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PROGRAMA DE PÓS-GRADUAÇÃO *STRICTO SENSU* EM CIÊNCIAS AMBIENTAIS E SUSTENTABILIDADE AGROPECUÁRIA

Análise Comparativa dos Provedores de Serviços de Abastecimento de Água e Esgotamento Sanitário no Brasil

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UNIVERSIDADE CATÓLICA DOM BOSCO
Inspira o futuro

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Sumário

Lista de Figuras

Lista de Tabelas

Lista de Abreviaturas

ABDIB	Associação Brasileira da Infraestrutura e Indústrias de Base
ANA	Agência Nacional de Águas
ANOVA	Analysis of variance
BCC	Banker, Charnes e Cooper
BID	Banco Interamericano de Desenvolvimento
CCR	Charnes, Cooper e Rhodes
DHC	Descending Hierarchical Classification
DMU	Decision Making Units
DEA	Análise Envoltória de Dados
JMP	Joint Monitoring Program
FUNASA	Fundação Nacional de Saúde
GIS	Geographic Information System
LCA	Life Cycle Assessment
MLR	Multivariate Linear Regression

OMS Organização Mundial da Saúde

ONU Organização das Nações Unidas

PAC Programa de Aceleração do Crescimento

Planasa Plano Nacional de Saneamento

Plansab Plano Nacional de Saneamento Básico

PNRH Política Nacional de Recursos Hídrico

SDG SustainableDevelopment Goals

SFA Análise de Fronteira Estocástica

SJR Journal Country Rank

SNIS Serviço Nacional de Informações sobre Saneamento

STU Simplified Treatment Unit

STP Sewage Treatment Plant

TS Text Segment

UN United Nations

USA United States of America

USAID United States Agency for International Development

WASH Water, Sanitation, and Hygiene

WHO World Health Organization

WTS	Water Treatment Station
WWTP	Wastewater Treatment Plant

RESUMO

O estudo apresenta o estado da arte voltado a temática de abastecimento de água e esgotamento sanitário com enfoque em análises de desempenho, sobre a perspectiva de duas técnicas, a abordagem envoltória de dados (DEA) e análise estocástica de dados (SFA). Foi realizado também uma análise de desempenho com os 95 maiores municípios brasileiros, afim de verificar diferenças na prestação dos serviços públicos e privados no abastecimento de água e esgotamento sanitário, por meio dessas mesmas técnicas. Observou-se que os estudos relacionados ao abastecimento de água avançaram e se concentram na área de gestão e indicadores, por meio das ferramentas de análise de eficiência. Para esgotamento sanitário, ficou evidente o uso de análises de eficiência mas na busca por tecnologias mais robustas e o seu desenvolvimento, sem a mesma preocupação com gestão e indicadores, como ocorre no abastecimento de água. Em relação à análise de desempenho dos municípios brasileiros, verificou-se um predomínio da iniciativa pública na provisão desses serviços. Os scores de eficiência apresentaram diferenças entre os provedores no serviço de abastecimento, para ambas metodologias (DEA e SFA), onde os provedores privados apresentaram maiores scores quando comparado aos públicos. Entretanto, ao longo do período de análise não houve elevação nos scores obtidos para o abastecimento de água. Enquanto no serviço de esgotamento sanitário não houveram diferenças significativas entre os provedores, mas diferente do abastecimento, houve elevação dos scores ao longo do período de análise, o que demonstra avanços no setor. O estudo salienta que as pesquisas relacionadas ao esgotamento ainda precisam incorporar uma discussão sobre gestão (planejamento, gerenciamento, políticas, governança e regulação) e o uso de indicadores para tornar o serviço prestado mais eficiente. Sugere-se que os instrumentos de incentivo à eficiência dos serviços sejam diferentes para abastecimento e esgotamento e que promovam a busca por uma melhor performance, possivelmente pela estrutura regulatória desses serviços e novas políticas públicas.

Palavras Chave: Análise de desempenho, Mineração de dados, Saneamento.

ABSTRACT

The study presents the state of the art focused on the theme of water supply and sewage with a focus on performance analysis, from a perspective of two techniques, an engaging data approach (DEA) and aesthetic data analysis (SFA). A performance analysis was also carried out with the 95 largest Brazilian cities, which allows to verify differences in the provision of public services and public consumption, in the supply of water and sanitary sewage, using these same techniques. Note that studies related to water supply have advanced and focus on management and indicators, using efficiency analysis tools. For sanitary sewage, the use of efficiency analyzes was evident, but in the search for more robust technologies and their development, without the same concern with management and indicators, as occurs in the water supply. In relation to the performance analysis of Brazilian cities, there was a predominance of public initiative in the provision of these services. The difference scores of difference between the providers of goods supply service, for the methodologies (DEA and SFA), where the score providers had higher scores when compared to the publics. However, over the analysis period, there was no increase in the results obtained for the water supply. While in the sewage service there are no significant differences between suppliers, but different from supply, there was an increase in scores over the analysis period, or which shows progress in the sector. The study highlighted that related research and burnout still requires a discussion of management (planning, management, policies, governance and regulations) and the use of indicators to make the service provided more efficient. Suggest that the instruments to encourage the efficiency of services are different to provide and exhaust and promote a search for better performance, possibly due to the regulatory structure of these services and new public policies.

Keywords: Data mining, Performance analysis, Sanitation.

INTRODUÇÃO

Para construção de sociedades mais igualitárias e sadias o saneamento eficaz juntamente com água de qualidade, são serviços indispensáveis. Grandes lacunas são encontradas entre o gerenciamento desses serviços em áreas urbanas e rurais, uma vez que o gerenciamento dos serviços ocorre de forma mais segura nas áreas urbanas do que em áreas rurais. Conforme a Organização Mundial da Saúde (OMS) cerca de 150 milhões cidadãos que estão em áreas rurais utilizam águas superficiais não tratadas (OMS, 2017).

Os dados mais recentes do Serviço Nacional de Informações sobre Saneamento (SNIS) sobre a situação atual do saneamento no país, indicam que mais da metade da população brasileira ainda não possui coleta de esgoto e somente 46% desse esgoto coletado é tratado. No serviço de abastecimento de água, o índice de perdas na distribuição é de 38,45% e 83,62% da população é atendida (SNIS, 2018).

