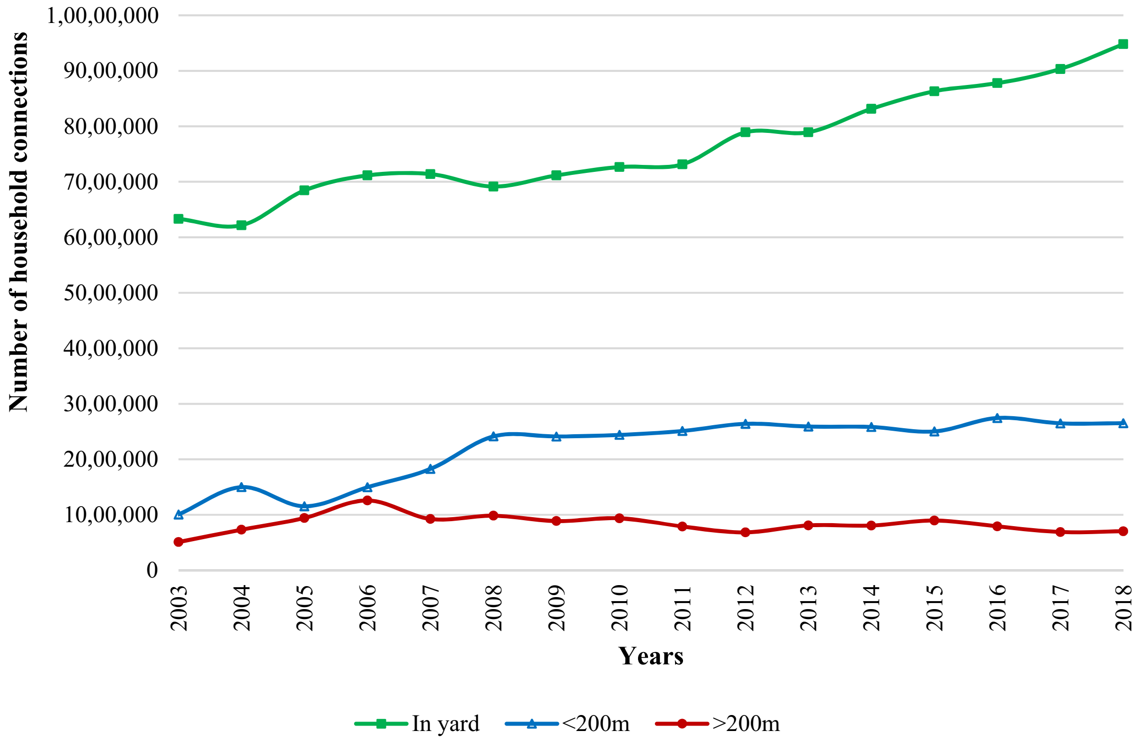

Fig. 2 Average domestic connections per water access type. Source: Author's own diagram

for panel regression. Detailed discussions of the assumptions of the FE and RE estimators are given in the literature (Park 2011; Reed and Ye 2011; Wooldridge 2015). The basic mathematical formulation for panel regression models is:

$$y_{it} = \alpha + x'_{it}\beta + v_i + \epsilon_{it} \tag{1}$$

where y_{it} is the dependent variable for entity i in time period t; α is the constant; x'_{it} is the independent variables; β is the coefficient for each independent variable; v_i is the specific error term for each entity which differs between entities but has a constant value for any particular entity; and ϵ_{it} is the "common" error term with the usual properties (i.e., mean 0, uncorrelated with itself, uncorrelated with x, uncorrelated with v, and homoscedastic). Normally, ϵ_{it} could be decomposed to $\epsilon_{it} = v_t + \omega_{it}$, assuming that ω_{it} is a conventional error term which better describes v_t. Regardless of the properties of v_t and ϵ_{it}, if Eq. 1 is true, then it is true that:

$$\overline{y}_i = \alpha + \overline{x}_i\beta + v_i + \overline{\epsilon}_i \tag{2}$$

where $\overline{y}_i = \sum_t y_{it}/T_i$ and $\overline{x}_i = \sum_t x_{it}/T_i$; while $\overline{\epsilon}_i = \sum_t \epsilon_{it}/T_i$. When Eq. 2 is subtracted from Eq. 1, then it must also be true that:

$$\left(y_{it} - \overline{y}_i\right) = \left(x_{it} - \overline{x}_i\right)\beta + \left(\epsilon_{it} - \overline{\epsilon}_i\right) \tag{3}$$

