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Determinants of transitions in drinking water service systems in developing economies: a case study of Uganda

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ABSTRACT

Limited research has been undertaken on significant factors associated with transitions between drinking water supply systems (DWSS) ladders. In this paper, we applied panel ordered logistic multinomial logistic regression models to seven datasets of the Uganda Demographic and Health Survey (1988–2021), with the SDG6 categorical levels of DWSS (unimproved, improved and piped into dwelling) as transition levels, and various socio-economic and demographic characteristics as covariates. Sex and education level of household head, toilet facility, electricity access, size of agricultural land and wealth index are significant factors. The main implication is the need to address socio-economic disparities in developing economies.

Key words: determinants, developing economies, drinking water services, socio-economic attributes, transitions, Uganda

HIGHLIGHTS

- Sheds light on significant factors associated with transitions between drinking water supply systems ladders.
- Informs the need to address socio-economic disparities to transition between drinking water service systems.
- Several factors are associated with the transition of drinking water service systems.
- Points to the need to address the socio-economic attribute disparity to accelerate options transitions.

INTRODUCTION

Provision of safe water and sanitation is vital for sustainable development, which requires transitions in the quality of drinking water service systems. This has been emphasised by the United Nations (UN) Sustainable Development Goal (SDG) No. 6, which aims at achieving universal access to safe and affordable water by 2030 and ensuring 'no one will be left behind', through an incremental development approach. The importance of transitions is strengthened by the Joint Monitoring Program (JMP) that introduced 'ladders' of safely managed, basic, limited, unimproved and surface water options that are applied to track progress in transitions in time and space at different stages of development (UNICEF & WHO 2021).

Globally, the number of people using piped water supplies increased from about 3.5 billion (57% of the global population) in 2000 to 5.07 billion (65%) in 2020, while those using improved, non-piped sources increased at a slower pace, from 1.66 billion (27%) to 2.18 billion (28%) in the same period. However, there are disparities between and within regions and countries, as well as along the rural–urban divide. For example, in least developed countries, the population with access to piped water supplies in the same period (2000–2020) increased from 20% to 33%, while those with access to improved non-piped water sources increased from 30% to 48%. However, in the same period, improvements in piped water sources in Sub-Saharan Africa were more modest, 29–35%, compared with the improved, non-piped sources (25%–43%). This does not compare favourably with other regions of the developing economies, such as Eastern and South-Eastern Asia, which increased access to piped water services from 49% in 2000 to 73% in 2020 (UNICEF & WHO 2019, 2021). Furthermore, service coverage is significantly lower in rural areas than in urban areas of developing countries. For instance, in 2020, only 19% of the rural population in the least-developed countries have access to piped water supplies, compared with 60% of the urban population (UNICEF & WHO 2021).

This paper examines factors that affect transitions made by households in developing countries to progress to accessing piped water services into their premises, which is a proxy for safely managed water supply sources. This study uses Uganda as a typical case study of a developing economy. In Uganda, increased access to water is among the goals of the National Development Plan (NDP III) and aims to increase access to improved water services from 75.4% to 85% in rural areas and from 79.4% to 100% in urban areas between 2020 and 2025 (National Planning Authority 2020). Between 1990 and 2015, there was an improvement in the proportion of the total population with safely managed water sources (4%–6%), basic water services (30%–39%) and limited access (30%–38%) (UNICEF & WHO 2017), in contrast to 27%–30% for safely managed water sources, 33%–35% for basic water services and 12%–13% for limited access between 2015 and 2020 (UNICEF & WHO 2019).

In terms of speed of transition in Uganda, the proportion of people gaining access to at least basic drinking water services has been increasing at an average of 0.59% per year for the period between 2000 and 2015 in contrast to 0.8% and 1.08% per year for rural and urban areas between 2015 and 2020 (National Planning Authority 2020). However, measuring transition progress and speed does not establish the determinants of transitions between options. Given this low progress, a big part of the population is still dependent on unimproved sources and low levels of water supply system options. Limited research has been undertaken on significant factors that are associated with transitions between water supply service ladders. There is a need, therefore, to investigate the socio-economic factors that have influenced the transitions in water sources which have occurred between urban and rural communities in developing economies over time; and examine the determinants of the choice of the drinking water service system. Studies have been carried out in several countries in the global South, on the determinants of drinking water choice. Findings from these studies have not been uniform, implying that contextual factors play an important role. Most of these studies have also been limited to only a single period and did not assess where these factors change between periods and location disparities.

This paper, therefore, addresses two research questions: (1) What are the factors that influence the choice of drinking water distribution system used by households? (2) How does variability of socio-economic characteristics influence the transition in choice of drinking water distribution system over time? This paper addresses the research gap by using seven longitudinal datasets of the Ugandan DHS to investigate the factors that influence the choice of drinking water distribution system used by households and how they have been changing over time. This is one of the few studies that have utilised panel datasets, spanning over 20 years, and collected by a reputable international development agency. We used multinomial logistic regression, which is a superior method because it maintains the heterogeneity in decision-making (Kisaakye *et al.* 2021; Sempewo *et al.* 2021a, 2021b). Understanding the socio-economic factors that influence the transition in choice of drinking water distribution system over time in Uganda can be used in prediction demand and transition modelling, as a first step for developing more appropriate and targeted water policies and projects aimed at removing disparities and or accelerating the transition between drinking water service systems particularly in developing countries (WHO/UNICEF 2020). The next section presents a brief review of the extant literature on factors influencing household access to improved water supply sources in developing economies.

Similar studies on factors influencing household access to improved water supplies

There have been a few studies conducted in developing economies on the factors influencing access to improved water supplies. Of interest to this paper are studies that have used secondary data covering whole countries. Many of these studies have utilised national population-based household survey data that are regularly collected by national governments and international development agencies, which offer a wealth of information on access to health and other welfare services, including water supply and sanitation services. These datasets include Multiple Indicator Cluster Surveys (MICS) by UNICEF, Demographic and Health Surveys (DHS) by USAID, National Malaria and AIDs Indicators Surveys by USAID and Living Standards Measurement Studies by the World Bank. For instance, a meta-study used all the aforementioned types of survey data collected in sub-Saharan countries to highlight inequalities in service delivery in geographical regions of 41 countries along with the urban/rural settlements. The study analysed data from 138 surveys undertaken between 1991 and 2012 in these countries. The study found highly significant geographical and urban/rural inequalities, but disparities were higher along geographical regions (Pullan *et al.* 2014).

National studies based on MICS and DHS datasets in various countries have all identified household wealth, geopolitical location and urban/rural residence as significant factors of access to improved water sources (Adams *et al.* 2016; Tuyet-Hanh *et al.* 2016; Mulenga *et al.* 2017; Abubakar 2019). In Vietnam, the study based on MICS data highlighted that wealth-based inequality increased tremendously over time: in 2000, wealthy households were 11 times more likely to have access to improved water sources than poor households, and this factor increased to over 40 times in 2011 (Tuyet-Hanh *et al.* 2016). The Ghanaian and Zambian studies based on DHS data also found that households headed by women had higher odds of having access to improved water sources than those headed by men (Adams *et al.* 2016; Mulenga *et al.* 2017).

Conversely, a more recent study in Nigeria, also based on DHS data, found households headed by men to have higher odds of having access to improved water sources (Abubakar 2019). However, both the Ghanaian and Nigerian studies found the education level of household heads to be a significant predictor of access to improved water sources (Adams *et al.* 2016; Abubakar 2019). The Nigerian study also found ethnicity, age of the household head, access to electricity and number of rooms in the house to be significant predictors of access to an improved water source (Abubakar 2019). Contrary to findings from the Nigerian study, the Ghanaian study found household size a significant factor (Adams *et al.* 2016; Abubakar 2019).

Two other national studies to determine factors influencing households' access to improved drinking water sources were conducted in Indonesia, using data from the 2007 Indonesia Family Life Survey; and Cameroun, based on survey data collected by the National Institute of Statistics in 2007. These studies came up with findings most of which are like the above-mentioned: significant factors included urban/rural residence, household income, household size, number of rooms in the home, education level and gender (in favour of women) of household head (Fotue & Sikod 2012; Irianti *et al.* 2016). The Indonesian study also found that geopolitical location significantly influences access to an improved drinking water source (Irianti *et al.* 2016).

RESEARCH SETTING AND METHODS

This study was conducted in Uganda, located in East Africa, and which lies across the equator. The last census showed that the total population of Uganda was about 34.6 million people in 2014, with a population density of 173 persons per square kilometre (Uganda Bureau of Statistics 2016). The 2014 census found that the population was growing at a rate of about 3.0% per annum. Thus, currently, the population has grown to over 40 million people. In March 2016, there were 259 urban centres that were inhabited by about 7.4 million people while the rest of the population of Uganda is rural. The status of safe water coverage for Uganda as of 2017 is presented in Figure 1.

The study was based on secondary data sourced from 2021, 2016, 2011, 2006, 2000–2001, 1995 and 1988–1989 Uganda Demographic and Health Survey (DHS) data on households. The Uganda DHS is a national survey sponsored by USAID which collects data on socio-economic characteristics and conditions of households and household members in all the districts of Uganda every five years. The characteristics include attributes such as age, sex, the source of water, the source of energy, the type of sanitation facilities, building materials for household dwellings and the type of assets owned by the households.

