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Estimating the Magnitude of Water Supply and Sanitation Subsidies

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Abstract

The water supply and sanitation sector remains heavily subsidized around the world. Yet, the accounting of water supply and sanitation subsidies globally has proved challenging due to utility-level data limitations and their often implicit nature. This paper develops a methodology to estimate water supply and sanitation subsidies that is adaptable to data scarce environments, while accounting for differences among service providers such as population served (to account for economies of scale), coverage of water and sanitation services individually, and their level of operational efficiency in terms of water losses and staffing. This methodology is based on Chile's *empresa modelo* (model firm) approach to cost-reflective tariff estimation and uses utility-level data from the World Bank's International Benchmarking Network for Water and Sanitation Utilities database. The results suggest that the cost of subsidies associated with the operations, maintenance, and major repair and replacement of existing water supply and sanitation infrastructure in much of the world (excluding, notably, China and India) is an estimated $289 billion to $353 billion per year, or 0.46 to 0.56 percent of the countries' combined gross domestic product. This figure rises, shockingly, to 1.59 to 1.95 percent if only low- and middle-income economies are considered, an amount largely due to the capital subsidies captured in the estimation. Subsidies of operating costs account for approximately 22 percent of the total subsidy amount in the full sample and for low-income economies separately. Annual subsidy amounts by region range from 0.05 to 2.40 percent of gross domestic product, and low-income economies are generally at the high end of this range. The estimations do not include capital expenditure for infrastructure expansion—which tends to be fully subsidized—or environmental costs. Therefore, the actual global magnitude of networked water supply and sanitation subsidies is much greater than the estimation.

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1. Introduction

The United Nations' Sustainable Development Goals (SDGs) for 2030 envision *all* the world's people as having equitable access to *safely managed* water and sanitation services (WSS)[2] by the year 2030. In 2016 the World Bank estimated that it would cost the world's nations approximately $114 billion a year in the period 2015–30 to attain this (Hutton and Varughese 2016). However high this estimate might sound, it does not even include the maintenance, repair, and replacement of existing infrastructure stock, or investment in climate-resilient infrastructure. These capital demands, coupled with sobering statistics on global rates of access to WSS services, underline a key fact: Securing the basic human rights of access to clean drinking water and sanitation depends on the *effective* and *efficient* use of scarce financial resources.

WSS subsidies are pervasive across all countries, regardless of their income status, and tend to consume a substantial amount of a country's scarce public resources (Andres et al. 2019). Subsidies occur when a user/customer pays less for a product or service than the service provider's cost, leaving a third party (e.g., government, other users, future generations) responsible for covering the difference. Subsidies may take the form of explicit financial transfers between two entities (e.g., a utility and a customer) or implicit transfers—such as nonpayment for electricity or deferred maintenance—which occur when products, services, or inputs are underpriced.

Although most subsidies are intended to ensure that WSS services are affordable for the poor, they tend to be heavily biased toward networked provision. Yet since poor households often face challenges in accessing piped water and sewered sanitation services, these subsidies tend to disproportionately benefit relatively well-to-do households (Abramovsky et al. 2020). Meanwhile, the poorest of the poor, who generally lack access to networked services, are left without their basic human rights to clean drinking water and sanitation.[3] As an example, the 2017 Global Analysis and Assessment of Sanitation and Water (GLAAS) report found that, in 13 countries, urban WSS expenditure accounted for 76 percent of public WSS expenditure, and that globally, official development assistance of "large systems" (including large urban distribution networks and/or treatment facilities) accounted for three-quarters of all official development assistance to the WSS sector in 2015, which amounted to approximately $5.6 billion of the $7.4 billion flowing into the sector (WHO 2017).

Given the pronounced bias of funding toward networked WSS services, a trend that likely holds true for subsidies as well, and the paucity of data on subsidies for decentralized, nonnetworked water and onsite sanitation services, this paper estimates the magnitude of subsidies associated with networked water and sewered sanitation services.

This paper develops a methodology to estimate WSS subsidies that is adaptable to data scarce environments, while still accounting for differences among service providers, including population served (to account for economies of scale), differing respective coverage rates of water and sanitation services , and level of operational efficiency in terms of water losses and staffing. This methodology is based on

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[2] To meet the criteria for having a safely managed drinking water service, people must use an improved source of water that is (i) accessible on household premises, (ii) available when needed, and (iii) free from contamination. An improved sanitation facility is safely managed if it is not shared with other households and ensures that excreta is (i) treated and disposed in situ, (ii) stored temporarily and then emptied and transported to treatment off-site, or (iii) transported through a sewer with wastewater and then treated off-site.

[3] Water and sanitation were recognized as human rights by the UN General Assembly and the Human Rights Council in Resolution 64/292 in 2010, and then again by the General Assembly in Resolution 70/169 in 2015.

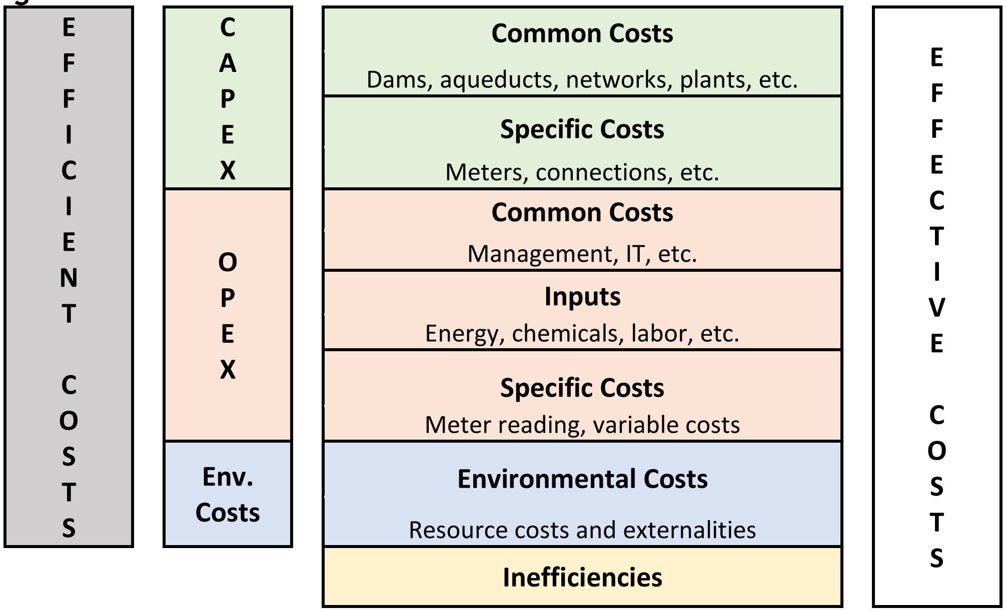
Chile's *empresa modelo* (model firm) approach to cost-reflective tariff estimation and uses utility-level data from the World Bank's IBNET database.

The paper is structured as follows: section 2 describes various approaches from the literature to estimating the cost of WSS services, section 3 details our methodology; section 4 presents the results of our analysis; section 5 describes the limitations to our approach; and the final section concludes with a summary of our findings and their policy implications.

2. Approaches to estimate the economic cost of water and sanitation

Since subsidies are the difference between (i) the costs of service provision and (ii) the amount paid by users, defining and estimating the first element of the equation is fundamental to any analysis. When computing the costs of service provision, total economic costs (and, eventually, inefficiencies, or slack[4]) are taken into account (see Figure 1).[5] In accounting terms, these costs include operating costs, debt service, return on equity, depreciation, taxes, and environmental costs. Beyond these, all service providers present some inefficiencies that result in additional, hidden, costs that should be taken into account.[6] An efficient level of regulation is assumed, which means that tariffs cannot be higher than the economic costs of service.

Figure 1 Costs of Water and Sanitation Service Provision



Source: Authors' compilation.
Note: CAPEX = capital expenditure; IT = information technology; OPEX = operating expenditure.

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[4] This is a controversial issue since the mere existence of a subsidy may create perverse incentives for the utility to relax its productive efficiency, hence augmenting the need for the subsidy. Subsidies to the supplier (i.e., those given directly to the utility like payment for labor, power, or chemicals) disincentivize production efficiency gains. Furthermore, the monopolistic nature of networked service, in combination with poor regulation, allows utilities to pass the costs of their inefficiency on to users (and, eventually, the government).

[5] Different service types typically entail different costs. The same utility may choose to provide services of varying quality levels to appeal to users with differing consumption needs or abilities to pay.

