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Academic Research Papers

Enhancing Sustainability and Cost Efficiency in Albania's Water Supply Sector: A Path Toward Responsible Water Resource Management

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Abstract

The Albanian water supply sector is facing important challenges despite the country's abundant natural water resources. In terms of coverage, only 71% of the population has access to safe drinking water. There are significant interruptions in supply, and many Water Utilities (WUs) underperform financially and technically.
This study aims to explore the cost structure of Albania's WUs, assess their operational sustainability (exploring their cost structure), and identify cost-saving opportunities.
Individual data for each WU (57 in total) for the period from 2008 to 2015 is used and a translog cost function to estimate economies of output, customer density, and economies of scale is applied. By employing a hedonic approach, the analysis incorporates technical variables such as network length, number of customers, water losses, and load factors along with output and input prices.
The results highlight the presence of diseconomies of output density, customer density, and scale, indicating that increasing water production or the customer base disproportionately raises operational costs. These findings reflect Albania's water supply inefficient infrastructure, a consequence of major network losses, poor network conditions, and limited capacity to manage increasing demand efficiently.
Several policy implications derive from this study. There is an urgent call for investment in infrastructure upgrades, and a strong sectorial reform to improve the financial and operational sustainability of WUs. Policymakers should also consider strategic tariff adjustments and potential regionalisation of services to mitigate rising costs along with regulators and national authorities to guide interventions in enhancing water service delivery, ensuring equitable access, and promoting long-term sustainability.

Keywords – Water utilities; Water supply management; Cost efficiency; Economies of Scale.

Paper type – Academic Research Paper

Sommario

Migliorare la sostenibilità e l'efficienza dei costi nel settore dell'approvvigionamento idrico in Albania: un percorso verso la gestione responsabile delle risorse idriche. – Il settore dell'approvvigionamento idrico albanese si trova ad affrontare sfide importanti nonostante le abbondanti risorse naturali del paese. In termini di copertura, solo il 71% della popolazione ha accesso ad acqua potabile sicura. Si verificano interruzioni significative nella fornitura e molte aziende idriche hanno prestazioni scadenti dal punto di vista finanziario e tecnico. Questo studio mira a esplorare la struttura dei costi delle aziende idriche albanesi, valutare la loro sostenibilità operativa (esplorando la struttura dei costi) e identificare opportunità di risparmio. Vengono utilizzati dati individuali per ciascuna azienda idrica (57 in totale) per il periodo dal 2008 al 2015 e viene applicata una funzione di costo translogaritmica per stimare le economie di produzione, la densità dei clienti e le economie di scala. Utilizzando un approccio edonico, l'analisi incorpora variabili tecniche come la lunghezza della rete, il numero di clienti, le perdite idriche e i fattori di carico insieme ai prezzi di produzione e di input. I risultati evidenziano la presenza di diseconomie tra densità di produzione, densità di clienti e scala, indicando che l'aumento della produzione di acqua o della base di clienti fa aumentare in modo sproporzionato i costi operativi. Questi risultati riflettono l'inefficienza delle infrastrutture di approvvigionamento idrico dell'Albania, come conseguenza delle gravi perdite di rete, delle cattive condizioni della stessa e della scarsa capacità di gestire in modo efficiente la domanda crescente. Da questo studio derivano diverse implicazioni politiche. Urgono investimenti nel potenziamento delle infrastrutture e una decisa riforma settoriale per migliorare la sostenibilità finanziaria e operativa delle aziende idriche. I politici dovrebbero anche considerare gli aggiustamenti tariffari strategici e la potenziale regionalizzazione dei servizi per mitigare l'aumento dei costi insieme a organismi regolatori e autorità nazionali per guidare gli interventi volti a migliorare la fornitura dei servizi idrici, garantire un accesso equo e promuovere la sostenibilità a lungo termine.

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1 Introduction

Albania has abundant water resources, one of the highest see river discharge in Europe, around 40km^3/year. Groundwater resources consist of 23% of the total renewable resources, the main source of drinking water, and the major source of irrigation (Water Action Hub. *Albania*). They are estimated to be around 288 cubic meters per second (m^3/s), with exploitable resources making up about 140 m^3/s, or roughly 50% of the total natural groundwater resources in most aquifers. Currently, urban and industrial water supply from groundwater in Albania is approximately 12 m^3/s, while rural water supply utilizes about 2.0 m^3/s, bringing the total water usage to around 14 m^3/s. (Eftimi, Shehu, & Sara, 2023).

Renewable water resources are one of the major assets of the Albanian economy, crucial for electricity production (Drin, Mati, and Bistrice rivers' hydroelectric plants produce 97% of Albania's energy in 2011, according to Osservatorio Balcani e Caucaso Transeuropa – OBCT), irrigation in agriculture (the biggest consumer of fresh water, around 60% of the total water use, according to Diku, 2011), industry, fishing, tourism, and drinking water sector. The paradox is that only 71% of the population in Albania has access to a safely managed drinking water service (UN Water, 2022) with discontinued water supply services (continuity of water supply for 2022 was 16.3 hours per day according to Water Regulatory Authority of Albania – WRA, 2022).

The water and sanitation sector (WSS) mainly operates through operators organised as a joint stock company owned by the local government. There are 57 operators, 53 of them operating under a WRA license and 48 operators that apply tariffs approved by WRA. Sewerage services are offered by 32 operators, five of which also do wastewater treatment, covering 12 counties and 61 municipalities (World Bank, 2022).

