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Water affordability analysis: a critical literature review

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ABSTRACT

Water and sanitation affordability has drawn researchers' attention over the past years due to the recent economic crisis and the growing role of tariffs on funding services. This paper conducted a systematic review of previous research on water and/or sanitation affordability and a critical qualitative discussion on the methodologies adopted. The research framework relied on a hybrid approach that combines systematic quantitative and narrative analyses. The literature review protocol applied returned 79 relevant studies published by journals and recognized international organizations and four key topics, namely affordability indicators, threshold, data source, and practical use of the analysis were identified and critically discussed. This paper contributes to the literature by presenting and discussing the most important water affordability issues and enlightening the potential role of the analysis in public financial policies.

Key words: affordability, infrastructure, public policy, sanitation access, tariff, water access

HIGHLIGHTS

- No consensus on a methodology or threshold for affordability analysis has been reached.
- Water bill and income are the most common data used in affordability analysis.
- Scarce and unreliable data are recurrent issues in developing countries, misleading affordability analysis.
- Affordability evaluation plays a crucial, but missing role in financial public policies.

1. INTRODUCTION

Water supply and sanitation services (WSS) involve multidisciplinary complex factors, such as social, cultural, technical, economic, and political ones. Millions of dollars are spent on health care due to low quality or lack of those services, since many countries are unable to provide water supply and sanitation due to technical challenges, cost of required infrastructure expansion and upgrades, and of operational and maintenance. An estimated 2.2 billion people worldwide do not have access to safe drinking water and 4.2 billion people do not have access to safe sanitation (WHO & UNICEF 2021a). Besides the lack of physical access, society has become aware of the growing affordability issue, since the pressure of tariffs for funding the infrastructure sector has increased (Reynaud 2016; Mack & Wrase 2017; Goddard *et al.* 2021). Costs for WSS connection, update of housing equipment, and payment of bills have become then a significant barrier for vulnerable families to benefit from water supply and sanitation.

Providing WSS services at an affordable price is included in Sustainable Development Goal (SDG) target 6.1, as several other human rights. As pointed out by WHO & UNICEF (2021b), SDG targets 6.1 and 6.2 will not be reached unless affordability can be measured and monitored towards recognizing the population with payment difficulties and acting more efficiently. However, the lack of a consensus definition or established methodology of affordability measurements has hampered progress evaluation locally and globally.

Although studies have focused on water affordability in low- and middle-income countries, international concerns over poor families based in richer nations have highlighted the burgeoning crisis worldwide (Sawkins & Dickie 2005; Martins *et al.* 2016; Mack & Wrase 2017; Goddard *et al.* 2021; Onda & Tewari 2021; Yoon *et al.* 2021; Meehan *et al.* n.d.). Studies of water and sanitation affordability have employed a great variety of approaches, according to available and scarce data and local socioeconomic contexts, in order to express the struggles faced by the population.

This paper aims to provide a comprehensive, holistic, and critical review of the methodologies of water and sanitation affordability measurements and the current affordability understanding by updating previous findings and crossing studies with multiple goals. It also identifies the main insights offered by the relevant literature, through a hybrid methodology including systematic quantitative review and narrative analyses (Jin & Wang 2016).

The literature review conducted provides readers with a better understanding of the limitations and advantages of the most used affordability indicators worldwide and discusses the different thresholds applied and the recurrent data availability problems. We observed that socioeconomic context plays a major role in the choice of the most appropriate indicator and threshold, and that application of affordability analysis in public financial policies deserves more attention and further research. Since this study is limited to the papers returned by the search methodology applied local successful examples from regulators or utilities around the globe might have been missed.

The paper is organized as follows. Section 2 describes the research methodology applied. Section 3 presents and discusses the main topics addressed by the studies. The final section provides the concluding remarks and suggestions for further research.

2. METHODS

This systematic review of water and sanitation affordability followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Protocols – PRISMA-P 2015 guidelines (Moher *et al.* 2016). PRISMA-P consists of a 17-item checklist for the preparation of a pragmatic protocol for systematic reviews. The main advantage of the method is the potential comparison between literature reviews and their replication. The methodology comprises several consecutive steps and can be adjusted to the author's objectives. The checklist proposed by PRISMA-P 2015 was adapted for the paper's purpose resulting in a six phases framework, as displayed in Figure 1.