Several variables from the seven DHS datasets were extracted and categorised into two major groups, i.e. the outcome and explanatory variables. The outcome variable was the main source of drinking water, which was modelled using three outcomes, i.e. piped water in the dwelling, other improved sources and unimproved sources. This variable was nominal in the analysis; the ordering of the codes assigned to each of the categories was of the least importance. The explanatory variables that were used in modelling transitions in drinking water sources included sex, age and education of the household head; household size; type of sanitation facility; access to electricity; ownership of radio and bicycle; the number of rooms used for sleeping; and size of agricultural land. It is important to note that some of the DHS datasets had missing data on some of these explanatory variables such as the sex of the household head.

This study relied on a random-effects panel ordered logit model multinomial logistic regression (MNL), following Muris (2016), to determine the demographic and socio-economic factors that influence the transitions in drinking water distribution systems. This study conceptualised that households have three transition choices, namely drinking water source from piped water in the dwelling, other improved sources and unimproved sources, given their demographic, socio-economic and production characteristics. This gives rise to different choices of access to drinking water sources, where households will rely on piped water in the dwelling; on other improved sources such as public taps and boreholes; or unimproved sources such as unprotected springs. For each of these alternatives, households aim at maximising utility conditioned on their demographic and socio-economic characteristics.

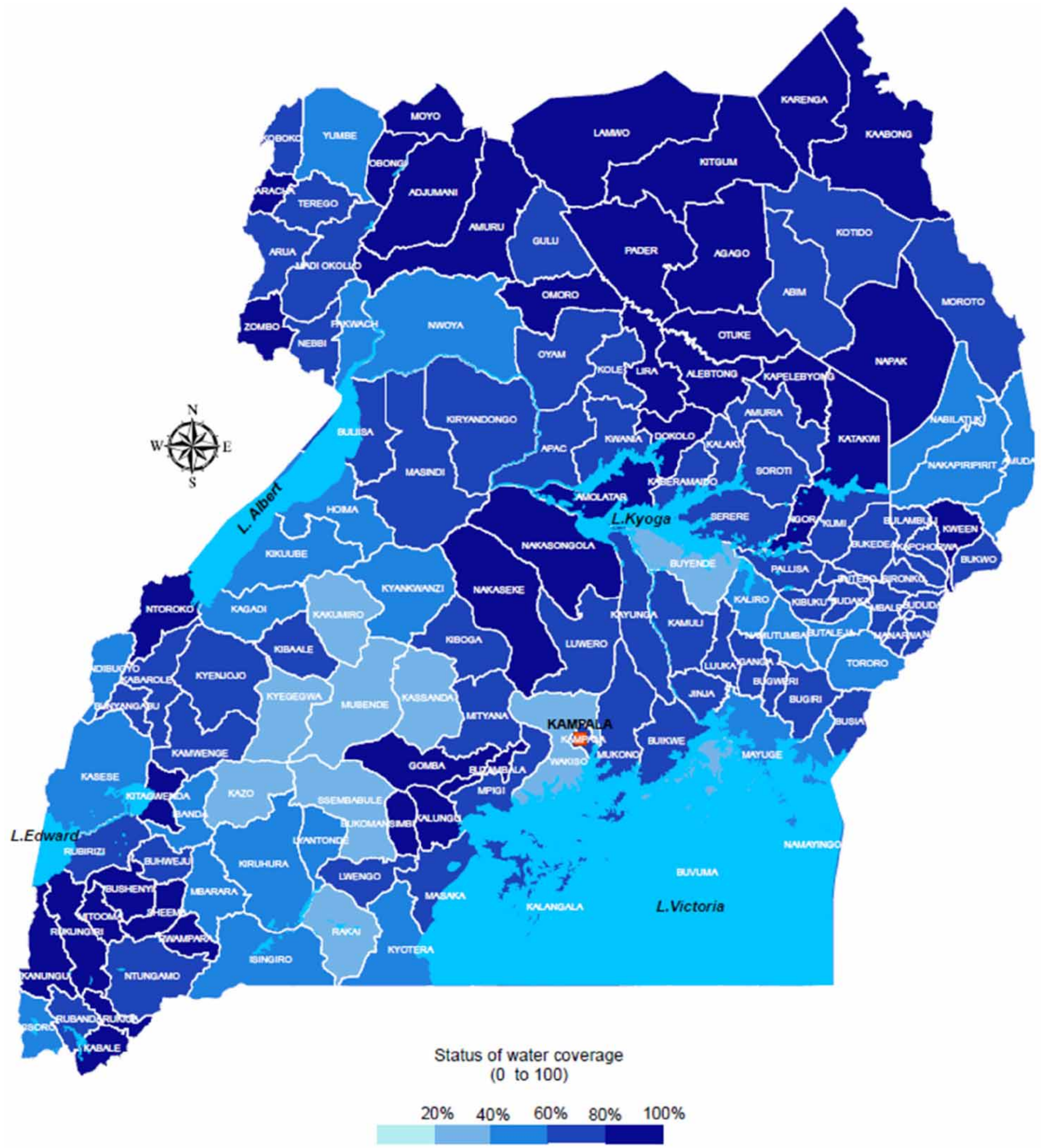

Figure 1 | Map of safe water coverage. *Source*: Uganda Water Supply Atlas (2017).

The theoretical description of the MNL model is presented in Equations (1) and (2) and its econometric derivation is found in Greene (2003), Verbeek (2004) and Cameron & Trivedi (2005):

$$y_j = \begin{cases} 1, & \text{if } y = j, \\ 0, & \text{if } y \neq j, \end{cases} \quad \text{for} \quad j = 1,\ 2,\ \ldots m \tag{1}$$

$$p_{ij} = \frac{\exp(x_i'\beta_j)}{\sum_{j=1}^{m}\exp(x_i'\beta_j)} \quad \text{for} \quad j = 1,\ 2,\ \ldots m \tag{2}$$

where y is the outcome for j alternatives for the ith household, x_i' is a vector of household characteristics and β_j is a vector of parameters to be estimated.

Equation (3) presents the empirical description of the MNL model that was used to determine the demographic and socio-economic factors that influence the transition in drinking water distribution systems by households:

$$p_{ij} = \Pr[\mathrm{USE}_i = j] = \frac{\exp\begin{pmatrix}\beta1\,SEX_i + \beta2\,AGE_i + \beta3\,EDUC_i + \beta4\,HSIZE_i + \beta5\,FLUSH_i + \beta6\,ELEC_i \\ + \beta7RAD_i + \beta8\,BIC_i + \beta9\,ROOM_i + \beta10\,ROHSIZE_i + \beta11\,AGLSIZE_i\end{pmatrix}}{\sum_{j=1}^{3}\exp\begin{pmatrix}\beta1\,SEX_i + \beta2\,AGE_i + \beta3\,EDUC_i + \beta4\,HSIZE_i + \beta5\,FLUSH_i + \beta6\,ELEC_i \\ + \beta7\,RAD_i + \beta8\,BIC_i + \beta9\,ROOM_i + \beta10\,ROHSIZE_i + \beta11\,AGLSIZE_i\end{pmatrix}}, \quad \text{for } j = 1, 2, 3 \tag{3}$$

where USE is the dependent variable, which is equal to 0 if the household used unimproved sources, 1 if the household used other improved sources or 2 for piped water in the dwelling; $\beta1$–$\beta11$ are parameters that were estimated; and the rest of the variables are defined in Table 1. Before fitting the model, all continuous variables were checked for normality and those that were found to be highly skewed were corrected using the hadimvo approach. The random-effects model was used to study the impact of socio-economic characteristics on a household (HH) transition between DWSS options (Hilmer & Hilmer 2014).

Twelve independent MNL models were estimated with one model for each of urban and rural households corresponding to each of the six DHS datasets. This enabled observation of the significant demographic and socio-economic factors that influence households to switch from one drinking water source to another across time as urbanisation takes place. These separate regression models also enabled us to overcome the need to follow the trend of decision-making of one household from 1988 to 2021, which information was not available in the DHS datasets. The regressions, therefore, enabled the identification of the socio-economic factors associated with the transition in options of drinking water sources. This enabled us to understand the implications of the observed patterns of socio-economic factors for policy changes to increase the uptake, efficiency and costs for drinking water source transitions. MNL analysis was performed using STATA statistical package version 14 to determine

Table 1 | Dependent and explanatory variables for a multinomial regression model

Variable name	Type	Description
USE	Categorical	0 if the household used unimproved sources, 1 if the household used other improved sources or 2 for piped water in the dwelling
SEX	Dummy	Sex of the household head (1 = female)
AGE	Continuous	Age of the household head (complete years)
EDUC	Continuous	Education of the household head (complete years)
HSIZE	Continuous	Number of household members
FLUSH	Dummy	Type of toilet facility (1 = have a flushing toilet, 0 = non-flushing toilet)
ELEC	Dummy	Has electricity (1 = yes)
RAD	Dummy	Has radio (1 = yes)
BIC	Dummy	Has bicycle (1 = yes)
ROOM	Continuous	Number of rooms used for sleeping
ROHSIZE	Continuous	The ratio of rooms to household size
AGLSIZE	Continuous	Size of agricultural land (ha)

the exponential coefficients that indicate the importance of the socio-economic attributes and the probabilities p (which indicate the significance of the coefficients) for the model in Equation (3).