O setor de saneamento desempenha uma importante função na manutenção da vida, saúde e preservação ambiental, sendo essas áreas afetadas pela falta desses serviços. Em uma análise de associação entre saneamento e saúde nos estados brasileiros, Teixeira e Guilhermino (2006) verificaram mudanças na qualidade de vida, com expansão dos serviços de saneamento, e afirmam que essa expansão pode proporcionar um declínio da taxa de mortalidade por doenças infecciosas e parasitárias. A garantia da qualidade e eficiência dos serviços de saneamento é um direito estabelecido pela Lei do Saneamento Básico n^o 11.445/07.

Salienta-se então a importância do monitoramento e avaliação como instrumentos de gestão, desses serviços prestados à população. A avaliação desse setor é de grande relevância também na economia, pois impacta na produção de bens e serviços gerados. Esse setor é caracterizado pela ausência de incentivos à eficiência, por constituir-se de um monopólio natural. Nessa situação de mercado, os investimentos necessários são elevados e os custos baixos com pouca rivalidade e consistindo também de bens exclusivos. Com isso, é fundamental a existência de alguma forma de regulação que proteja os interesses dos consumidores e indústria para equilíbrio da qualidade do serviço e custos. O novo marco do saneamento (PL 162/2019), busca estimular investimento privado através de licitação entre empresas públicas e privadas para ampliações dos serviços de saneamento disponibilizados à população, e a cria de um comitê para melhoria estrutural das condições de sanemanto básico. Como também, com o não cumprimento de metas as empresas podem perder o direito de executar o serviço . Assim, a avaliação da eficiência do setor de saneamento, incentiva o aprimoramento da performance, proporcionando melhores práticas na utilização de recursos.

Mediante a isso, o estudo busca contribuir com os prestadores dos serviços de abastecimento de água, esgotamento sanitário e reguladores, efetuando um levantamento de pesquisas científicas que abordam análise de desempenho como ferramenta, afim de verificar a finalidade do uso dessas técnicas nos sistemas relacionadas ao abastecimento de água e esgoto sanitário. Ainda, objetivou-se realizar uma avaliação dos provedores desses serviço em cidades brasileiras, por meio da estimação do nível de eficiência, fazendo distinção entre a inciativa pública e privada.

OBJETIVOS

OBJETIVO GERAL

Avaliar o desempenho dos provedores públicos e privados no âmbito do abastecimento de água e esgotamento sanitário no Brasil.

OBJETIVOS ESPECÍFICOS

a) Efetuar uma análise baseada em text mining voltada à temática da análise de desempenho nos serviços de saneamento.

b) Analisar a performance dos provedores relacionados aos serviços de abastecimento de água, esgotamento sanitário, por meio de duas técnicas de modelagem matemática.

c) Comparar modelos matemáticos que estimam a eficiência.

REVISÃO BIBLIOGRÁFICA

Evolução do Saneamento

Desde que o homem passou a desenvolver atividades agrícolas e a criação de animais, a vida nômade foi deixada para trás passando a se fixar em vilas, o que desencadeou a necessidade de atender as atividades em comunidade para irrigação de culturas, dando origem aos primeiros sistemas de abastecimento. Ruínas de canais de irrigação podem ser observados na Mesopotâmia, Egito e Turquia, os quais foram datados do período de 5.000 a 4.000 A.C (Mays et al., 2000).

Os romanos foram pioneiros em obras de Engenharia Sanitária, quando passaram a construir aquedutos e reservatórios para trazer água de fontes para a cidade, como também a construir banheiros públicos, pois observaram a relação entre uma água com impurezas, acúmulos de resíduos e a disseminação de doenças (Azevedo Netto, 1984). Com a queda do império romano houve um retrocesso nas questões sanitárias e várias epidemias começaram a surgir, uma vez que a responsabilidade desses serviços passou do governo para os cidadãos, que não sabiam como realizá-los de forma adequada, causando contaminações (Mays et al., 2000).

A idade Moderna marcou a criação de novos modelos de abastecimento e destinação dos esgotos domésticos. A distribuição de água canalizada foi incrementada com a fabricação de tubos de ferro fundidos por Johan Jordan, na França e a invenção do vaso sanitário por Joseph Bramah, na Inglaterra. A idade Contemporânea iniciada no período de 1790 que corresponde aos dias atuais, tem como marco inicial a intensificação do combate à poluição das águas por meio de leis, e administração e legislação do saneamento em conjunto com outros serviços públicos (Azevedo Netto, 1984).

Saneamento no Brasil

As primeiras iniciativas relacionadas à política de saneamento no Brasil surgiram em 1971, no governo militar com a instituição do Plano Nacional de Saneamento (Planasa). Esse plano objetivou a expansão do acesso a água potável para a população urbana. Com a crise econômica e mudanças do governo em 1988, por meio da Carta Magma a responsabilidade sobre as políticas de saneamentos brasileiras passaram para a esfera municipal. Com essa mudança os investimentos relacionados à expansão do saneamento perderam força e o Planasa foi extinto (Leoneti et al. 2011; Parlatore, 2000).

Em 1996 com o objetivo de coletar informações de sistemas de abastecimento de água e de esgotamento sanitário, fornecidas pelos prestadores de serviços, o Sistema Nacional de Informações sobre Saneamento (SNIS) foi criado. O SNIS tem como : planejamento e execução de políticas públicas; orientação da aplicação de recursos; avaliação de desempenho dos serviços; aperfeiçoamento da gestão, elevando os níveis de eficiência e eficácia; orientação de atividades regulatórias; e benchmarking e guia de referência para medição de desempenho (SNIS, 2018).

A Lei n^{o} 9.433/97 conhecida como Política Nacional de Recursos Hídricos (PNRH), em 1997 definiu o Estado como encarregado do gerenciamento dos recursos hídricos nacionais. Foram estabelecidos nessa política objetivos como: a garantia de disponibilidade hídrica à população presente e futura, utilização integrada e racional dos recursos hídricos e prevenção de eventos hidrológicos no país. Para regulação e cumprimento dos objetivos estabelecidos na PNRH, em 2000 a Agência Nacional de Águas (ANA) foi criada. Por meio da ANA o acesso aos recursos hídricos passou a ser regulado por outorgas, juntamente com o monitoramento de rios com a União e elaboração de estudos nas esferas municipais, estaduais e federal (Brasil, 1997; Brasil, 2000).