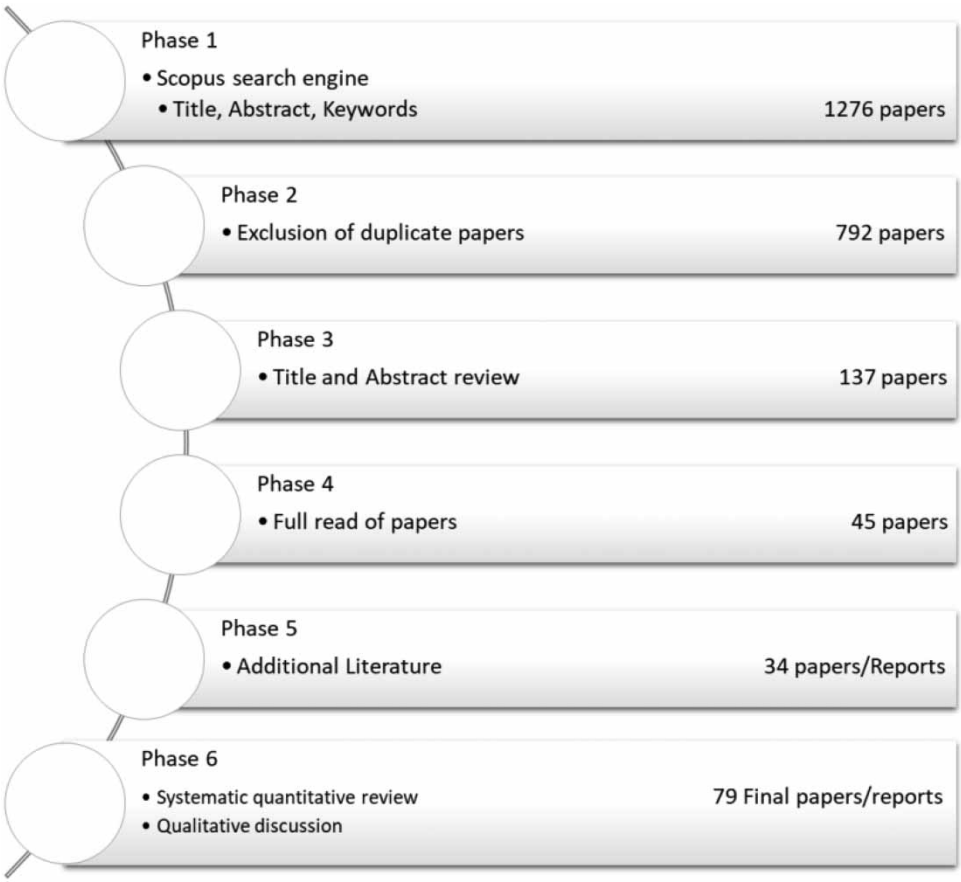

Figure 1 | Research framework based on titles, abstracts, and keywords.

The first phase searched papers based on title, abstract, and keywords. Scopus was selected as the primary search engine, as in previous studies (Pinto & Marques 2015; Fuente 2019; Lima *et al.* 2021; Machete & Marques 2021). No time restrictions were applied, and further discussion is based on all studies found until June 2022.

In order to reach the most relevant literature, we selected only books, book chapters, and journals written in English. The 24 keyword combinations displayed in Table 1 were based on this paper's main subject. The keywords for a literature review must be not only broad enough to encompassing all relevant studies, but adequately specific to produce a coherent group of advanced science.

In the second phase, duplicated papers were eliminated. Based on the title and abstract, the third phase removed papers not related to the main topic – water and/or sanitation affordability. The full reading of all studies, during the fourth phase, selected the papers that empirically or theoretically analysed affordability measurements. Additional relevant published works were identified through citations in the core literature (e.g., scientific papers not found in the previous steps, and technical reports from the World Bank, Organisation for Economic Cooperation and Development (OECD), American Water Works Association, European Bank for Reconstruction and Development, World Health Organization (WHO), and the United Nations). Finally, the sixth and last phase was devoted to a systematic quantitative review and qualitative critical analysis of the publications. The former showed the studies' geographical distribution, main journals, research groups' and case studies' countries. Power Business Intelligence software (Power BI, 2022) was used for the geographical distribution analysis. As displayed in Figure 1, from 1,276 papers initially found, the main findings from 79 papers and reports from international organizations are critically discussed. Papers that neither used types of affordability measurement, nor analysed the

Table 1 | Scopus search engine results

Search Number	Keywords			Results
1	Affordability	Wastewater	Access	11
2			Income	11
3			Vulnerable	2
4			Tariff	5
5		Water	Access	169
6			Income	123
7			Vulnerable	27
8			Tariff	55
9		Sanitation	Access	47
10			Income	29
11			Vulnerable	7
12			Tariff	10
13	Subsidy	Water	Access	184
14			Income	281
15			Vulnerable	44
16			Tariff	123
17		Wastewater	Access	6
18			Income	12
19			Vulnerable	4
20			Tariff	13
21		Sanitation	Access	58
22			Income	41
23			Vulnerable	7
24			Tariff	18
TOTAL				1,276

current methodologies were excluded – three empirical studies that did not mention the data source for affordability ratio calculation were also excluded. Reports from International Organizations were included due to their quantitative affordability analysis or critical qualitative discussion.

3. RESULTS AND DISCUSSION

3.1. Systematic quantitative review

The number of studies on water and sanitation affordability published in scientific and technical journals has increased in recent years. Research published from 2011 to 2021 includes 57 (72%) of the articles analysed, followed by 1999–2010 with 28% of relevant literature. This literature review revealed 37 journals published studies related to the topic – the leading journals in the publication of water and sanitation affordability are the *Utilities Policy*, *Journal of American Water Works Association*, and *Water Policy*. At the same time, the leading international organizations are the World Bank, OECD, and WHO (see Table 2).

Since the sample included worldwide research, Power BI tools we used for the geographical analysis for facilitating the visualization of quantitative data (see Figures 2 and 3). Figure 2 shows unlike the case studies (Figure 3), most studies were developed by research centres based in high-income countries. According to the results (Figure 3), African countries and Latin America may be worthwhile areas for future research, although data sources are still a challenge in low- and middle-income countries, as further discussed.

3.2. Critical qualitative discussion

The literature about water supply and sanitation affordability has become more frequent over the past years due to an economic crisis faced mostly by vulnerable families, and due to a (slow) path to full cost recovery tariff. Most studies returned by this systematic review are empirical, working with the scarce available data worldwide. A considerable variation in ratios, data sources, and thresholds used was observed and all those methodological dissimilarities hamper comparisons of countries, although affordability measurements should not be compared worldwide.

