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Efficiency in public and private companies in the basic sanitation sector: a study using Data Envelopment Analysis (DEA)

Eficiência em empresas públicas e privadas do setor de saneamento básico: um estudo com aplicação da Data *Envelopment Analysis* (DEA)

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Abstract
Current discussions about the lack of investments in basic sanitation, a sector forgotten by governments, point out the emergence of private companies operating in the sector as a potential solution. Against this backdrop, this study compares the efficiency of state-owned enterprises (SOEs) and private companies operating in basic sanitation in the South of Brazil. The method adopted was data envelopment analysis (DEA), collecting inputs and outputs for 2016, 2017, and 2018 from the companies owned by the Brazilian states of Santa Catarina, Rio Grande do Sul, and Paraná, respectively, Casan, Corsan, and Sanepar; and from the private companies, "Aegea" and "Iguá." The results show that Sanepar was the most inefficient company in the years analyzed. In the documenos analyzed, SOEs confirm the difficulty of providing universal basic sanitation by relying solely on public investments, suggesting the implementation of partnerships with private companies, which proves the importance of a revision in the business framework and the current sanitation plan.
Keywords: basic sanitation. data envelopment analysis; state-owned enterprises; private companies.

Resumo
A falta de investimentos no setor de saneamento básico é pauta de discussões atuais, o setor foi esquecido e a implantação de empresas privadas surge como uma solução plausível. Assim, o objetivo do estudo é comparar a eficiência das empresas públicas e privadas de saneamento da Região Sul brasileira. O método utilizado foi a *Data Envelopment Analysis (*DEA*)*, com coleta de *inputs* e *outputs* divulgados de 2016 a 2018 pelas entidades estaduais: Companhia Catarinense de Águas e Saneamento, Companhia Riograndense de Saneamento e a Companhia de Saneamento do Paraná e pelas privadas: Aegea e Iguá. Dentre os principais resultados, destaca-se que a Sanepar foi a empresa com menor eficiência. As entidades estatais admitem dificuldade da universalização do saneamento básico apenas com investimentos públicos, sugerindo a implantação de parcerias com entidades privadas, comprovando a importância da revisão no quadro de atuação no setor e no atual plano de saneamento brasileiro.
Palavras-chave: saneamento básico; *data envelopment analysis*; entidades públicas e privadas.

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1 INTRODUCTION

Discussions on the lack of investments in basic sanitation in Brazil have focused on the performance of state-owned enterprises (SOEs) and private companies operating in the sector (MARGULIES, 2018). The sector must be prioritized and the attraction of private investors has been considered an option to replace SOEs that are sometimes loss-maker companies (PEREIRA, 2019). The emergence of mixed or private sanitation companies finds support in their ability to respond to market opportunities, obtain resources and investments, generate wealth, and access cutting-edge technology (DANEBERG et al., 2014).

According to the organization Instituto Trata Brasil (2017), basic sanitation comprises a set of infrastructures commonly managed and regulated by the government to improve the environment and the population's living conditions, trying to inhibit the dumping of polluting and toxic materials in nature through qualified treatment and ecologically correct disposal. Data from 2017 on the South region of Brazil showed that 88.34% of the population in the state of Santa Catarina had access to treated water, 22.96% had access to sewage collection, and 28.01% to sewage treatment. In Paraná, 93.74% of the population had access to treated water, 69.53% to sewage collection, and 71.58% to sewage treatment. Finally, the numbers in the state of Rio Grande do Sul showed that 86.14% of the population had access to treated water, 31.08% to sewage collection, and 25.82% to sewage treatment (INSTITUTO TRATA BRASIL, 2017).

Zhou et al. (2018) point out that the United Nations (UN) Millennium Development Goals (MDGs) and Sustainable Development Goals (SDGs) have resulted in a growing focus on the development of innovative and sustainable sanitation techniques to meet the demand for adequate and equitable sanitation in low-income areas. The authors examined the background, current situation, challenges, and prospects of global sanitation. They found that most research occurs in developed countries, although sanitation problems are more severe in developing countries.

According to Matsuda (2014), data from the Brazilian Institute of Geography and Statistics (IBGE) show that although 98% of the population has access to treated water, about 17% of households do not have piped water supply, mainly due to the quality of the pipeline transporting water. The author demonstrates that 99% of the population in urban areas access drinking water, while this percentage in the rural population drops to 84% (MATSUDA, 2014).