The three Eqs. (1, 2 and 3) provide the basis for estimating β in panel regression analysis. For the FE estimator (also called the within estimator), it amounts to using the ordinary least squares (OLS) to estimate Eq. 3. However, the RE estimator is a weighted average of estimates produced by the between and within estimators, which is equivalent to estimating:

$$\left(y_{it} - \theta\overline{y}_i\right) = (1-\theta)\alpha + \left(x_{it} - \theta\overline{x}_i\right)\beta + \{(1-\theta)v_i + (\epsilon_{it} - \theta\overline{\epsilon}_i)\} \tag{4}$$

where θ is a function of σ_v^2 and σ_ϵ^2. If $\sigma_v^2 = 0$, it means v_i is 0, then $\theta = 0$ implying that Eq. 2 can be directly estimated using the OLS. However, if $\sigma_\epsilon^2 = 0$, it means ϵ_{it} is 0, then $\theta = 1$, suggesting that the within estimator returns all the information available.

This study uses both FE and RE to estimate the impact of capital expenditure and population growth on access to water services. This is done by separately estimating the three types of access to water services (i.e., in the yard, within 200 m, and more than 200 m away) as functions of capital expenditure and population. Each water access type is estimated using a separate regression model. Two control variables (i.e., operating revenue from water services and population density) that are expected to have an impact on access to water in each municipality are also included in each model. Thus, three models are estimated separately, one for access in the yard, the second for access within 200 m of the yard, and the third for access more than 200 m away. These models are respectively shown as follows:

$$INYARD_{it} = \alpha_{it} + \beta_1 CAPEX_{it} + \beta_2 POP_{it} + \beta_3 OPREV_{it} + \beta_4 POPDEN_{it} + v_i + \epsilon_{it} \quad (5)$$

$$LESS200m_{it} = \alpha_{it} + \beta_1 CAPEX_{it} + \beta_2 POP_{it} + \beta_3 OPREV_{it} + \beta_4 POPDEN_{it} + v_i + \epsilon_{it} \quad (6)$$

$$GREAT200m_{it} = \alpha_{it} + \beta_1 CAPEX_{it} + \beta_2 POP_{it} + \beta_3 OPREV_{it} + \beta_4 POPDEN_{it} + v_i + \epsilon_{it} \quad (7)$$

where $INYARD_{it}$ is the number of household connections accessing water services in the yard for municipality i in year t; $LESS200m_{it}$ is the number of household connections accessing water services within 200 m of the yard for municipality i in year t; $GREAT200m_{it}$ is the number of household connections accessing water services more than 200 m away from their yards for municipality i in year t; $CAPEX_{it}$ is the capital expenditure toward water services by municipality i in year t; POP_{it} is the size of the population served by municipality i in year t; $OPREV_{it}$ is the operating revenue received from water services by municipality i in year t; and $POPDEN_{it}$ is the population density for municipality i in year t.[2]

The data used in this study refer to a heterogeneous sample due to differences in municipal type, size, and operating environments. Therefore, apart from the data including very big numbers which also use different units of measurement, heterogeneity in the sample is expected to produce data that are not normally distributed. To address the expected skewness of the data, it is imperative to transform the data into natural logarithms and estimate elasticities. Transforming the data to natural logarithms makes results more valid and easy to interpret (Gujarati and Porter 2021). Therefore, the data are transformed to natural logarithms and Eqs. 5, 6 and 7 will respectively transform to Eqs. 8, 9 and 10 as follows:

$$lnINYARD_{it} = \alpha_{it} + \beta_1 lnCAPEX_{it} + \beta_2 lnPOP_{it} + \beta_3 lnOPREV_{it} + \beta_4 lnPOPDEN_{it} + v_i + \epsilon_{it} \quad (8)$$

$$lnLESS200m_{it} = \alpha_{it} + \beta_1 lnCAPEX_{it} + \beta_2 lnPOP_{it} + \beta_3 lnOPREV_{it} + \beta_4 lnPOPDEN_{it} + v_i + \epsilon_{it} \quad (9)$$