Nevertheless, governments must be aware of water affordability for targeting those that require public resources spending. As highlighted by Kessides *et al.* (2009), the methodology for such a calculation must take into account the local socioeconomic context, including the macroeconomic situation and available data. This section critically discusses measurement approaches separated by main topics.

Table 2 | Leading journals and organizations

Scientific papers	
Journal	**Number of studies**
Utilities Policy	5
Journal – American Water Works Association	4
Water Policy	4
Global Issues in Water Policy	3
Water Economics and Policy	3
World Development	3
Others	38
International reports	
Organization	**Number of studies**
The World Bank	6
OECD	4
WHO	4
Others	5

Figure 2 | Frequency and geographical distribution of research centres.

Figure 3 | Frequency and geographical distribution of case studies.

3.2.1. Affordability ratios

Among all the studies cited, the authors proposed a wide variety of affordability ratios. As shown in Figure 4, the numerators and denominators were distinct, reaching 15 ratio possibilities addressed elsewhere. Affordability indicators aim at quantifying the burden of a service or some good on families' budgets. The numerator expresses expenditure on services, whereas the

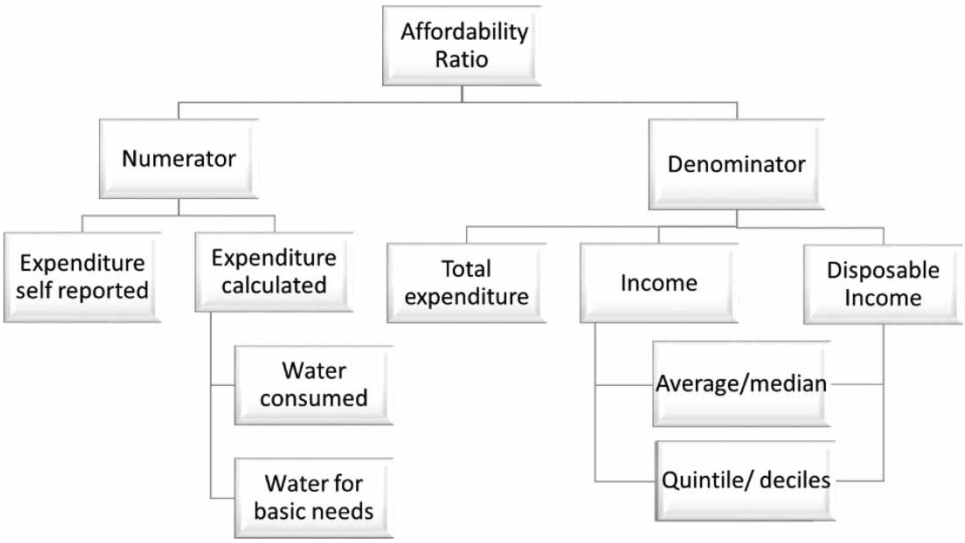

Figure 4 | Possibilities of affordability ratio.

denominator denotes the total budget or available income. Figure 5 shows the distribution of approaches adopted in the studies returned by the review.

As shown in Figure 5, 40.6% of the studies adopted water bills as a numerator for calculating the amount spent by families, and 35.9% used water expenditure – the actual value households are spending on WSS (or only on water services, as observed in 20 studies). Those 75.6% considered average consumption, unlike the 18.8% that used the volume of water for basic needs and the water tariff structure to calculate the numerator, or the 4.7% that considered families' self-reported spending for calculating a price for basic needs. Figure 5 also reveals that the denominator is slightly more standardized, since 65.5% of the studies used income, 15.5% adopted total expenditure, and 17.2% adopted disposable income. The different approaches applied by researchers were influenced by the available data and the context in which the study was conducted (such as low-income countries, rural, or urban areas), as discussed below.

3.2.1.1. Numerator. Part of the studies claimed that the main advantage of self-reported water expenditure is to bring in all the costs inferred to a household, including those from multiple paid – and commonly informal – resources. Self-reported

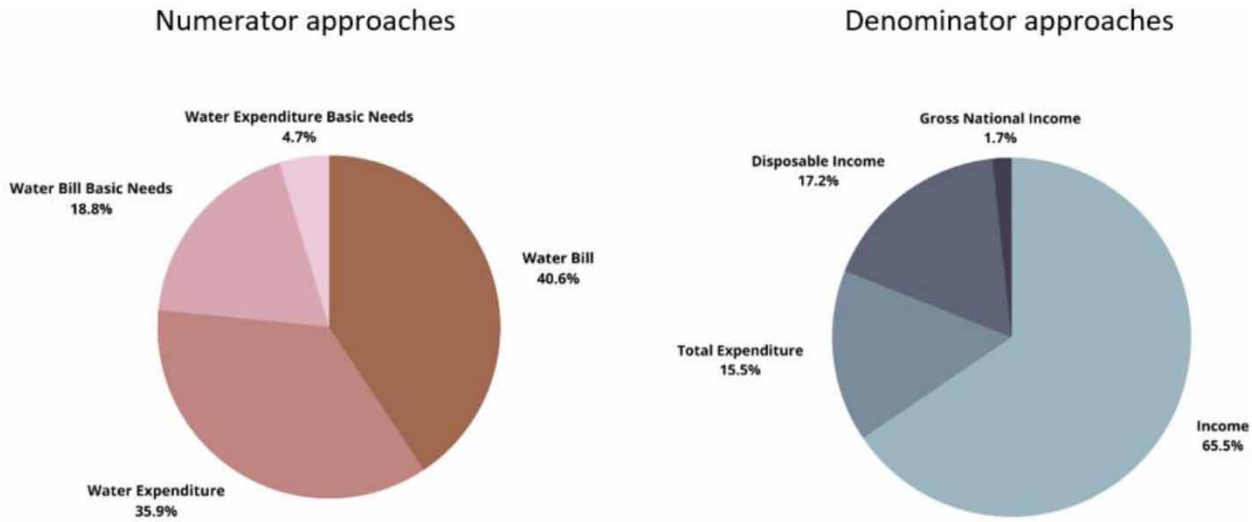

Figure 5 | Ratio approaches.