In recent decades, Albania has developed a strong regulatory and legal framework for water services delivery and introduced changes in institutional arrangements to improve service delivery. Moreover, the legislation for Integrated Water Resources Management in Albania will improve compliance with the Water Framework Directive – WFD (Alla, 2019). The integrated management of water resources is based on six principles (Article 6 Law No. 111/2012 "On the Integrated Management of Water Resources", amended):

- sustainable development: respecting the integrity of water basins and balancing water use to meet the current needs, and simultaneously guarantee the water resources quality and quantity, without compromising the ability of future generations to meet their own needs;
- efficiency: using water resources efficiently, respecting the principle of recovering the costs of water services, including the costs of environment, under the "polluter pays" principle[1];

[1] The Polluter Pays Principle (PPP) in the water sector states that those who cause water pollution should bear the costs of managing and mitigating the pollution, aiming to incentivize polluters to reduce their environmental impact

- environmental protection: preserving water ecosystems, biodiversity, and natural habitats through responsible water management practices and all principles of environmental protection[2];
- equity and social justice: ensuring balanced and equitable water use and fair access to clean water for all;
- precaution: applying the precautionary principle to manage risks associated with water resources and prioritising actions to prevent harm;
- transparency: maintaining openness and accountability in decision-making processes related to water management to build trust and confidence among stakeholders.

Albania does not lack adequate water resources and therefore should be able to provide its entire population with safe and fresh drinking water. Nevertheless, most of the water utilities in Albania continue to perform poorly, both technically and financially. An important indicator of their performance is “non-revenue water”, consisting of the lost volume of produced water due to non-metered connections in the network and technical losses due to amortisation of the distribution infrastructure. For the year 2022, according to WRA, this indicator was about 63.7% on average among operators (WRA, 2022). This results in low levels of service to the population and to businesses, and an inability to extend services to those without them, especially the most vulnerable in the peri-urban and rural areas of the country. Around 20 % of the rural population has no piped access at home. Most utilities are chronically dependent on central government funding; 37 out of the 58 municipal water companies continued to rely on budget support (World Bank, 2022).

The situation in Albania is a product of the low performance of operators in the sector of drinking water in the context of largely renewable natural water resources. Exploring the cost structure of the water supply operators will give us valuable hints in terms of their operational sustainability. The individual cost structure explored in time will provide information about the presence of economies of customer density and scale. The objective of this work is to assess the cost structure of WUs in Albania, identifying the most significant drivers that influence the operational costs and providing some practical policy implications to improve the situation of the water and sanitation sector performance.

The article is organized as follows: Section 2 will revise critically the related literature and Section 3 will describe the data and the variables of the analysis in detail. Section 4 will focus on the model specification, stating the theoretical function model, the econometric techniques used, and the calculation of the cost economies. Section 5 will present the results from the translog cost approach,

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by making them financially responsible for the damage they cause (practically imposing fines, fees, or charges on industries and individuals that discharge pollutants into water bodies).

[2] It is defined in Law No. 10 431, dated 9.6.2011, “For Environment Protection”. https://albcold.gov.al/wp-content /uploads/2021/05/Law-No.-111-2012-On-Integrated-Management-of-Water-Sources.pdf.

along with the cost economies results and robustness check to validate the results. The Section 6 will provide the conclusions and policy implications of the article.

2 Related literature

There is a wide literature on the water supply and utilities sector, specifically focusing on cost efficiency, regulatory frameworks, and the relationships between operational and environmental factors. Several key studies have contributed to the understanding of how utility companies manage their costs, and efficiency levels, and respond to external pressures like regulation and environmental changes. However, these works are focused more on developed realities, and the unique context of developing countries, where infrastructure challenges and evolving regulatory environments play a major role, remains partially or less explored. This section reviews the main contributions of pioneer and recent studies to the field and highlights how this work fits into and contributes to the existing literature.

2.1 Operational and environmental factors and utility efficiency

Kim (1987) investigates the presence of economies of scale in firms producing multiple products. Using a translog cost function to model the cost structure of multi-product firms, the study examines whether increasing output across different product lines leads to cost advantages. The analysis uses firm-level data to estimate the economies of scope and scale. Traces of economies of scale were found in certain industries. Additionally, related to economies of scope, it was found that producing multiple products jointly is more cost-efficient than separately.

Mizutani and Urakami (2001) conducted a detailed analysis of Japanese water supply utilities, focusing on how cost efficiency is affected by the network density and the scale of operations. They applied a translog cost function approach to data from numerous water utilities across Japan, and they were able to quantify the presence of economies of scale and their relationship with operational size. Their findings demonstrated that smaller-sized water utilities (specifically those serving densely populated areas) benefit from economies of scale (i.e., as their output and service areas increase, their average costs decrease). However, the study also found a turning point beyond which the expansion of utilities (particularly larger ones) leads to diseconomies of scale. Due to higher infrastructure costs, and logistical challenges in larger service areas, increasing the size of operations results in higher average costs, suggesting that while small to medium-sized utilities can achieve cost savings through expansion, larger utilities may face inefficiencies that counteract these benefits. The study's findings highlight the need to carefully consider the optimal size of utilities and the role of network density in maintaining operational efficiency, particularly in densely populated regions.

The article by Fabbri and Fraquelli (2000) analyses the cost structure and technological efficiency in the Italian water industry, focusing on the relationships between scale, scope, and output density. The authors use a translog cost function to estimate the cost structure of water utilities, utilising data from 53 Italian water companies. The objective is to assess whether economies of scale and scope exist in the industry and to identify the impact of customer and output density on costs. The results indicate economies of scale for smaller firms but diseconomies of scale for larger companies, suggesting inefficiencies in large-scale operations. Additionally, the study finds evidence of economies of scope when combining water production and distribution, recommending better resource integration to reduce costs.

Garcia and Thomas (2001) explored similar issues in the French water industry, conducting a detailed analysis of the cost structures of local water utilities, focusing on the relationship between economies of scale and operational efficiency. Their research found there is a significant cost savings scenario that could be achieved by larger utilities (particularly those that managed both water distribution and wastewater treatment services, called multiple output utilities). This finding supports the argument that where utilities combine multiple water-related functions (integrated service provision) can lead to decreased average costs and improved financial and operational sustainability. It was highlighted that economies of scale were strong in areas where utilities were able to expand their service areas and customer base, suggesting that larger utilities benefit from spreading fixed costs over a greater volume of water supplied. Moreover, it was found utilities that combine water and wastewater services were able to achieve additional cost efficiencies and further reduce operational expenses (through shared infrastructure and administrative systems).