Contemplando os serviços de abastecimento de água, esgotamento sanitário, manejo de resíduos sólidos e águas pluviais urbanas, em 2007 a Lei n^{o} 11.445/07 denominada como Política Nacional do Saneamento Básico (PNSB), atribuiu ao Governo Federal o dever para elaboração do Plano Nacional de Saneamento Básico (Plansab) e estabeleceu como meta a universalização dos serviços de saneamento. Em 2012 o Plansab foi aprovado, instituído como eixo para a articulação nacional da implementação das diretrizes da Lei do Saneamento, sendo definidas metas de curto, médio e longo prazo para universalização dos serviços de saneamento até 2033 (Leoneti et al., 2011; Brasil, 2007).

Em 2019, o projeto de lei (PL 4162/2019) atualiza a estrutura legal do saneamento básico, atribuindo novas competênica a ANA. Para melhoria das condições estruturais do saneamento básico cria um Comitê Interministerial de Saneamento Básico. Autoriza a União a participar de um fundo único para financiamento dos serviços técnicos especializados, apoiando a estruturação e o desenvolvimento de projetos de concessão e parcerias público-privadas da União, dos Estados, do Distrito Federal e dos municípios (Brasil, 2019).

Modelos de Provisão e Regime dos Serviços de Saneamento

A prestação do serviço de saneamento é realizado por diferentes protagonistas. Dentre esses, estão envolvidos na provisão de serviços de saneamento o poder público (União, Estados, Distrito Federal, Municípios), prestadores de serviço (públicos ou privados), agências reguladoras, intermediadores financeiros, consumidores e outros órgãos e instituições podem impactar a provisão dos serviços de saneamento (SNIS, 2018).

O poder público tem como função garantir o controle das políticas públicas desses serviços, proporcionando melhorias à sociedade no âmbito da saúde pública e da preservação do meio ambiente. Considerando as entidades regulatórias, essas devem possuir independência, transparência, e possuir objetividade noss processos decisórios (Brasil, 2007).

Aqueles que realizam o intermédio financeiro para aporte dos serviços se saneamento são operacionalizados pela Caixa Econômica Federal, Banco Nacional de Desenvolvimento Econômico e Social e pela Fundação Nacional de Saúde (FUNASA). Com as principais fontes de financiamentos por meio do Fundo de Garantia do Tempo do Serviço e Fundo de Amparo do Trabalhador (SNIS, 2018).

Os prestadores do serviços de saneamento são caracterizados pela abrangência regional, microrregional e local, classificados de acordo com a organização jurídica: administração direta, autarquia, sociedade de economia mista, empresa pública, empresa privada e organização social (SNIS, 2018).

O Brasil possui uma relação histórica com a atuação das inciativas públicas e privadas, como responsáveis pela gestão dos serviços de saneamento. Entre os séculos XIX e XX, a inciativa pública passou a atuar nesse setor na implantação de estruturas sanitárias para coleta de esgotos domésticos. Essa intuição é organizada em forma de companhias estaduais atuando de forma autônoma nos municípios. Com relação à iniciativa privada, essas empresas começaram a avançar na década de 90 devido às politicas liberais. Essa iniciativa é composta por meio de consórcios por capital nacional ou por capital estrangeiro (De Oliveira,2005).

Considerando o regime de regulação, o serviço de saneamento brasileiro é baseado nos custos operacionais incorridos e de investimentos dos serviços, a prestadora aplica uma remuneração do capital e regula a fixação de tarifas. Essa regulação deve estar alinhada s diretrizes estabelecidas na PNSB (Madeira, 2010; Junior et al., 2009).

Investimentos no Saneamento

Anterior à Lei do Saneamento Básico, no período de 1998 a 2007, a média anual de investimento no setor de sanamento foi cerca de R$ 4 bilhões por ano. Em 2007, com o decreto da Lei do Saneamento Básico e a instituição do Programa de Aceleração do Crescimento (PAC) I, os investimentos transpuseram para valores próximos a R$ 9 bilhões por ano. Por fim, em 2011, foi lançado o PAC II, promovendo um novo aumento nos investimentos, dessa vez bem menos expressivo. Após esse marco regulatório houve um aumento expressivo dos Recursos Federais comprometidos com o saneamento básico, mas esses valores continuaram bastante inferiores (Trata Brasil, 2019).

Conforme os dados do Instituto Trata Brasil (2019), sobre a Saneamento Brasileiro, em uma análise no período entre 2004 e 2016, o investimento em saneamento passou de R$ 3,1 bilhões para R$ 11,4 bilhões, o que indicou um crescimento de 11,5% ao ano. Nesses anos de observação, o investimento alcançou R$ 145,4 bilhões (valores constantes), o que equivaleu a um montante de R$ 60,80 por brasileiro por ano.

O estudo estimou que serão necessários R$ 443,5 bilhões em 20 anos para que todos os brasileiros tenham acesso aos serviços de água e esgoto, ou seja, necessita de um investimento anual mínimo de R$ 22,2 bilhões. Os dados desse estudo também mostraram que os investimentos em saneamento sustentaram 142 mil empregos por ano no país e geraram R$ 13,6 bilhões por ano de renda na economia brasileira entre 2004 e 2016 (Trata Brasil, 2019). No ano de 2017 o total investido no setor foi de R$ 11,0 bilhões e para o ano de 2018, houve um acréscimo de 20,1% em relação a 2017, sendo R$ 13,2 bilhões investidos no saneamento (SNIS, 2018).

Saneamento como Ferramenta Estratégica

Proporcionar as infraestruturas de saneamento é um problema de saúde pública, e conforme Ascher e Krupp (2006) descrevem, a infraestrutura é a base de uma economia desenvolvida e um suporte da qualidade de vida. Para um desenvolvimento econômico, investir em saneamento é uma estratégia para assegurar diversas externalidades que impactam na qualidade de vida, saúde pública e meio ambiente. Em uma análise de associação entre saneamento e saúde nos estados brasileiros, Teixeira e Guilhermino (2006) afirmam que a ampliação da infraestrutura sanitária é um investimento capaz de proporcionar melhorias nas condições de saúde pública,contribuindo para a redução de gastos públicos e particulares com medicina curativa.

Devido às diferentes formas de provisão dos serviços de saneamento, estudos relacionados a essa temática começaram a avaliar o desempenho entre os provedores, levando em consideração aspectos como custo de provisão, cobertura do acesso, qualidade dos serviços, entre outros fatores. Toneto e Saiani (2006), em uma análise das determinantes da retração dos investimentos no setor de saneamento, observaram que os investimentos no saneamento básico no Brasil, são influenciados por aspectos econômicos. Parte dos baixos índices de produtividade resultam da elevada utilização política dos provedores de serviços, o que também explica a maior tolerância com a inadimplência, evasão de receitas e com a prática de tarifas insuficientes para a cobertura de custos.