expenditure can also include a fraction of the coping costs (Pattanayak *et al.* 2005; Nastiti *et al.* 2017; Komarulzaman *et al.* 2019), which are costs not paid directly to the provider, but expended by users, not necessarily in cash, such as time travel, storage tanks, and extra treatment equipment (Cook *et al.* 2015). The value of time spent for obtaining WSS lacks consensus; however, researchers have advocated the inclusion of non-financial costs when analysing affordability to avoid technological options with low financial costs, but high coping costs (e.g., long journeys for obtaining the service) (WHO & UNICEF 2021b). As pointed out by Pattanayak *et al.* (2005), coping costs affect both connected and non-connected households, according to the local service quality. The authors empirically studied all coping expenditures related to irregular water supply in Nepal, in 2001, and concluded approximately 45% of the coping costs were due to the value of time spent on water collection, 10% resulted from pumping, and 2% referred to water purchase. Moreover, such costs could represent up to 1% of monthly income and were lower than estimates of willingness to pay (WTP) for improved services. Based on data from a 2012 household survey conducted in Indonesia, Nastiti *et al.* (2017) estimated the hidden mitigation costs of groundwater extraction and water boiling in three scenarios, of which the worst level included the groundwater extraction, storage, and boiling costs, and the best one the cost for water supply 24 h. The burden of proper water supply service in the lowest income group was the same as that of the current situation with all hiding mitigation costs (5.2%).

In addition, self-reported water expenditure depends on surveys (official or not) and, most importantly, their methodologies. Besides the cost of implementing regular expenditure surveys, they are always a sample from a whole population and depend on users' memories and perceptions. On top of that are the definitions of acceptable WSS that do not always match the acceptable levels of the United Nations (WHO & UNICEF 2021a). In addition, a one-time interview does not consider seasonal variations in services and goods consumption and in expenditure.

Self-reported water expenditure does not separate overconsumption from the essential or reasonable use of water, which can overestimate affordability ratios, misleading public action. The opposite way also applies, i.e., using microeconomic data from the 2015/2016 Portuguese Household Budget Survey, Martins *et al.* (2019) observed vulnerable families in Portugal were consuming less than a reasonable volume of water due to budget constraints, while their affordability ratio was below the established threshold. Vanhille *et al.* (2018) and Gawel *et al.* (2013) also highlighted the importance of identifying whether households prefer such a consumption bundle and face non-income constraints. Overconsumption cases can be either real overconsumption, due to a family choice, or overconsumption, due to inefficient water equipment (Sebri 2015; Vanhille *et al.* 2018), or large families – the latter two usually in poorer households.

Accurate measurement of affordability is particularly challenging in contexts where households have access to multiple sources of water, resulting in wide variations in service levels in terms of quality, distance, or reliability. Households lacking piped water connections on premises often rely on free sources, thus, falsely indicating that the water is affordable (Israel 2007; Komarulzaman *et al.* 2019). Describing this as 'hidden affordability', which affects 17.8% of Indonesian households, Komarulzaman *et al.* (2019) calculated a proxy value for water expenditures by multiplying the average local water price by the minimum water needs. The results showed that unserved families would spend 6.3% of their total expenditure on water if they were connected to the public piped network. Similarly, in areas where water utilities are highly subsidized, households do not bear the true cost of water and hence, their water expenditure may be below the affordability threshold (Andres *et al.* 2020).

The use of water bills or water tariff structures to calculate the service expenditure is easier for utilities and policymakers since data are available. However, the main disadvantage of the approach is the exclusion of non-connected households, which obtain their water from either free and questionable resources, or private vendors, who usually charge higher prices per cubic meter. Komarulzaman *et al.* (2019) reported 75% of Indonesian households do not have affordability problems, since the families do not pay for water, as they get from free resources and are not connected to the water supply network. Moreover, the non-financial costs are not translated to the analysis when the affordability ratio relies on utilities' bills or tariff structure.

For both calculation options of the numerator, policymakers struggle with a common problem, i.e., the unknown quality of service. Despite some useful international average prices, the health and environmental water and sanitation standards can vary among countries, and the affordability analysis does not capture quality – whether households are connected or not. When available, complementary information on providers' performance might be necessary to understand the context of affordability analysis, given that an affordable but inadequate service is not reaching SDG 6.

Concerning the water volume used in the affordability ratio calculation, researchers have proposed a minimum amount of water for basic needs (Miniaci *et al.* 2008; García-Valiñas *et al.* 2010a, 2010b; Gawel *et al.* 2013; Martins *et al.* 2013, 2019;