2.2 Efficiency in water utilities: ownership structure, privatisation, and regulation role

Bhattacharyya, Harris, Narayanan, and Raffiee (1995) investigate the impact of ownership structure on the economic efficiency of water utilities in the United States. Using a translog cost function and panel data, they estimate the cost structures of publicly and privately owned water utilities to assess differences in efficiency. The study finds that publicly owned utilities tend to operate less efficiently compared to their private counterparts, primarily due to less stringent cost controls and managerial practices. The authors highlight that private utilities face stronger incentives to minimize costs, leading to better performance. The results suggest that ownership type plays a significant role in influencing the economic efficiency of water utilities, with policy implications for the privatization and management of such services.

Saal and Parker (2000) explored the effects of privatisation and regulation on cost efficiency focused on the water and sewerage industry in England and Wales. Privatisation has been found to have a limited direct impact on cost efficiency, while effective regulation played a more important role in reducing costs and ensuring that savings were passed on to consumers. This study offers a relevant perspective for understanding how cost structures in utilities evolve in response to both market changes and regulatory interventions. It emphasises the variation in regulatory practices, which is critical in understanding how water utilities in different countries perform under varying market conditions. The findings underline the importance of robust regulatory practices in ensuring utility efficiency, a theme that echoes in many studies focused on developed countries but is less addressed in developing economies like Albania, where regulatory reforms are still in progress.

Pazzi, Tortosa-Ausina, Duygun, and Zambelli (2016) investigate the cost efficiency of water utilities with a particular focus on the impact of public ownership. Using a panel dataset from Italian water utilities, the study employs stochastic frontier analysis to assess whether public ownership influences operational efficiency. The findings suggest that public ownership, by itself, does not necessarily lead to inefficiency, but the governance structure and management practices associated with public entities can significantly affect performance. The authors highlight that publicly owned utilities tend to perform worse in environments where governance oversight is weaker, suggesting that the quality of management and regulatory frameworks play a crucial role in driving efficiency, rather than ownership per se. This work contributes to the debate on privatisation versus public ownership in the utilities sector by showing that ownership effects are context-dependent and that improving governance is key to enhancing cost efficiency in publicly owned utilities.

2.3 Cost structure of water utilities in developing countries

The literature is notably sparse when it comes to water management in developing countries, especially concerning cost structures in highly fragmented and inefficient utility networks like those found in Albania. A few consulted papers are described as follows.

Nauges and van den Berg (2008) conducted an important study on the economies of scale, scope, and density in the water supply and sewerage sectors across four developing and transition economies: Brazil, Moldova, Romania, and Vietnam. Using a translog cost function in a panel data context, from their research emerged that economies of scale were present in most countries, except for Brazil. This result has a great impact since indicates that larger utilities could reduce average costs by expanding operations, particularly in Moldova, Romania, and Vietnam. Additionally, the study found evidence of economies of density (i.e., including new water connections, in densely populated areas, can lower average costs). Economies of scope were also identified, in the scenario of combining water supply and sewerage services under the same utility, rather than operating them separately. From the study, it was emphasised the important role of utility size and service integration in improving operational efficiency in the water sectors of these countries. However, Nauges and van den Berg (2008) identified the significant challenges that utilities face in realising these efficiencies, such as the limited infrastructure and fragmented utilities. In developing economies, outdated infrastructure, high levels of non-revenue water (water loss), and fragmented service delivery networks can affect negatively the potential cost savings from economies of scale and scope. For instance, utilities often struggle to maintain and expand services due to financial limitations, dependence on central government funding, and the need to service dispersed populations.

Similarly, Tsegai, Linz, and Kloos (2009) examined the cost structure of water utilities in the Middle Olifants sub-basin of South Africa, estimating the marginal cost of water supply and tracing the presence of economies of scale. Their study used the same methodology (a translog cost function) and data from the South African National Treasury to estimate the marginal cost of water supply and evaluate the financial sustainability of Water Service Authorities (WSAs). Authors found evidence of economies of scale, suggesting an important implication: merging smaller WSAs into larger utilities could reduce costs and improve efficiency. The study underscores the importance of setting appropriate water tariffs that reflect the true cost of service provision and the potential benefits of consolidating smaller utilities to achieve greater operational efficiency. Both under-pricing and fragmented networks create financial strain on utilities, limiting their ability to invest in necessary infrastructure upgrades, which in turn exacerbates issues of water loss and service inefficiencies.

Zhao (2020) conducts an in-depth analysis of productivity change in China's privatised water sector between 1999 and 2006, using and applying a translog stochastic frontier production function and the Malmquist productivity index (MPI) to assess efficiency and productivity dynamics over time. By examining panel data from 38 water utilities across various Chinese cities, Zhao investigates how privatisation and regulatory reforms impacted the sector's productivity. The methodology makes an explicit distinction between operational improvements efficiency and technology advancements, providing valuable insights into whether productivity gains were driven by better resource management or technological innovation. The study's results stated that privatisation alone did not uniformly enhance operational performance across the sector.

Lajqi, Đurin, Vataj, and Nakic (2023) work represents one of the few works for the region (Kosovo, a country neighbour of Albania). They utilised data from water utilities across the country to evaluate key efficiency metrics, including water loss rates, energy consumption, and cost management, and to evaluate the level of financial and operational efficiency. The authors applied benchmarking techniques and several performance indicators, and it merged a significant level of inefficiencies in the water distribution system due to the outdated infrastructure, high degree of non-revenue water, and inadequate resource allocation. They suggested targeted interventions for the case water sector in Kosovo, starting from prioritising the infrastructure upgrading, improving metering systems, and enhancing staff training.