$$lnGREAT200m_{it} = \alpha_{it} + \beta_1 lnCAPEX_{it} + \beta_2 lnPOP_{it} + \beta_3 lnOPREV_{it} + \beta_4 lnPOPDEN_{it} + v_i + \epsilon_{it} \quad (10)$$

where $lnINYARD_{it}$ is the logarithm of water access in the yard; $lnLESS200m_{it}$ is the logarithm of water access within 200 m; $lnGREAT200m_{it}$ is the logarithm of water access more than 200 m away; $lnCAPEX_{it}$ is the logarithm of capital expenditure; $lnPOP_{it}$ is the logarithm of population served; $lnOPREV_{it}$ is the logarithm of operating revenue; and $lnPOPDEN_{it}$ is the logarithm of population density.

While estimation is done using both FE and RE, results of the best model between the two estimators will be presented. To do this, the study uses the Hausman test which is the most common test used to choose between the FE and RE estimators in the literature (Park 2011; Reed and Ye 2011; Wooldridge 2015). The null hypothesis of the Hausman test is that FE coefficients are not statistically different from RE coefficients. If the test statistic is significant, the decision would be to reject the null hypothesis; thus, FE coefficients are consistent and would therefore be the right model to choose, and otherwise. Prior to estimation, diagnostic tests are performed to detect the problem of multicollinearity in the selected independent variables. The existence of multicollinearity would lead to spurious relationships among the independent variable, making it difficult to fit the model which consequentially result in incorrect inferences (Drukker 2003; Gujarati and Porter 2021). Hence, the Spearman's correlation procedure is used to test the existence of multicollinearity in this study.

Data and descriptive statistics

This study uses panel data for 52 big municipalities for the period 2009 to 2018. The data which comprise 8 metropolitans, 17 districts, and 27 locals (categories B1 and B2) were obtained from the municipal financial and non-financial census data published by Statistics South Africa. The selected municipalities had consistent data and are home to a larger percentage of the country's population and contribute significantly to the country's economic performance (Donaldson et al. 2020; Marais and Cloete 2017). Municipalities excluded from the sample were those without consistent datasets for the period, those that were not WSAs, and categories B3 and B4 which are usually rural. Examining bigger municipalities gives a clear picture of the overall impact of the phenomena studied because many South Africans reside in these municipalities. Descriptive statistics for the data are given in Table 1.

INYARD is the number of domestic connections accessing water services in their yards. This is the most preferred type of access to potable water services and will be used as a dependent variable in the first regression model. LESS200m refers to the number of domestic connections accessing water services less than 200 m from the yard. This is a dependent variable in the second model. GREAT200m refers to the number of domestic connections accessing water services more than 200 m away from the yard. This

[2] A full description of these variables is given in the next section.

Table 1 Descriptive statistics ($N=520$; $n=52$; $T=10$)

Variable	Description		Mean	Std dev	Minimum	Maximum
INYARD	Number	Overall	116,676	182,561	0	858,021
		Between		182,045	1262	772,219
		Within		27,619	− 27,428	267,162
LESS200m	Number	Overall	37,507	52,936	0	237,332
		Between		48,935	0	214,910
		Within		21,193	− 75,109	142,053
GREAT200m	Number	Overall	10,841	26,400	0	163,783
		Between		22,844	0	131,434
		Within		13,569	− 58,249	123,802
CAPEX	Rands (‘000)	Overall	156,496	215,000	6300	1,760,000
		Between		183,000	6920	786,000
		Within		115,000	20,000	1,130,000
POP	Number	Overall	839,671	1,017,315	38,628	5,198,893
		Between		1,023,627	39,598	4,699,090
		Within		72,720	306,259	1,339,475
OPREV	Rands (‘000)	Overall	464,576	1,020,000	400	6,960,000
		Between		990,000	9408	5,090,000
		Within		284,000	20,000	2,730,000
POPDEN	Number/km^2	Overall	279	519	4	3160
		Between		522	4	2857
		Within		34	− 45	583

is a dependent variable in the third model. Table 1 shows higher overall and between standard deviations for these three dependent variables, confirming the existence of heterogeneity in the sample.