In Brazil, Law 11445 of January 5, 2017 (BRASIL, 2017) states the rights, obligations, and duties of companies responsible for the sewage and water treatment and distribution. This legislation ensures basic sanitation for the entire population and establishes national guidelines for universal access to water supply, sanitary sewage, urban cleaning, and adequate urban drainage.

However, theoretical dilemmas are observed when the sanitation infrastructure faces difficulties jeopardizing the delivery of sanitation services ensured by legislation (SILVA et al., 2021). Although over ten years have passed since the law on basic sanitation was enacted, the improvement in access to treated water and sanitary sewage has increased by only a few percentage points, reaching just over half of the population (VELASCO, 2017).

Institutional and economic reform in sanitation is essential to the country's economic and financial growth, preventing blockages in expanding the service due to lack of investments, for example. Thus, holistic solutions that consider economic viability and the different aspects of sanitation are essential. They must be adapted to local conditions and count on

government support, social acceptance, and technological reliability (ZHOU et al., 2018).

The privatization of SOEs operating in basic sanitation is a way out of the lack of resources for investments and improvements. A large country like Brazil cannot depend only on public entities to meet the current demand. In this context, private companies enter to help manage such demands and provide the necessary service expansion. Unlike SOEs, private companies do not depend on government transfers to invest in improvements – transfers that are subject to cuts according to the country's economic situation (ARCOVERDE, 2020).

In general terms, SOEs operate with large numbers and operations involving significant financial values, giving the impression of high efficiency – which is not necessarily the case. Also, the performance of the company is enough so the organization is sustainable. However, they fail to focus on returns for the community regarding innovative and technological solutions, which is something private companies are better equipped to provide. Private companies also can make substantial investments and offer high returns (OLIVEIRA, 2018).

When comparing private companies and SOEs, private companies have more predictability regarding the resources available for investment, which is something SOEs may struggle since the investment decision-making may take more time and involve elements other than the company's interest, jeopardizing its ability to bring new technology and innovation. Thus, private companies are more equipped to make such decisions and innovate, becoming more competitive and benefiting the population. In this regard, the SOE Corsan declared in its management report that public-private partnerships would be a solution to raise the BRL 10.8 billion investment in technology and other items needed to reach universal basic sanitation in the Brazilian state of Rio Grande do Sul. These partnerships may be an alternative to integrate the system with more advanced technology (CORSAN, 2022).

Even though Brazilian SOEs have made significant investments in the sector, they are still far from achieving the goals of the national plan on basic sanitation (PLANASB). In order to reach these goals, the enterprises would have to increase investments by 60%. However, Arcoverde (2020) states that the Brazilian federal government funding to SOEs has been falling in recent years.

The SOEs serve different municipalities from a single office, complying with certain standards and maintaining the accounting records of all municipalities. On the other hand, private entities serve just over 6% of the municipalities nationwide and can act through public-private partnerships (OLIVEIRA, 2018). However, Barbosa and Barbosa (2016) state that the National Sanitation Plan (PLANASA) is replaced by more flexible models, aiming to encourage the participation of the private sector.

The efficiency of SOEs and private companies operating in the basic sanitation sector can be evaluated and compared through data envelopment analysis (DEA). DEA analyzes whether each company operates properly regarding the resources applied and results obtained when compared to companies in the same branch or sector of activity or those with compatible characteristics, without needing to adjust the variables in monetary values (CASADO; SOUZA, 2007).

DEA aims to (i) compare the number of decision-making units (DMUs) that consume different proportions of inputs and produce different proportions of outputs in activities with common characteristics; (ii) Identify efficient DMUs and locate the lowest efficiency of those that have not reached the ideal; (iii) Implement strategies to achieve the minimum efficiency expected from the units and

maximize the efficient ones (MELLO et al., 2003).

This article was developed considering the research question: What are the most efficient companies in water treatment and distribution, SOEs or private companies? The objective of the research is to analyze the efficiency of these two types of organizations in the basic sanitation sector, focusing on those that serve municipalities in the South of Brazil.

This research is relevant since it addresses a theme crucial to the country's development. Also, although the inefficiency of water and sewage treatment services in Brazilian municipalities and states is currently well debated, there is a theoretical gap this research seeks to fill. The study hypothesizes that private companies are more efficient than SOEs. This hypothesis was formulated based on discussions encompassing various arguments, from, on one side, understanding that basic sanitation services must be produced through public-private partnerships to, on the other side, the notion that SOEs alone can efficiently supply the services in this sector.