Barde & Lehmann 2014; Sebri 2015; Teodoro 2018; Vanhille *et al.* 2018; Borja-Vega *et al.* 2019; Komarulzaman *et al.* 2019; Mastracchio *et al.* 2020; Balazs *et al.* 2021; Goddard *et al.* 2021). Instead of water expenditure or average water bill, those studies analysed the burden on families from a minimum volume perspective, avoiding over or under-consumption. Although no consensus has been reached on the value, discussions surround the amount of water necessary for surviving and that required for regular life, including, for example, laundry. Such volume varied among the studies. American researchers used values from California and Texas authorities' recommendations – around 189 litres per capita per day (lpcd) for indoor use (Teodoro 2018) and Balazs *et al.* (2021) and Goddard *et al.* (2021) appropriated the available and regular information for 600 cubic feet in California, i.e., around 140 lpcd. European case studies used 100 lpcd (García-Valiñas *et al.* 2010a, 2010b; Vanhille *et al.* 2018). Martins *et al.* (2013), for instance, calculated affordability ratios with 40 lpcd, and for the first tariff block in Portugal. In Peru's case, the volume was 70 lpcd (Barde & Lehmann 2014). Some studies preferred mathematical water demand functions to find out the basic water volume for a normal life (García-Valiñas *et al*. 2010; Sebri 2015; Reynaud 2016). Based on a Stone-Geary utility function, García-Valiñas *et al.* (2010) estimated a minimum of 128 m^3 per year as appropriate for Southern Spain municipalities. Among the studies, the demand varied from as low as 7.5 lpcd in Cambodia (Chamberlain & Sabatini 2014), up to 378 lpcd in the United States (Mack & Wrase 2017), and 320 lpcd in Canada (Janzen *et al.* 2016).

The topic is far from being a consensus among public authorities, utilities, or academics. As highlighted by several authors, the acceptable minimum consumption relies on local climate, culture, socioeconomic conditions, and water availability, thus hampering the establishment of a worldwide value. WHO recommends 20 lpcd as a minimum amount in case of scarcity, 50 lpcd as an intermedium amount with low health risk, and 100 lpcd as an optimum value, with very low health risk (Howard & Bartram 2003). Although the importance of affordability for water basic needs has been lit up, only 12% of the studies compared the current affordability situation with the one using basic needs volume (García-Valiñas *et al.* 2010; Gawel *et al.* 2013; Sebri 2015; Vanhille *et al.* 2018; Borja-Vega *et al.* 2019; Komarulzaman *et al.* 2019; Martins *et al.* 2019).

3.2.1.2. Denominator. The denominator of an affordability indicator expresses the household's budget and can be either total expenditure or income. Some studies stated income data should be as reliable as possible, embracing seasonal, variable, and informal income, which is a common situation in low-income countries (Fankhauser & Tepic 2007; Andres *et al.* 2020).

Some researchers choose total expenditure over income (Fankhauser & Tepic 2007), since the former includes all families' spending, and it might be a better way to express the local living expenses faced by families. However, total expenditure may be inaccurate due to its dependence on household members' memories and on the period during which the survey was carried out. As an example, the total expenditure during the pandemic was probably very distinct from that of a normal lifetime, and the expenditure also can vary throughout the whole year. Another issue is related to savings and families' choices. Many surveys do not take into account the family's savings in the total expenditure information, neither the services chosen by users as their payment priority. In other words, the survey methodology largely affects the results, when it comes to total expenditure, as mentioned earlier. Andres *et al.* (2020) and Hutton (2012) recommend the use of income over total expenditure if the available data are sufficiently reliable.

As for income, some researchers have started to discuss the use of disposable income as a realistic indicator of user's ability to pay (Reynaud 2010; Gawel *et al.* 2013; World Bank 2014; Teodoro 2018; WHO & UNICEF 2021b). Teodoro (2018) considered disposable income the total income minus costs of taxes, housing, food, medicine, health care, and home energy, since, according to them, those services are as important as WSS for a regular life (Gawel *et al.* 2013). OECD (2003) suggests a procedure to express household incomes on a per equivalent adult basis, assigning a higher weight to the first adult in a household, lower values to subsequent adults or non-dependent children, and still lower values to each dependent child. The recommendation is based on the fact some housing costs do not increase proportionately in larger households and children's needs are generally lower than adults' ones.

Discussions about gross or disposable income rely on the fact affordability is the ability to pay for a service without jeopardizing access to other essential goods. Therefore, from a public policy point of view, the whole situation faced by the population must be considered. Unfortunately, no consensus on what a minimum basket of services should be has been reached, which defines the heart of the affordability issue, since households must have access to all essential services (e.g., health, education, housing, energy, and heating), and goods at an affordable price. Researchers, governments, and other stakeholders have struggled to propose basic guidelines on the topic; however, it is still an area for further research. Since the

purchasing power varies greatly even within a country, the definition of affordable service would involve multiple sectors and specific surveys, with close attention to poorer households (WHO & UNICEF 2021b).

More important than discussions on gross or disposable income is the fact results are very different when the analysis is specific for the poorest households. Studies have introduced the use of quintiles or deciles for deeper analysis of poorer families' situations. According to the literature review conducted, 53% of the studies included vulnerable families in the affordability analysis (Carlos *et al.* 2002; Al-Ghuraiz & Enshassi 2005; Sawkins & Dickie 2005; Fankhauser & Tepic 2007; Israel 2007; Mahmood & Sharma 2009; OECD 2010; Wang *et al.* 2010; Gawel *et al.* 2013; Hoque & Wichelns 2013; Martins *et al.* 2013; Barde & Lehmann 2014; Chan 2015; Mack & Wrase 2017; Nastiti *et al.* 2017; Walter *et al.* 2017; Burt *et al.* 2018; Teodoro 2018; Vanhille *et al.* 2018; Borja-Vega *et al.* 2019; Cardenas & Whittington 2019; Yoon *et al.* 2019; Andres *et al.* 2020; Leflaive & Hjort 2020; López-Ruiz *et al.* 2020; Mastracchio *et al.* 2020; Goddard *et al.* 2021; Onda & Tewari 2021; Patterson & Doyle 2021; Zhang *et al.* 2022).