The two key explanatory variables for all models are CAPEX and POP. CAPEX refers to the capital expenditure toward water services provision. It is expected to have a positive relationship with INYARD and LESS200m, and an inverse relationship with GREAT200m. Thus, municipalities spending more on water services infrastructure will have more households accessing water services in the yard or at least within 200 m, with the number of those accessing water more than 200 m away decreasing. Table 1 shows an average CAPEX of R156 496 000 (i.e., approximately US$10,683,852).[3] POP refers to the population served by each municipality and is expected to have a negative relationship with INYARD as municipalities battle to deal with for population sprawls, and a positive relationship with GREAT200m. South African population statistics are compiled every 10 years through the national census. However, mid-term statistics are published in the General Household Survey (GHS). The sample falls within two census periods; thus, two population statistics were available. Therefore, statistics for the other years were computed using the 2011 and 2016 figures and the published population growth rates.

Further, two control variables OPREV and POPDEN are included among the explanatory variables. OPREV is the operating revenue received from the sale of water services. Municipalities with higher operating revenues are expected to have more connections in the yard or at least within 200 m, and less households accessing water services more than 200 m away. On the other hand, POPDEN is the population density computed as the number of people per square kilometer (km^2). POPDEN is expected to have a positive relationship with INYARD, and negative relationships with LESS200 m and GREAT200 m. Thus, municipalities with high population densities are expected to have more households accessing water in the yard because they may find it less expensive to build water infrastructure for households clustered together than those widely spaced. Both OPREV and POPDEN have higher overall and between standard deviations implying heterogeneity in the sample.

The direction and strength of the relationship between the independent variables is tested to determine whether the problem of multicollinearity exists. As explained earlier, multicollinearity among independent variables effects modeling and leads to spurious results (Drukker 2003; Gujarati and Porter 2021). Correlation can be examined using the Pearson, Spearman, or Kendall tests. The Pearson correlation test is commonly used in the literature but is more appropriate when measuring the strength of the linear relationship between normally distributed variables. However, when variables are neither normally distributed nor linear,

[3] US$1 = R14.65 on 9 August 2021.

Table 2 Spearman's correlation coefficients

	CAPEX	POP	OPREV	POPDEN
CAPEX	1.000			
POP	0.758 (0.000)	1.000		
OPREV	0.212 (0.000)	0.357 (0.000)	1.000	
POPDEN	0.359 (0.000)	0.540 (0.000)	0.708 (0.000)	1.000

p values in brackets ()

shed light into the performance of municipal categories in terms of household access to water services. Therefore, the average domestic connections per municipal category are extrapolated for each access type and presented in Fig. 3.

Metropolitans (A) have the highest average domestic connections accessing water in the yard, followed by locals with larger towns or cities as urban core (B1). This revelation implies that municipalities with bigger budgets and better economic activities do well in providing households with access to water services in the yard. On the other hand, districts (C) reported the largest average domestic connections accessing water services more than 200 m from the yard. This can be true because some districts supply water services to rural and poor local municipalities. Also, metropolitans have the second largest average connections accessing water services more than 200 m from the yard. This is mostly due to urbanization as people prefer residing in metropolitan areas because of better opportunities. Thus, it is important to examine the impact of capital expenditure and population growth on water access type.