Também realizando uma análise comparativa da atuação de prestadores de serviços de saneamento públicos e privados no Brasil, Pinheiro et al. (2016), observaram que os prestadores privados obtiveram melhor desempenho em uma série de aspectos como a produtividade, retorno e acesso aos serviços, e com isso concluíram que as concessões e parcerias público-privadas foram uma estratégia viável para alcançar a universalização do acesso aos serviços de saneamento. Com uma abordagem diferente, investigando a participação conjunta das iniciativas pública e privada no fornecimento dos serviços de água e esgotamento sanitário no Brasil, por meio de um modelo teórico-econométrico capaz de detectar as diferenças de eficiência entres as empresas, Oliveira (2004) verificou que essas diferenças foram substanciais na alocação de recursos e utilização de insumos.

Indicadores dos Serviços de Água e Esgotamento Sanitário

Conforme Hammond et al. (1995), a palavra “indicador” tem como origem o verbo *indicare* que significa apontar, revelar tornar público e estimar. Esses significados demonstram que a função do indicador, nada mais é do que esclarecer uma informação de interesse geral. O uso de indicadores no saneamento para acompanhamento da prestação do serviço, regulação e planejamento, vem sendo utilizado cada vez mais no âmbito nacional e internacional (Sperling e Sperling, 2013).

Os indicadores no âmbito nacional são calculados pelo SNIS, a partir das informações primárias fornecidas pelos provedores do serviço. Cada indicador possui uma fórmula matemática para o cálculo, que são fornecidos em formato tabular na plataforma digital. A consulta a esses dados pode ser realizada por meio da abrangência dos serviços: local, regional, microrregional e natureza jurídica, no portal. Ainda, o sistema disponibiliza a coleção completa de informações e indicadores (série histórica), que pode ser consultada através da abrangência e do ano desejado (SNIS, 2018).

Atualmente o SNIS calcula 84 indicadores referentes à prestação dos serviços de Água e Esgotos e 47 referentes à prestação dos serviços de manejo de Resíduos Sólidos Urbanos e 25 para os serviços de manejo de Águas Pluviais. Esse sistema de informação é o maior sistema de informações da América Latina. O Chile, a Argentina e a Colômbia possuem sistemas de informações sobre a prestação dos serviços de água e esgotos. Na Europa, a Inglaterra também possui um sistema de informações igualmente sobre a prestação dos serviços de água e esgotos (SNIS, 2018).

Análise de Desempenho e Metodologias de Estimação

Os estudos relacionados à análise de desempenho do setor de saneamento, consistem em técnicas matemáticas para modelagem de dados e indicadores. Segundo Berg (2007) a metodologia de Benchmark permite a comparação do desempenho entre diferentes empresas, e com essa avaliação cria uma ponte entre as melhorias práticas das organizações e as pesquisas acadêmicas.

A avaliação do desempenho é o ponto de partida para tomada de decisão, e tem sido utilizada em conjunto com modelos de gestão, servindo de auxílio no processo de conhecimento e não sendo somente um instrumento de auditoria (Brostel et al., 2002; Lyrio et al.,2007). Segundo Ohira e Scazufca (2009) a melhoria do desempenho dos prestadores de serviços deve ser quantificada para que de forma transparente garanta a uniformidade e sustentabilidade na qualidade e eficiência dos serviços.

As abordagens para determinação da eficiência de uma empresa, ou indústria, possuem como base a metodologia de Bottom-Up e Top-Down. A primeira permite o cálculo dos custos de operação eficientes, a partir dos processos e atividades da empresa, e a segunda consiste de um levantamento dos custos operacionais de um conjunto de empresas e das variáveis que o determinam.

Análise Envoltória de Dados e Análise de Fronteira Estocástica

As técnicas mais usuais para a avaliação do desempenho são Análise Envoltória de Dados (Data Envelopment Analysis - DEA) e a Análise de Fronteira Estocástica (Stochastic Frontier Analysis - SFA). Essas análises podem assumir a abordagem Top-Down e proporcionam um método de programação matemática para estimação da fronteira de eficiência com diferentes conjuntos de dados, conhecidos como Unidades Tomadoras de Decisão (Decision Making Units - DMUs). As DMUs são os indivíduos a serem analisados formados comumente por indicadores do sistema, por meio de entradas (inputs) e saídas (outputs) com diferentes unidades de medidas, as quais formam uma fronteira de produção para represntação da fronteira de eficiência (Bogetoft and Otto, 2010).

Considerando a DEA, essa técnica consiste em uma abordagem não paramétrica, ou seja, é um método que pode ser aplicado em diferentes situações, pois não exige que os dados obedeçam a certas premissas, como a distribuição normal (Bogetoft e Otto, 2010). Os modelos tradicionais se baseiam em pesquisas cientificas, de programação matemática, como também relacionados aos conceitos de econometria, sendo mais comuns: CCR (Charnes, Cooper e Rhodes) e BCC (Banker, Charnes e Cooper). A diferença entre os métodos é que a CCR trabalha com retorno constante, sendo assim uma variação no input é proporcional ao output, e o BCC trabalha a variação no input que poderá promover um acréscimo no output, proporcional ou não, ou até mesmo um decréscimo (Cooper et al., 2007).

Com relação a técnica SFA, esse modelo é pautado em uma abordagem paramétrica, sendo assim essa modelagem assume que os dados possuem algum tipo de distribuição como Poisson, normal, exponencial. Esse tipo de modelagem permite medir a ineficiência técnica, um dos seus conceitos essenciais é o termo de erro, que é composto por duas partes: um componente unilateral e um componente simétrico. O componente unilateral capta os efeitos da ineficiência relativa à fronteira, e o componente simétrico capta os efeitos de erros de medidas entre as variações aleatórias entre a fronteira e os indivíduos (Aigner et al., 1977; Meeusen e Van Den Broeck, 1977).

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CAPÍTULO 1

Measuring the Efficiency of Water Supply and Sanitation Services by DEA and SFA: A Text Mining Approach

Abstract

We use text mining techniques to analyze the content of articles that address the topic of water supply and sanitation. We seek to focus on papers that analyze performance using two robust techniques: Data Envelopment Approach (DEA) and Stochastic Frontier Analysis (SFA). Studies related to water supply usually employ SFA to evaluate performance. This research focus on management by employing indicators. On the other hand, sanitation studies prefer the use of DEA and focus on which are the best technologies. In the case of sanitation studies we find that we need more discussion on management issues and use of indicators to evaluate performance.