Nyathikala, Jamasb, Llorca, and Kulshrestha (2023) conducted a detailed study examining the governance structures, incentive mechanisms, and performance outcomes in India's urban water sector. The researchers employed a panel data methodology, utilising data from 24 urban water utilities across India over five years. By applying a stochastic frontier analysis (SFA) model, the study aimed to measure the technical efficiency of water utilities while accounting for variations in governance and incentive structures. Moreover, they applied a two-stage analysis to isolate the impact of governance and incentives on utility efficiency, finding that utilities with more decentralised governance and stronger performance-based incentives tended to operate more efficiently than those with centralised or less flexible governance structures.

2.4 Contributions to the literature

Most existing research has focused on utilities operating within well-established regulatory frameworks and with stable infrastructures, leaving a significant gap in understanding the dynamics of water utilities in more volatile and infrastructure-constrained environments. The contribution of the work is multiple: providing (in our best knowledge) probably one of the first) empirical analysis at the level of the operators-structure cost for the case of Albania as a developing country contributing also to the sparse literature about the cost structure of operators in the water industry of developing countries, (ii) offering a consolidated methodology to provide reliable and robust findings using through the estimation of the translog cost function and the measurement of economies of customer density and scale (important indicators for water policies related to planning or water tariffs), (iii) offering a valuable document to the policymakers, regulators and national authorities to better formulate the needed interventions in the sector.

3 Data

Data is collected from WRA Performance Reports for the period 2008-2015, for 57 utilities for a total of 390 observations. The choice of the period of study was driven by the interest in examining the situation before the 2018 reform under the National Strategy on Integrated Water Resources Management (2018-2027). This allows for an evaluation of the sector's dynamics before the reform, providing a baseline against which future developments and policy impacts can be assessed.

Several indicators (performance, economic, financial) are extracted from the reports. The Water Utilities (WUs) included in the dataset have differences in size, water resources, geological distribution area's characteristics, production technology (gravitational system or electrical pumps system for extracting the underground water resources), and customer demand and are located across Albania, in a national level. Table 1 summarizes the descriptive statistics.

Table 1 – Sample descriptive statistics

Variable	Unit	Mean	SD	Min	Max
Variable costs	1000 ALL	62201.58	160967.634	0	1640971
Output	1000 m3 /year	4833.165	14081.691	0	109052.268
Labor price	1000 ALL/ worker/year	248.451	162.345	0.575	700.097
Energy price	ALL/1000 m3/year	2.366	6.372	0	39.063
Material price	ALL/1000 m3/year	15.151	38.393	0	429.914
Network length	km	117.017	239.403	3.1	2267.783
Customers	1000	46503.741	117844.948	866.252	911916.738
Network losses	%	0.461	0.736	0.083	1
Load	%	0.538	0.736	0	9.323
System type	-	0.394	0.489	0	1

Source: Author's elaboration

Our variable of interest is the Water[3] Variable Cost of each utility (*WVC*), which is expressed in thousands of Albanian Lek (ALL). It is used the cost function versus the production function for the analysis of the WUs technology following Shephard (1953). The analysis will be based on one output y_{prod} (the total water volume produced expressed in thousands of cubic meters per year. Input prices w_L, w_{MA}, *and* w_E are respectively the unit price of labour, materials, and electricity; w_L is derived as labour

[3] Sewerage and water treatment processes are not included since only 32 out of 57 offer sewerage services and only 5 do wastewater treatment.

costs divided by the number of staff for each utility (expressed in thousands ALL per worker annually). Electricity price w_E and material price w_{MA} are expressed in ALL per thousands of cubic meters annually and derived respectively as the ratio of energy costs and material costs divided by the output produced.

To consider some technical variables, three variables are included: the number of customers (*cust*) expressed in thousands, the network losses (y_{loss}) derived as the differences between the total water volume produced and total volume sold (expressed in thousands of cubic meters per year) and served as a proxy for the quality of the network infrastructure, and the load factor (*load*) a proxy of the percentage of the water volume sold over the total volume produced. As a control variable, a proxy for the existing capital was considered the network length (*length*) expressed in kilometres (km).

As a proxy for the type of system technology (gravitational or pumping system) a dummy variable (*systype)* was included with value 1 if the volume of water produced from the gravitational system is higher than the one produced with the pumping system, and 0 otherwise. Moreover, to capture any effect of public regulation changes, the intention was to include a second dummy for the effect of the National Strategy on Integrated Water Resources Management 2018-2027, but data stopped 3 years before its implementation.

4 Model specification

4.1 Theoretical model

There was a choice made between variable and total costs and it was oriented by the assumption that using total costs implies that the utilities are at their long-term equilibrium (their production factors minimize the total costs). For the case of the water utilities, this is a strong assumption (their capital stock probably is not at its optimal level since it is relatively costly to modify it and water utilities are demand-specific (their activity depends on the seasonal and unexpected demand variations), so the capital stock is assumed to be fixed in the short-run and it can adjust partially to the long-run equilibrium (Baranzini and Faust, 2009). So, the variable costs include labour, electricity, materials, and other costs.

The traditional costs functional form usually includes as determinants only output and price of inputs without considering the characteristics of the served areas of each utility, technical variables (such as network performance measures), or unexpected events in terms of public regulation. This limited framework does not consider other environmental variables, very important for their impact on costs, especially for water sectors with a higher degree of heterogeneity. For the reasons mentioned previously, a hedonic approach was preferred to use in this context; operator-specific indicators will be included to capture any operator specificity.