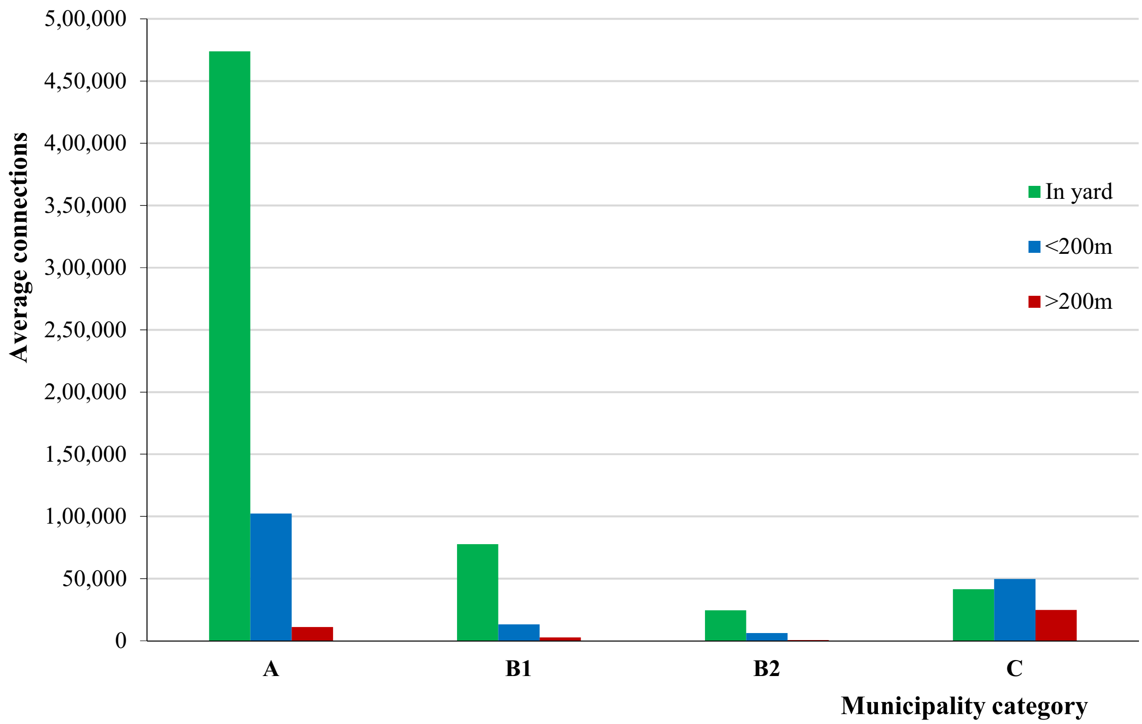

Fig. 3 Average domestic connections per access type for each municipal category

the Spearman's correlation test is more appropriate (Gujarati and Porter 2021). The data used in this study are not normally distributed; thus, the Spearman's correlation test is used. Correlation coefficients together with their p values are presented in Table 2.

Correlation coefficients between 0 and 0.3 indicate weak relationships, while those between 0.3 and 0.7 indicate moderate relationships (Ratner 2009). Coefficients in Table 2 range from 0.212 to 0.758, indicating weak to moderate relationships between the explanatory variables. This suggests that the problem of multicollinearity is not a major concern in the data. Thus, the variables can be used together in modeling. However, before modeling is performed, it is important to also understand trends in the dependent variables according to municipal categories. Such an analysis would

Table 3 Results for access in the yard (lnINYARD)

		Whole sample	Metros	Districts	Locals
lnCAPEX		0.047*** [0.011]	0.084*** [0.021]	0.105*** [0.038]	0.032*** [0.011]
lnPOP		2.105*** [0.182]	1.145*** [0.308]	3.862*** [0.570]	1.581*** [0.224]
lnOPREV		− 0.050*** [0.017]	0.047 [0.060]	− 0.043* [0.026]	0.006 [0.040]
lnPOPDEN		omitted	omitted	omitted	omitted
_cons		− 16.470*** [2.333]	− 6.473* [3.700]	− 43.229*** [7.711]	− 9.494*** [2.392]
N		472	79	138	255
n		52	8	17	27
Prob > F		0.000	0.000	0.000	0.000
Sigma_u		1.778	0.313	1.459	0.655
Sigma_e		0.224	0.091	0.300	0.190
Rho		0.984	0.922	0.959	0.922
R^2	Within	0.279	0.497	0.351	0.297
	Between	0.441	0.940	0.245	0.876
	Overall	0.484	0.926	0.258	0.828

Standard errors in parenthesis []

***, ** and * = significance at 1%, 5%, 10% level, respectively

Results

While both FE and RE were used to estimate all three models (i.e., INYARD, LESS200m, and GREAT200m models), the Hausman test showed respective significant p values of 0.000 and 0.003 for the INYARD and LESS200m models. However, an insignificant *p* value of 0.452 was reported for the GREAT200m model. Thus, the test recommended FE for the INYARD and LESS200m models, and RE for the GREAT200m model. Therefore, results presented for INYARD and LESS200m are based on the FE estimator, while those for GREAT200m are based on the RE estimator. Further, it is important to acknowledge that the descriptive statistics presented in the previous section showed evidence of heterogeneity which was believed to be due to differences in the operating environments of the sampled municipalities. Therefore, the study stratifies the sample based on municipal categories. Stratifying the sample allows for a fair comparison of municipalities with similar characteristics. This is still possible because each stratum has sufficient observations to produce reliable results since the dataset is panel with a time period of 10 years. Therefore, each model is estimated per municipal category. Thus, for INYARD, estimation is separately done for metropolitan, district, local, and for all municipalities combined. This is also done for the LESS200m and the GREAT200m models. Results for the INYARD model are given in Table 3.