Keywords: Water and sanitation utilities, Quantitative techniques, Efficiency, Text Mining.

Introduction

We contribute to the literature on water supply and sanitation using a novel approach. We use text mining to assess how the literature addresses these two themes, which are studied separately in general. We find that studies using stochastic frontier analysis (SFA) focus on the use of indicators to assess the performance of companies that provide water supply services. On the other hand, studies that focus on sanitation use Data Envelopment Analysis (DEA) and discuss what are the best technologies to provide this type of service.

Both services are essential for the maintenance of public health. Our results suggest that the water supply service is in a much more advanced stage than sanitation. However, both have an impact on public health. So, improving sanitation service management requires further studies and improvement.

Effective sanitation, together with quality water, are essential services for building more equitable and healthy societies. According to the Joint Monitoring Program (JMP) report, many countries require data on the sanitation services quality. The management of these services in urban and rural areas have large gaps, as they occur more safely in urban areas than in rural areas. Of the 159 million citizens who use untreated surface water, 150 million are in rural areas (WHO, 2017).

The United Nations (UN), through the 2030 Agenda, establishes 17 Sustainable Development Goals (SDGs), which consists of millennium goals adopted by UN members to be met by 2030, one of which is ensuring availability and sustainable water and sanitation management for all United Nations Nations' (2015).

Improving management of the provisions of these services matters for public health. In a review of the impact of drinking water and sanitation Wolf et al. (2018) showed significant potential reductions in the risk of diarrhea diseases through interventions aimed at improving drinking water, sanitation, and hygiene.

In another study also relating sanitation conditions and diseases associated with this service, Gizaw et al., (2019) observed that after an intervention there is a significant improvement in the water, sanitation, and hygiene (WASH) performance at the end of the study compared to the baseline. They also found that the final prevalence of intestinal parasites infections was lower after the intervention.

In an analysis of the association between sanitation and health in Brazilian states, Teixeira et al., (2011) found that changes in quality of life, the purchasing power of families and the expansion of sanitation services can lead to a decline in the mortality rate for infectious and parasitic diseases. The authors also state that the expansion of the health infrastructure is an investment capable of providing improvements in the condition of public health and thereby to contribute to a reduction in public and private spending on curative medicine.

Recent studies have detected the presence of the SARS-CoV-2 virus in wastewater and raised the hypothesis of fecal-oral transmission (Ahmed et al., 2020; Lodder and de Roda Husman, 2020; Wu et al., 2020; Medema et al., 2020; La Rosa et al., 2020), and as a possible consequence their effects can be seen directly in global public health, being as places that have a provision of water supply services and sanitation deficits are the most affected.

In this context, an increase in the importance of evaluating these services in order to know the main factors that affect the operational performance, as well using the regularity tool and detection of services provided is essential. The techniques employed for performance evaluation are data envelopment analysis (DEA) and stochastic frontier analysis (SFA). Considering the DEA, this technique consists of a non-parametric approach, that can be applied in different situations, as it does not require that the data to obey certain premises, such as data distribution. In the SFA technique, the method is based on a parametric approach, so this modeling requires that the data assume some type of distribution (Bogetoft and Otto, 2010). Several studies focus on this methodological approach in sanitation and water supply systems such as Sun et al., (2014); Qian and He, (2011); Estache and Rossi, (2002); Ferro et al., (2014); Hu et al., (2006); Hernández-Sancho and Sala-Garrido, (2009);Lorenzo-Toja et al., (2015).

According to Ohira and Scazufca (2009) the improvement in the performance of service providers must be quantified so that transparently, they guarantee uniformity and sustainability in quality and efficiency. Performance assessment is the starting point for decision-making. It has been used in conjunction with management models, serving as an aid in the knowledge process and not just being an audit tool (Lyrio et al., 2007). Fu et al., (2013) while mapping research on water, through a bibliometric analysis, observed an increase in research in this area.

Through a literature review, Cetrulo et al., (2019) sought to carry out an analysis of the efficiency of water and sanitation companies in developing countries, using the databases Scopus, Science Direct and Google Scholar. In a review of the global development of sanitation, Zhou et al. (2018) verified a predisposition for research aimed at new technologies, pollutant removal, water quality, and epidemiology. This bibliometric research consists of a tool for mapping literature on a given topic, in which qualitative and statistical analyzes are used for the discretion and distribution of publications, in order to check global trends on a given topic, country or entity (Vergidis et al., 2005; Falagas et al., 2006).

Our paper conducts a text mining approach and a bibliometric survey on the theme of water and sanitation aimed at analyzing the performance of water supply and sewage services. Our focus is to identify the objective in use the DEA and SFA methodologies through qualitative and statistical analyzes, in scientific vehicles between 2000 and 2017.

Materials and methods

Data

We used a bibliometric research, from the perspective of a narrative review. This review is not based on explicit and systematic criteria, which apply sophisticated and exhaustive search strategies. We seek studies related to the performance of sanitation services, focusing on quantitative methods for assessing the performance of service providers. The search took place through the Science Direct and Google Scholar databases, from 2000 to 2017.

We searched for the following terms in titles and keywords "sanitation analysis", "DEA water supply", "SFA water supply", "indicators water supply", "efficiency water supply", "analysis water supply", "DEA wastewater", "SFA wastewater", "indicators wastewater", "efficiency wastewater", "analysis sewage", "DEA sewage", "SFA sewage", "indicators sewage" and "efficiency sewage. "

As a criterion for the selection of publications, we use the Scimago Journal & Country Rank (SJR), which should have a value greater than 1 (> 1), as well as English language. With this approach, we selected 43 articles, and we employed only their abstracts for the analysis. Through this, we carried out the construction of the textual corpus, one characterized by presenting the DEA methodology (corpus 1) and the other by SFA (corpus 2), both also addressed in their summary: benchmark, performance dashboard, performance indicators and efficiency (Table 1, Table 2, Table 3).

Pre-processing

The pre-processing for construction of the textual corpus took place through the substitution of acronyms with complete words; capital letters only in proper names; removal of special characters; replacement of hyphen by underline; and numbers only in numeric character.