RESULTS AND DISCUSSION

Characteristics of households

Table 2 presents the demographic and socio-economic characteristics of households that participated in the six DHS (2021, 2016, 2011, 2006, 2000–2001, 1995 and 1988–1989). Almost two-thirds of the households that participated in the six DHS were male-headed with no significant differences between urban and rural households. The heads of these households were young with rural household heads being significantly ($p \leq 0.05$) older than their urban counterparts.

The average age of rural household heads has been constant over time while that for urban households has been increasing. Urban household heads were found to have significantly ($p \leq 0.05$) more years of education than their rural counterparts, and the average education levels for both types of households improved over time. The findings also show that household size in Uganda has been declining since 1988–1989 among both rural and urban households, but rural households have remained significantly ($p \leq 0.05$) larger than their urban counterparts.

The findings further show that ownership of radio and telephone has also been improving since 1988/1989, with a larger proportion ($p \leq 0.05$) of urban households owning these sources of water, sanitation and hygiene information sources relative to their rural counterparts. Similarly, ownership of bicycles and motorcycles has also been improving over time, with more rural households owning bicycles compared with their urban counterparts while the reverse is true for motorcycles. Both bicycles and motorcycles are important means of transport among households, which they use to access water sources, seek technical support about water sources, and also rely on to access shops that sell spare parts for their water sources.

Since 1988–1989, there has not been a significant improvement in the proportion of households accessing improved sanitation facilities. Pit latrines have been the major sanitation facility used by households from 1988 to 1989, followed by those who did not have any sanitation facilities and those who used flush toilets. The findings further show that flush toilets are more prevalent among urban households and there are very few among rural households.

Most of the households that participated in the seven DHS studies did not have access to electricity in their houses, with most of these being rural households. The findings also show that access to electricity has been improving among both urban and rural households since 1988/1989. The results also show that housing conditions of both rural and urban households have been improving. The majority of the rural households lived in houses with earth or sand floors; walls made from thatch, mud, poles; and thatch, papyrus, tins and wood roofs. Most of these have transitioned to earth and brick walls, and iron sheet roofs, although most still have earth or sand floors. The majority of their urban counterparts resided in houses with cement or concrete floors; walls made from earth or clay bricks; and iron sheets, tiles and cement roofs. The findings also show that rural households have significantly more rooms used for sleeping than their urban counterparts. Although urban households were found to own a larger size of agricultural land, a larger proportion of rural households than their urban counterparts owned agricultural land.

As reported by previous studies (Adams *et al.* 2016; Abubakar 2019) and as discussed in the previous section, socio-economic, location and demographic characteristics affect the distribution and transition in drinking water systems. This section investigates whether there exists a relationship between the choice of drinking water service systems, the transition between them, and the socio-demographic factors elaborated in Table 2.

Location of residence

Table 3 shows the significant difference between rural and urban households DWSS and the respective transition from the period 1988 to 2021 ($\chi^2 =$ 5,600, $p = 0.000$, urban $\chi^2 = 1{,}800$, $p = 0.000$, rural $\chi^2 = 7{,}800$, $p = 0.000$). Chi-square is a test statistic used to measure differences between expected and observed data with a large value signifying a larger difference between actual and observed values. For example, in this case, the χ^2 value indicates that the observed responses are larger than the expected responses by 5,600 hence signifying a large difference in household DWSS between urban and rural areas.

The results in Table 3 show a significant variation in the distribution of DWSS by location of residence in rural and urban areas across the transition period between 1988 and 2021 ($p = 0.00$). In the results across the study period, the highest coverage of piped water sources in houses and improved water sources was in urban areas. For example, the proportion of houses with DWSS option of water in the house for urban and rural regions (respectively) during the study period was as follows:

Table 2 | Demographic and socio-economic characteristics of households that participated in DHS surveys of 1988/1989–2021

	1988–1989		1995		2000–2001		2006		2011		2016		2021	
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Sex of household head†														
Male			71.41	76.14	68.75	73.15	66.4	69.55	67.35	70.07	66.3	69.75	67.87	68.95
Female			28.59	23.86	31.25	26.85	33.6	30.45	32.65	29.93	33.7	30.25	32.13	31.05
Age of household head‡			35.75 (12.71)	42.49 (16.56)	36.26 (13.43)	42.26 (16.31)	36.73 (13.62)	43.31 (15.89)	37.58 (13.28)	43.57 (15.97)	39.39 (14.61)	43.19 (16.26)	41.51 (12.32)	44.65 (11.65)
Education level of household head (complete years)‡	6.40 (3.88)	2.98 (3.02)	7.37 (4.20)	3.91 (3.47)	8.24 (4.89)	4.37 (3.90)	8.83 (4.66)	4.56 (3.94)	9.21 (4.78)	4.84 (4.18)	9.04 (5.01)	5.54 (4.23)	8.48 (3.79)	6.23 (2.46)
Number of household members‡	6.32 (3.52)	6.79 (3.51)	4.43 (3.00)	4.93 (2.87)	4.39 (2.98)	5.01 (2.83)	4.29 (2.83)	5.28 (2.81)	4.12 (2.66)	5.32 (2.76)	4.02 (2.54)	4.84 (2.76)	4.22 (1.81)	5.88 (2.89)
Has radio†														
No	33.82	75.91	35.28	66.73	25.08	52.86	22.73	45.91	28.97	40.57	33.9	46.44	36.46	55.32
Yes	66.18	24.09	64.72	33.27	74.92	47.14	77.27	54.09	71.03	59.43	66.1	53.56	63.54	44.68
Has television†														
No	85.36	99.81	85.83	99.24	77.27	98.25	69.71	97.7	55.82	96.34	56.03	93.9	42.43	91.33
Yes	14.64	0.19	14.17	0.76	22.73	1.75	30.29	2.3	44.18	3.66	43.97	6.1	57.57	8.67
Has bicycle†														
No	75.83	64.52	71.71	63.25	75.28	58.53	82.45	60.63	79.34	59.63	78.25	63.7	57.89	48.26
Yes	24.17	35.48	28.29	36.75	24.72	41.47	17.55	39.37	20.66	40.37	21.75	36.3	42.11	51.74
Has motorcycle†														
No	96.89	99.39	97.96	99.43	94.71	98.03	95.4	97.78	89.81	93.86	88.01	90.57	85.87	96.65
Yes	3.11	0.61	2.04	0.57	5.29	1.97	4.6	2.22	10.19	6.14	11.99	9.43	14.13	3.35
Sanitation facility†														
No facilities	1.66	15.4	3.65	21.45	3.13	17.18	1.65	17.11	2	16.95	2.86	11.07	1.58	7.98
Pit latrine	71.03	83.22	83.8	77.77	87.58	81.76	88.06	82.02	85.73	82.24	83.93	87.25	68.65	88.66
Flush toilet	26.9	0.64	10.96	0.29	9.01	0.47	10.22	0.12	11.41	0.17	12.8	0.61	28.98	2.54
Other	0.42	0.74	1.58	0.49	0.28	0.6	0.07	0.75	0.86	0.63	0.4	1.08	0.79	0.82
Has electricity†														
No	48.86	98.11	62.89	98.46	60.18	97.77	54.32	97.54	46.06	96.36	41.17	83.36	32.46	77.89
Yes	51.14	1.89	37.11	1.54	39.82	2.23	45.68	2.46	53.94	3.64	58.83	16.64	67.54	22.11

(*Continued.*)

Table 2 | Continued

	1988–1989		1995		2000–2001		2006		2011		2016		2021	
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Main floor material†														
Earth, sand	23.98	74.24	29.99	69.74	22.87	63.18	15.3	42.86	13.94	47.79	22.54	56.36	14.83	64.68
Cow dung, rudimentary	3.86	17.01	6.46	23.13	8.35	27	7	44.37	7.87	36.13	6.92	22.72	2.88	9.65
Cement, concrete	70.91	8.67	62.31	7.01	46.11	6.68	75.4	12.71	74.72	15.93	64.09	20.33	78.54	24.04
Parquet, polished wood, tiles	1.25	0.08	1.25	0.12	22.67	3.14	2.31	0.05	3.46	0.15	6.45	0.59	3.75	1.63
Main wall material†														
Thatch, mud, poles	31.17	90.94			26.94	66.71	14.3	51.41	11.51	47.82	15.14	42.63	12.53	38.87
Earth, clay bricks	23.01	4.64			67.34	32.56	83.35	48.03	82.96	50.32	81.62	56.55	78.86	59.86
Cement blocks, concrete	45.82	4.42			5.72	0.73	2.36	0.55	5.54	1.87	3.24	0.82	8.61	1.27
Main roof material†														
Thatch, papyrus, tins, wood	8.44	54.19			7.98	45.78	8.28	51.42	10.06	45.27	9.41	39.22	7.68	38.45
Iron sheets, tiles, cement	91.56	45.81			92.02	54.22	91.72	48.58	89.94	54.73	90.59	60.78	92.32	61.55
Number of rooms used for sleeping‡			1.49 (0.85)	1.84 (0.94)			1.66 (1.13)	1.83 (0.93)	1.63 (0.97)	1.92 (1.00)	1.78 (1.04)	1.95 (1.03)	1.98 (1.12)	2.32 (1.22)
Owns land usable for agriculture†														
No							62.92	15.96	53.3	18.04	55.45	23.36	48.78	24.84
Yes							37.08	84.04	46.7	81.96	44.55	76.64	51.22	75.16
Size of agricultural land (ha)‡							12.58 (8.98)	1.79 (2.96)	19.21 (9.61)	11.73 (8.39)	14.02 (6.93)	10.73 (7.68)	12.46 (8.32)	16.36 (6.54)

Note: Standard deviation in parentheses.
†Chi-square tests.
‡Student *T*-tests.