Results show positive and significant coefficients for lnCAPEX and lnPOP across all four models. These variables are consistently significant at 1%, suggesting that they are strongly related to water access in the yard. This implies that an increase in any of these variables increases access to potable water services in the yard (lnINYARD). For example, a unit increase in capital expenditure toward water service provision increases access to water in the yard by about 0.047 in the whole sample, 0.084 in metropolitan municipalities, 0.105 in district municipalities, and 0.032 in local municipalities. Thus, the impact of lnCAPEX varies from 0.032 to 0.105 depending on the category of the municipality. The positive and significant impact of capital expenditure confirm a priori expectations that municipalities spending more on water infrastructure will have more households accessing water services in the yard. This is consistent with findings from other studies in the literature which also report some positive relationships between capital expenditure and improved access to water services (Kumasi 2019; Ruch and Geyer 2017).

In terms of lnPOP, a unit increase in the population increases access to water in the yard by about 2.105 in the whole sample, 1.145 in metropolitan municipalities, 3.862 in district municipalities, and 1.581 in local municipalities. Thus, the impact of population growth varies from 1.145 to 3.862 depending on the category of the municipality. These coefficients are relatively large, for example, a 10% increase in the population leads to a 38.6% increase in access to water services in the yard for district municipalities, while an increase of the same percentage would increase access to water in the yard by about 15.8% in the local municipalities. These revelations are not consistent with a priori expectations where population growth was expected to have a negative impact on access to water in the yard. However, these findings indicate that South African municipalities are doing exceptionally well in providing households with improved access to water services amid increasing population statistics.

On the other hand, lnOPREV was statistically significant in the whole sample and districts' models only, both with negative coefficients. For the districts, the coefficient of − 0.043 suggests that a 10% increase in operating revenue from water services reduces access to potable water services in the yard by about 0.4%. This is contrary to a priori expectations where lnOPREV was expected to have a positive impact on lnINYARD since municipalities with more revenues would be expected to invest more on water infrastructure. The hypothesized impact is reflected in the positive coefficient of lnOPREV under the metropolitan and local models. However, the coefficients for lnOPREV in these models are statistically insignificant, implying that the variable does not have any impact on lnINYARD in both metropolitan and local municipalities.

Very large and strongly significant negative intercepts are reported, suggesting that apart from the specified variables, other variables that have a negative impact on lnINYARD across all municipal categories exist. Literature identifies several other factors including the source of development, the type of topography, infrastructure development cost, availability of fresh water, geopolitical, and environmental factors, among others (Antunes and Martins 2020; Legge et al. 2022; Sintondji et al. 2017; Tholiya et al. 2022). While these variables were worth exploring and could have improved the models estimated in this study, it should be emphasized that data for most of these variables are not easily available in many developing countries. This is because of data gaps and inconsistent data management which is usually the case in many developing countries. Therefore, this study limits the control variables to OPREV and POPDEN whose data were readily available in the context of the sample adopted in this study. Results are still reliable because these variables were not the key explanatory variables. However, where data for these variables exist, future studies can include such variables in modeling as this would significantly improve the model.

The study also examined the impact of the same independent variables on LESS200m. Generally, LESS200 m is the second-best type of water access where households cannot access water services in the yard. The Free Basic Water policy of 2001 prescribes that each municipality should supply every household with 6 000 L of potable water, free of charge every month, and this water should be accessed within 200 m of each household's home. Therefore, LESS200m is examined in the same manner as INYARD using the FE estimator, for the whole sample, metropolitans, districts, and locals. Results are presented in Table 4.