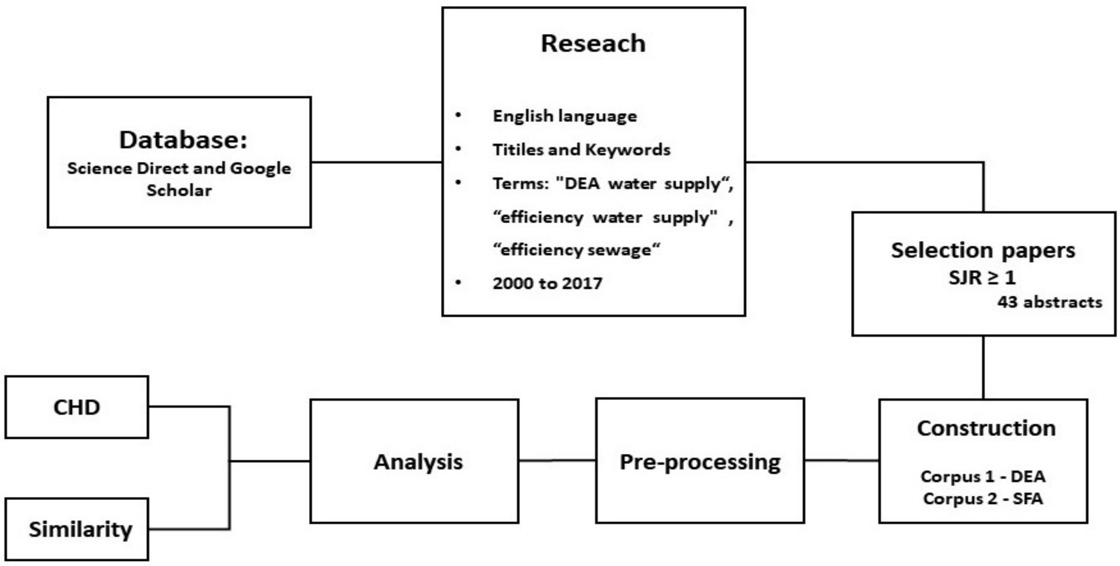
Processing

For the processing of the analysis of the textual corpus, we use the software IRAMUTEQ (Interface of R pour les Analyzes Multidimensionnelles de Textes et de Questionnaires). It consists of an open-source software, developed by Pierre Ratinaud (Lahlou, 2012; Ratinaud and Marchand, 2012) that allows a statistical analysis of the textual corpus, which employs the software R (www.r-project.org) and the Python language (www.python.org).

The types of analysis possible with the IRAMUTEQ [1] on textual corpus are classic textual statistics, contrast analysis of the modalities of variables, descending hierarchical classification (DHC) as described by Reinert (Reinert, 1987; Reinert, 1990), similarity and word cloud.

In this study we used: DHC analysis and similarity.DHC analysis is a technique that seeks to relate text segments with similar vocabulary, separating them into classes. This classification occurred of simple form through text segment (TS) with a frequency greater than 2 (> 2), default mode. For the result of this analysis to be valid, they must present a minimum percentage of 70 % (Camargo 2005). As for the similarity analysis, it establishes the connection between the words, helping to identify the textual structure. Figure 1 shows the flowchart of the analysis process.

Figure 1: Flowchart of the analysis process.



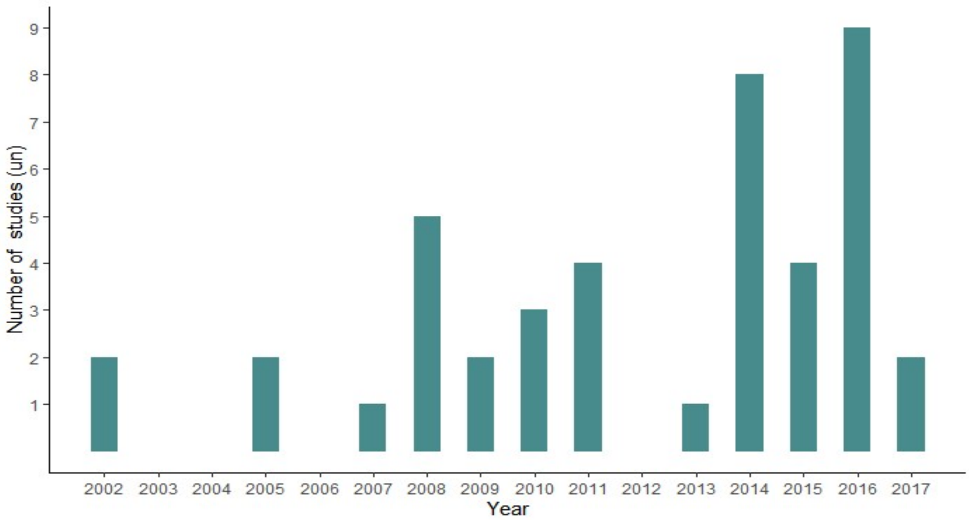
[1] http://www.iramuteq.org/

Results and discussions

Database characteristics

In a chronological analysis, we can see in Figure 2 that the studies took place between 2002 and 2017, being that in the years 2003, 2006 and 2012, no study was found following the criteria established in the research and the years 2014 and 2016 were the ones that presented the most publications, with 8 and 9 publications respectively. Until 2007, few studies analyzed the subject of efficiency in water supply and sanitation services, and in 2008, there was an increase in the publication about the subject until the year 2011. In 2012 there was no publication in the field and from 2013, it started to increase again, with a great peak 2014. With this behavior, there is a tendency for this subject to be studied again.

Figure 2: Chronological analysis.



The studies range from 2008 to 2017, with the year 2014 with the highest occurrence. Many studies used secondary data from public entities, government organizations, agenciesfrom the sanitation sector, as well as data from the companies themselves. These studies are characterized by having an empirical focus, using the DEA methodology, carried out in WWTPs and water utilities, and in WWTPs with higher frequency (Table 1).

Table 1: Articles with DEA methodology and others.