Table 3 | Influence of location of household on transition in DWSS

Water source transition by location of residence	Year of study (%) 1988	1989	1995	2000	2001	2006	2011	2016	2021	Net transition	Annual transition rate
Urban											
Piped into dwelling	81 (8.90)	9 (15.50)	349 (14.50)	88 (5.90)	29 (2.90)	88 (6.30)	239 (9.40)	303 (6.80)	345 (7.78)	−1.12	−0.03
Improved sources	734 (81.00)	48 (82.80)	1,556 (64.60)	1,243 (83.60)	861 (85.20)	1,154 (83.00)	2,076 (81.40)	3,847 (86.10)	3,788 (85.37)	4.37	0.13
Unimproved sources	91 (10.00)	1 (1.70)	505 (21.00)	156 (10.50)	120 (11.90)	148 (10.60)	236 (9.30)	319 (7.10)	304 (6.85)	−1.15	−0.03
Rural											
Piped into dwelling	10 (0.40)	2 (0.20)	6 (0.10)	6 (0.30)	0 (0.00)	9 (0.10)	28 (0.40)	70 (0.50)	80 (0.51)	0.11	0.00
Improved sources	1,756 (63.50)	574 (57.50)	2,254 (43.90)	1,397 (58.30)	1,525 (51.20)	4,927 (65.90)	4,358 (67.20)	11,164 (73.80)	12,282 (77.65)	14.15	0.43
Unimproved sources	1,001 (36.20)	423 (42.30)	2,877 (56.00)	992 (41.40)	1,456 (48.80)	2,544 (34.00)	2,096 (32.30)	3,885 (25.70)	3,456 (21.85)	−14.35	−0.43

Note: Differentials in water source coverage across regions were investigated using Pearson chi-square test, where $\chi^2 = 5{,}600$, $p = 0.000$.
Positive (+) signifies that there was an increased transition.
Negative (−) signifies that there was a reduction in transition.

7.78% versus 0.51% in 2021, 6.8% versus 0.5% in 2016, 9.4% versus 0.4% in 2011, 6.3% versus 0.1% in 2006, 2.9% versus 0.0% in 2001 and 14.5% versus 0.1% in 1995. Similarly, improved water sources were predominant in urban areas. For example, the proportion of houses with improved water sources in urban and rural areas during the study period was as follows: 88.11% versus 76.66% in 2021, 86.1% versus 73.8% in 2016, 81.4% versus 67.2% in 2011, 83% versus 65.9% in 2006, 85.2% versus 51.2% in 2001 and 64.6% versus 43.9% in 1995.

The results show a decrease of 1.1% in urban households with piped water into dwellings compared with a 0.1% increase in rural households. The increase in households that use unimproved sources is 4.4% in urban areas in contrast to 14.2% in rural areas. Between 1988 and 2021, the most significant transition is observed in improved sources among rural community (63.5%–77.65%) households as compared with their urban counterparts (81%−85.37%). On the other hand, the most significant abandonment of water sources was observed in rural areas at 14.4% in contrast to 1.2% in urban areas. Whereas there has been a transition in the proportion of people using the different water system options between 1988 and 2021 for both rural and urban areas, the speed of transitioning varies greatly between these two regions. Worthy to note is that the pace of transition among DWSS is faster in rural areas as compared with urban areas. The disparity is attributed to rapid population growth in the urban areas that has outstripped the existing DWSS of their capacity to meet the water demand. For both rural and urban areas during the entire transition period, improved DWSS remained the most widely used water source option. Similar to previous studies, it is more likely that there are more infrastructure investments in the water supply services in urban areas and so urban residents have higher access to improved water sources compared with their rural counterparts. Nonetheless, the findings show that rural households have also significantly transitioned from unimproved water sources to improved sources and a few to piped water.

Geographical location

Table 4 shows the distribution of DWSS and the respective transition from the period 1988 to 2021 by the four regions of Eastern, Northern, Western and Southern. Variations in the distribution of the water sources (dependent) by geographical location (independent) were investigated using the Pearson chi-square test; associations were established to be $\chi^2 = 2{,}900$, $p = 0.000$.

The results in Table 4 show a significant variation in the distribution of water sources by geographical region of Eastern, Northern, Western and Southern.

The results across the study period show that the highest level of access to piped water into dwellings was in the Central region. For example, the proportion of households with the DWSS option of piped water into a dwelling in the Central, Eastern, Northern and Western geographical locations was 5.48%, 0.97%, 0.52% and 1.35%, respectively, in 2021; 5.3%, 0.9%, 0.5% and 1.2%, respectively, in 2016; 6.1%, 1.6%, 0.8% and 2.3%, respectively, in 2011; and 3.1%, 0.4%, 0.1% and 0.3%, respectively, in 2006.

The most significant transition during the study period is observed for improved sources in Northern region households (56.3.5%−87.8%) as compared with the Eastern region (62.8%−86.11%), Western region (66.90%−68.34%) and Central region (73.30%−74.34%). The results show a reduction of 32.12%, 20.99%, 2.3% and 2.4% with unimproved DWSS in Northern, Eastern, Central and Western households, respectively. The findings also show that there has been an overall reduction in the proportion of HH using unimproved DWSS across the regions particularly. The reduction is attributed to the recent campaign to achieve the Millennium Development Goals and the subsequent Sustainable Development Goals which aim to reduce the number of people without access to safe and clean water. In addition, there has been donor focus on Northern and Eastern Uganda under the peacebuilding and Northern Uganda reconstruction program. The results show that the slowest pace of transition is in piped water into dwellings with 1.2%, 0.95% and 0.52% for Central, Western and Northern, respectively, and a reduction of 2.4% in Eastern Uganda. The results corroborate the findings of earlier studies (Mulenga *et al.* 2017; Abubakar 2019) that show that geographical locations influenced the choice of DWSS. The variability in socio-economic, water resources potential and climate and topographical characteristics and state and donor biases in infrastructure investments could be the reasons for the disparity in levels of transition between the geographical regions.

Level of education

Education has been identified as a key driver for socio-economic transformation (Grant 2017). There is rich literature confirming that education is an important factor for technological, scientific, anthropogenic and industrial transformation in many countries across the world. Recently, it has been identified as one of the factors that affect a household's choice for a DWSS option (Ozturk 2001; Abubakar 2021). According to Abubakar (2021), increasing the level of education increases

Table 4 | Influence of geographical location on household DWSS

Water source transition by geographical region	Year of study (%) 1988	1989	1995	2000	2001	2006	2011	2016	2021	Net transition	Annual transition rate
Central											
Piped into dwelling	57 (4.30)	7 (1.20)	128 (5.30)	38 (3.00)	25 (1.70)	81 (3.10)	175 (6.10)	248 (5.30)	268 (5.48)	1.18	0.04
Improved sources	981 (73.30)	358 (61.70)	1,091 (44.80)	896 (70.40)	809 (54.40)	1,609 (62.50)	1,927 (67.30)	3,428 (72.60)	3,633 (74.34)	1.04	0.03
Unimproved sources	301 (22.50)	215 (37.10)	1,215 (49.90)	339 (26.60)	652 (43.90)	885 (34.40)	760 (26.60)	1,046 (22.20)	986 (20.18)	−2.32	−0.07
Eastern											
Piped into dwelling	29 (3.40)		93 (4.70)	32 (3.30)	0 (0.00)	7 (0.40)	30 (1.60)	36 (0.90)	41 (0.97)	−2.43	−0.07
Improved sources	543 (62.80)		1,233 (62.0)	797 (82.80)	626 (68.30)	1,552 (83.10)	1,549 (84.40)	3,416 (85.90)	3,634 (86.11)	23.31	0.71
Unimproved sources	293 (33.90)		664 (33.40)	134 (13.90)	291 (31.70)	309 (16.50)	257 (14.00)	523 (13.20)	545 (12.91)	−20.99	−0.64
Northern											
Piped into dwelling	0 (0.00)	0 (0.00)	16 (1.50)	10 (1.80)	0 (0.00)	3 (0.10)	19 (0.80)	29 (0.50)	30 (0.52)	0.52	0.02
Improved sources	90 (56.30)	1 (100.00)	653 (59.5)	421 (77.40)	332 (64.70)	1,906 (73.60)	1,983 (79.40)	4,965 (86.40)	5,112 (87.80)	31.5	0.95
Unimproved sources	70 (43.80)	0 (0.00)	429 (39.10)	113 (20.80)	181 (35.30)	682 (26.30)	494 (19.80)	750 (13.10)	680 (11.68)	−32.12	−0.97
Western											
Piped into dwelling	5 (0.40)	4 (0.80)	118 (5.80)	14 (1.30)	4 (0.40)	6 (0.30)	43 (2.30)	60 (1.20)	64 (1.35)	0.95	0.03
Improved sources	876 (66.90)	263 (55.30)	833 (41.10)	526 (47.70)	619 (57.60)	1,014 (55.20)	975 (53.00)	3,202 (62.20)	3,233 (68.34)	1.44	0.04
Unimproved sources	428 (32.70)	209 (43.90)	1,074 (53.00)	562 (51.00)	452 (42.00)	816 (44.40)	821 (44.60)	1,885 (36.60)	1,434 (30.31)	−2.39	−0.07

Positive (+) signifies an increase.
Negative (−) signifies a reduction.

the financial capability required to accelerate a transition between DWSS options as well as increasing awareness and the need to have improved DWSS options (Arouna & Dabbert 2010; Mahama *et al.* 2014). Table 5 shows that the level of education of household heads significantly influences household transition in DWSS ($\chi^2 = 4{,}500$, $p = 0.001$).