[6] See background paper 2 (listed in appendix A) for an analysis and quantification of the impact of inefficiencies on costs and subsidies.

There are two theoretical approaches to estimating efficient costs: top-down and bottom-up. Top-down models evaluate systems using aggregate economic variables, whereas bottom-up models consider technological and contextual characteristics that vary across service providers.[7]

Due to the requirement for detailed data on specific assets or activities, bottom-up models have thus far been restricted to local and regional estimations. For example, Ebinger (2004) uses a Hidden Costs Calculator model to estimate total subsidies in the energy and water sectors for a subset of countries within Europe and Central Asia. Countries are limited to those with sufficient data on costs of operation and asset values in order to calculate an average cost recovery price, from which actual revenue is then subtracted. Meanwhile, Clark et al. (2002) develop equations to estimate the cost of system construction, expansion, and rehabilitation and repair for water distribution systems in the United States.[8] Similarly, Marchionni et al. (2015) propose cost functions for various water supply system assets in Portugal on the basis of known hydraulic and physical characteristics.

Most commonly, bottom-up models are used at the country level for the regulation of various types of service provision. In telecommunications, the hybrid cost proxy model (HCPM), a forward-looking economic cost model developed by the United States' Federal Communications Commission, is the best example of a pure bottom-up model used for regulatory purposes (FCC 2009, Gasmi et al. 2002). In the electricity and WSS sectors, the model firm (*empresa modelo*) approach has been applied in several Latin American countries, notably in Chile (Chavez 2002, Dammert et al. 2008).

Chile adopted a model firm approach to WSS regulation in 1988 through Decree DFL no. 70/1988, which seeks to induce efficiency by setting tariffs based on efficient operation and maintenance costs, while accounting for necessary capital expenditures to meet expected future demand. As described by Bitrán and Arellano (2005), "In Chile, to avoid transferring the cost of inefficiencies to users, the rate setting process emulates competitive conditions by using a fictitious company that would theoretically meet demand over the next five years in the most efficient way."

The paucity of data on the costs of WSS service provision in most countries makes estimating subsidy levels for networked services at the global level a daunting task. Due to these data constraints, prior global estimations of subsidies have taken a top-down approach. For example, Kochar et al. (2015) estimated global WSS subsidies using a price gap approach by subtracting actual revenues from estimated costs. The authors use a reference full cost-recovery price of $1 per cubic meter, which is taken from work done by the Global Water Intelligence in 2004 (GWI 2004) and is assumed to be the same for drinking water and wastewater. They then adjust this price for each country to account for three factors: (i) general price inflation that occurred between 2004 and 2012; (ii) lower labor costs in low- and middle-income countries; and (iii) varying levels of water scarcity.

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[7] As noted by the Intergovernmental Panel on Climate Change: "The basic difference is that each approach represents technology in a fundamentally different way. The bottom-up models capture technology in the engineering sense: a given technique related to energy consumption or supply, with a given technical performance and cost. In contrast, the technology term in top-down models, whatever the disaggregation, is represented by the shares of the purchase of a given input in intermediary consumption, in the production function, and in labor, capital, and other inputs. These shares constitute the basic ingredients of the economic description of a technology in which, depending on the choice of production function, the share elasticities represent the degree of substitutability among inputs."

[8] Rather than calculating an aggregated cost function the authors estimate different cost functions for unit operations such as base installed pipe; trenching and excavation; embedment; backfill and compaction; valves, fittings, and hydrants; dewatering; and so on.

3. Methodology

In this paper, we sought a methodology for estimating the magnitude of subsidies that could be adapted to data scarce environments while better accounting for differences among service providers, such as population served (to account for economies of scale), coverage of water and sanitation services individually, and their level of operational efficiency in terms of water losses and staffing. Accounting for these considerations, Chile's model firm approach provides a solid methodology through which cost-reflective tariffs are calculated for each utility, which can then be used to estimate their magnitude of subsidy.

Superintendencia de Servicios Sanitarios (SISS), the Chilean water regulator, uses an efficient (optimized) bottom-up model[9] that provides valuable information on the greenfield capital investment[10] needed for the provision of WSS services that, for the purposes of the present study, we extrapolate to utilities in other countries. It is important to note that our methodology does not seek to benchmark these utilities against Chilean utilities. Instead, our decision to use the efficient model developed by the Chilean regulator is predicated on its sophisticated and novel framework for estimating costs and measuring performance.

To compute an efficient WSS tariff for each utility with sufficient data for the period 2010–15 in the World Bank's International Benchmarking Network for Water and Sanitation Utilities (IBNET) database,[11] we develop a methodology that complements utility-specific data with estimates of the long-term incremental costs of efficient model firms, as determined by the Chilean regulator.[12] We then adjust this tariff to account for the relative losses and labor inefficiencies of each utility to obtain a full tariff, which allows a return compatible with a utility's economic opportunity cost of capital (i.e., to be economically sustainable). The subsidies for each firm can then be computed as the difference between this cost-reflective full tariff and the effective tariff that a utility collects.[13]

In order to obtain countrywide subsidy amounts for those countries with partial representation in the IBNET database, we extrapolate the results of those utilities that are listed in IBNET to the rest of the country based on 2015 WSS coverage rates estimated by the Joint Monitoring Programme[14] and population data from the World Bank. Average per capita subsidy figures were then obtained for each of the World Bank's four country classifications—high income, upper middle income, lower middle income,

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[9] The Chilean method aims to maximize both allocative efficiency (by setting tariffs equal to marginal costs) as well as productive efficiency (by producing efficient quantities at the lowest cost possible, without passing on additional inefficiencies to the customers through pricing) and also allows each utility to generate enough revenue to cover the costs incurred in providing the service. The customer bases of the various Chilean water and sanitation utilities range widely in size, from a few thousand to even over a million, reflecting the heterogeneity present within the sector globally. The resulting data capture the nuances of various cost structures, improving the accuracy of the Chilean model firms when compared with other countries that have undertaken similar approaches.

[10] In this context, greenfield capital investment refers to the capital investment required to construct all facilities necessary to provide a given level of WSS services to a utility's customer base, independent of any preexisting infrastructure or site-related constraints.

[11] The World Bank's International Benchmarking Network for Water and Sanitation Utilities (IBNET) database (https://www.ib-net.org/) is an initiative that supports WSS utilities in compiling a set of core cost and performance indicators that are made publicly available to facilitate performance comparisons towards improved service delivery.

[12] Although utilities in many countries treat fecal sludge collected from on-site sanitation options, these costs are excluded from our estimation due to data constraints.

[13] See more details about the methodology in appendix B.

[14] A collaborative effort of the United Nations and World Health Organization, the Joint Monitoring Programme is tracking international progress toward the Sustainable Development Goals.

and low income—allowing us to extrapolate to the remaining countries based upon their estimated coverage rates of piped water and sewered sanitation services.

This method estimates the magnitude of subsidies associated with the operations, maintenance, and replacement of existing infrastructure, taking into account each utility's particular levels of inefficiency. For our purposes, operating expenditure (OPEX) includes that required for the utility to provide services at current levels of efficiency and quality, as well as for regular maintenance. Our estimate of capital expenditure (CAPEX) includes that required for the major repair and/or replacement of existing infrastructure, spread out equally across an assumed 35-year design life of each asset. However, it does not include CAPEX for infrastructure expansion or environmental costs, both of which contribute significantly to the total magnitude of subsidies.

Since infrastructure expansion tends to be fully subsidized, the actual global magnitude of networked WSS subsidies is much greater than our estimation. Environmental costs, which include any ecosystem degradation and depletion caused by either water abstraction or the resulting emission of pollutants, as well as the opportunity costs of using a resource, must be taken into account in any policy decision. Since the magnitude of these costs will vary greatly from utility to utility because of a variety of technological, environmental, and societal factors, calculating an estimate of global environmental costs associated with networked water and sewered sanitation services is not currently feasible and is beyond the scope of this report. However, these costs should be assessed on a case-by-case basis through a thorough environmental impact assessment.

Because of a lack of data, China and India are both excluded from our estimations. Proportional to the size and number of their utilities, both countries have very little representation in IBNET; this, coupled with a lack of data from other sources, prevents us from accurately extrapolating subsidies at the country level. Although the estimates of global water and sanitation subsidies put forward in Kochhar et al. (2015) include both China and India, using a comparable price gap approach, we have decided not to include these numbers in our global estimates since they are based on significant assumptions – different from those undertaken in our approach – that would reduce reliability.