Author	Local	N	Collect	Contribution	Gap	Method	Theoretical / Empirical
Cumming, Elliott, Overbo and Bartram (2014) (16)	Global	151 countries rural and urban area	secondary data from the Joint Monitoring Programme (JMP)	creation of a model to assess the overall progress in water and sanitation in both scenario	establish a single benchmark at the critical level of home access and water and sanitation together	hierarchical clustering method and gap statistic analysis and benchmarking	empirical
Haider, Sadiq and Tesfamariam (2016) (36)	Okanagan basin, British Columbia, Canada,	-	company database	presents a hybrid model for analyzing the efficiency of the water sector with social, operational, quality and economic variables	the weights of different PIs established can be revised, as also an involving larger number of SMWU in a region	benchmarking model (IU-PBM)	empirical
Haider, Sadiq and Tesfamariam (2014) (35)	Canada, Australia, United Kingdom, Wales, Asia, Arabia, Afica, South Africa, Armenia	-	data from organizations and agencies in the sanitation sector	evaluates individual performance indicators with respect to their comprehensibility, measurability and comparability (ie, within and through comparisons of public services), covering aspects: personal, operational, customer satisfaction, economic	consistent review and improvement of the selected suitable performance indicators (PIs) over time	-	theoretical
Hernández-Sancho and Sala-Garrido (2009) (40)	Valencia Region, Spanish	338 Wastewater Treatment Plants (WWTP)	secondary data from Entitat de Sanejament d'Aigües (EPSAR)	creation of an efficiency index for each plant by means of mathematical programming techniques	calculation of efficiency indicators for each input used in the treatment process. Evaluate the possible relationships between these efficiency indicators and the size of the plant	Data Envelopment Analysis (DEA)	empirical
Longo, D'Antoni, Bongards, Chaparro, Cronrath,Fatone and Hospido (2016) (49)	Global	125 WWTPs	papers	gives an overview of the literature of WWTP energy-use performance and of the state of the art methods for energy benchmarking	data collection and analysis via automated systems for energy use monitoring and data acquisition, and customized analysis and reporting	-	theoretical
Lorenzo-Toja, Vázquez-Rowe, Chenel, Marın-Navarro, Moreira and Feijoo (2015) (51)	Spanish	centering113 WWTPs	secondary data from Water Technology Centre (CETAQUA)	operational efficiency, obtaining benchmarks for inefficient plants and associated environmental gains for reduction of inputs, verifying eco-efficiency criteria.	use of aWindows analysis model in DEA	Data Envelopment Analysis (DEA) and Life Cycle Assessment (LCA)	empirical
MacGillivray and Pollard (2008)(53)	-	-	-	introduces a model for benchmarking and improving the processes of risk analysis and risk based decision making within water and wastewater utilities	descriptive research on the practical form of risk management within the utility sectors	benchmarking model	theoretical
Marques, Bergand and Yane (2014) (54)	Japan	1.144 Japanese water utilities in 2004 and 2007	companies database	this research extends the extant literature by controlling for a large number of exogenous factors (institutional and operational environment)	the development of robust performance and more longer database	Data Envelopment Analysis (DEA)	empirical
Miralles (2008)(56)	Spanish region of Catalonia	133 municipalities in 2000 and 2001	questionnaire	analyzes the effect of recent privatization on the difference between the marginal water price paid by the average industrial customer and the marginal price paid by the average residential user	a wider, longer database could contribute to confirm the major findings	multiple linear regression	empirical
Molinos-Senante and Sala-Garrido (2017) (57)	Chile	18 of the main Chilean WaSCs for the 2005–2014 period	secondary data from Superintendencia de Servicios Sanitarios (SISS)	It analyzes the contribution of inputs and products to the productivity growth of water and sewage companies (WaSC)	it only provides an aggregate index of productivity and therefore, specific information regarding the contribution of inputs, desirable outputs and undesirable outputs integrated in the assessment cannot be derived.	Data Envelopment Analysis (DEA)	empirical
Molinos-Senante, Hanley and Sala-Garrido (2015) (59)	Spanish	25 WWTPs	calculated	estimates the shadow price of CO2 for a sample of wastewater treatment plants (WWTPs)	hybrid modeling, insertion of more data and tests	Mann–Whitney and Kruskal–Wallis non-parametric tests	empirical
Onda, Crocker, Kayser, and Bartram (2014) (63)	Global	124 countries	secondary data from the JMP, UNESCO, WHO and World Bank	create a new typology of country clusters specific to the water and sanitation (WatSan) sector based on similarities across multiple WatSan-related indicators	Further research on the WatSan country cluster typology could involve cluster validation, or creating targeted clusters for specific regional or sub-national applications	hierarchical clustering method and a gap statistic analysis	empirical
Sadiq, Rodríguez and Tesfamariam (2010) (71)	Québec, Canada	10 water utilities	companies database	detailed case study for developing performance indicators using OWA operators. Demonstrating that it is possible to develop methodologies that combine several qualitative approaches and qualitative indicators to evaluate the performance of water companies	different hierarchical structure schemes of aggregation of indicators can be tested to improve results	ordered weighted averaging (OWA) operators	empirical
Hernández-Sancho, Molinos-Senante and Sala-Garrido (2011) (39)	Spanish	99 WWTPs	secondary data from Catalan Water Agency (ACA)	provides efficient scores for a sample of operating under four different technologies in wastewater treatment plants (WWTPs) for identify best practices and optimize resource-use	develop an assessment with a range of wastewater treatment technologies	Data Envelopment Analysis (DEA)	empirical

Those published between 2002 and 2015, most frequently in the years 2005 and 2014, were in water service providers and WWTPs, with the water service being the most frequent (Table 2).

Table 2: Articles with SFA methodology and others.