Translog functional form for the cost function was chosen versus the Cobb-Douglas one since is a flexible form that provides a second-order approximation for every cost function to be estimated. The translog specification of the model (all the variables except for the dummy one are expressed in natural logs) is presented as follows:

$$\begin{aligned} WVC_{it} = \alpha_0 + \sum_t \alpha_t + \beta_{y_{prod}} y_{prod\ i,t} + \sum_{i=1}^{3} \beta_{w_i} w_{i,it} + \sum_{k=1}^{4} \beta_{z_k} z_{k,it} + + \ 1/2 \beta_{y_{prod} y_{prod}} \left(y_{prod\ i,t}\right)^2 \\ + 1/2 \sum_{i=1}^{3} \sum_{j=1}^{3} \beta_{ij} w_{i,it} w_{j,it} + 1/2 \sum_{k=1}^{4} \sum_{m=1}^{4} \beta_{km} z_{k,it} z_{m,it} + \sum_{i=1}^{3} \beta_{iy_{prod}} w_{i,it} y_{prod\ i,t} \\ + \sum_{i=1}^{3} \sum_{k=1}^{4} \beta_{ik} w_{i,it} z_{k,it} + \sum_{k=1}^{4} \beta_{ky_{prod}} z_{k,it} y_{prod\ i,t} + \beta_{systype} systype_{it} + u_{it} \ , \end{aligned} \quad (1)$$

where: α_0 is the constant term, α_t the time effect, $\beta_{y_{prod}} y_{prod\ i,t}$ is the linear term for the output, $\sum_{i=1}^{3} \beta_{w_i} w_{i,\ it}$ is the linear terms for input prices (i=1, 2, 3) such as labor, electricity, and material prices, $\sum_{k=1}^{4} \beta_{z_k} z_{k,\ it}$ is the linear terms for the hedonic variables included (k=1,2,3,4) such as network length (*length*), number of customers served (*cust*), water losses *(yloss)* and load factor (*load*), and $\beta_{systype}$ for the technology. Each $\sum_{i=1}^{3}$, $\sum_{i=1}^{3} \sum_{j=1}^{3}$, and $\sum_{i=1}^{3} \sum_{k=1}^{4}$ are the coefficients of interaction terms, and ε_{it} the error term.

4.2 Econometric issues and estimation techniques

Costs and input prices were normalized by the price of materials to guarantee homogeneity in input prices and the symmetry is achieved from the condition $\beta_{ij} = \beta_{ji} \ \forall i \neq j$, and $\beta_{km} = \beta_{mk} \ \forall k \neq m$. The homogeneity restriction ensures that the cost function is homogeneous of degree one in input prices $\sum_{j=1}^{3} \beta_{ij} = 0$, $\sum_{i=1}^{3} \beta_{iy_{prod}} = 0$, for each input price i, and $\sum_{i=1}^{3} \beta_{w_i} = 1$. By applying the symmetry and homogeneity restrictions to the translog cost function, it is ensured that it behaves in line with economic theory[4], making it suitable for modelling cost functions in applied econometric analysis.

To profit from the econometric point of view, a joint estimation of equation 1 and the cost-share equations 2.1 and 2.2 will be performed. This dual approach increases the number of degrees of freedom, producing more precise estimators and controlling for possible correlations among disturbances' equations (Bottaso & Conti, 2009). According to Shephard's Lemma[5], taking the partial derivative of the translog cost function concerning w_i will produce the cost-share equation for each input i as follows:

$$S_{i,it} = \frac{\partial WVC_{it}}{\partial w_{i,it}} \tag{2}$$

There will be two equations, only for electricity and labour cost share. The cost-share equation for material is not included due to singularity issues.

$$S_{L,it} = \alpha_L + \beta_L w_{L,it} + \beta_L w_{E,it} + \beta_{Ly_{prod}} y_{prod,it} + \sum_{k=1}^{4} \beta_{Lz_k} z_{k,it} + \beta_{Lsystype} systype_{it} + u_{Lit}\ , \tag{2.1}$$

$$S_{E,it} = \alpha_E + \beta_E w_{E,it} + \beta_E w_{L,it} + \beta_{Ey_{prod}} y_{prod,it} + \sum_{k=1}^{4} \beta_{Ez_k} z_{k,it} + \beta_{Esystype} systype_{it} + u_{Eit}. \tag{2.2}$$

Zellner's (1962) Seemingly Unrelated Regression (SUR) method will be applied. This method will estimate the systems of equations 1, 2.1, and 2.2 jointly, providing more efficient estimates than OLS (residuals of the equations are correlated). The output and input prices are considered exogenous as is common in the study of public utility (Fabbri & Fraquelli, 2000).

Generalised Least Square (GLS) estimators will be produced as a robustness test, corrected for heteroscedasticity and autocorrelation of first order among ν_{it} (Greene, 2018). Moreover, a hedonic Cobb-Douglas cost function functional form will be performed along.

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[4] The monotony and concavity are tested after the estimation of costs, controlling that the Hessian matrix is a negative semi-definite matrix and marginal costs are positive.

[5] It states that the cost-minimizing share of any input in total costs is the partial derivative of the cost function concerning the input price producing the respective input demand function.

4.3 Cost economies

After the estimation of equations 1, 2.1, and 2.2, the economies of output density, customer density, and economies of scale are evaluated. Economies of output density *(EOD)* measure the variance of costs with the increasing of output, keeping fixed the rest of the variables (input prices, load factor, the number of served customers, and the network length):

$$EOD = \frac{1}{\frac{\partial WVC}{\partial Y_{prod}}} = \frac{1}{\varepsilon_{WVC, Y_{prod}}} , \tag{3}$$

where EOD is for the economies of production density, WVC is the water variable cost, Y_{prod} is the volume of water produced, and $\varepsilon_{WVC, Y_{prod}}$ is the cost elasticity of the output. There are economies of output density if EOD is greater than 1, otherwise, there are EOD diseconomies. In terms of WUs, EOD exists if the operational average cost decreases as the volume of water produced increases, while the number of served customers and the served size area remain fixed. As an indicator is relevant for the decision of whether local monopoly or competition is the most efficient form in the water production and distribution sector.