3.1 Defining an efficient, cost-reflective tariff

The required revenue for WSS service provision in a given year can be defined as follows:

$$RR_i = O\&M_i + D_i + T_i + r * K_i^{INI} \quad (1)$$

Where RR_i is the required revenue in period *i* for water and sanitation; $O\&M_i$ are the operating costs in period *i* for water and sanitation; D_i is the economic depreciation in period *i* for water and sanitation; T_i are the taxes in period *I;* r is the opportunity cost of capital; and K_i^{INI} is the initial capital in period *i* for water and sanitation.

From this equation, the cost-reflective tariff (i.e., the tariff that would yield the required revenue given a certain level of demand over a certain time period) can be computed as follows:

$$T_c = \frac{\sum \frac{RR_i}{(1+r)^i}}{\sum \frac{Qe_i}{(1+r)^i}} \quad (2)$$

Where T_c is the cost-reflective tariff and Qe_i are the units sold in period *I.*

3.2 Estimating a utility's asset base

We begin our calculations by estimating the value of the asset base for each utility with adequate representation in IBNET. To do so, we first estimate the average efficient asset base per customer for small, medium, and large utilities. Currently SISS regulates 59 utilities varying greatly in size; one is categorized as large (almost 1.7 million customers), seven as medium size (between 200,000 and 700,000 customers), and the remaining as small (fewer than 200,000 customers). Thirty-seven small utilities are excluded from our sample, as they serve fewer than 5,000 customers. Additionally, four medium size utilities are removed (three had yet to present their tariff revision studies, while one was deemed an outlier due to its reported assets), resulting in an overall sample of 15 (see Table 1).

Table 1. Sample of 15 Chilean water and sanitation utilities

Utility	Customers		Data Source	
	Water	**Sanitation**	**Year of Tariff Revision**	**Year of Data**
Aguas Andinas	1,691,195	1,652,946	2015	2013
ESSBIO	657,785	585,562	2011	2009
ESVAL	576,285	524,750	2015	2013
Nuevosur	204,343	193,202	2011	2009
ESSAL	192,311	180,554	2011	2009
Aguas del Valle	180,457	172,409	2011	2009
Aguas Araucania	175,505	164,015	2011	2009
Aguas Cordillera	126,613	123,295	2010	2008
Aguas del Altiplano	142,155	137,779	2013	2011
Aguas Chañar	85,606	82,012	2014	2012
Aguas Magallanes	46,415	45,707	2011	2010
Aguas Décima	37,017	34,624	2009	2007
SEMBCORP Aguas Chacabuco	19,677	18,739	2014	2012
Aguas San Pedro	10,292	10,189	2010	2009
SEMBCORP Aguas Lampa	5,655	3,939	2010	2008
Total	4,151,311	3,929,722	2014	2012

Source: Water and sanitation clients for each utility were obtained from their latest tariff study as submitted to SISS. The fourth column denotes the year that each tariff study was published, while the final column denotes the year of associated data collection.

In Chile, assets are estimated using a greenfield scenario at the start of every five-year period. To this end, the regulator models each utility based upon its size, network characteristics, services provided, and the sub-activities conducted for each service (e.g., production, treatment, and distribution), taking into account any necessary expansion stemming from demand growth. Efficient, optimized asset values for each service provided (water and/or sanitation) are obtained from calculating the net present value of future investments in the *j* sub-activities related to that service:

$$K^l = \frac{\sum_{i,j} Investments_i^{j,l}}{(1+r)^i} \quad (3)$$

Where K is the efficient optimized asset base value for each service *l* and $Investments_i^j$ are the investments in the *j* sub-activities (production, treatment, distribution).

Information on the efficient asset base for each utility (in Chilean pesos) is obtained from its latest available tariff review.[15] We convert this value to U.S. dollars and apply an inflation factor to express all

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[15] See http://www.siss.gob.cl/586/w3-propertyvalue-6385.html; see also Aguas Andinas (2015).

values in 2017 U.S. dollars (Table 2). It is important to note that the variation in the share of asset base for sanitation is largely driven by differences in coverage.

Chile's mechanism for determining tariffs is based on a greenfield project with a 35-year[16] time horizon. Therefore, the asset base computed by SISS is a function of demand growth over 35 years. SISS estimates the annuity of investments and associated customers over that time period, allowing us to construct a unit capital cost indicator that will properly account for demand growth (Table 2). Formally:

$$Unit\ K^{l}\ \left(\frac{USD}{Customers}\right) = \frac{Annuity\ (Investments^{l})}{Annuity\ (Customers^{l})} \quad (4)$$

Where $Investments^{l}$ are the investments in each service *l; $Customers^{l}$* are the customers in each service *l;* and $Unit\ K^{l}$ are the unit capital costs in dollars for each service *l.*

Table 2. Asset bases and capital costs of 15 Chilean utilities

Utility	Asset base ($ million)			Customers		Unit capital costs ($/customer)		
	Water	Sanitation	Total	Water	Sanitation	Water	Sanitation	Total
Aguas Andinas	6,686	7,913	14,599	1,691,195	1,652,946	3,954	4,787	8,741
ESSBIO	1,999	2,877	4,876	657,785	585,562	3,039	4,914	7,952
ESVAL	2,413	2,458	4,870	576,285	524,750	4,186	4,684	8,870
Nuevosur	537	819	1,356	204,343	193,202	2,626	4,239	6,865
ESSAL	700	979	1,679	192,311	180,554	3,639	5,422	9,060
Aguas del Valle	756	913	1,669	180,457	172,409	4,191	5,294	9,485
Aguas Araucania	542	710	1,252	175,505	164,015	3,088	4,330	7,418
Aguas Cordillera	1,347	512	1,859	126,613	123,295	10,638	4,155	14,793
Aguas del Altiplano	1,020	536	1,556	142,155	137,779	7,174	3,893	11,066
Aguas Chañar	847	379	1,226	85,606	82,012	9,893	4,623	14,516
Aguas Magallanes	218	262	480	46,415	45,707	4,700	5,736	10,436
Aguas Decima	117	124	241	37,017	34,624	3,163	3,574	6,737
SEMBCORP Aguas Chacabuco	79	86	165	19,677	18,739	4,010	4,575	8,585
Aguas San Pedro	30	40	70	10,292	10,189	2,901	3,908	6,810
SEMBCORP Aguas Lampa	21	19	41	5,655	3,939	3,739	4,930	8,670

Source: Authors' elaboration of SISS information.

Next, we calculate weighted averages of the unit asset base for small, medium, and large utilities respectively (Table 3).

Table 3. Average unit asset base of 15 Chilean utilities, categorized by size of customer bases

Category	Customers	Unit asset base ($/customer)		
		Water	Sanitation[17]	Total
Large	200,000+	3,717	4,794	8,512
Medium	100,000-200,000	5,342	4,602	9,944
Small	0-100,000	6,411	4,662	11,073

Source: Authors' elaboration of SISS information.

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[16] See Chilean law 70 from 1988.

[17] Though the difference is not statistically significant, large utilities display a slightly higher value for sanitation assets per customer, probably because of differences in how each utility reports its assets.

This unit cost is then applied to the IBNET customer field to obtain an optimized asset value of water and sanitation services separately for each utility represented in the IBNET database:[18]

$$K^{INI\ s,l,m}(USD) = Unit\ K^{l,m} * Customers\ IBNET^{s,l} \quad (5)$$

Where $K^{INI\ s,l,m}$ is the estimated asset base for each service *l*, of size *m* for *s* utilities in the IBNET database; $Unit\ K^{s,l,m}$ is the unit asset base for each service *l*, of size *m*; and $Customers\ IBNET^{s,l}$ are the customers in each service *l*, for *s* utilities in the IBNET database.

3.3 Estimating a country's cost of capital and taxes

Our next step is to estimate the pretax cost of capital for each country represented in the IBNET database, since thus far the unit asset base reflects Chile's 7 percent cost of capital. To do this, we first calculate a pretax weighted average cost of capital (WACC). This cost of capital reflects the opportunity cost of a WSS utility without considering country-specific risks. But almost all regulators in emerging economies add a country-specific risk premium to account for differences in risks among countries.[19] In line with this practice, we estimate the cost of capital for each country represented in the IBNET database by adding a country-specific risk premium to the cost of debt and the cost of equity:

$$r^s = r_d^s * (1 - t_s) * \frac{D}{D+E} + r_e^s * \frac{E}{D+E} \quad (6)$$

$$r^s\ pretax = \frac{r^s}{(1 - t^s)} \quad (7)$$

$$real\ r^s\ pretax = \frac{(1 + r^s\ pretax)}{(1 + expected\ inflation)} - 1 \quad (8)$$

Where r^s is the cost of capital for utility *s;* $r^s\ pretax$ is the cost of capital on a pretax basis for utility *s;* $real\ r^s\ pretax$ is the pretax cost of capital in real terms for utility *s;* t^s is the corporate tax rate for utility *s* (country specific); ${r_d}^s$ is the cost of debt for utility *s* (country specific); and ${r_e}^s$ is the cost of equity for utility *s* (country specific).