The results in Table 5 show a variation in the distribution of water sources by the level of education. The (+) positive signifies an increase and the (−) negative signifies a reduction in the distribution of water sources by the level of education. The results show that the highest transition was in HH where the household head had obtained higher education followed closely by HH where the head had secondary education. The least transition was observed where the level of education for the HH head was lower than secondary education. This suggests that the difference between households where the heads lack education and those with primary education does not matter in access and transition in water options in Uganda. Household heads with secondary and higher education have the highest likelihood of transitioning to the more improved water options. It is worth noting that irrespective of the level of education, households transitioned to improved sources. This could be attributed to the fact that several significant global initiatives that aimed to increase access to safe water and sanitation such as the International Decade of Water Supply and Sanitation, and the Millennium Development Goals (MDGs, 2005–2015) were skewed to improve water sources, which slowed down progress on achieving piped water into dwellings.

Our findings are consistent with previous studies such as Brown *et al.* (2008) and Sempewo (2012) which found that the transition between water systems options is a socio-technical problem. The findings are also consistent with the findings of earlier studies (Mulenga *et al.* 2017; Abubakar 2019) that educated households use improved water options more than less-educated households that are locked into using a lower rank of drinking water options. These findings imply that as the level of a HH head's education improves, it is more likely for them to transition from unimproved water sources to improved water sources, and finally to piped water into dwellings. Educational attainment is thus a key parameter in accelerating progress in the transition between water source options.

The most significant increased transition during the study period is observed for improved sources where the level of education for the HH head was higher (14.4%) as compared to (10.7%) where the HH Head had secondary education, 3.57% where the HH head had primary education and 12.5% where the HH head had no education. On the other hand, there was a reduction in transition in the proportion of 14.1%, 10.41%, 1.05% and 0.2% across HH with higher, secondary, primary and no education with piped water into a dwelling. Our findings are consistent with studies such as Abubakar (2021), who found that the more educated the HH head was, the more likely they were to utilise a drinking water source of a higher level because these HH understand the advantages of using improved water sources as well as meeting their lifestyle requirements.

Whereas the likelihood of transitioning between water source options is associated with a change in the level of education, it was observed generally that there was an increase in improved sources vis-à-vis a reduction in piped water into a dwelling. The disparity in transitions between the different levels of education is likely attributed to the fact that the recent global campaigns to accelerate progress to reduce the number of people without access to safe and clean water have been biased towards the improved water source technological option, which is cheaper, can be managed by the communities themselves and has low and affordable operation and maintenance costs. In addition, higher technological options are not affordable at the HH level in terms of meeting the investment costs as well as footing the monthly bills. Whereas a transition to higher technologies was expected, this was not the case possibly due to cost and technological limitations. Piped water requires higher investment costs that are seldom affordable by the government and the communities. Moreover, these piped water systems require robust institutions to manage them that are not readily available. The second school of thought to explain this reduced disparity is that the investments undertaken in the water sector have not been in tandem with the rapid population growth in the country. According to Cohen (2006), Sempewo & Kyokaali (2019), Bischoff-Mattson *et al.* (2020) and Olugbamila *et al.* (2020), rapid population growth has outstripped the capacity of governments and water utilities to provide safe water to communities.

Gender of HH head and access to electricity

This section presents the influence of the gender of the HH head and access to electricity on the transition between HH DWSS (Table 6). As shown in Table 6, the gender of the household head (χ^2 (10) $= 43$, $p = 0.000$), as well as access to electricity (χ^2 (10) $= 6{,}000$, $p = 0.000$) significantly influence transition in DWSS options. Despite having a similar degree of freedom, the chi-square value of the association between access to electricity ($\chi^2 = 6{,}000$) and a HH transition is higher than that of gender ($\chi^2 = 43$), indicating that access to electricity has a greater influence than gender in influencing transitions.

The highest transition was observed for improved water sources for HH headed by men followed closely by HH where the head is female. The least transition was observed among female-headed HH for piped water into the dwelling followed by

Table 5 | Influence of level of education on the transition between HH DWSS

Water sources transition by level of education	Year of study (%) 1988	1989	1995	2000	2001	2006	2011	2016	2021	Net transition	Annual transition rate
No education, preschool											
Piped into dwelling	8 (0.60)	0 (0.00)	10 (0.50)	1 (0.10)	1 (0.10)	3 (0.20)	4 (0.20)	14 (0.40)	15 (0.40)	−0.2	−0.01
Improved sources	851 (64.70)	160 (50.80)	827 (44.60)	495 (61.60)	487 (55.30)	1,192 (61.40)	1,173 (66.90)	2,343 (73.50)	2,865 (77.2)	12.5	0.38
Unimproved sources	457 (34.70)	155 (49.20)	1,019 (54.90)	308 (38.30)	393 (44.60)	747 (38.50)	576 (32.90)	831 (26.10)	864 (22.39)	−12.31	−0.37
Primary											
Piped into dwelling	21 (1.10)	5 (0.80)	79 (2.00)	6 (0.30)	1 (0.05)	5 (0.10)	34 (0.80)	35 (0.30)	38 (0.37)	−0.73	−0.02
Improved sources	1,270 (68.10)	386 (61.30)	1,954 (50.10)	1,197 (64.70)	1,207 (57.23)	3,245 (67.30)	3,047 (69.40)	7,588 (74.50)	7,298 (71.69)	3.59	0.11
Unimproved sources	574 (30.80)	239 (37.90)	1,865 (47.80)	647 (35.00)	901 (42.72)	1,572 (32.60)	1,308 (29.80)	2,563 (25.20)	2,844 (27.94)	−2.86	−0.09
Secondary											
Piped into dwelling	59 (12.30)	5 (4.60)	204 (13.70)	25 (3.40)	9 (1.30)	20 (1.40)	79 (4.10)	86 (2.20)	88 (1.89)	−10.41	−0.32
Improved sources	362 (75.30)	73 (67.60)	882 (59.10)	570 (78.40)	472 (69.40)	1,101 (79.00)	1,491 (77.90)	3,239 (82.50)	4,010 (85.98)	10.68	0.32
Unimproved sources	60 (12.50)	30 (27.80)	407 (27.30)	132 (18.20)	199 (29.30)	272 (19.50)	344 (18.00)	601 (15.30)	566 (12.14)	−0.36	−0.01
Higher											
Piped into dwelling	3 (27.30)	1 (25.00)	39 (36.40)	61 (13.90)	18 (7.90)	66 (11.10)	146 (16.10)	227 (11.10)	243 (11.82)	−14.1	−0.43
Improved sources	7 (63.60)	3 (75.00)	53 (49.50)	330 (75.30)	163 (71.50)	451 (76.10)	671 (74.10)	1,653 (81.00)	1,787 (80.40)	14.4	0.44
Unimproved sources	1 (9.10)	0 (0.00)	15 (14.00)	47 (10.70)	47 (20.60)	76 (12.80)	88 (9.70)	160 (7.80)	122 (7.78)	−1.5	−0.05
Unknown											
Piped into dwelling			23 (11.90)	1 (1.60)	0 (0.00)	3 (2.50)	4 (5.60)	11 (4.40)		−7.5	−0.27
Improved sources			94 (48.70)	48 (76.20)	57 (61.30)	92 (76.70)	52 (72.20)	188 (75.80)		27.1	0.97
Unimproved sources			76 (39.40)	14 (22.20)	36 (38.70)	25 (20.80)	16 (22.20)	49 (19.80)		−19.6	−0.70

Table 6 | Influence of gender of HH head and access to electricity on the transition between HH DWSS

Water source transition by gender	Year of study (%)										
	1988	1989	1995	2000	2001	2006	2011	2016	2021	Net transition	Annual transition rate
Water source transition by gender											
Male											
Piped into dwelling			266 (4.70)	78 (2.80)	24 (0.80)	62 (1.00)	185 (3.00)	241 (1.80)	265 (1.9)	−2.8	−0.11
Improved sources			2,856 (50.70)	1,836 (66.50)	1,684 (58.20)	4,195 (68.50)	4,433 (70.80)	10,230 (75.7)	11,234 (80.66)	29.96	1.15
Unimproved sources			2,509 (44.60)	845 (30.60)	1,183 (40.90)	1,868 (30.50)	1,642 (26.20)	3,037 (22.50)	2,429 (17.44)	−27.16	−1.04
Female											
Piped into dwelling			89 (4.60)	16 (1.40)	5 (0.50)	35 (1.30)	82 (3.00)	132 (2.20)	211 (2.79)	−1.81	−0.07
Improved sources			953 (49.80)	804 (71.60)	702 (63.80)	1,886 (68.70)	2,001 (72.20)	4,781 (78.60)	5,698 (75.34)	25.54	0.98
Unimproved sources			873 (45.60)	303 (27.00)	393 (35.70)	824 (30.00)	690 (24.90)	1,167 (19.20)	1,654 (21.87)	−23.73	−0.91
Water source transition by access to electricity											
No											
Piped into dwelling	3 (0.1)	3 (0.3)	66 (1)	6 (0.2)	2 (0.1)	3 (0)	29 (0.4)	27 (0.2)	24 (0.17)	−0.07	0.00
Improved sources	2,110 (66.5)	573 (57.7)	3,262 (49.6)	2,091 (65.4)	2,022 (57)	5,423 (67.4)	5,181 (69.8)	10,976 (76)	9,898 (70.48)	3.98	0.12
Unimproved sources	1,060 (33.4)	417 (42)	3,243 (49.4)	1,099 (34.4)	1,522 (42.9)	2,625 (32.6)	2,211 (29.8)	3,440 (23.8)	4,122 (29.35)	−4.05	−0.12
Yes											
Piped into dwelling	88 (17.6)	8 (12.5)	288 (29.6)	88 (12.9)	27 (6.3)	94 (11.5)	238 (14.8)	346 (6.7)	446 (8.23)	−9.37	−0.28
Improved sources	380 (76.00)	49 (76.60)	547 (56.2)	546 (80.1)	353 (81.9)	658 (80.3)	1,253 (77.7)	4,035 (78.4)	4,286 (79.11)	3.11	0.09
Unimproved sources	32 (6.4)	7 (10.9)	138 (14.2)	48 (7)	51 (11.8)	67 (8.2)	121 (7.5)	764 (14.8)	686 (12.66)	6.26	0.19