Although some governments use average income, the information provided can mask the real affordability problem at a vulnerable population level. Especially if the country shows high inequality, the average income as a denominator does not alert policymakers on the affordability issues faced by poorer families. As an example, 62% of the studies in this literature review reported affordability issues, and in 100% of those cases, poorer families were struggling to pay their water bills.

According to OECD (2003), macro affordability indicators are developed by relating national average household water charges to either average household income or expenditure. Alternatively, micro affordability indicators disaggregate the former by income groups, family types, or regions. The study also states in half the OECD countries, water affordability for low-income families either is a current issue or may become one.

Martins *et al.* (2016) used disaggregated household level data from a questionnaire-based survey performed in 2012 in Portugal to assess micro water affordability and concluded macro measures masked serious affordability issues for vulnerable households. The self-reported households' income was matched with water bill information provided by utilities. While the macro affordability ratio for the whole sample (1.9%) suggested the absence of affordability issues, it was above the 3% threshold for the lowest income group. In addition, for the second lowest income group, the 2.3% affordability ratio hid 21.6% of households faced an affordability ratio above the 3% threshold.

3.2.2. Data source

WSS traditionally carry data problems, especially considering all their dimensions, namely social, technical, political, and economic. Information is either missing or controversial among the stakeholders involved (López-Ruiz *et al.* 2020). The literature review showed 68% of the studies used National Official Surveys for income or total expenditure information for the affordability ratio denominator. Almost 20% carried out their own interviews, and around 12% adopted international data, as in this paper, reports from the World Bank, OECD, and the United Nations were included. Regarding the numerator, almost 75% of the studies used data from National or State level Surveys, Utility databases, or regulatory authorities' reports, and around 19% employed water expenditure from their own questionnaires, due to lack of data. Studies often mixed different data sources to reach their goal, due to a lack of national or local official robust information.

Scarce or non-existent data are recurrent in low- and middle-income countries. All the studies, except one (Martins *et al.* 2016), that applied interviews were conducted in those countries (Al-Ghuraiz & Enshassi 2005; Wang *et al.* 2010; Gawel *et al.* 2013; Mason 2014; Nastiti *et al.* 2017; Walter *et al.* 2017; Burt *et al.* 2018; Acey *et al.* 2019; Cardenas & Whittington 2019; Hoque & Hope 2020). Although international organizations, such as the World Bank and the United Nations, have attempted – with some success – to influence the standardization of national surveys, they still face difficulties to benchmark results worldwide (WHO & UNICEF 2021b). Studies also faced problems with the frequency of official data, given that some countries do not produce regular census surveys, leading to outdated information (Lee 2011; Hutton 2012). Even though non-official surveys may be useful as a complementary source to affordability analysis, they are infrequently conducted and might not be publicly available (WHO & UNICEF 2021b). Carlos *et al.* (2002) evaluated inequities in water access in 11 countries of Latin America and the Caribbean, using different official available data and recommended countries should improve their surveys to facilitate national establishment of more equitable subsidy programs. Narzetti & Marques (2020) also faced data availability problems benchmarking models of subsidies for WSS in South American countries, especially in Brazil, Paraguay, and Argentina. The authors found that price discrimination was assigned according to the socioeconomic characteristics of customers or consumption levels, which make data accuracy even more crucial.

3.2.3. Threshold

Policymakers rely on benchmarks to compare and judge results from affordability analysis and evaluate whether the tariff is affordable. Many organizations and governments have suggested different thresholds to classify WSS service as affordable, such as 3–5% by the World Bank, 5% by Asian Development Bank, 2.5% by the United States Environmental Protection Agency, and 3% by OECD.

According to the literature review, 90% of the studies that used some threshold to classify tariff affordability varied the percentage between 2 and 5%. Some used higher thresholds, considering the country's average income, such as in the USA (Teodoro 2018; Mastracchio *et al.* 2020) or that the suggested poorer population is likely to spend higher proportions of their income on infrastructure services, with a case study of Cambodia (Chamberlain & Sabatini 2014; Teodoro 2018; Mastracchio *et al.* 2020). Martins *et al.* (2019), for instance, adopted 10, 15, and 20% threshold, since their evaluation included joint affordability for electricity, water, and communication services in Portugal.

However, establishing a limit for expenditure on WSS may be too inflexible for a situation with such context – scarce data, growing need for investments, and interdependency with other sectors. If the affordability ratio is 3.2%, for example, it may be affordable, especially if other local expenses have a reasonable impact on families' budgets. As discussed elsewhere, since affordability aims to maintain the ability to pay for all essential needs, the analysis is highly dependent on local reality (Banerjee & Morella 2011; Andres *et al.* 2020; Hoque & Hope 2020; Pierce *et al.* 2021). High-income localities with affordable living costs may not face water affordability problems if they spend 6% of their budget on WSS bills. Contrastively, some vulnerable families may struggle to spend as little as 2% of their income if the other essential services and goods are high in a broader context.

Although with no consensus, the use of a threshold (or a range) might be useful for the capture of local or regional affordability situations, such as the proportion of families above a specific threshold (or range). If the affordability problem is faced by a few households, policymakers and regulators may use cross-subsidy, social tariffs, or even direct subsidies to overcome the situation. On the contrary, localities with high percentages of poor families pose different challenges to governments, such as rethinking the public infrastructure financial policy or even improving social programs.