The DEA contributed to the research since the method is commonly used in the field and was able to offer an efficiency scale for the analyzed companies. Also, the method highlighted the aspect that indicated the inefficiency of an organization compared to the others in the sample and how to overcome such inefficiency.

2 THERORETICAL FRAMEWORK

Concern about water quality and sewage disposal increased with the increasing knowledge about the harmful effects that the lack of these elements cause to people and the environment (FERREIRA; GARCIA, 2017). Brazil has a universalized and comprehensive water supply network. On the other hand, the sewage system is deficient, with poor collection and treatment services (FERREIRA; GARCIA, 2017).

Frischtak et al. (2017) discuss Brazil's poor basic sanitation infrastructure, which affects the economy's productivity and the population's well-being. For the authors, there is little investment due to fiscal restrictions the state governments have faced for years. Also, it is challenging for governments to redirect resources in a budget absorbed by current and mandatory expenditures.

The federal government launched the national basic sanitation plan (PLANASB), offering goals to improve the sector. The implementation of PLANASB was supported by studies that show the return on adequate investments and how insufficient investment brings little return to society and companies providing such services. Velasco (2018) reinforces that one of the reasons for the sector's little development was the decrease in public investments.

Prüss-Üstün et al. (2008) found a relationship between investment in basic sanitation and poverty reduction, with a satisfactory effect. According to the authors, each dollar invested toward achieving the millennium development goals generates, on average, an economic benefit of USD 12.

Saiani and Azevedo (2018) state that the local private mode of organization decreases morbidity rates and that the hybrid mode of organization – where decision-making is shared between private agents and the state government – does not deteriorate service quality. For these authors, the privatization of basic sanitation services is not necessarily subject to a compromise between quality and cost, even if the quality indicators are not contractable.

According to the Associação Brasileira das Concessionárias Privadas de Água e Esgoto (ABCON) [Brazilian Association of Private Water and Sewage Concessionaires], the private sector manages these services in just over 5% of municipalities in Brazil (316 municipalities) while state public companies serve 70% of the municipalities.

ABCON (2016) advocates that the universalization of sewage access will be possible only with the participation of private companies.

Incentives for creating public-private partnerships (PPPs) are implemented to motivate the economy and the search for new technologies to meet the community's interests. These incentives promote new services since private companies have less bureaucracy than SOEs, which often have insufficient resources from the public administration (BARBOSA; BARBOSA, 2016).

According to the Strategy Map for Industry 2018-2022, published by the Brazilian National Confederation of Industry (CNI), infrastructure is currently one of the main obstacles to advancing competitiveness and technologies. Also, the state will not be able to increase investments to the necessary level without the participation of the private sector.

Daneberg et al. (2014) state that the privatization of sanitation services prioritizes: (i) increasing participation of private investors in listed enterprises controlled by the state; (ii) public-private partnerships (PPPs) to improve the provision of water supply and sanitation or both, even if privatization is the most appropriate choice and; (iii) forming municipal consortia to enable the privatization of services in the case of municipalities served by SOEs.

At the national level, Daneberg et al. (2014) compare the returns of the SOEs Companhia Catarinense de Água e Saneamento (Casan) and Companhia de Saneamento do Paraná (Sanepar) through a descriptive analysis of the entities' financial statements. Researchers have used DEA to compare the efficiency of management of applied resources and services, the results obtained from the states, comparing the performance of public and private providers.

This study is related to the literature presented in Table 1, which shows the importance of the topic, the variables (inputs and outputs) adopted, and the methods.

Table 1 – Studies on the sanitation sector in Brazil using DEA

Authors/ Year	Description	Variables	Method
Cruz and Ramos (2012)	Using DEA to analyze the efficiency of basic sanitation management and its impacts on health promotion	Input (5) Water supply networks coverage; Sewage collection networks coverage; Degree of urbanization; doctors per group of 1,000 inhabitants; Per Capita GDP. Output (1) Number of children over 5 years old.	DEA-BCC output-oriented
Hora *et al*. (2015)	Using DEA to analyze the efficiency of sanitation services in the municipalities of the Brazilian state of Rio de Janeiro	Input (1) Operating expenses. Output (4) Volume of water consumed; Extension of the water network; Number of users connected to the water system; Number of users connected to the sewage system.	DEA-BCC output-oriented
Motta *et al.* (2013)	Using DEA to evaluate the efficiency of solid waste collection and processing services in Brazilian municipalities	Input (2) Total number of employees hired; total equipment available. Output (2) Total solid waste collected; total solid waste processed.	DEA-BCC output-oriented
Schappo *et al.* (2017)	Using DEA to analyze the efficiency of resources applied by the public and private sectors to manage urban solid waste in municipalities	Input (1) Total expenses with urban solid waste collection (BRL/year). Output (3) Quantity of solid waste collected in the municipalities (ton/year); Population served by the waste collection service; Amount of recyclable waste collected (ton/year).	DEA-BCC output-oriented