3.4 Estimating depreciation and capital remuneration

Once we have an estimate of the cost of capital and the *Unit K* parameter, we can compute both depreciation and capital remuneration by calculating an annuity:

$$D^s + real\ r^s\ pretax * K^{INI\ s} = \frac{K^{INI\ s}}{(1 - (\frac{1}{(1 + real\ r^s\ pretax)^n})/real\ r^s\ pretax} \quad (9)$$

Where $K^{INI\ s}$ is the estimated asset base for each utility *s* in the IBNET database; D^s is the estimated depreciation for each utility *s* in the IBNET database; and n is the 35-year life span of a greenfield in Chile.

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[18] In case of missing sanitation data in the IBNET database, if only one of a utility's number of sewerage connections or volume of wastewater processed was missing, the analogous data from the utility's water coverage were used in its place (sewerage customers = water customers or wastewater treated = water sold). Utilities without any sanitation data were classified as water-only providers.

[19] Country-specific risk premiums can be found at Damodaran: http://www.damodaran.com.

The use of an annuity instead of individual values for depreciation and return on capital serves two purposes. First, it simplifies the calculations. Second, the use of a constant annuity implies adopting an increasing pattern of depreciation. Given that we evaluate capital over a 35-year period, an increasing depreciation rate provides the correct allocative signal, since the system is bound to have excess capacity at the beginning of the period.

3.5 Estimating operation and maintenance costs

In general, during tariff revision processes, and in particular when estimating long-run marginal costs, a generalized percentage of total assets is used to estimate annual operation and maintenance (O&M) costs when no detailed information is available. The reference values generally fall between 2.5 percent and 3 percent of invested assets. For the purposes of this study, the upper limit of 3 percent is assumed as a reference value. [20] When this methodology is applied to all utilities represented in the IBNET database, O&M costs represent an average 24.7 percent of total efficient costs, which is similar to the average 28 percent figure from our sample of Chilean model firms.

3.6 Estimating efficient tariffs for utilities listed in IBNET

Having estimated the operating costs, depreciation, taxes, and capital remuneration for utilities listed in IBNET, we can now compute an efficient revenue requirement for water and sanitation services separately for each utility using Equation 1. We then estimate an efficient average tariff by dividing the efficient revenue requirement by total sales (as reported in IBNET), formally:

$$T_{Efficient} = \frac{RR_{Efficient}}{Demand} \quad (10)$$

Where $T_{Efficient}$ is the efficient tariff; $RR_{Efficient}$ is the efficient revenue requirement; and $Demand$ are the sales by utility s as reported by IBNET.

3.7 Estimating full tariffs for utilities listed in IBNET

The tariffs computed in the previous section are intended to recuperate the capital and O&M costs of an efficient model firm. But this assumption of efficiency is unrealistic: most utilities present larger inefficiencies mostly having to do with excessive operations and maintenance costs due to overstaffing and water production losses. However, capital expenditures can also be inflated since extra assets are required to increase production to make up for incurred water losses. The objective of this section is to compute a tariff that reflects the effective level of efficiency of each utility in the IBNET database in terms of two variables: losses and labor costs. We call this a *full tariff,* since it allows a return compatible with a utility's opportunity cost of capital (i.e., to be economically sustainable) with costs including a certain level of inefficiency.

3.7.1 Water Losses

SISS in Chile assumes overall water losses of 15 percent in their model firms. But the losses of most utilities, particularly in developing countries, are substantially higher. Assuming that losses of 15 percent

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[20] The reported operations costs from IBNET in 2017 U.S. dollars were not sufficiently reliable to be used in the estimate, as random cross-checks against original sources (that is, the balance sheets of various utilities) showed significant differences for several observations.

are to be expected regardless of how efficient a utility is, any difference between this and a utility's actual, total losses can be referred to as "inefficient losses."

A higher level of losses implies higher costs. In terms of O&M, higher losses are linked to the use of more energy and chemical products. On the capital side, higher losses imply greater investment to cover the additional production needed to serve customers. We estimate the incremental cost associated with the difference between the 15 percent assumed in the model firm estimate and the level reported in IBNET with the following equation:

$$\Delta C_{losses}{}^{s} = \Delta O\&M_{losses}{}^{s} + \Delta CAPEX_{losses}{}^{s} \quad (11)$$

> Where $\Delta C_{losses}{}^{s}$ is the total cost differential associated with higher losses for utility *s*; $\Delta O\&M_{losses}{}^{s}$ is the O&M cost differential associated with higher losses for utility *s*; and $\Delta CAPEX_{losses}{}^{s}$ is the CAPEX differential associated with higher losses for utility *s*.

$$\Delta O\&M_{losses}{}^{s} = (EC^{s} + CC^{s}) * (ToL^{s} - TeL) \quad (12)$$

$$\Delta CAPEX_{losses}{}^{s} = \frac{(ToL^{s} - TeL)}{(1 - ToL^{s})} * \left(K^{s,Prod,m} * Customers\ IBNET^{s,Water}\right) \quad (13)$$

> Where EC^{s} are the reported electricity costs for utility *s*; CC^{s} are the reported chemical costs for utility *s*; ToL^{s} are the reported total losses for utility *s*; TeL are the efficient total losses from the Chilean sector; $K^{s,Prod,m}$ is the estimated asset base for water production of size *m* for utility *s* in the IBNET database (calculated using weighted average of the unit water production asset base for small, medium, and large utilities); and $Customers\ IBNET^{s,Water}$ are the reported water customers of utility *s* in the IBNET database.

The estimated asset base for water production is calculated using the weighted average water production asset base per customer from the Chilean model firms of similar size: 3,572, 2,165, and 952 USD per customer for small, medium, and large utilities respectively.

Finally, in denoting the total sales of utility s as Demand, we can compute a tariff differential as:

$$T_{losses} = \frac{\Delta C_{losses}}{Demand} \quad (14)$$

> Where T_{losses} is the tariff differential due to water losses.

3.7.2 Overstaffing

The model firm developed by SISS in Chile defines an efficient level of employees per customer for each firm. The efficient ratio of employees per customer[21] we adopt is based on a weighted average of our sample of 15 Chilean model firms by size: 5.2, 4.4, and 2.4 employees per 1,000 customers for small, medium, and large utilities respectively. In general, most WSS providers, particularly in developing countries, have staff numbers that are substantially higher.

Overstaffing implies higher O&M costs. To account for this cost differential, we estimate the incremental cost associated with the difference between (i) the efficient ratio of employees per customer and (ii) the level reported for each utility in IBNET, using the following equation:

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[21] A generally accepted benchmark for staff efficiency is 5 employees for every 1,000 customers, although we refrain from using this, since it does not reflect economies of scale and thus may result in the illusion that large companies have efficient staffing levels.

$$\Delta C_{employees}{}^{s} = Labor\ Costs^{s} - (\frac{Labor\ Costs^{s}}{Staff^{s}} * optimal\ staff\ ratio * MAX(Customers\ IBNET^{s,Water}, Customers\ IBNET^{s,Wastewater})/1000\ ) \quad (15)$$

Where $\Delta C_{employees}{}^{s}$ is the total cost differential associated with overstaffing in utility s; $Labor\ costs^{s}$ are the reported labor costs of utility s; $Staff^{s}$ are the reported number of employees in utility s; $optimal\ staff\ ratio$ is the efficient ratio of employees per 1,000 customers; $Customers\ IBNET^{s,Water}$ is the reported number of water service consumers of utility s in IBNET database; and $Customers\ IBNET^{s,Wastewater}$ is the reported number of wastewater service consumers of utility s in IBNET database.

Based on this equation we estimate the cost and tariff differential associated with inefficient levels of employment for each utility in IBNET:

$$T_{Employees} = \frac{\Delta C_{employees}}{Demand} \quad (16)$$

Where $T_{Employees}$ is the tariff differential due to overstaffing.