When considering also the customers along with the increasing output (keeping fixed the rest of the variables such as input prices, load factor, and the network length), the economies of customer density *(ECD)* can be quantified as follows:

$$ECD = \frac{1}{\frac{\partial WVC}{\partial Y_{prod}} + \frac{\partial WVC}{\partial cust}} = \frac{1}{\varepsilon_{WVC, Y_{prod}, cust}}, \tag{4}$$

where ECD is for economies of customer density, WVC is the water variable cost, Y_{prod} is the volume of water produced, $cust$ is the number of served customers, and $\varepsilon_{WVC, Y_{prod}, cust}$ is the cost elasticity of the output and customers served. There are economies of consumer density if ECD is greater than 1, otherwise, there are not. This indicator is important when analyzing the service cost for an area of service that becomes more densely populated.

Lastly, economies to scale *(ES)* measures the variability of the costs after a simultaneous increase in output, customers, and network length (holding fixed the rest of the variables such as input prices and load factor) as follows:

$$ES = \frac{1}{\frac{\partial WVC}{\partial Y_{prod}} + \frac{\partial WVC}{\partial cust} + \frac{\partial WVC}{\partial length}} = \frac{1}{\varepsilon_{WVC, Y_{prod}, cust, length}}, \tag{5}$$

where ES is the return to scale, WVC is the water variable cost, Y_{prod} is the volume of water produced, $cust$ is the number of served customers, $length$ is the network length of the WUs, $\varepsilon_{WVC,\,length}$ is the cost elasticity of the network length, and $\varepsilon_{WVC,\,Y_{prod},\,cust}$ is the cost elasticity of the output, customers served, and network length. There are economies of scale if ES is greater than 1, otherwise there are diseconomies of scale. ES gives very important information about the market structure of the water sector in terms of the concentration level of WUs or for analysing the impact on costs of merging two near WUs.

5 Results

5.1 Empirical results

Table 2 reports only the first-order coefficients. Since expressed in natural logs, can be interpreted as cost elasticities for each variable.

The high value of R^2 shows a good fit for estimating the translog model. The coefficient of the output, labour and energy price, and the number of customers served are statistically significant respectively for 1%, 1%, 5%, and 10% and have the expected sign. The capital stock, proxied by the network length, as suggested by the theory, has a negative impact on variable costs, even though the coefficient resulted statistically not significant. Also, the load factor resulted in the expected sign, although not significant. The higher the losses, the higher the variable costs (statistically significant at 1%). This means that WUs can invest in increasing the infrastructure quality, minimising the network losses, and benefiting in terms of variable costs from the increased quality of the distribution infrastructure. The time trend coefficient resulted in a negative sign, meaning that there is a decreasing tendency of the WUs variable costs in time, even though not statistically significant. Finally, as expected, the system type variable coefficient is negative and significant at 1%, confirming that the WUs whose activity is based on the gravitational water production and distribution system, are profiting in terms of variable costs since they are using less electricity input in the process (around 40% less compared to WUs that are using pumping water production and distribution system).

Table 2 – Parameter estimates of the translog variable cost function

Variable	Parameter	SUR -Coefficient	Robust SD Error
Constant	α_0	5.814	50.614
Output	$\beta_{y_{prod}}$	4.796 (***)	1.278
Labor price	β_{w_L}	1.402 (***)	0.233
Energy price	β_{w_E}	0.479 (**)	0.222
Material price	β_{w_M}	-	-
Network length	β_{length}	-0.877	0.648
Customers	β_{cust}	2.063 (*)	1.213
Network losses	$\beta_{y_{loss}}$	0.390 (***)	24.307
Load	β_{load}	8.217	23.2
System type	$\beta_{systype}$	-0.405 (***)	0.049
Time trend	α_t	-0.004	0.009
R^2		0.955	
Observations		321	

Note: ***p<0.01, **p<0.05, *p<0.1.

Source: Author's elaboration

5.2 Robustness tests

The first robustness check is the evaluation of the same system of equations (1, 2.1, 2.2) using the Random Effects (Generalised Least Squares – GLS) procedure. The results are summarized in Table 3.

They are relatively consistent with the ones in Table 2 and the signs of the coefficient are as expected (except for the customers and load factor coefficients that resulted surprisingly negative). Moreover, as expected, the network length coefficient, used as a proxy for the fixed capital of WUs, resulted significantly at 10%.

Table 4 summarizes the results for the Cobb-Douglas costs functional form.

The signs of the estimated coefficient are as expected, while fewer variables resulted significantly compared to the scenario of the translog cost function (Table 2). Moreover, for comparability of the results, it was used a hedonic Cobb-Douglas version, including also the environmental and technical variables as in the translog cost function, confirming that the latter was the appropriate choice to model the variable cost function for the Albanian WUs.

Table 3 – Parameter estimates of the translog variable cost function with the GLS method

Variable	Parameter	SUR -Coefficient	Robust SD Error
Constant	α_0	-18.709	41.076
Output	$\beta_{y_{prod}}$	6.509 (***)	1.225
Labor price	β_{w_L}	1.243 (***)	0.168
Energy price	β_{w_E}	0.444 (**)	0.212
Material price	β_{w_M}	-	-
Network length	β_{length}	-1.019 (*)	0.568
Customers	β_{cust}	-3.820 (***)	1.239
Network losses	$\beta_{y_{loss}}$	-13.879	19.404
Load	β_{load}	-4.884	18.839
System type	$\beta_{systype}$	-0.475 (***)	0.056
Time trend	α_t	0.008	0.008
Observations		320	

Note: ***p<0.01, **p<0.05, *p<0.1.