Barbosa *et al.* (2019)	Using DEA to propose a methodology to measure the efficiency of drinking water supply and sanitary sewage in the Brazilian state of Minas Gerais.	Input (1) Exploration Expenses. Output (2) Volume of water consumed; Extension of the water network; Number of users connected to the water system.	DEA-BCC output-oriented

Source: Elaborated by the authors (2019)

Cruz and Ramos (2012) studied the relationship between infant mortality and the quality of sanitation by analyzing the public administration in different regions of Brazil from 2000 to 2006. The authors concluded that there was greater efficiency in the South Region, followed by the Southeast and the North. The Northeast Region of Brazil had the least efficiency.

Motta et al. (2013) used DEA to verify the efficiency of solid waste collection and processing in Brazilian municipalities in 2008. The authors concluded that the greatest efficiency is in municipalities in central and southern Brazil, with a predominance of private companies providing the service.

Schappo et al. (2017) studied the efficiency of resources directed to solid waste management provided by private companies and SOEs in Brazilian municipalities in 2015. The authors concluded that the state of Paraná had the most municipalities with efficient use of resources. They also observed that the increase in investments alone did not necessarily result in service efficiency.

Barbosa et al. (2019) proposed a methodology to measure the efficiency of sewage and water supply systems in 49 municipalities in the state of Minas Gerais. Based on 2016 data, they concluded that only 12 municipalities were efficient and observed that more investments did not necessarily result in efficiency. Also, the authors concluded that municipalities in urban areas are more likely to be efficient, and there is no relationship between efficiency and the municipalities' proximity to the state capitals.

Hora et al. (2015) analyzed the efficiency of basic sanitation services in the municipalities of the state of Rio de Janeiro using the 2010 census data released by the Brazilian Institute of Geography and Statistics (IBGE). The authors used DEA to conclude that the population of the urban areas had better sewage and water services. Leonetti et al. (2015) evaluated the PPPs in the context of universal sanitation in Brazil, discussing the limitation of the public sector in dealing with the investment required and how the first investment took place through a PPP. Oliveira et al. (2019) found that the implementation of the Pesquisa Nacional de Saneamento Básico PNSB (National Basic Sanitation Survey) – which explores conditions of basic sanitation in Brazil – helped sanitation companies to achieve better results regarding the universalization of access to water.

Cavalcanti et al. (2020), when analyzing the efficiency of basic sanitation management in 1628 Brazilian municipalities from 2008 to 2016, used multiple data envelopment analysis (M-DEA) to find that it was possible to increase service coverage and operating results by 60% with the infrastructure already available.

Finally, Pereira et al. (2021) analyzed sewage and water supply services in the 95 largest municipalities in Brazil, using DEA and stochastic frontier analysis (SFA) between 2013 and 2018. The authors concluded that private companies were more efficient in water supply services than SOEs. They also identified a lack of incentives to increase efficiency in the sector.

Thus, the topic is relevant since it is a current issue in Brazilian society, and the goal of universalizing access to treated water has been neglected. Previous research indicates the importance of increasing the participation of private companies in the

sector, as they allow greater chances to reach this goal when working with SOEs.

3 METHODOLOGY

This quantitative research analyzes a sample with the SOEs and private companies that offer basic sanitation services to municipalities in the South of Brazil: Aegea, Casan, Corsan, Iguá Saneamento, and Sanepar.

Ferreira et al. (2016) state that the South region has the lowest number of total cases of sanitation-related diseases in all studied years, from 2001 to 2010. This indicates that when it comes to the Brazilian population's health, sanitation is more efficient in the South region, where the rate of illness caused by lack of health care is lower (0.19%). The South is one of Brazil's most developed regions, and it has the third-largest concentrated population. Ferreira et al. (2016) highlight the region's high indicators in terms of education, economics, and prevention of diseases through sanitation.

The South region was responsible for 14.49% of the total amount charged for water supply services in Brazil in 2000, and was the most efficient in terms of collecting the water payments (CARMO, 2003). Therefore, this study selected the public companies owned by the state governments in the three states of the region and private companies operating in this part of the country in the years analyzed (2016 to 2018). SOEs run by local governments were disregarded because they did not present complete and/or relevant data for the research.