Table 4 Results for access within 200 m of the yard (lnLESS200m)

		Whole sample	Metros	Districts	Locals
lnCAPEX		0.087*** [0.043]	0.179 [0.210]	0.241*** [0.050]	0.055 [0.056]
lnPOP		1.130* [0.690]	3.294 [3.019]	1.640** [0.759]	− 0.450 [1.138]
lnOPREV		0.025 [0.060]	− 0.995* [0.592]	− 0.022 [0.031]	0.546*** [0.195]
lnPOPDEN		omitted	omitted	omitted	omitted
_cons		− 7.414 [8.823]	− 19.498 [36.359]	− 15.906 [10.190]	2.919 [12.301]
N		419	76	128	215
n		50	8	16	26
Prob > F		0.032	0.391	0.000	0.011
Sigma_u		0.954	1.204	0.780	1.499
Sigma_e		0.766	0.890	0.366	0.863
Rho		0.608	0.647	0.820	0.751
R^2	Within	0.024	0.045	0.249	0.057
	Between	0.706	0.496	0.302	0.013
	Overall	0.580	0.311	0.251	0.021

Standard errors in parenthesis []

***, ** and * = significance at 1%, 5%, 10% level, respectively

Results show positive and significant coefficients for lnCAPEX and lnPOP in the whole sample and districts' models only. This means that although these variables positively affect access to water services within 200 m in the whole sample and in districts, the same impact does not exist in metropolitan and local municipalities. Thus, lnCAPEX and lnPOP are not important determinants of access to water services within 200 m in metropolitan and local municipalities. For districts, the results imply that a 10% increase in capital expenditure increases access to water within 200 m of the home by about 2.4%, while a 10% increase in the population increases access to water within 200 m of the home by about 16.4%. The results for districts were expected since evidence presented earlier showed districts to have the greatest number of households accessing water more than 200 m away. Thus, access to water services within 200 m is a reasonable improvement in access to water services for municipalities in this category. This is not the case with other categories where the number of households accessing water more than 200 m away was relatively lower, for example in the metropolitan municipalities.

Further, the operating revenue received from the sale of water services was observed to have a negative and significant impact on access to water within 200 m of the home in the metropolitan municipalities but had a positive and significant impact in the local municipalities. This implies that

Table 5 Results for access to water services more than 200 m away (lnGREAT200m)

		Whole sample	Metros	Districts	Locals
lnCAPEX		− 0.025 [0.061]	− 0.826** [0.412]	− 0.077 [0.094]	0.048 [0.067]
lnPOP		1.453*** [0.250]	5.576*** [1.656]	0.811 [0.666]	0.738 [0.500]
lnOPREV		0.087 [0.061]	− 1.667 [1.095]	0.107* [0.058]	0.253 [0.172]
lnPOPDEN		− 0.766*** [0.210]	− 2.196*** [0.447]	− 0.381 [0.422]	− 0.080 [0.390]
_cons		− 8.223*** [2.710]	− 6.969 [8.012]	− 0.107 [8.174]	− 6.842 [5.233]
N		247	26	112	109
n		42	5	16	21
Prob > Chi^2		0.000	0.000	0.275	0.011
Sigma_u		1.101	0	0.885	1.089
Sigma_e		0.759	1.233	0.678	0.640
Rho		0.678	0	0.630	0.743
R^2	Within	0.018	0.170	0.031	0.066
	Between	0.477	0.748	0.161	0.272
	Overall	0.423	0.615	0.089	0.319

Standard errors in parenthesis []

***, ** and * = significance at 1%, 5%, 10% level, respectively

a 10% increase in revenue from the sale of water services reduces access to water within 200 m by about 10% in the metropolitan municipalities. The result reported for metropolitan municipalities is consistent with a priori expectations since evidence presented earlier showed that this category of municipalities had the greatest number of households accessing water in the yard. Thus, more revenue reduces the number of households accessing water outside the yard and increases access in the yard. The insignificant intercepts reported across all models suggest that the selected variables sufficiently accounted for access to water within 200 m of the yard. Thus, the model is robust and the results reliable.

While water policies in South Africa suggest that households should access water services within 200 m of the yard, most municipalities are battling backlogs and many households still access water services more than 200 m from the yard. Worse, some households do not even have access to potable water services, and rely on natural sources like rivers, springs, and wells (Enwereji and Uwizeyimana 2021; Hove et al. 2019; Moriarty et al. 2013). Therefore, this study further examined the impact of capital expenditure and population growth on access to water services more than 200 m away (GREAT200 m). The hypothesis was that high capital expenditure reduces the number of households accessing water more than 200 m away, while population growth increases it (Dos Santos et al. 2017; Kumasi 2019; McGuirk and Argent 2011). Estimation is done separately for each municipal category and the whole sample. Results are given in Table 5.