3.7.3 Full Tariff

Once we have computed the cost differential associated with water losses and staffing levels, we calculate the full tariff for each utility in IBNET, adding these two elements to the efficient tariff computed earlier for accounting for inefficiencies:

$$T_{Full} = T_{Efficient} + T_{losses} + T_{Employees} \quad (17)$$

Where T_{Full} is the full tariff.

As previously discussed, we allocate the tariff differential due to excessive losses to the water tariff, while the tariff differential due to overstaffing is distributed across the water and sanitation tariffs proportionally based on the respective asset bases.

3.8 Estimating subsidies for utilities listed in IBNET

Once we have computed the efficient and full tariff for each utility's service in the IBNET database, we quantify the implicit subsidies at the firm level. Strictly speaking, the subsidy is the difference between the efficient tariff and the effective tariff received for each service by the utility, which can be approximated by the average revenue. Formally:

$$S_{Efficient} = T_{Efficient} - AvgR \quad (18)$$

Where $S_{Efficient}$ is the subsidy, or difference between efficient and effective tariff; and $AvgR$ is the average revenue.

This estimate, however, does not account for inefficiencies found at the utility level. This means that the efficient tariff would allow only an efficient utility (i.e., with losses of 15 percent and five employees per 1,000 customers) to cover the economic costs of providing service. If, following the hidden cost approach, we want to consider the actual efficiency level of each utility, we need to use the full tariff estimated in section 3.7.3. Formally:

$$S_{Full} = T_{Full} - AvgR \quad (19)$$

Where S_{Full} is the full subsidy, or difference between full and effective tariff.

From equation (17), we can replace and rearrange the terms to obtain:

$$S_{Full} = S_{Efficient} + T_{losses} + T_{Employees} \quad (20)$$

In other words, the full subsidy can be expressed as the sum of the pure subsidy plus the two inefficiency terms (inefficient losses for water and overstaffing for both water and sanitation).

3.9 Extrapolating subsidies within countries

IBNET contains data for utilities in 91 countries, [22] but not all utilities providing either water or sanitation services in each country are included in the database. We can measure the degree of coverage for water and sanitation services respectively in each country by comparing the population served by utilities listed in the IBNET database with the total population served in the country overall. The total population served for water and sanitation services was estimated by multiplying coverage rates from the World Health Organization/United Nations Children's Fund for piped water facilities and sewered sanitation facilities by population data from the World Bank.[23]

By dividing the total population served in a country by the population served in IBNET, we compute an extrapolation factor for each service. Assuming that the average tariff charged by utilities not included in IBNET is equal to that of the utilities in IBNET, and that the average efficiency of both groups is also similar, we estimate total subsidies for each service at the country level by multiplying the total subsidies of the service for utilities in IBNET by the extrapolation factor for that service. The total estimated subsidy level for the WSS sector in each country is then the sum of all utilities' subsidies in that country.

Nine countries represented in the IBNET database are estimated to have a negative subsidy. Most of these are developed countries, where efficiency may be pushed beyond the level assumed in the Chilean model.[24] Where this is the case, subsidies are assumed to be zero.

3.10 Estimating the subsidies for countries not in IBNET

To extrapolate subsidy estimates to countries not included in the database, we first separate out China and India, while the remaining countries are grouped into four clusters—high income, upper middle income, lower middle income, and low income—based upon the World Bank's country classifications by income for fiscal year 2019. Next, for water and sanitation separately, we calculate an average subsidy per person served for countries with representation in IBNET, disaggregated into the four clusters (see Appendix B). Then, for countries not in the IBNET database, we multiply the per person subsidy for its cluster by the total population served by the respective service (estimated by multiplying the country's coverage rate[25] and its total population). Since the main drivers for these estimates are the unit cost in the asset base calculations, the results presented in the report assume a +/-10 percent variation in the unit asset base estimates.

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[22] China and India were not extrapolated due to low proportional representation in IBNET and a general lack of data availability.

[23] Water and/or sanitation coverage data for 6 countries (Bahrain, Fiji, Indonesia, Kosovo, Kuwait, and Solomon Islands) were incomplete, and were thus supplemented by additional data and estimates. Refer to Appendix B for details.

[24] See Appendix C for a list of all countries with "negative" subsidies.

[25] Water and/or sanitation coverage data from the World Health Organization/United Nations Children's Fund for 3 countries (Austria, Isle of Man, and Micronesia), in addition to the 6 previously cited with partial IBNET data, were incomplete, and were thus supplemented by additional data and estimates. Refer to Appendix B for details.

4. Results

Using our method, as outlined above, the global subsidy level is estimated at $289 billion to $353 billion per year, or 0.46–0.56 percent of the countries' combined gross domestic product (GDP). As a percentage of GDP, this figure rises, shockingly, to 1.59–1.95 percent if only low- and middle-income economies are considered, an amount largely due to the capital subsidies captured in our estimation. Table 4 disaggregates subsidies for CAPEX and OPEX across World Bank regions.

Table 4 OPEX and CAPEX Subsidies, by Region (2017 $ and average % GDP)

Region	OPEX Subsidy ($ billion)	CAPEX Subsidy ($ billion)	Total Subsidy ($ billion)	OPEX Subsidy/GDP (%)	CAPEX Subsidy/GDP (%)	Total Subsidy/GDP (%)
*World Bank geographical regions**						
Africa	4.1–5.1	17.2–21.1	21.4–26.1	0.24–0.30	1.03–1.25	1.28–1.56
East Asia and Pacific (without China)	5.0–6.2	18.0–22.0	23.1–28.2	0.22–0.26	0.78–0.96	1.00–1.22
Europe and Central Asia	13.1–16.0	45.6–55.8	58.7–71.8	0.33–0.41	1.16–1.42	1.48–1.81
Latin America and the Caribbean	23.4–28.6	77.8–95.1	101.2–123.7	0.45–0.55	1.51–1.85	1.96–2.40
Middle East and North Africa	10.2–12.5	37.6–46.0	47.9–58.5	0.35–0.43	1.31–1.61	1.66–2.03
South Asia (without India)	2.3–2.8	3.2–3.9	10.9–13.3	0.39–0.47	1.43–1.75	1.82–2.22
Advanced and nonadvanced economies (as categorized by IMF)						
Advanced economies	7.8–9.6	17.6–21.5	25.4–31.0	0.018–0.022	0.036–0.044	0.054–0.066
Nonadvanced economies	58.1–71.1	204.9–250.5	263.1–321.6	0.35–0.43	1.24–1.52	1.59–1.95
Total	66.0–80.7	222.5–271.9	288.5–352.6	0.11–0.13	0.35–0.43	0.46–0.56

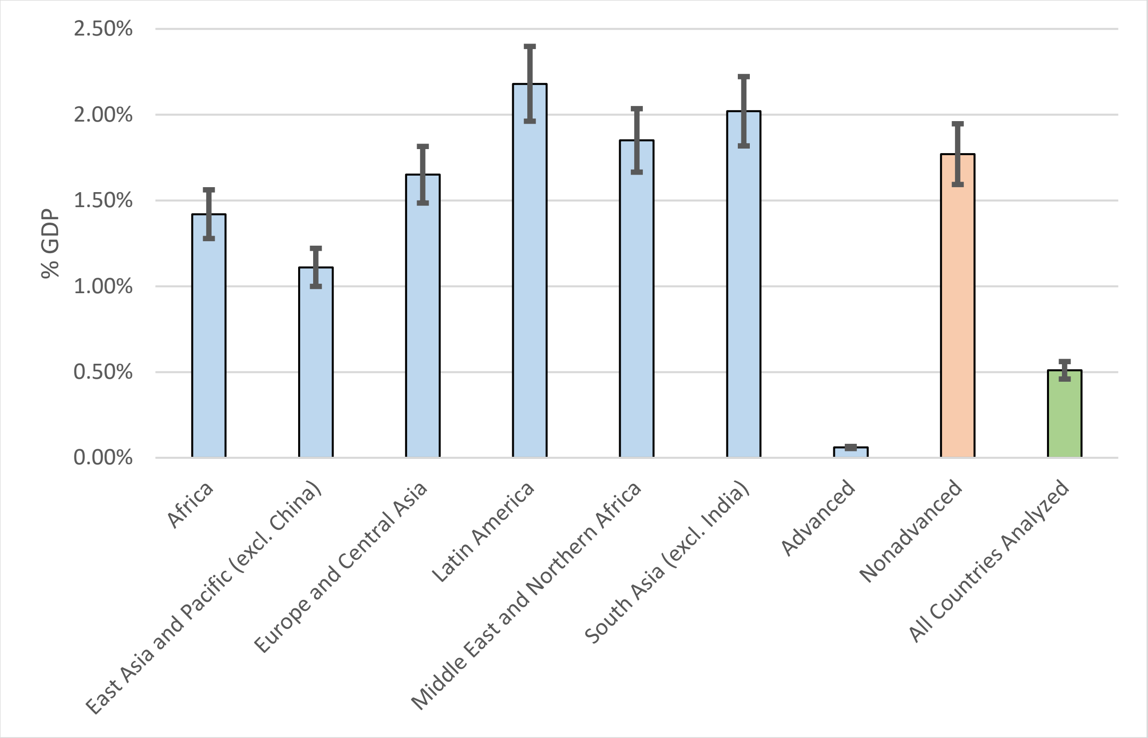
Source: Authors' compilation.