The states of Paraná, Santa Catarina, and Rio Grande do Sul count 1,191 municipalities, and not all of them were served by the five companies of the sample. In these cases, it was not possible to identify how basic sanitation services were rendered (if by companies owned by the local governments or small private companies) or access information on the management of water and sewage systems. Therefore, the research focused on the 866 municipalities served by the companies of the sample.

Data collection was carried out directly from the five organizations' websites and on the website of the Brazilian Stock Exchange Brasil, Bolsa, Balcão (B3), which contains economic and financial data from the three companies of the sample that are publicly traded (Sanepar, Iguá Saneamento, and Casan). Data analysis was conducted individually, observing the company's efficiency and results and exploring the improvement or worsening in a given decision-making unit (DMU).

The documents analyzed were financial statements, management reports, release presentations, explanatory notes, information disclosed to investors, and other forms and reports the companies made available. Data collection in these documents was conducted after selecting the DEA's inputs and outputs. During this process, some inputs and outputs were not found in the sources researched and, therefore, were excluded.

Casan, Corsan, and Sanepar are SOEs, and Aegea and Iguá are private companies operating through public-private partnerships. A limitation of this study lies in the number of companies that serve the municipalities of the region since around 30% of the municipalities are not served by these fice organizations and did not provide information on the management of their basic sanitation systems in the period researched. The information was unavailable probably because these municipalities had their own SOEs, and these small companies did not disclose financial statements or the municipalities simply did not inform the type of service provider (whether private companies or SOEs). In addition, due to the particularities of the basic sanitation sector in the different Brazilian regions, elements of this research cannot be replicated or adopted in studies focusing on other territories, which can be

considered another limitation of this research.

Table 2 shows the companies, their classification as private companies or SOEs, the number of municipalities they serve, and the states where they operate.

Table 2 – Companies of the sample and municipalities they served between 2016-2018

Company	Type	Number of municipalities	States where companies operate
Casan	SOE	195	Paraná and Santa Catarina
Corsan	SOE	317	Rio Grande do Sul
Sanepar	SOE	347	Paraná and Santa Catarina
Aegea	Private	4	Santa Catarina
Iguá	Private	3	Paraná and Santa Catarina
Sample	**-**	**866**	**3**

Source: Elaborated by the authors (2019)

Aegea only serves municipalities in the state of Santa Catarina in the South of Brazil but has businesses in other regions of the country. The SOE Corsan only serves municipalities in Rio Grande do Sul. It is noteworthy that the two private companies serve a small number of municipalities compared to the SOEs. However, this fact is not a limitation for comparison since the data collected refer to the entity as a whole and its consolidated results, encompassing its units throughout the country. This criterion allows comparing the two types of organizations, considering that, different from the private companies, the SOEs only operate in the South of Brazil.

3.1 *Data Envelopment Analysis* (DEA)

DEA measures efficiency through production frontiers (CASADO, 2007). According to Belloni (2000), these measures compare the results achieved through the resources employed, and in the case of lower efficiency than expected, the DEA indicates where it is concentrated and how it can be extinguished. According to the author, there are two criteria for efficiency in producing the good or service: productive and allocative. Productive efficiency consists of the physical aspect aiming at minimum waste, using the resources applied to generate the maximum results, or applying minimum resources for certain production. Allocative efficiency, in turn, is the ability to combine resources and results in the best possible proportions to make the most of the use of prevailing prices (BELLONI, 2000).

Despite the financial aspect, DEA was developed to analyze the variables even if they are not related to finances, determining the efficiency of the production unit itself. DEA operates considering that if a given production unit can generate an "X" output applying "Y" input, all similar production units must achieve the same if they are efficient (CASADO, 2007).

DEA has two models for calculating the efficiency of decision-making units (DMUs): the BCC model (Banker, Charnes, and Cooper), or input-oriented variable returns to scale (VRS), able to keep the same productivity when decreasing inputs (SOUZA et al., 2011); and the CCR model (Charnes, Cooper, and Rhodes), or output-oriented constant returns to scale (CRS), where an increase in inputs produces a proportionate increase in outputs (CHARNES et al., 1978).

Table 3 shows the variables selected to measure the efficiency of the companies in the sample. Notably, the values collected are in the same proportion for all companies and refer to the same year. Therefore, the total general investments are in units of BRL per year, referring to all the investments the company made each year in improving its services (obtained from its financial statements); the same procedure was adopted for the net revenue from water supply. The other data are in simple (nominal) units of measure.