Positive (+) signifies an increase.
Negative (−) signifies a decrease.

male-headed HH. This is consistent with previous studies that found that a female-headed HH had a higher probability of transitioning to improved sources (Mulenga *et al.* 2017; Abubakar 2021). On the other hand, the study found that HH access to electricity influences a HH transition in DWSS options. Households connected to electricity exhibited the highest transition rate for the DWSS option of piped water connected into the dwelling while those without electricity showed that they were more associated with transitions in the DWSS option of improved sources. Accordingly, the gender of the household head and access to electricity are important factors in understanding transitions of DWSS options in Uganda. The findings agree with those of Simelane *et al.* (2020) and Abubakar (2019).

Household wealth

The DHS uses a composite measure to estimate the wealth index of a household. The wealth index is computed based on easy-to-collect data obtained from the household on materials used for housing construction; ownership of selected assets, such as bicycles and televisions; and types of water supply and sanitation facilities (Rutstein & Staveteig 2013). The impact of HH wealth on the transition in DWSS options was investigated using the Uganda Domestic Household Survey based on five wealth quintiles: lowest, second, middle, fourth and highest. As shown in Table 7, the HH wealth (χ^2 (10) = 3,700, $p = 0.000$) significantly influences transition in DWSS options. Table 7 indicates a significant relationship between household wealth and DWSS (χ^2 (40) = 16,540.3, $p = 0.001$).

The highest transition in the DWSS option was observed in improved water sources and unimproved sources for an increase and reduction, respectively, across all wealth classes. In contrast, the least transition was observed in the DWSS option of piped water into the dwelling with the wealthiest HH exhibiting the highest transition probability. The likely reason for this contrast is that whereas piped water into premises is the sole responsibility of the HH head, getting improved water sources has been largely the preserve of the government. In addition, wealthier HHs have all the resources at their disposal required to fund their luxurious lifestyles. This corroborates the findings of those who found that wealthier HHs were

Table 7 | Influence of wealth on the transition between HH DWSS

Water sources transition by HH wealth	2006	2011	2016	2021	Net transition	Annual transition rate
Lowest						
Piped into dwelling	0 (0)	0 (0)	0 (0)	0 (0)	–	–
Improved sources	1,435 (67)	1,502 (74.5)	3,573 (78.9)	4,265 (86.14)	19.14	1.28
Unimproved sources	708 (33)	515 (25.2)	955 (21.1)	686 (13.86)	−19.14	−1.28
Second						
Piped into dwelling	0 (0)	2 (0.1)	3 (0.1)	6 (0.13)	0.13	0.01
Improved sources	1,128 (64.5)	1,039 (65.4)	2,836 (71.7)	3,463 (77.13)	12.63	0.84
Unimproved sources	621 (35.5)	547 (34.4)	1,116 (28.2)	1,021 (22.74)	−12.76	−0.85
Middle						
Piped into dwelling	0 (0)	0 (0)	8 (0.2)	9 (0.22)	0.22	0.01
Improved sources	958 (61.6)	894 (61.7)	2,511 (69.7)	3,212 (77.51)	15.91	1.06
Unimproved sources	598 (38.4)	554 (38.3)	1,083 (30.1)	923 (22.27)	−16.13	−1.08
Fourth						
Piped into dwelling	1 (0.1)	4 (0.3)	9 (0.2)	12 (0.33)	0.23	0.02
Improved sources	1,018 (67.9)	1,087 (71.1)	2,790 (77.1)	3,012 (81.91)	14.01	0.93
Unimproved sources	481 (32.1)	437 (28.6)	822 (22.7)	653 (17.76)	−14.34	−0.96
Highest						
Piped into dwelling	96 (5)	261 (10.6)	353 (9.1)	389 (10.58)	5.58	0.37
Improved sources	1,542 (80.2)	1,912 (78)	3,301 (85)	3,211 (87.33)	7.13	0.48
Unimproved sources	284 (14.8)	279 (11.4)	228 (5.9)	189 (5.14)	−9.66	−0.64

Positive (+) signifies an increase.
Negative (−) signifies a decrease.

likely to have improved DWSS options in contrast to their poorer counterparts who are locked into unimproved HH DWSS (Adeoti & Fati 2020; Boing *et al.* 2021). Quite often these poorer HHs wait for government-aided transitions in contrast to their wealthier counterparts who rely on both government and self-funded and aided transitions. Furthermore, the costs for piped water into residences that require high investment and operation and maintenance costs cannot easily be afforded by most communities. In addition, recent investments in the sector have been biased towards improved sources that were perceived to be cheaper and can be managed by the communities. With the recent introduction of the SDGs, the focus is now on piped water into a dwelling, and this is expected to accelerate progress in achieving piped water into dwellings.

PREDICTORS OF HH TRANSITIONS IN DWSS

The transitions in DWSS were investigated across socio-demographic and housing characteristics of respondents across regions in a multinomial logistic regression. The transition in DWSS was represented by three categorical levels following the SDG structures; unimproved DWSS (lowest), improved DWSS (middle level) and piped into a dwelling which according to this study is regarded as the highest.

The marginal effects of each level were used to determine the percentage change in the probability of transitioning between a given level of DWSS given a unit change in each of the independent variables that are socio-economic characteristics. Table 8 presents the results of the ordered probit model for predictors or the estimated marginal effects (dy/dx) of HH transitions in DWSS.

Marginal effects evaluate the impact of a change of a variable on the results while maintaining other variables constant. Estimated marginal effects (dy/dx) were adopted in the study, as widely applied to understand determinants of changes between any categorical levels in many studies (e.g. Kisaakye *et al.* 2021; Sempewo *et al.* 2021a, 2021b) and because it offers an intuitive economic meaning (Hilmer & Hilmer 2014). The p-value presents the statistical significance of the overall model at a 99% degree-of-confidence level.

Results of the ordered probit model (Table 8) show that all factors are statistically significant except the ratio of rooms to HH size, number of HH members and the age of the HH head in influencing the probability of the HH transitioning to a different level of DWSS.

The current findings differ from those of Brown *et al.* (2008) who found that changes in the socio-economic regime influenced transitions in water-system options hence concluding that transitions are a socio-technical problem.

Results in Table 8 show that holding all other predictors constant, access to electricity additively increases the probability of transitioning to a DWSS of piped water into a dwelling by 13.2%. In addition, access to electricity additively increases the probability of transitioning to a DWSS of an improved water source by 1.4%. Overall access to electricity appears to give a higher chance of transitioning to piped water into dwelling DWSS as compared with an improved DWSS (Flörke *et al.*

Table 8 | Model estimates for predictors that influence HH transitions in DWSS

Independent variable	Unimproved water		Improved water		Piped into dwelling	
	dy/dx	***p*-value**	***dy/dx***	***p*-value**	***dy/dx***	***p*-value**
Has electricity	−0.16436	0.000	0.01394	0.000	0.132428	0.000
Wealth index	−0.06125	0.000	0.00571	0.000	0.05433	0.000
Education level of household head	−0.05163	0.000	0.00472	0.000	0.04491	0.000
Type of toilet facility	−0.04123	0.000	0.00388	0.000	0.036869	0.000
Sex of household head	−0.03552	0.000	0.00328	0.000	0.031238	0.000
Ratio of rooms to household size	−0.01544	0.027	0.00136	0.029	0.012987	0.027
Size of agricultural land	−0.00433	0.000	0.0003	0.000	0.002934	0.000
Number of household members	−0.00018	0.871	0.00001	0.871	0.000152	0.871
Age of household head	−0.00015	0.23	0.00001	0.232	0.000125	0.232
Number of rooms for sleeping	0.03312	0.000	−0.00305	0.000	−0.02898	0.000
Has bicycle	0.04645	0.000	−0.00428	0.000	−0.04067	0.000
Has radio	0.04679	0.000	−0.00445	0.000	−0.04233	0.000

2013; Zhang *et al.* 2019). This is consistent with the findings of Dongzagla (2022) and Abubakar (2019), who found that access to electricity increases the likelihood of a household using improved water sources.