Note: * Regional estimates exclude "advanced economies," as categorized by the International Monetary Fund. CAPEX = capital expenditure; GDP = gross domestic product. IMF = International Monetary Fund; OPEX = operating expenditure. Estimates for East Asia and Pacific and nonadvanced economies exclude China, while estimates for South Asia exclude India. Estimates for nonadvanced economies exclude both China and India.

Subsidies of operating costs account for approximately 22 percent of the total subsidy amount both in the full sample and for low- and middle-income economies separately. While our overall estimation is in line with existing literature, most studies systematically underestimate CAPEX subsidies (e.g., no adjustments to the asset base or cost of capital are applied). With its inclusion of full cost-reflective tariffs, our approach is thus a better way to estimate hidden costs.

At around $101 billion to $124 billion per year, Latin America and the Caribbean exhibits the largest amount of subsidy both in absolute terms and as a percentage of GDP (including both operating and capital subsidies). It should be noted, however, that if China were included in our analysis, the East Asia and Pacific region's total amount of subsidies would be substantially higher. Previous estimates (see Kochhar et al. 2015) that used the price gap approach and included China and India attributed the largest subsidies in nominal terms to Asia, at over $190 billion per year, of which 60 percent was in China alone. Figure 2 displays the magnitude of subsidization as a percent of GDP by region.

Figure 2 Magnitude of WSS Subsidies by Region (% GDP)



Source: Authors' compilation.

Note: GDP = gross domestic product. Bars indicate the midpoint of the estimation range, while the black brackets represent the full estimation range. World Bank regional estimates exclude countries classified as advanced economies by the IMF. Advanced and nonadvanced countries refer to these IMF classifications. Estimates for East Asia and Pacific and nonadvanced economies exclude China, while estimates for South Asia exclude India. Estimates for nonadvanced economies exclude both China and India.

Annual subsidies relative to GDP within regions range from 0.05 percent up to 2.40 percent. The lowest rates are clustered in advanced economies (as classified by the International Monetary Fund) and the highest in Latin America. In figure 2, advanced economies were removed from their respective regions. If this had not been done, values for these regions would have been lower.

These results are in line with previous estimates: most high-income countries tend to charge water tariffs close to the level required to cover operating expenditures and asset depreciation, as well as maintain infrastructure. On the other hand, water tariffs far from cost recovery are most often found in low- and middle-income countries. Utilities in Sub-Saharan Africa, for example, usually operate at a loss and end up lowering their capital expenditures to continue operating, which ultimately leads to a decline in service quality.

Subsidies of networked water far exceed those for sewered sanitation globally, accounting for 64 percent of the total subsidy amount. Overall, advanced economies allocate a higher percentage of subsidies toward sewered sanitation than do nonadvanced economies (44 percent). Sub-Saharan Africa and East Asia and Pacific allocate the lowest proportion (6 percent and 11 percent, respectively). These differences are largely due to the higher rates of access to networked water than to sewered sanitation globally, and the varied rates of access to sewered sanitation across regions.

5. Discussion

It is important to note a few limitations to our use of the Chilean model firm data. An assumption embedded in our methodology is that Chile's geographical conditions are shared by all utilities. In our model, we assign a unit asset base (unit capital cost) value based on data from 15 Chilean firms, while in reality capital costs are strongly influenced by the geographical conditions of the area it serves. For example, different countries have access to different water sources that facilitate (or complicate) extraction, leading to lower (or higher) expenditures on assets. In addition, access to technology plays a role: newer and better machinery can greatly reduce a utility's operational expenditures. Also, Chile is among the world's most open economies, with low to nonexistent import taxes, while commercial barriers in other countries drive up the cost of imported assets, resulting in higher capital expenditures. Quality standards also vary between countries: low-income countries usually have lower standards than high-income countries, necessitating more investment to improve service quality.

The most directly comparable estimate of subsidies was conducted by Kochhar et al. (2015). Instead of the model firm approach taken here, the authors use a reference full cost-recovery price of $1 per cubic meter, which is taken from work done by the Global Water Intelligence in 2004 (GWI 2004) and is assumed to be the same for drinking water and wastewater. They then adjust this price for each country to account for three factors: (i) general price inflation that occurred between 2004 and 2012; (ii) lower labor costs in low- and middle-income countries; and (iii) varying levels of water scarcity. Revenue is approximated using data on utility drinking water and wastewater tariffs for a sample of over 80 countries in 2012 from the GWI. The authors estimate that water and sanitation subsidies provided through public utilities were about $456 billion, or 0.6 percent of global gross domestic product (GDP), in 2012. Across regions, subsidies range from between 0.3 percent and 1.8 percent of GDP. Note that these estimates include China and India, the former with an estimate of around $130 billion, or about 1.5 percent of its GDP in 2012. Without China and India, this estimate becomes 0.5 percent of global GDP, or, adjusted for general price inflation from 2012 to 2017, $347 billion. Both of these numbers fall within our estimation range.

While our estimates of subsidies for OPEX are relatively straightforward—they predominantly represent explicit expenditures required to sustain service provision at current levels of efficiency and quality—our estimates of subsidies for CAPEX, or that required for the major repair and/or replacement of existing infrastructure, require additional nuance.[26] Because of a lack of data on most countries' direct expenditure on networked water and sewered sanitation, our model instead estimates the CAPEX required for the replacement of existing infrastructure. However, there have been several recent attempts to extrapolate direct expenditure from countries with more comprehensive and transparent expenditure data to regional, and even global, levels of expenditure.

Prior estimations of global and regional direct CAPEX on WSS services in low- and middle-income countries, making use of data available from a limited number of countries, are between 0.4 and 0.5 percent of GDP. Fay et al. (2017) have found that the WSS sector has traditionally received a small share of Latin America and the Caribbean's investments in infrastructure, hovering between a quarter and a third of a percent of GDP in the period 2000–12. Data from Foster and Briceño-Garmendia (2010) suggest that Africa spends around 0.5 percent of GDP, while Andres, Biller, and Dappe (2013) estimate that South Asia spent an average of 0.41 percent of its GDP in the period 2000–11. A more recent, and global, estimation of subsidies in the WSS sector can be inferred from Fay et al. (2019), who estimate infrastructure investments in low- and middle-income countries. Their report does not directly

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[26] It is again important to acknowledge that our estimation does not include CAPEX for infrastructure expansion. Since infrastructure expansion tends to be fully subsidized, the actual global magnitude of networked WSS subsidies is much greater than our estimation.