Source: Author's elaboration

Table 4 – Parameter estimates of the Cobb-Douglas variable cost function with the RE method

Variable	Parameter	SUR -Coefficient	Robust SD Error
Constant	α_0	-0.793	0.653
Output	$\beta_{y_{prod}}$	0.534 (***)	0.130
Labor price	β_{w_L}	0.946 (***)	0.038
Energy price	β_{w_E}	0.033	0.037
Material price	β_{w_M}	-	-
Network length	β_{length}	0.104	0.071
Customers	β_{cust}	0.248 (**)	0.108
Network losses	$\beta_{y_{loss}}$	0.095	0.174
Load	β_{load}	0.199	0.215
System type	$\beta_{systype}$	-0.419 (***)	0.119
Time trend	α_t	-0.015	0.009

Note: ***p<0.01, **p<0.05, *p<0.1.

Source: Author's elaboration

5.3 Cost economies results

Table 5 presents the results for cost elasticities to output, output, and customers and output, customers, and network length simultaneously, the respectively EOD, EOC, ES, and marginal costs. What emerged is that there is the presence of diseconomies of output density, diseconomies of customer density, and diseconomies of scale (the respective indicators are less than 1) when cost elasticities are estimated at the sample mean.

Diseconomies of output density occur when an increase in the volume of water produced leads to a more than proportional increase in costs (the WU produces more water and becomes less efficient). The presence of diseconomies of output density Albanian water sector suggests that expanding water production leads to rising costs rather than cost savings. This could be due to limitations in infrastructure (e.g., water treatment plants or pipelines), inefficiencies in resource management, or the use of more expensive sources of water as output increases. WUs might struggle to meet higher demand without driving up costs, which could result in higher prices for consumers or financial strain on the WUs.

Table 5 – Cost elasticities and economies, and marginal costs for translog variable cost function

$\varepsilon_{WVC, Y_{prod}}$	**EOD**	$\varepsilon_{WVC, Y_{prod}, cust}$	**EOC**	$\varepsilon_{WVC, Y_{prod}, cust, length}$	**ES**	**MC**
4.787 (***)	0.209	2.358 (***)	0.424	1.368 (***)	0.731	61.619 (***)
(1.277)		(0.667)		(0.525)		(16.442)

Note: ***p<0.01, **p<0.05, *p<0.l.
The Delta method was used to calculate the standard errors (in parenthesis).
They are calculated at the sample mean.

Source: Author's Elaboration

Diseconomies of customer density occur when increasing the number of customers served leads to a disproportionate rise in costs. This means that serving additional customers, particularly in low-density rural areas or challenging terrain, raises costs per customer rather than reducing them. This can happen: (i) in geographically dispersed or challenging-to-serve areas, and (ii) in rural ones: serving rural areas often comes with higher costs due to lower population densities, meaning that fixed costs (e.g., building and maintaining water lines) are spread over fewer customers, raising the average cost per customer; and due to (iii) the network strain: the existing network infrastructure might be insufficient to handle the increasing number of customers, leading to higher maintenance costs, network bottlenecks, and water losses. This is an indicator that the infrastructure of the Albanian water sector is not well-suited to handling additional connections efficiently, possibly leading to increased operational and maintenance expenses. This could be a sign that expanding service areas without upgrading infrastructure or improving operational efficiency may be unsustainable.

Diseconomies of scale occur when an increase in the scale of the water utility (i.e., expanding the service area or increasing output and customer base) increases the average cost of providing services. This means that as the utility increases in size (in terms of both output and customer base), its cost per unit of service rises rather than falls. For the Albanian water sector, this suggests that WUs are becoming less efficient as they scale up. Larger water utilities might face higher management and coordination costs, more complex logistical challenges, or increased infrastructure strain, all of which contribute to rising costs. This could indicate a need for decentralisation, operational improvements, or targeted investments in infrastructure to achieve better cost-efficiency.

6 Conclusions

Albania is a Southern European country, situated in the Western part of the Balkan peninsula, favoured by rich natural water resources per capita. Speaking in terms of water supply coverage and duration, operating WUs do not cover with service all the population and the duration of service is not 24 hours per day. These facts tell about a very challenged water sector in Albania, with 57 operators struggling to survive financially.

The focus of this study is to explore the situation of the water sector in Albania. For all the operating WUs financial and economic data was collected for the period from 2008 to 2015 and elaborated in terms of modelling the cost structure of them, using it to trace the presence of economies of output density, consumer density, and scale. The approach used was a hedonic one, including also technical and environmental variables along with output and input price variables.

The analysis of Albania's water supply sector reveals significant inefficiencies in operational performance, most notably reflected in the presence of diseconomies of output density, customer density, and scale. These inefficiencies point to critical structural and operational challenges within Albania's Water Utilities (WUs). Despite an increase in the customer base and the volume of water produced, the expected cost reductions have not materialised. In contrast, expanding operations often lead to higher operational costs, suggesting that the current infrastructure is incapable of efficiently handling a rise in water demand. This limitation is particularly concerning given the projected increases in water demand driven by population growth, urbanisation, and industrial activities.

Addressing diseconomies of scale and density. The diseconomies of output density indicate that as water production increases, WUs incur disproportionately higher costs, leading to inefficiency. Several factors influence these dynamics: aging infrastructure (i.e., it cannot support the increased output due to the increased demand), and the customer base geographical distribution (especially in rural areas). Trying to reach low densely populated or remote areas requires major infrastructure investments, not expected to scale efficiently (serving a small number of customers). This scenario will probably increase the cost per unit of service, putting another challenge on the financial viability of WUs. These findings highlight the need for policymakers to focus and prioritise firstly the improving of the existing infrastructure efficiency and then to plan about expanding capacity. A potential, worth-to-be-considered solution is to encourage urban densification. By promoting higher population densities in urban areas, WUs can benefit from more concentrated service areas, where the cost of infrastructure can be spread over a larger customer base. This would reduce the per capita cost of service provision, helping to mitigate the diseconomies of scale and density. Rural areas from the other side, can be the object of targeted water conservation initiatives and local water management solutions such as promoting rainwater harvesting or decentralized water treatment systems. These activities could reduce the investments for infrastructure expansion while helping rural communities meet their water needs more efficiently.