Table 3 – Input and output variables

Input	***Output***
Total general investment – BRL(thousands)/year	Population served by water supply Number of municipalities served Number of water treatment plants (WTPs) Number of employees Net revenue from water supply (BRL/year) Water savings met

Source: Elaborated by the authors (2019)

The choice of inputs and outputs refers to variables related to water supply in South Brazil, corroborating studies listed in Table 1. The choice also refers to variables that can affect the improvement or worsen the companies' services.

After choosing the variables and collecting the data, the DEA model selected was the input-oriented BCC. For Belloni, (2000, p.69, our translation), "the indicator of technical efficiency obtained from applying the BCC model allows identifying technical inefficiency by isolating the component associated with scaling inefficiency from production inefficiency."

4 ANALYSIS AND DISCUSSION OF RESULTS

4.1 Statstical Description

The descriptive statistics present the variables used for each company and its evolution in 2016, 2017, and 2018.

Table 4 below shows the data for the input and output variables listed in Table 3 for the five companies of the sample in the period analyzed.

Table 4 – Descriptive statistics of the variables

Year	Variables	Casan	Corsan	Sanepar	Aegea	Iguá
2016	Total general investments – BRL (thousands)	240,160	273,237	701,300	460,800	86,634
	Population served by water supply (millions)	2.8	6.0	8.0	4.6	6.6
	Number of municipalities served	198	316	346	47	18
	Number of WTPs	303	178	164	35	33
	Number of employees	2,622	5,943	7,344	2,490	1,499
	Net revenue from water supply – BRL (thousands)	762	2,195	2,146	819,995	342,657
	Water savings met (Units)	1,107,387	2,584,006	3,730,000	873,841	430,700
2017	Total general investments – BRL (thousands)	248,431	355,328	880,500	527,200	105,412
	Population served by water supply (millions)	2.7	6.0	8.0	5.4	6.6
	Number of municipalities served	196	317	346	47	18
	Number of WTPs	305	178	166	35	33
	Number of employees	2,551	5,703	7,671	2,989	1,601
	Net revenue from water supply – BRL (thousands)	838	2,408	2,453	1,047,417	393,179
	Water savings met (Units)	1,134,265	2,584,006	3,848,500	1,232,347	443,190
2018	Total general investments – BRL (thousands)	238,361	364,125	1,030,000	636,300	292,633
	Population served by water supply (millions)	2.7	6.0	8.0	8.9	6.8
	Number of municipalities served	196	317	346	50	18
	Number of WTPs	305	178	168	40	33
	Number of employees	2,555	5,900	7,165	4,060	1,337
	Net revenue from water supply – BRL (thousands)	886	2,520	2,618	1,404,101	420,474

Water savings met (Units)	1,127,043	2,584,006	3923,,400	1,677,965	455,358

Source: Elaborated by the authors (2019)

The data in Table 4 offer an overview of the companies of the research sample, allowing a comparative analysis between them and observing their evolution over the years.

4.2 Analysis of Results

Table 5 presents the results of the input-oriented DEA regarding the companies' efficiency in providing water supply services.

The results help identify best practices among the companies. An index of 1.000 means the company is efficient and indices closer to 0.000 indicates inefficiency.

Table 5 – Evolution of the companies' efficiency (2016-2018)

DMUs	Efficiency		
	2016	**2017**	**2018**
Casan	1.000	1.000	1.000
Corsan	1.000	1.000	1.000
Sanepar	0.562	0.597	0.478
Aegea	0.457	0.546	1.000
Iguá	1.000	1.000	1.000

Source: Elaborated by the authors (2019)

The SOEs Casan and Corsan, and the private company Iguá, showed efficiency in the three years studied. The SOE Sanepar, the largest company in the sample in terms of financial and nominal values (number of municipalities served), did not present the expected results in the three years analyzed. Sanepar obtained 56.2% efficiency in 2016, improving to 59.7% in 2017 and declining to 47.8% in 2018. This finding is aligned with Barbosa et al. (2019), who concluded that greater investment and company size do not necessarily mean efficiency. However, it is not consistent with Schappo et al. (2017), who found that the state of Paraná has the largest number of municipalities considered efficient in the sector.

The private company Aegea demonstrated an important development throughout the years analyzed. It showed low efficiency (45.7%) in 2016, improving to 54.6% in 2017, and achieving 100% in 2018. Thus, both private companies analyzed had 100% efficiency in 2018, which goes in the same direction as the argument developed by Motta et al. (2013). The authors studied the efficiency of sanitation services in municipalities and observed that those served by private companies tend to present higher efficiency.