Both the key explanatory variables (i.e., lnCAPEX and lnPOP) reported statistically significant coefficients for the metropolitans. However, these variables are insignificant in the other models (i.e., the models for district and local municipalities). Results for the metropolitans are consistent with a priori expectations where lnCAPEX was expected to have a negative impact on lnGREAT200m, while lnPOP was expected to have a positive impact on the variable. A 10% increase in capital expenditure was found to reduce access to water services more than 200 m away by about 8.3%, while a 10% increase in population increased access to water services more than 200 m away by about 55.8%. Thus, while capital expenditure significantly reduces access to water more than 200 m away, population sprawls are undoing municipal efforts by increasing the number of people accessing water more than 200 m away in the metropolitan municipalities. Generally, this is consistent with the reality that metropolitan municipalities are commonly at the receiving end of rural-to-urban migration. Several studies on urbanization reiterate that population sprawls cause the growth of slums in many urban areas, thus creating numerous challenges in access to potable water services (Chikozho et al. 2019; Dos Santos et al. 2017; Osei et al. 2015; Sartorius and Sartorius 2016).

Further, the results show a negative coefficient for population density in the model for metropolitan municipalities, implying that high population densities (i.e., more people per square kilometer) would result in less numbers of households accessing potable water more than 200 m away.

This is consistent with earlier expectations that high population densities have an inverse relationship with access to water services more than 200 m away. Generally, municipalities find it less costly to develop water infrastructure for households that are closer to each other than for those widely spaced (Horn 2019; McGuirk and Argent 2011; Sartorius and Sartorius 2016). Thus, the results for metropolitan municipalities imply that when people reside closer to each other, authorities can improve the way people access water services. However, the same is not true for districts and locals where the variable is a statistically insignificant determinant of access to water services more than 200 m away. Finally, the intercept is significant across the different municipal categories, implying that the variables included in estimation sufficiently account for access to water services more than 200 m away.

Conclusion

This study was set to examine the impact of capital expenditure and population growth on access to potable water services in South Africa. Fixed and random effects estimators were used to analyze panel data for 52 big municipalities for the period 2009 to 2018. Four key findings were reported. First, South African municipalities are doing well in providing households with access to water services in the yard despite population growth. Second, capital expenditure and population growth are not important determinants of access to potable water services within 200 m of the yard in metropolitan and local municipalities. However, these variables positively affect access to potable water services within 200 m of the yard in the district municipalities. Third, while capital expenditure reduces access to potable water from sources more than 200 m away, population sprawl is undoing efforts by authorities in metropolitan municipalities as it increases the number of people accessing water more than 200 m away. There is growth in the number of people migrating to metropolitan areas which gives rise to the emergence of informal settlements, mostly in areas with no water infrastructure. Finally, high population densities were found to reduce the number of households accessing water services more than 200 m away in the metropolitan municipalities.

Results from this study are important to water policy makers who need to craft and implement evidence-based policies in the pursuit of SDG 6. The main implication of the results is that authorities in metropolitan municipalities should give sufficient attention to population growth which continues to challenge efforts toward improved access to water services. Thus, evidence-based planning that is backed by scientific and reliable population growth forecasts can provide a solid foundation for improved access to water services. Capital expenditure toward water service provision should be informed by scientifically deduced population growth rates as well as existing backlogs. Further, clustering households closer to each other makes it less complex and less costly for municipalities to improve access to water services. Therefore, authorities should make efforts to cluster households together, especially in the informal settlements where people access water further from the dwelling.

Future research on access to water services can explore the sufficiency of capital expenditure on access to water services in areas where poor populations reside. Evidence exists that such areas are usually marginalized and improving access to water services in those areas is essential for the achievement of the SDG 6 mandate of universal access to improved water services by 2030. Further, future research can include variables, such as the type of topography, infrastructure development cost, availability of fresh water, geopolitical, and environmental factors, which were omitted in this study because of data unavailability. These variables together with other dimensions like water source locations and density can help to understand the volume of capital expenditure required to make a water supply network denser. Including these variables would highlight whether the proposed supply level can support increased water demand or not. This is because in cases where there is no surplus water, bringing water closer to homes will neither help the population nor result in efficient capital utilization.

Data availability The author states that data used in the study will be made available to the journal upon request.

Declarations

Conflict of interest The author states that there is no conflict of interest.

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