Existing infrastructure modernisation and new investments. The traced inefficiency in Albania's water sector is further worsened by the outdated infrastructure. With an average water loss rate of 63.7% across operators (high levels of non-revenue water), a considerable proportion of the produced output is lost due to leaks, illegal connections, and other forms of wastage. This represents a substantial financial burden, as these losses increase operational costs without generating corresponding revenue. To address this, infrastructure modernization should be a top priority for both policymakers and WUs. Investments should focus on the following areas:

- *Improving distribution networks*. The aging and poorly maintained distribution networks are the main source of water losses. Investments oriented towards leak detection technologies, inefficient (energy-intensive) pipe replacement programs, and qualitative maintenance practices can be some needed interventions. The results are an improved short-run operational efficiency (less non-revenue water that is a burden to the WUs' budget) but also more improved quality of water services, contributing significantly to the long-term financial sustainability.
- *Increasing the degree of the sector formalising*. The phenomenon of illegal connections and unmetered water connections (they are recognised in the network, but do not have a meter, paying in this way not based on the consumption, but a flat tariff) contribute significantly to non-revenue water levels. The installation of water meters for all connections can reduce illegal

water consumption. Policymakers should be supportive of this by creating incentives for households to legalize their connections (subsidies or payment plans for low-income and marginalised households).

- *Adopting leak detection technologies*. To improve system efficiency and to minimise water losses, modern leak detection technologies can be implemented identifying leaks in the distribution network more quickly, lowering the time of response and improving the overall system efficiency. To consider that these technologies are suggested to be an organic part of the maintenance practices to detect leaks, interventions need to take place, before they lead to significant water loss.

Considering and prioritising the infrastructure challenges, it can be feasible for Albania's WUs to reduce operational costs, improve service delivery, and at the same time enhance financial sustainability. Note that this is translated into some important investment, from government authorities or potentially from private sector partnerships. Exploring several financing options, such as international development grants, public-private partnerships (PPPs), or concessional loans should be considered by policymakers to fund these critical infrastructure projects.

Labour costs and workforce efficiency. Another critical finding from the analysis is the impact of labour costs on operational efficiency. In the Albanian water sector, labour costs have a higher impact on total costs compared to energy prices, which is somewhat expected given the sector's overstaffing issues. WUs often employ more staff than necessary, which drives up operational costs without corresponding increases in efficiency. This overstaffing issue is compounded by the fact that many processes within the WUs are manual or require significant human intervention, further inflating labour costs. To address this important problem, policymakers should encourage the adoption of operational automation and digitalization from WUs. Routine tasks, (e.g., meter reading, billing, and maintenance scheduling) could be perfectly automated and in turn, reduce the excessive staff, improving also the accuracy and efficiency. Moreover, training of the workforce and capacity-building are tools to be considered in the transition to more technical and specialised roles of the staff. In cost terms, by improving staff efficiency indicators through automation, each WUs can reduce manual labour reliance, achieving more sustainable operational models.

Regionalisation and decentralisation of water services. From the findings of this work, it emerged the presence of diseconomies of scale in larger water utilities suggests that these utilities face operational challenges related to resource management and coordination. Aiming to expand their service areas and customer bases, WUs face increased complexity in infrastructure and human resources management, and operational financial aspects administration, leading to inefficiencies (as the customer base increases, the operational costs increase also). One form to address this issue policymakers could be water services regionalisation (smaller, more manageable utilities are created to serve specific areas) leading to the reduction of the operational complexity faced by larger utilities while meeting the unique needs of each region. This fact, in terms of governance, would require localised governance of water services, so the response to local challenges would be faster providing more tailored solutions to be implemented. Decentralisation should be seen also in the decision-making process of local authorities (or smaller utility entities), leading to greater accountability (local managers can be more directly accountable to the communities they serve). There is an issue that should be considered, the careful planning of regionalisation and decentralisation, meaning that WUs should preserve their financial and operational capacity to meet their obligations. regional water management boards or cooperatives can be created by the policymakers to ensure the technical support and financial resources for all WUs to operate efficiently.

Summarising, several policy recommendations for sustainable water services can be formulated:

- incentivising urban densification (i.e., it can be achieved a reduced per capita cost of water service provision in highly dense urban areas, mitigating the presence of diseconomies of scale and density);
- promoting water conservation practices in rural areas (e.g., rainwater harvesting and decentralised water treatment systems initiatives can reduce the need for costly investments in low dense and difficult to be reached rural areas);
- infrastructure investments (distribution networks should be prioritised to be upgraded with the installation of leak detection technologies in order to reduce non-revenue water level and improve WUs financial and operational stability and sustainability;
- the implementation of processes automatisation and digitalisation to reduce labour costs and improve operational efficiency along with labour force training;
- regionalisation and decentralisation (the creation of smaller, more manageable WUs with decentralised decision-making for higher responsiveness and accountability;
- alternative financing mechanisms (public-private partnerships (PPPs), international development grants, or concessional loans could support several costly infrastructure investments).

By implementing these recommendations, Albania can create a more sustainable, efficient, and resilient water supply sector. Policymakers should act accordingly to address the critical inefficiencies identified in this study, ensuring that the country's water utilities are prepared to meet the growing demand for water services in the face of population growth, urbanization, and climate change. In the end, water is a human right and should be managed as a common god, not as a commodity, and the government authorities have the responsibility to explore additional ways to enhance the sustainability of water supply services in Albania.

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