Similarly, wealth tends to additively increase the probability of transitioning to a DWSS of piped water into a dwelling by 5.4%, which is lower than expected. A likely explanation for the low percentage is the difficulty in accurately measuring wealth from informal economic activities that are predominant in low-income countries. For example, using ownership of bicycles and radios can be misleading, glossing over the different bands of the commodities used such as radios varying from $5 to $2,000 which are all taken as a single indicator. On the other hand, wealth also tends to additively increase the probability of transitioning to a DWSS of an improved water source by 0.6%. These findings corroborate those of Adams *et al.* (2016), Mulenga *et al.* (2017) and Abubakar (2019) who found that a wealthier HH is more likely to afford improved DWSS. This finding may be explained by the fact that wealth tends to positively correlate with having the resources required to afford piped water into a dwelling owing to the high water-demand required to meet an affluent lifestyle (Madanat & Humplick 1993).

The study findings also show that the education level of the HH head is associated with a HH transitioning to a different level of DWSS. With all other variables constant, the level of education tends to additively increase the probability of transitioning to a DWSS of piped water into a dwelling by 4.5% in contrast to 0.5% for transitioning to a DWSS of an improved water source. This is consistent with the findings of Abubakar (2019), who found that an increase in the level of education raises the likelihood of a household using improved water sources. Education not only improves the household capacity to transition to a higher-level DWSS, but it also empowers the HH head in terms of water literacy. For example, Gebremichael *et al.* (2021) argue that there is a difference between how the literate and the illiterate perceive and handle water. Education is also considered a proxy for the socio-economic status of a household (Desai & Alva 1998). Hence, education is a key ingredient in accelerating progress towards transitioning between DWSS options. To accelerate progress in the transition between DWSS options, there is a need to enhance the education of communities and water literacy, which will help break the barriers to the adoption of new DWSS options as postulated by Grant (2017), who argues that education empowers communities to respond to the SDGs.

The model results, in addition, showed a significant relationship between the type of toilet facility and the HH transitioning to a different level of DWSS. The findings show that holding other factors constant, the type of HH toilet facility tends to additively increase the probability of transitioning to a DWSS of piped water into a dwelling by 3.7% in contrast to 0.4% for transitioning to a DWSS of an improved water source.

The study findings also show that the sex of a HH head is a strong predictor of a HH transitioning to a different level of DWSS. The findings indicate that holding other factors constant, male-headed HHs tend to additively increase the probability of transitioning to a DWSS of piped water into a dwelling by 3.1% in contrast to 0.3% for transitioning to a DWSS of an improved water source. This is attributed to the fact that Uganda is one of the countries that practice a patriarchy system where males more than females are more likely to access and control resources that can then be translated into the ability to finance transitioning. Conversely, female-headed households tend to be associated with lower levels of DWSS options. These findings corroborate those of Bonabana-Wabbi (2002), who found that male-headed households are more likely to have access to an improved source of water compared with female household heads. The findings contradict those of Adams *et al.* (2016), Mulenga *et al.* (2017) and Abubakar (2019), who found that female-headed households are more likely to adopt improved innovations. The role of gender in the elimination of barriers in transitioning between DWSS options is documented (Mulenga *et al.* 2017; Adeoti & Fati 2020; Behera *et al.* 2020).

The present analysis also demonstrates that the ratio of rooms to household size positively increases, but not significantly (only at a 95% level of significance), the probability of transitioning to a DWSS of piped water into a dwelling by 1.3% in contrast to 0.1% for transitioning to a DWSS of an improved water source. The findings corroborate those of Adams *et al.* (2016) who found that a household with more rooms increased the probability of using improved DWSS by around 9%. The ratio of rooms to HH size shows the level of congestion in a home and is also an indicator of the financial ability to resource the desired transition between DWSS options. Number of rooms is a proxy for rural area households that have more rooms, and hence are more capable of accommodating a transition to improved water sources because of their more modest available incomes, compared with urban areas whose incomes have more items to spend on.

The results also show a significant relationship between the size of agricultural land and the HH transitioning to a different level of DWSS. The findings show that holding other factors constant, the size of agricultural land tends to additively increase the probability of transitioning to a DWSS of piped water into a dwelling by 0.3%. In agricultural societies of which Uganda is one the size of agricultural land is more likely to demonstrate access and control resources that can then be translated into resources to fund transitioning between options. Moreover, land could be a critical requirement for the construction of a DWSS option.

The size of the HH positively increases, but not significantly, the HH probability of transitioning to a different level of DWSS. With all other variables held constant, having more HH members compared with fewer HH positively but not significantly decreases the probability of a HH transitioning to a different level of DWSS. This finding contrasts with the results of Adams *et al.* (2016) and Abubakar (2021), who found that larger households showed a significantly higher probability of using improved DWSS. This result may point to the connection between smaller families and household transition between DWSS options. A possible reason is that smaller household size is associated with the education level of the HH head, and therefore, higher income levels making smaller households not only interested in but also having the resources to bankroll the transition between DWSS. On the other hand, increased population accelerates the pace at which current facilities are outstripped their capacity to meet population demand.

Lastly, the model results still show a significant relationship between the number of rooms for sleeping, owning a bicycle and radio, and the HH transitioning to a different level of DWSS. The findings show that holding other factors constant, number of rooms for sleeping, owning a bicycle and radio tend to reduce the probability of transitioning to a DWSS of piped water into a dwelling by 2.9%, 4.07% and 4.23%, respectively, in contrast to 0.3%, 0.4% and 0.4% for transitioning to a DWSS of an improved water source. These results contrast with those of Abubakar (2021), who found that an increase in rooms increases the probability of transitioning from a DWSS to an improved water source. However, the factors that have been used are a proxy for HH wealth which also has its challenges such as owning a radio having been overtaken by innovation and communication technology advances that have made it easy for most HH to have a radio via their phones. A likely explanation for the reduction in the proportion of HH access to safe water is that progress made in accelerating access to safe water is being outstripped by rapid population growth as postulated by Wang *et al.* (2022) and Thomas-Possee (2023).

CONCLUSIONS

Providing improved access to drinking water supply systems is key to improving socio-economic development and contributing to poverty development. This study contributes to our understanding of household socio-economic characteristics associated with the transition in drinking water systems for developing economies. The study is essential in informing the acceleration of the pace of shifting the proportion of people using safely managed drinking water services as highlighted by the United Nations Sustainable Development Goal No. 6.

Panel data regression analysis results based on at least six rounds of household data show that socio-economic attributes influence the probability of transitioning a HH to a different level of DWSS. The results indicate that the sex of the household head, education level of the household head, type of toilet facility, access to electricity, size of agricultural land and wealth index are some of the drivers that can significantly positively trigger and sustain the transition of drinking water service systems. On the other hand, the number of rooms for sleeping, owning a bicycle and radio tend to reduce the probability of transitioning to a DWSS of piped water into the dwelling.

The aforementioned overarching factors are proxies of income or wealth which can be used to measure a community's ability to pay for services. However, wealth used to measure this is criticised for not being a good and representative measure as it is based on ownership of property and items such as bicycles and radio, which can be misleading because it does not take into account the values of the different properties being owned. Nonetheless as found in previous studies (Irianti *et al.* 2016) wealth is significantly associated with a transition in DWSS. This places into focus the need to address the inequalities in developing economies such as Uganda.

From a policy perspective, the results suggest that the speed in the transition in the proportion of people changing from a lower-level to a higher-level drinking water service system option in Uganda will be enhanced if additional attention is given to the attendant household socio-economic factors as well, such as sex of household head, education level of household head, type of toilet facility, access to electricity, radio, bicycle, number of rooms for sleeping, size of agricultural land and wealth index. This therefore calls for government to complement funding in the development of water infrastructure by paying attention to the attendant socio-economic attributes of the intervention area such as increasing access to education. The findings suggest that accelerating transitions in DWSS will be a challenge in developing economies if no attention is placed on dealing with the disparity in socio-economic attributes associated with HH.

The study also contributes to the debate on accelerating progress towards attaining Target 1 of SDG 6, providing an evidence-base for the need to focus on inequalities among communities in developing economies as a first step towards accelerating progress towards the achievement of the SDG 6 target that aims to achieve universal access to safe and affordable drinking water for all by 2030. The recent and ongoing global shocks such as COVID-19, climate change and geopolitical tensions have exacerbated the inequalities (UN 2021). All available dissemination channels should be utilised to deliver this important message to practitioners, policy-makers and politicians, that reducing inequalities within different sections of society will enhance transitions to better DWSS. Certainly, not only attaining but accelerating progress towards Target 1 of SDG 6 will be a challenge for developing economies if no attention is placed on addressing the disparity in socio-economic attributes associated with accelerating progress in the transition in levels of DWSS options.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

REFERENCES

Abubakar, I. R. 2019 Factors influencing household access to drinking water in Nigeria. *Utilities Policy* **58**, 40–51.

Abubakar, I. R. 2021 Understanding the socioeconomic and environmental indicators of household water treatment in Nigeria. *Utilities Policy* **70**, 101209.

Adams, E. A., Boateng, G. O. & Amoyaw, J. A. 2016 Socioeconomic and demographic predictors of potable water and sanitation access in Ghana. *Social Indicators Research* **126**, 673–687.

Adeoti, O. & Fati, B. O. 2020 Barriers to extending piped water distribution networks: the case of Ekiti State, Nigeria. *Utilities Policy* **63**, 100983.

Arouna, A. & Dabbert, S. 2010 Determinants of domestic water use by rural households without access to private improved water sources: a seemingly unrelated Tobit approach. *Water Resources Management* **24**, 1381–1398.