The analysis of Sanepar numbers – the company served almost the entire state of Paraná – shows that a reduction in investments in 2016 by 44% to adapt to outputs would increase efficiency. Efficiency could be increased by modifying the outputs according to the inputs as follows: increase the population served by 8% (equivalent to about 660,000 people); increase the number of municipalities served from 346 to about 456 (or 32%); increase WTPs by 57% (over half more than in 2016); increase the number of employees by 1,200 (or 17%); and increase net revenue from water supply by 48%. The variable "water savings met" was efficient when observing the relationship input-output (Table 6).

In the case of Aegea, it would have been possible to achieve efficiency in 2016 if the company had reduced its investments

by 54%; increased the population served by 245% (about 11 million people); increased WTPs by 132%; increased the number of employees by 47%; and increased the water savings met by 188,000 units. The relationship input-output was efficient for the variables "number of municipalities served" and "net revenue from water supply" (Table 6).

Table 6 – Input and output changes required for the companies to achieve efficiency in 2016

DMUs	Total general investments BRL/year	Population served by water supply	Number of municipalities served	Number of WTPs	Number of employees	Net revenue from water supply	Water savings met
Casan	0%	0%	0%	0%	0%	0%	0%
Corsan	0%	0%	0%	0%	0%	0%	0%
Sanepar	-44%	8%	32%	57%	17%	48%	0%
Aegea	-54%	245%	0%	132%	47%	0%	22%
Iguá	0%	0%	0%	0%	0%	0%	0%

Source: Elaborated by the authors (2019)

When observing the numbers for 2017, Sanepar could have achieved efficiency if it had decreased the total investments by 40%; increased the population served by around 800,000 people (11% increase); increased the number of municipalities served by 123 (36%), from 346 to 469; increased the number of WTPs by 10%; and increased net revenue from water supply by 45% (Table 7).

For Aegea, the changes the company should have made to achieve efficiency in 2017 encompasses a decrease in total investments by 45%; an increase in the population served by 228%; an increase in municipalities served from 47 to about 54 (15%); an increase in the number of WTPs by 161%; and it should have expanded the workforce by 1,300 people (46%). The other variables were efficient in the year analyzed (Table 7).

Table 7 – Input and output changes required for the companies to achieve efficiency in 2017

DMUs	Total general investments BRL/year	Population served by water supply	Number of municipalities served	Number of WTPs	Number of employees	Net revenue from water supply	Water savings met
Casan	0%	0%	0%	0%	0%	0%	0%
Corsan	0%	0%	0%	0%	0%	0%	0%
Sanepar	-40%	11%	36%	59%	10%	45%	0%
Aegea	-45%	228%	15%	161%	46%	0%	0%
Iguá	0%	0%	0%	0%	0%	0%	0%

Source: Elaborated by the authors (2019)

Only Sanepar was not efficient in 2018. The adjustments that would have taken the SOE to 100% efficiency regarding input would be reducing total investments by 52%. As for outputs, the changes would be increasing the population served by 117,000 people (1%); increasing the number of municipalities served by 24%, i.e., 83 municipalities more; increasing WTP by 43%; increasing the number of employees by 11%; and increasing net revenue from water supply services in 30% (Table 8).

Table 8 – Input and output changes required for the companies to achieve efficiency in 2018

DMUs	Total general investments BRL/year	Population served by water supply	Number of municipalities served	Number of WTPs	Number of employees	Net revenue from water supply	Water savings met
Casan	0%	0%	0%	0%	0%	0%	0%
Corsan	0%	0%	0%	0%	0%	0%	0%
Sanepar	-52%	1%	24%	43%	11%	30%	0%
Aegea	0%	0%	0%	0%	0%	0%	0%
Iguá	0%	0%	0%	0%	0%	0%	0%

Source: Elaborated by the authors (2019)

It is noteworthy that Aegea went through changes during the period, perhaps beyond those indicated by the statistics, since the company managed to become 100% efficient compared to previous years, as expected.

4.3 Discussion of Results

The results pointed out that the SOE Sanepar and the private company Aegea presented low efficiency in 2016 and 2017 and that only Sanepar did not achieve 100% efficiency in 2018. Therefore, the municipalities of the state of Paraná served by Sanepar suffered the most with a lack of efficiency in the three years analyzed.