3.2.4. Additional indicators

Aware of the threshold matter, researchers and practitioners have started to introduce new indicators towards a holistic view of the community's socioeconomic status, gathering multiple information. This literature review found 10% of the studies used additional indicators to analyse affordability issues (Gawel *et al.* 2013; Teodoro 2018; Mastracchio *et al.* 2020; Balazs *et al.* 2021; Goddard *et al.* 2021; Patterson & Doyle 2021).

Teodoro (2018) adopted hours of labour at minimum American wage, which measures the hours the user has to work to pay his/her WSS bill. Mastracchio *et al.* (2020) combined the affordability ratio for the lowest quintile and the Poverty Prevalence Indicator (PPI), which measures the number of poor households in a community – in this case, households earning below 200% of the U.S. Federal Poverty Level. PPI provides an idea of the economic situation of the whole community, indicating for example, whether a cross-subsidy would be enough to solve the issue. Water shutoff rates have also become a concern among practitioners and researchers, and permanent or temporary water disconnection has been suggested as a water poverty indicator as well (Meehan *et al.* n.d.).

Analysing the water supply in informal settlements in Kampala (Uganda), a study revealed vulnerable population struggles to pay the connection fee, which could represent up to 74% of their average monthly income (World Bank 2014). The results highlight connection fees and housing adaptation are a great and underestimated burden for vulnerable families and might be an extra indicator for the evaluation (Kayaga & Franceys 2007; World Bank 2014).

The aforementioned indicators have been developed towards better-guiding policymakers on WSS policies, and their use (or not) will rely on the following main purposes: do decision-makers want to know the impact of basic water needs price on vulnerable families, or on the whole community? Could they solve the affordability issue by optimizing the cross-subsidies (if existing), or should a new social program be designed?

3.2.5. Potential affordability

Self-reported water expenditure or expenditure calculated from the water tariff structure may hide potential affordability issues (Gawel *et al.* 2013; Martins *et al.* 2019). This might be even more important analysis in contexts where tariffs are becoming the predominant revenue source, and full cost recovery is encouraged. As WSS coverage increases, it is essential

to understand the impact on families' budgets of the full cost recovery tariff of a regular improved service – which can be either national or SDG 6 'safely managed' service standards (WHO & UNICEF 2021b). Martins *et al.* (2019) studied the potential affordability considering the expenses of families for covering basic water needs in Portugal. Using the ratio of individual services and total expenditure, they demonstrated from 9% of families facing affordability issues, 16% would struggle to pay their utilities bill for the national average consumption, considering 20% as the threshold for water, energy, and communication services combined.

Researchers have also calculated the burden on families' budgets if a full cost recovery tariff were applied to the water sector (Fankhauser & Tepic 2007; Banerjee & Morella 2011; Nauges *et al.* 2015; Janzen *et al.* 2016; Reynaud 2016; Burt *et al.* 2018). Janzen *et al.* (2016) investigated the cost of water supply to 25 small communities in Canada and concluded 48% of the systems would have to charge more than the 2% median household income, to achieve full cost recovery, thus raising affordability concerns. Reynaud (2016) assessed the impact of implementing the full cost recovery for water services on European households' income. In general, and considering 3% of the threshold, no affordability problem was detected, except for the first income decile in Bulgaria and, to a less extent, in Estonia and France. Fankhauser & Tepic (2007) estimated future income growth and demand for utility services and calculated the affordability ratio for a hypothetical full cost recovery tariff scenario in 27 transition countries. The authors concluded households in the three lowest income deciles would pay more than 10% of their household expenditure for power and heating and 5% for water. Besides those findings, 20 studies calculated the affordability ratios only for water services due to a lack of sewage or data, increasing the potential affordability if both services were in place.

3.2.6. WTP and application of affordability analysis

Some studies have combined affordability measurements with the WTP indicator and users' perception of water prices to understand population acceptability. Walter *et al.* (2017) investigated the impact of packaged drinking water on affordability and equity of access by the urban poor of Jakarta, Indonesia, and reported that lower-income households consider packaged water the most affordable safe drinking water source available, despite representing the second highest per unit cost source. Concomitantly, the population considered piped water more expensive despite its low per unit volume cost, because of the total costs associated. Al-Ghuraiz & Enshassi (2005) revealed that people from the Gaza Strip were willing to pay the cost recovery of water improvement to meet the WHO standards, despite it represented 4% of their income. Moreover, Wang *et al.* (2010) interviewed 1,500 households in China and concluded people would reject price rises, although the average economic burden was only 1.5–2.1%. Marques *et al.* (2016) investigated the WTP for the water supply service in Cape Verde and reported households would in general not be WTP more for significant improvements in their current water supply services. Non-connected areas demonstrated higher WTP, unlike places where water resources were abundant. Curiously, the overall results showed levels of WTP fell short of the reported current expenditure levels for water services.

According to the results, policymakers and researchers should analyse both indicators carefully. A community with very low-quality services probably would not be willing to pay the full cost recovery tariff due to a lack of trust in the provider. This does not mean the price is unaffordable. On the contrary, a community can be willing to pay a great amount of money to access services, but sooner or later would struggle to pay WSS bills due to its financial situation.