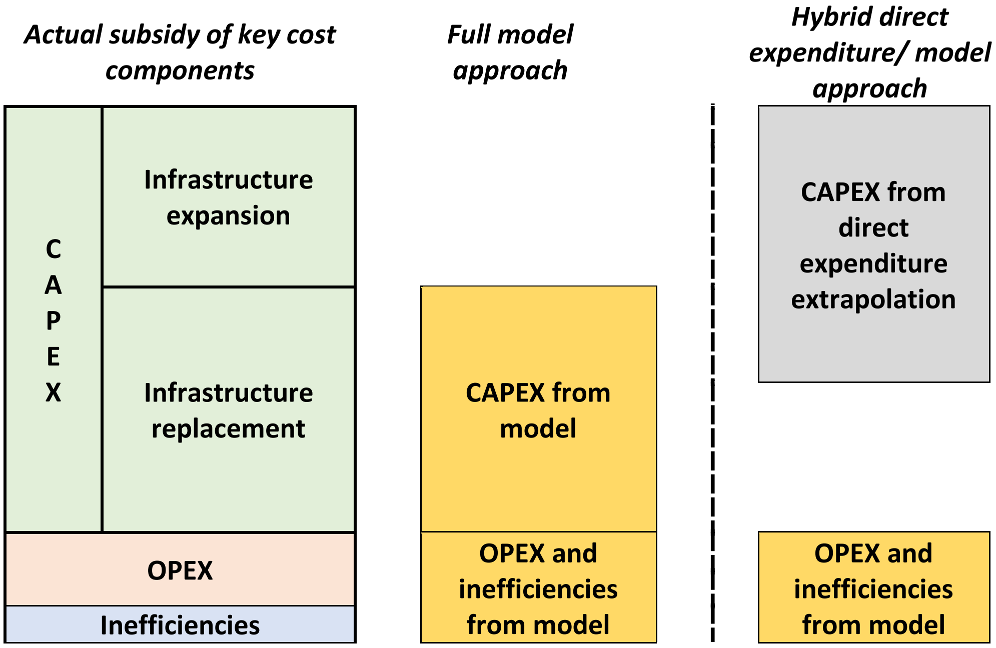
disaggregate CAPEX by sector. However, evidence from BOOST allows the authors to investigate the evolution of public infrastructure spending by sector over the period 2009–16. During this time, infrastructure spending in the WSS sector began at about 0.3 percent of global GDP, climbing to a peak of about 0.6 percent in 2012, before falling back to 0.3 percent. The average expenditure for this period was around 0.4 percent of global GDP.

When combined with our estimates for OPEX, the use of the limited direct CAPEX data available results in total networked water and sewered sanitation subsidies in low- and middle-income countries in the range of 0.75–0.95 percent of GDP. While these estimates are below our estimate of 1.59–1.95 percent of GDP for low- and middle-income countries, such discrepancy is not unexpected given key differences between the two approaches followed.

First, the use of direct expenditure significantly underestimates the CAPEX subsidies provided to the sector for existing infrastructure due to the deferral of maintenance—a phenomenon especially common in low- and middle-income countries. It has been well-documented that low- and middle-income countries in particular struggle with revenue collection and limited fiscal capacity, and are thus prone to significant deferrals of maintenance, as well as major repairs and replacement of existing infrastructure. Yet, even if these expenditures are not currently being made—either through taxes, transfers, or tariffs—they will need to be covered by future generations to maintain existing WSS services over time. Since our model allocates such expenditure in equal installments across the design life of the asset, its estimates are significantly higher by reflecting these intergenerational subsidies.

Second, while our model accounts for the full costs of required major repairs and replacement of existing infrastructure, it does not account for expenditures towards infrastructure expansion. In a steady-state situation whereby infrastructure expansion is limited, both estimates should be reasonably similar since actual direct CAPEX would be exclusively and comprehensively covering the maintenance and replacement of existing infrastructure. These key differences between the two models are depicted in figure 3.

Figure 3 Estimating the Magnitude of Subsidies: Two Approaches



Source: Authors' compilation.

Note: CAPEX = capital expenditure; OPEX = operating expenditure. The full model approach estimates CAPEX, OPEX, and inefficiencies using our model, which complements utility-specific data with estimates of the long-term incremental costs of efficient model utilities. The hybrid direct expenditure/ model approach, meanwhile, substitutes direct expenditure data in the place of the CAPEX model estimates, while maintaining the model's estimates for OPEX and inefficiencies.

Finally, it is worth mentioning that these estimates are global, and therefore represent regional and global average levels of subsidies in the WSS sector. Estimates at the country level may differ significantly from these ranges due to the many contextual factors that vary across countries. The estimation of subsidies at the country level would therefore require additional data and a refined methodology.

6. Conclusion

Subsidies are pervasive across countries, irrespective of region or income level. This is despite the fact that, as of 2015, about 29 percent of the world's population lacks safely managed drinking water, and about 61 percent lacks access to a safely managed sanitation service (WHO and UNICEF, 2017). Subsidies are particularly prevalent among networked and sewered WSS services, as illustrated by the IBNET database. Only 14 percent of the 1,549 listed utilities generate enough revenue to cover the total economic costs of service provision, while only 35 percent are able to cover, at a minimum, the operation and maintenance costs of service provision.

The cost of subsidies associated with the operations, maintenance, and major repair and replacement of existing WSS infrastructure in much of the world (excluding, notably, China and India) is an estimated $289 billion to $353 billion per year, or 0.46–0.56 percent of these countries' combined gross domestic product (GDP). This figure rises, shockingly, up to 1.59–1.95 percent if only low- and middle-income economies are considered, an amount largely due to the capital subsidies captured in our estimation. Subsidies of operating costs account for approximately 22 percent of the total subsidy amount both in the full sample and for low-income economies separately. At $101 billion to $124 billion per year, the region of Latin America and the Caribbean has the largest amount of subsidies (including both operating and capital subsidies), in absolute terms and as a percentage of GDP. Annual subsidy amounts by region range from 0.05 percent to 2.40 percent of GDP, and low-income economies are generally at the high end of this range. It is important to note that our estimation does not include either capital expenditure for infrastructure expansion—which tends to be fully subsidized—or environmental costs. Therefore, the actual global magnitude of networked water and sanitation subsidies is much greater than our estimation.

The SDGs for water supply and sanitation set out a transformational vision for the future whose achievement will require substantial financial resources. Given the scarcity of public resources globally, it is more important than ever to ensure that those public resources already allocated to the sector are used efficiently to achieve universal delivery of water supply and sanitation services. Yet while subsidies of WSS service provision are generally implemented in pursuit of worthwhile objectives, poor design often undermines these objectives, rendering subsidies pervasive, expensive, poorly targeted, nontransparent, and distortionary (Andres et al, 2019). Recognition of the large amount of both implicit and explicit subsidies currently flowing into the sector should motivate governments and policy makers to ensure that these funds effectively advance the goal of equitable access to affordable, sustainable, and quality WSS services, while maximizing the targeting of the poor, promoting transparency, and minimizing distortion.

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Appendix A. Cost of capital

Our methodology to estimate the cost of capital is based on the weighted average cost of capital (WACC). The cost of capital is then an average of the costs of the two main sources of funding – equity and debt - weighted by the shares of debt and equity to total capital (debt + equity). Formally:

$$r_k = r_d\,(1\text{-}t)\,D/(D+E) + r_e\,E/(D+E)$$

> Where r_k is the utility's cost of capital; t the corporate tax rate; r_d the utility's cost of debt; r_e the utility's cost of equity; E the value of equity; and D the value of debt.

Modern regulatory practices tend to consider a firm and not its shareholders as the regulated subject, which forces us to consider the firm's total capital as its asset base instead of equity. This way, depending on the way weights are considered in the cost of capital estimation (between debt and equity) and debt treatment, the firm is given the power to decide on its own financing structure, thus creating incentives for allocative efficiency.

In the following sections, we describe the estimation of each component of the cost of capital.

Cost of equity

There are several theoretical approaches to estimate a firm's cost of capital: the capital asset pricing model (CAPM), the dividend growth model, the arbitrage pricing model, and the country risk rating model, among others. The CAPM is widely used to estimate the cost of capital in regulated and nonregulated utilities, and it is, for many, the preferred model. However, when there is little or no information available, the country risk rating model can be used to estimate the cost of equity for a specific country.

We apply a modified CAPM, complemented by the country risk rating model. Both models are outlined below.

Capital asset pricing model

Formally, the model can be summarized in the following equation:

$$r_e = r_f + \beta * (r_m - r_f)$$

> Where r_f is the risk-free rate; β is the sensitivity of the expected excess asset returns to the expected excess market returns; and *(rm - rl)* is called the market risk premium.

In general, regulators of emerging economies have used a modified version of CAPM to include domestic risk (or country risk) not present in developed markets. Although there are different ways to include the domestic risk from different assumptions, the more generalized model is the "country debt spread" model.

The cost of equity is estimated by applying the original CAPM equation, plus an additional term reflecting the country risk premium:

$$r_e = r_f + \beta * (r_m - r_f) + r_{country}$$

> Where r_f is the risk-free rate; β is the sensitivity of the expected excess asset returns to the expected excess market returns; $(r_m - r_f)$ is the market risk premium; and $r_{country}$ is the country risk premium.

The country risk premium is generally estimated as the difference between the return on a local sovereign bond and the return on a sovereign bond issued by an AAA credit rating country, or a "risk-free" rate.