Behera, B., Rahut, D. B. & Sethi, N. 2020 Analysis of household access to drinking water, sanitation, and waste disposal services in urban areas of Nepal. *Utilities Policy* **62**, 100996.

Bischoff-Mattson, Z., Maree, G., Vogel, C., Lynch, A., Olivier, D. & Terblanche, D. 2020 Shape of a water crisis: practitioner perspectives on urban water scarcity and 'Day Zero' in South Africa. *Water Policy* **22** (2), 193–210.

Bonabana-Wabbi, J. 2002 *Assessing Factors Affecting Adoption of Agricultural Technologies: The Case of Integrated Pest Management (IPM) in Kumi District, Eastern Uganda.* MSc thesis, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA.

Boing, A. F., Boing, A. C. & Subramanian, S. F. 2021 Inequalities in the access to healthy urban structure and housing: an analysis of the Brazilian census data. *Cadernos de Saúde Pública* **37**, e00233119.

Brown, R., Keath, N. & Wong, T. 2008 Transitioning to water sensitive cities: historical, current and future transition states. In: *11th International Conference on Urban Drainage*, 31 August–5 September, Edinburgh, Scotland.

Cameron, A. C. & Trivedi, P. K. 2005 *Microeconometrics: Methods and Applications*. Cambridge University Press, Cambridge, UK.

Cohen, B. 2006 Urbanization in developing countries: current trends, future projections, and key challenges for sustainability. *Technology in Society* **28** (1–2), 63–80.

Desai, S., Alva, S. 1998 Maternal education and child health: Is there a strong causal relationship? *Demography* **35** (1), 71–81. doi: 10.2307/3004028.

Dongzagla, A. 2022 Socioeconomic and demographic factors affecting urban household access to improved water and sanitation in Ghana. *GeoJournal* **87** (6), 4763–4773.

Gebremichael, S. G., Yismaw, E., Tsegaw, B. D. & Shibeshi, A. D. 2021 Determinants of water source use, quality of water, sanitation and hygiene perceptions among urban households in North-West Ethiopia: a cross-sectional study. *PLoS ONE* **16** (4), e0239502.

Flörke, M., Kynast, E., Bärlund, I., Eisner, S., Wimmer, F. & Alcamo, J. 2013 Domestic and industrial water uses of the past 60 years as a mirror of socio-economic development: a global simulation study. *Global Environmental Change* **23** (1), 144–156.

Fotue, L. A. T. & Sikod, F. 2012 Determinants of the households' choice of drinking water source in Cameroon. *Journal of Sustainable Development in Africa* **14** (3), 86–97.

Grant, C. 2017 *The Contribution of Education to Economic Growth*. K4D Helpdesk Report. Institute of Development Studies, Brighton, UK.

Greene, W. H. 2003 *Econometric Analysis*, 7th edn. Prentice Hall, NJ, USA.

Hilmer, C. E. & Hilmer, M. J. 2014 *Practical Econometrics: Data Collection, Analysis and Application*. McGraw-Hill Education, New York, USA.

Irianti, S., Prasetyoputra, P. & Sasimartoyo, T. P. 2016 Determinants of household drinking-water source in Indonesia: an analysis of the 2007 Indonesian family life survey. *Cogent Medicine* **3**, 1151143. http://dx.doi.org/10.1080/2331205X.2016.1151143.

Kisaakye, P., Ndagurwa, P. & Mushomi, J. 2021 An assessment of availability of handwashing facilities in households from four East African countries. *Journal of Water, Sanitation and Hygiene for Development* **11** (1), 75–90.
Madanat, S. & Humplick, F. 1993 A model of household choice of water supply systems in developing countries. *Water Resources Research* **29** (5), 1353–1358.
Mahama, A. M., Anaman, K. A. & Osei-Akoto, I. 2014 Factors influencing householders' access to improved water in low-income urban areas of Accra, Ghana. *Journal of Water and Health* **12** (2), 318–331.
Mulenga, J. N., Bwalya, B. B. & Kaliba-Chishimba, K. 2017 Determinants and inequalities in access to improved water sources and sanitation among the Zambian households. *International Journal of Development and Sustainability* **6** (8), 746–762.
Muris, C. 2016 Estimation in the fixed effects ordered logit model. Available at: https://ipl.econ.duke.edu/seminars/system/files/seminars/1448. Pdf (accessed 20 June 2023).
National Planning Authority 2020 *National Development Plan III (NDPIII), 2020/21–2024/25*. National Planning Authority, Kampala, Uganda.
Ozturk, I. 2001 The role of education in economic development: a theoretical perspective. *Journal of Rural Development and Administration* **33** (1), 39–47.
Olugbamila, O. B., Adeyinka, S. A., Odunsi, O. M., Olowoyo, S. A., Isola, O. L. & Adanlawo, T. D. 2020 Community participation in the provision of environmental sanitation infrastructure in Akure, Nigeria. *Environmental & Socio-economic Studies* **8** (3), 48–59.
Pullan, R. L., Freeman, M. C., Gething, P. W. & Brooker, S. J. 2014 Geographical inequalities in use of improved drinking water supply and sanitation across Sub-Saharan Africa: mapping and spatial analysis of cross-sectional survey data. *PLoS Medicine* **11** (4), e1001626. doi:10.1371/journal.pmed.1001626.
Rutstein, S. O. & Staveteig, S. 2013 Making the demographic and health surveys wealth index comparable. In: *27th IUSSP International Population Conference*, 26–31 August, BEXCO, Busan, Korea. Available from: https://iussp.org/sites/default/files/event_call_for_papers/ComparativeWealth-DRAFT-IUSSP.pdf (accessed 3 June 2023).
Sempewo, J. I. 2012 *Transitioning of Urban Water Distribution Systems*. PhD thesis, School of Civil Engineering, College of Engineering, University of Birmingham, Birmingham, UK
Sempewo, J. I. & Kyokaali, L. 2019 Comparative performance of regression and the Markov based approach in the prediction of the future condition of a water distribution pipe network amidst data scarce situations: a case study of Kampala Water, Uganda. *Water Practice and Technology* **14** (4), 946–958.
Sempewo, J. I., Mushomi, J., Tumutungire, M. D., Ekyalimpa, R. & Kisaakye, P. 2021a The impact of COVID-19 on households' water use in Uganda. *Water Supply* **21** (5), 2489–2504.
Sempewo, J. I., Kisaakye, P., Mushomi, J., Tumutungire, M. D. & Ekyalimpa, R. 2021b Assessing willingness to pay for water during the COVID-19 crisis in Ugandan households. *Social Sciences & Humanities Open* **4** (1), 100230.
Simelane, M. S., Shongwe, M. C., Vermaak, K. & Zwane, E. 2020 Determinants of households' access to improved drinking water sources: a secondary analysis of Eswatini 2010 and 2014 multiple indicator cluster surveys. *Advances in Public Health* **2020**, 6758513.
Thomas-Possee, M. L. H. 2023 *Domestic Drinking Water Availability in Sub-Saharan Africa: Investigating Drivers and Indicators*. PhD thesis, Faculty of Environmental and Life Sciences, University of Southampton, Southampton, UK.
Tuyet-Hanh, T. T., Lee, J., Oh, J., Minh, H. V., Lee, C. O., Hoan, L. T., Nam, Y. & Long, T. K. 2016 Household trends in access to improved water sources and sanitation facilities in Vietnam and associated factors: findings from the Multiple Indicator Cluster Surveys, 2000–2011. *Global Health Action* **9** (1), 29434. doi:10.3402/gha.v9.29434.
Uganda Bureau of Statistics 2016 *The National Population and Housing Census 2014 – Main Report*. Uganda Bureau of Statistics, Kampala, Uganda.
Uganda Water Supply Atlas 2017 Uganda Water Supply Atlas 2017. Ministry of Water and Environment, Kampala, Uganda. Available at: https://www.mwe.go.ug/library/water-supply-atlas-2017 (accessed 20 June 2023).
UNICEF and WHO 2017 *Progress on Drinking Water and Sanitation: 2017 Update*. World Health Organization, Geneva, Switzerland, and UNICEF, New York, USA.
UNICEF and WHO 2019 *Progress on Household Drinking Water, Sanitation and Hygiene 2000–2017, Special Focus on Inequalities*. World Health Organization, Geneva, Switzerland, and UNICEF, New York, USA.
UNICEF and WHO 2021 *Progress on Household Drinking Water, Sanitation and Hygiene 2000–2020: Five Years into the SDGs*. World Health Organization, Geneva, Switzerland, and UNICEF, New York, USA.
United Nations 2021 *The Sustainable Development Goals Report 2021*. United Nations, New York, USA.
Verbeek, M. 2004 *A Guide to Modern Econometrics*, 2nd edn. Wiley, Hoboken, NJ, USA.
Wang, Y., Huang, C., Wu, G. & Wang, W. 2022 Status and challenges of water resources and supply in the Guangdong-Hong Kong-Macao Greater Bay Area (GBA) of China. *Water Cycle* **3**, 65–70.
WHO/UNICEF 2020 The WHO/UNICEF Joint Monitoring Programme Estimates on WASH. Available at: http://washdata.org (accessed on 2 August 2022).
Zhang, T., Shi, X., Zhang, D. & Xiao, J. 2019 Socio-economic development and electricity access in developing economies: a long-run model averaging approach. *Energy Policy* **132**, 223–231.

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