Achieving SDG 6 demands affordability measurement and monitoring, which in turn demands methodologies capable of translating the real and potentially hidden problem of accessing WSS services, especially considering that the principle of equity mentioned in several human rights demands that poorer households should not be disproportionately burdened with the costs comparing to richer families (WHO & UNICEF 2021b). The literature review showed no consensus on the best methodology and a threshold has been reached. Instead, researchers have adopted different approaches based on the local context the study was conducted and on the available data. Wherever surveys are updated and reliable, and coping costs are absent or insignificant, income data as denominator and water bills as numerator have been revealed to be the most preferred. Studies have also revealed affordability analysis must be performed for different income groups for elucidating the WSS economic access of vulnerable families, even in richer countries. The choice of the most appropriate indicator relies on local conditions, such as WSS coverage, socioeconomic reality, and, again, available data. Affordability analysis of connected households in high-income countries are much simpler when compared to non-connected rural or isolated areas in low-income nations, where poor quality water sources may be available at no cost and long travel times might be intrinsic to families' lives. Thus, the WTP for service improvement is very low, or, in the worst scenarios, there is no ability to pay whatsoever. Towards not excluding those in real need, whoever desires to develop an affordability study should include

more than one indicator, especially if the analysis area is heterogeneous. Since data strongly influence the robustness of the affordability analysis, national surveys can also be gradually improved, incorporating simple WSS affordability questions and covering the population in extreme poverty and/or living in very low-income neighbourhoods such as informal settlements (WHO & UNICEF 2021b). Meanwhile, complementary information can be useful, especially from regulatory agencies, which can gather accurate data. The review also highlighted the core problem of the WSS affordability concept, namely the threshold definition. Since every human being should have access to all essential services and goods at an affordable price, which greatly varies among localities, the establishment of an isolated WSS affordability threshold would be incomplete, and perhaps mistaken. Although still very difficult to implement, affordability standards should be defined by a participatory process at the national or local level, along with affordability analysis of other sectors, and the involvement of poorer families (Heller 2015).

Identifying the population with payment difficulties has an important but missing role in financial public policies. Towards overcoming the challenge of universal access, the work of utilities, regulators, and governments must be synchronized to optimize subsidies and public resources. Utilities play a crucial role in universalizing WSS to all, keeping the services as efficient as possible, since efficient public services are reflected in lower tariffs. Nauges *et al.* (2015) simulated tariff reforms for the Egyptian Water Regulatory Agency, taking into account a 3-year planning period, operation and maintenance cost recovery, and affordability. According to the authors, despite the increase in prices, water services would remain affordable for the low-income group, considering planned water bills' impact on total expenditure. Concomitantly, utilities can facilitate payment for poorer houses through additional time or punctual social aid (Marques *et al.* 2023).

Regulators are also important key players in assuring physical and economic WSS access to all. Inducing high coverage and performance, along with a well-designed tariff structure, they can optimize subsidies and provide more affordable bills. Borja-Vega *et al.* (2019) showed that although Mexican households do not face affordability problems (water expenses lower than 2% of total income), consumption subsidies through increasing block tariffs do not perform well and are significantly regressive. The wealthy populations benefit more from water subsidies than the poor, i.e., proportionally, poor deciles spend a larger portion of their income when compared to rich ones. Nauges & Whittington (2017) developed a modelling framework to analyse alternative municipal water tariff designs and the results also showed poor performance of increasing block tariffs in terms of targeting subsidies to low-income households. According to the authors, if the correlation between household income and water use is low, subsidies are always poorly targeted, despite the level of cost recovery, or the size of the fixed charge. As observed, the WSS tariff and its design strongly influence the effectiveness of subsidies. Since the revenue for WSS derives mainly from the three T's (taxes, tariffs and transfers), as stated by OECD (2010), a robust assessment of the cost of regular service and its appropriate financing mix has the potential to reach SDG 6. Affordability analysis could be the first step for the understanding where the tariff can play the main role and where public fund (or other source) complementation would be necessary. Therefore, through financial public policies, governments can target subsidies where they are actually required (Kessides *et al.* 2009).

4. CONCLUSIONS

The measurement of the affordability of public services is not an easy task. The first problem is to shape the most appropriate definition of affordability, which depends on available data and socioeconomic context, including other essential services' prices. This literature review, based on 79 papers and international reports, revealed researchers use different ratios for best evaluating the population's ability to pay for WSS. According to the studies, affordability analysis should also take into account vulnerable groups, such as low income and large families, since poorer households tend to spend a higher proportion of their income on WSS in comparison to rich ones.

There are several limitations for affordability measurements, such as multiple data sources (when available), unconnected households, coping costs, and unknown service quality, which hamper benchmarking, leading to the conclusion that comparisons of affordability results between localities may not be the best approach. A set of indicators (e.g., affordability ratio for quintiles and deciles, average and basic water needs volume, water and sanitation coverage, and proportion of households at poverty and at poverty risk) can be adopted to enrich the analysis.

Affordability analysis also has an important but missing role in financial public policies. Since resources have become more and more scarce over time, governments, utility managers, and regulators must work together to optimize the allocation of public resources for WSS universal access, considering users' ability to pay. OECD (2010) has already addressed the topic

throughout the 3T's policy – taxes, tariffs, and transfers. It is evident the importance of strategic financial planning for shaping the right balance of the 3Ts and providing WSS for all, assuring even the most vulnerable households have physical and economic access to the services, without jeopardizing their access to other essential goods.

The present study faces some limitations. Although the results covered all studies published until the first semester of 2022, the sample was restricted to those listed by the Scopus search engine and technical reports from worldwide recognized international organizations. The documents were also restricted to the 24 keyword combinations used. Few studies that neither mentioned data sources nor made a deep critical analysis of the affordability *status quo* were discarded. Although the subject has risen interest in the past decade, further research on the use of affordability analysis for financial public policy and affordability of public services and essential goods combined are necessary for the development of methodologies that set local affordability thresholds (or range of).

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DATA AVAILABILITY STATEMENT

All relevant data are available from an online repository or repositories.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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