Of the 866 municipalities served by the companies of the sample, 619 were served by efficient companies in 2018 (71.47% of the municipalities). Barbosa et al. (2019) found a different result when studying an equally economically developed area of the country. The authors observed that only 24.49% (12 out 49) of the municipalities of the metropolitan region of Belo Horizonte (Brazil's Southeast region) counted on efficient basic sanitation and concluded that there is no relationship between GDP and efficiency. However, the results obtained in this study are aligned with Ferreira et al. (2016), who, as mentioned before, observed that the South of Brazil is a well-developed region. The fact that 80% of the companies in the sample were efficient indicates their commitment to contributing to the development of communities, municipalities, and states.

Sanepar was far from the expected efficiency standards during the period from 2016 to 2018. However, Carmo (2003, p. 44, our translation) used data from 2000 in a DEA with the same SOEs analyzed in this study, observing that all three companies were 100% efficient. The authors stated that "[...] DEA's efficiency depends on the number of variables applied to the model. Some companies can be considered efficient because they cannot be compared with others and not because they are superior to the others in the sample." Therefore, the difference between the results by Carmo(2003) and the findings obtained in this research for Sanepar may be explained by the use of slightly different variables. Notwithstanding, it is not possible to infer that Sanepar's low efficiency is related to its nature as an SOE, and further studies are needed to identify why the company presented such results while its counterparts managed to be consistently efficient.

Although Aegea's efficiency level was lower than expected in two of the three years analyzed, its net revenue from water supply proved efficient concerning the input applied. In contrast, Sanepar's efficiency level was low for this variable in the three years (although the revenue index was close to the expected efficiency each year).

Although the study managed to offer a thorough analysis comparing the companies in the sample, it was not possible to address the hypothesis formulated at the beginning – which stated that private companies were more efficient than SOEs. This difficulty emerges from the fact that only three public and two private companies serving municipalities in the South of Brazil were identified when preparing the sample.

5 FINAL CONSIDERATIONS

This research analyzed the efficiency of SOEs and private companies in the basic sanitation sector operating in the South of Brazil, accomplishing its objective. The hypothesis suggested at the beginning could not be addressed since the units of each type of company identified in the process of forming the sample were in a different number (three SOEs and two private), resulting in an unfair comparison. The DEA showed that two SOEs were efficient in all the three years analyzed, and the two private companies were efficient in 2018.

The SOE Sanepar was the least efficient company, presenting low efficiency in 2016, 2017, and 2018, with no indication of improvement. On the other hand, the private company Aegea was less efficient in 2016 and 2017 but improved from one year to the other until obtaining total efficiency in 2018. The development of the private company throughout the years compared to the erratic pattern observed in the case of Sanepar may indicate that private companies are more autonomous in achieving efficiency and contributing to the community, as observed by Pereira et al. (2021) when finding that private companies demonstrated greater efficiency to provide water supply services.

This study adopted DEA considering the number of DMUs and the need to compare the companies analyzed. The companies that stood out in terms of efficiency in all three years were Casan, Corsan, and Iguá. In 2018 Aegea achieved the same efficiency status as these three.

The findings and insights from this research indicate the need for governments to assess the efficiency of all companies operating in the territory, observing which aspects may lead to optimal results. Companies must seek maximizing production without jeopardizing performance, and the DEA is one way to know which decisions may lead to improvements. The method is a way to establish goals concerning the appropriate inputs and outputs for a company to be considered efficient (CARMO, 2003).

It is possible to observe that there is no model or ready-made plan to achieve success in this type of service. It depends on each reality where the company operates. However, countries with good performance regarding the universalization of basic sanitation claim that partnerships with the private sector are crucial. The model currently adopted was developed in 1970 and is outdated. Nowadays, the resources do not supply the demand, and, in addition, inspection, regulation, and planning of the service have become more rigid.

This research encompassed 866 municipalities in the South of Brazil served by the six companies in the sample for 2016, 2017, and 2018. It was a challenge to search for input and output variables since the companies did not disclose much of the data, which led to the exclusion of variables that could be valuable to improve the study, such as the volume of water lost and/or wasted.

Future research could analyze how companies owned by local governments (municipalities) offer sanitation services, particularly regarding the issue of responding to the demand and the use of technology, and how they cope with the periodic disclosure of statements. Thus it will be possible to incorporate these companies in samples to improve research in this field. Future studies could compare other states in Brazil and identify regional characteristics. Finally, further research is needed to explain the results observed for Sanepar and analyze why there was such a difference in efficiency between the companies analyzed in this study.

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