The model assumes that the risk of the activity does not differ depending on the country, and that the differences lie mainly in the domestic (nondiversifiable) risks, which are captured by an additional premium.

Cost of debt

The cost of debt refers to the cost faced by the utility to fund its operations through third parties, that is, the return required by creditors. In those countries where there is a developed financial market, it is customary to estimate the cost of the debt from corporate bonds yields. However, in emerging countries capital markets are generally insufficiently developed to find the corporate bonds of public enterprises. In fact, only those utilities with a relatively good credit rating have access to this type of market.

Taking into account the notion of country risk, the cost of debt is generally considered to be similar to the country cost of debt. While some utilities obtain loans at lower interest rates than those obtained by the country where they are located, this is unlikely to be feasible in the long run. Indeed, a utility cannot have a lower risk than its country, since the state can always appropriate the benefits, mainly through tax mechanisms.[27] Conversely, a utility's cost of debt can be higher than the country's cost of debt, lending credence to the addition of an industry premium to the country's cost of debt.

The cost of debt can be approximated with the following equation:

$$r_d = r_f + r_{country} + r_{corp}$$

> Where r_f is the risk-free rate; $r_{country}$ is the country risk premium; and r_{corp} is the corporate risk premium. The corporate risk premium is linked to the utility's credit risk (business risk, volatility, stability in revenues, etc.).

Estimation

Table A.1 provides the values of all relevant parameters used in the calculation of the cost of capital, alongside their sources.

Table A.1 Benchmark cost of capital

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[27] This is generally referred to in the literature as the "sovereign ceiling."

Parameter	**Value**	**Source of value**
r_f	2.4%	U.S. rate
Debt premium	1.5%	Regularly used by regulators for water supply and sanitation utilities
r_d	3.9%	2017 long-term return on U.S. bonds
Equity beta	1	Consistent with the U.K. regulator’s approach
MRP	5.1%	U.S. historical market risk premium as of January 2018
r_e	7.5%	U.S. rate
D/V	50.0%	Optimal capital structure, consistent with U.K. regulator’s approach
t	24.0%	Average U.S. tax rate
WACC	5.2%	Author’s calculation
WACC pretax	6.9%	Author’s calculation
Expected inflation	1.9%	U.S. rate
WACC pretax real	4.9%	Author’s calculation

Source: Authors’ elaboration and Damodaran.

Note: D/V = debt/value of the firm; MRP = market risk premium; r_d = cost of debt; r_e = cost of equity; r_f = risk-free rate; t = tax rate; WACC = weighted average cost of capital.

Appendix B. Extrapolation

Extrapolation within a country

The IBNET database does not include all utilities in each country represented. Therefore, its coverage rates represent only a fraction of the actual population with access to WSS services. Separate linear expansions for water supply and sewered sanitation are used to extrapolate the results to the total population served in the country.

Extrapolation to other countries

Upon calculating a total subsidy amount, disaggregated by service, for each country represented in the IBNET database, we extrapolate these results to other countries not included. To do so, we divide all countries into four clusters—high income, upper middle income, lower middle income, and low income—in accordance with the World Bank country classifications by income for fiscal year 2019. For each cluster, average subsidies per person served for water and sewered sanitation are then calculated from the IBNET-represented countries. These average subsidies per person are then used to extrapolate to each country not represented in the IBNET database within the same cluster. Tables B.1 and B.2 show the percentages covered by cluster in the IBNET database.

Table B.1 Average water subsidy per person served within IBNET, by type of country

Cluster	**IBNET countries' GDP ($ million)**	**IBNET countries' population (million)**	**GDP per capita ($)**	**Population served, IBNET (million)**	**Total subsidy, IBNET ($ million)**	**Average subsidy ($/person served)**
Low income	362,069	516	701	58	4,478	77
Lower middle income	1,688,092	756	2,234	158	12,379	78
Upper middle income	6,152,026	719	8,558	263	34,548	131
High income	9,292,121	297	31,282	118	2,003	17

Source: Author's elaboration.

Table B.2 Average wastewater subsidy per person served within IBNET, by type of country

Cluster	IBNET countries' GDP ($ million)	IBNET countries' population (million)	GDP per capita ($)	Population served, IBNET (million)	Total subsidy, IBNET ($ million)	Average subsidy ($/person served)
Low income	362,069	516	701	5	706	144
Lower middle income	1,688,092	756	2,234	26	2,913	110
Upper middle income	6,152,026	719	8,558	175	22,785	130
High income	9,292,121	297	31,282	102	1,715	17

Source: Author's elaboration.

Water and Sanitation Coverage Data

Country-level coverage data are obtained from the World Health Organization/United Nations Children's Fund. However, nine countries lacked water and/or sewerage coverage data within this database. The alternative information sources used to estimate coverage rates for these countries are as follows:

Austria
- 100% piped water coverage in 2012 per the World Bank's Danube Water Program: https://sos.danubis.org/eng/country-notes/austria/

Bahrain
- 95% sewerage coverage estimate for 2013 provided by ministry officials in: http://archive.siww.com.sg/industry-news/bahrain-use-gcc-funds-water-sanitation-projects.html

Fiji
- 20% sewerage coverage estimated using African Development Bank data that 36% of the urban population in 2015 had access to sewered sanitation: https://www.greenclimate.fund/documents/20182/574760/Funding_proposal_-_FP008_-_ADB_-_Fiji.pdf/9c0c8d07-9e83-47d1-8e4a-012fd691c9e4

Indonesia
- 0.8% sewerage coverage estimate obtained using an approximated 1.5% urban coverage from the World Bank's "Improving Service Levels and Impact on the Poor: A Diagnostic of Water Supply, Sanitation, Hygiene, and Poverty in Indonesia" from 2017: https://openknowledge.worldbank.org/bitstream/handle/10986/28505/W17018.pdf

Isle of Man
- 30% sewerage coverage estimated based upon an approximate 50/50 split of customers of the capital's utility between septic emptying services and sewerage, cited in their 2017 annual report: https://www.manxutilities.im/media/1744/manx-utilities-annual-report-201718-v21.pdf

Kosovo
- 69.6% piped water and 56.8% sewerage coverage data obtained from the "Kosovo National Water Strategy Document 2017-2036" http://knmu.kryeministri-ks.net/repository/docs/Water_Strategy_final.pdf

Kuwait
- No available data for piped water coverage. Since WHO/UNICEF database indicates a 2015 sewerage coverage rate of 100%, assumed 100% for piped water.

Micronesia
- 1% sewerage coverage rate approximated using information in "Federated States of Micronesia IWRM Outlook Summary and NWTF" from 2012: https://www.preventionweb.net/files/27083_fsmwatsanoutlook.pdf

Solomon Islands
- 1.3% sewerage coverage estimated using a 2017 9% coverage rate in the service area of Honaira, the only sewerage network in the country. This coverage rate is from the World Bank Project Information Document: http://documents.worldbank.org/curated/en/639301534465283028/pdf/Concept-Project-Information-Document-Integrated-Safeguards-Data-Sheet-Urban-Water-Supply-and-Sanitation-Sector-Project-P165872.pdf

Appendix C. Countries with negative subsidies

Table C.1 lists the countries (most of them developed) that present negative subsidies in our estimation. These so-called negative subsidies do not represent actual transfers from consumers (or the state) to utilities. Instead, they most probably result from (1) water loss or staffing levels below those assumed to be efficient in the Chilean model, (2) assumptions in the methodology (which relied on data from Chile that cannot necessarily be applied to other contexts) or (3) inaccurate data in the Benchmarking Network for Water and Sanitation Utilities (IBNET) database.

Table C.1 Countries with negative subsidies

Country	W % covered by IBNET	WW % covered by IBNET	Water Subsidy	Wastewater Subsidy	Total Net Subsidy
Australia	81.6	79.5	-2586.9	-2646.3	-5233.2
Czech Republic	58.4	56.5	-43.9	-219.9	-263.9
Denmark	7.5	10.8	-11.8	-72.9	-84.7
Norway	12.5	16.0	-44.9	-74.3	-119.2
Oman	30.9	0.0	-84.5		-84.5
Papua New Guinea	52.7	100.0	-14.0	7.8	-6.3
Poland	17.6	30.8	-57.8	-361.0	-418.8
Korea, Rep.	98.1	95.6	402.8	-3094.7	-2691.9
United Kingdom (England and Wales)	7.6	8.0	-393.5	-73.0	-466.5

Source: Authors' elaboration.