Author	Local	N	Collect	Contribution	Gap	Method	Theoretical / Empirical
Abrate, Erbetta and Fraquelli (2011) (1)	Italy	46 local regulators of water supply	companies database	analyzes the cost efficiency embedded in budget plans define to local authorities to evaluate the actual capability of local regulators to adequately orientate firm performance	more richer information on cost determinants	Stochastic Cost Frontier	empirical
Aubert and Reynaud (2005)(8)	Wisconsin, USA	211 water utilities observed from 1998 to 2000	companies database	assesses the effects of regulatory policies on the cost efficiency of water companies	generate a model with technical progress that investigates empirically the effect of new investments, for to test effect of price-cap regulatio	Stochastic Cost Frontier	empirical
Corton (2011)(15)	Peru	43 water providers during the years from 1996 to 2005	National Superintendence of Sanitation Services (SUNASS)	investigates economies of scale and cost inefficiencies	to investigate the political effect on interference in water supply	Stochastic Cost Frontier	empirical
Da Silva e Souza, Faria and Moreira (2007) (17)	Brazil	279 firms	Brazilian System for Information on Sanitation (SNIS)	assesses cost efficiencies of public and private companies of water supply	-	Stochastic Frontier	empirical
Daraio and Simar (2005)(18)	USA	-	simulation	formulates a general model with external environmental factors that can influence production processes	define another criterion for cross-validation of likelihood for the density of Z	Nonparametric Frontier Models	theoretical
Estache and Rossi (2002)(21)	Asian and Pacific	50 firms surveyed in 1995 in 19 countries	Asian Development Bank	assesses cost efficiencies of public and private companies of water supply	the data do not allow for testing of trade offs between efficiency gains and quality reductions	Stochastic Cost Frontier	empirical
Faust and Baranzini (2014)(23)	Switzerland	141 water distribution utilities over the years 2002–2009	Swiss Gas and Water Industry Association (SGWA)	measures the performance in terms of costs of drinking water utilities accounting for environmental factors	a more in-depth analysis with alternative models	Stochastic Cost Frontier	empirical
Filippini, Hrovatin and Zorić (2008) (25)	Slovenian	over the 1997-2003 period	companies database	estimates cost inefficiency and economies of scale of water distribution utilities with different methods	explore the possibility to solve this problem using semiparametric and nonparametric methods	Stochastic Frontier	empirical
Haider, Sadiq and Tesfamariam (2014) (35)	Canada, Australia, United Kingdom, Wales, Asia, Arabia, Afica, South Africa, Armenia	-	data from organizations and agencies in the sanitation sector	evaluates individual performance indicators with respect to their comprehensibility, measurability and comparability (ie, within and through comparisons of public services), covering aspects: personal, operational, customer satisfaction, economic	consistent review and improvement of the selected suitable performance indicators (PIs) over time	-	theoretical
Miralles (2008)(56)	Spanish region of Catalonia	133 municipalities in 2000 and 2001	questionnaire	analyzes the effect of recent privatization on the difference between the marginal water price paid by the average industrial customer and the marginal price paid by the average residential user	a wider, longer database could contribute to confirm the major findings	multiple linear regression	empirical
Molinos-Senante, Hanley and Sala-Garrido (2015) (59)	Spanish	25 WWTPs	calculated	estimates the shadow price of CO2 for a sample of wastewater treatment plants (WWTPs)	-	Mann–Whitney and Kruskal–Wallis nonparametric tests	empirical
Onda, Crocker, Kayser, and Bartram (2014) (63)	Global	124 countries	secondary data from the JMP, UNESCO, WHO and World Bank	create a new typology of country clusters specific to the water and sanitation (WatSan) sector based on similarities across multiple WatSan-related indicators	Further research on the WatSan country cluster typology could involve cluster validation, or creating targeted clusters for specific regional or subnational applications	hierarchical clustering method and a gap statistic analysis	empirical
Sadiq, Rodríguez and Tesfamariam (2010) (71)	Québec, Canada	10 water utilities	companies database	detailed case study for developing performance indicators using OWA operators. Demonstrating that it is possible to develop methodologies that combine several qualitative approaches and qualitative indicators to evaluate the performance of water companies	different hierarchical structure schemes of aggregation of indicators can be tested to improve results	ordered weighted averaging (OWA) operators	empirical

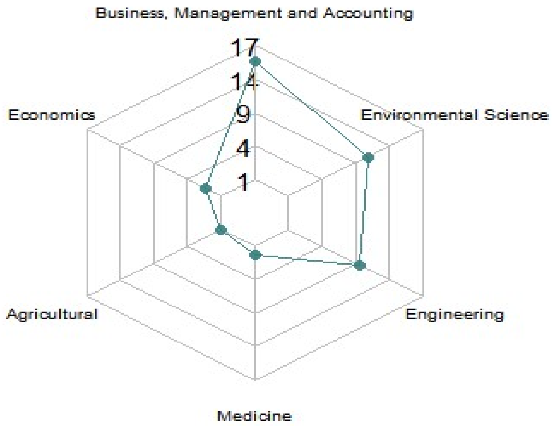
Studies based on methodologies such as DEA, hybrid simulation models, life cycle analysis (LCA), geographic information system (GIS), and statistical analysis, took place between the period 2002 to 2017, with 2016 being the year of greatest publication (Table 3).

Table 3: Benchmark articles, performance dashboard, performance indicators and efficiency.

Author	Local	N	Collect	Contribution	Gap	Method	Theoretical / Empirical
Dong, Zhang and Zeng (2017) (20)	China	736 sample plants	simulation and systems database	evaluates the eco-efficiency of the WWTP during the process of development of wastewater projects, taking into account the efficiency results and estimating the greenhouse gas emissions (GHG) of the systems	a similar analysis, but with real data	Data Envelopment Analysis (DEA)	empirical
Angelis-Dimakis, Arampatzis and Assimacopoulos (2016) (4)	industrial water-service systems (freshwater and wastewater)	8 studies case	mapping of the systems	analysis of eco-efficiency through the implementation of innovative technologies in water use systems	more categories and introduce additional indicators to assess environmental impacts and freshwater	Systemic Environmental Analysis Tool (SEAT) and Economic Value chain Analysis Tool (EVAT)	theoretical and empirical
Arampatzis, Angelis-Dimakis, Blind and Assimacopoulos (2016) (5)	Water supply sistem	milk production unit of a dairy industry	mapping of the systems	evaluates eco-efficiency improvements of innovative technologies in water use systems	to carry out similar studies, with benchmarks known and validated with the indicators used in the study	EcoWater Toolbox, Economic Value chain Analysis Tool (EVAT) and Systemic Environmental Analysis Tool (SEAT)	empirical
Franceschini and Turina (2011)(26)	Piemonte, Italy	13 Water and Sewage Companies (WaSCs)	secondary data from Optimal Territorial Area Authorities (A.ATO)	creation of critical indicators (performance panel) for the evaluation and monitoring of the service provided of water and sewage	detail the impact on water service exerted by the proposed performance dashboard.	Balanced Scorecard (BSC)	empirical
Garriga,Palencia and Foguet (2013) (31)	Distrito de Homa Bay, no Quénia, Distrito de Kibondo, Tanzânia e Município de Manhiça, Moçambique	-	combines a mapping of water sources with a stratified survey of households	proposes an improved approach for water, sanitation and hygiene (WASH) data collection at decentralised level in low income settings	accurate and reliable data at local level have to be accessible and routinely collected and adequately disseminated	Clooper-Pearson	empirical
Giné-Garriga,Palencia and Foguet (2015) (30)	Distrito de Homa Bay, no Quénia, Distrito de Kibondo, Tanzânia e Município de Manhiça, Moçambique	-	combines a mapping of water sources with a stratified survey of households	defines new indices to cover the issues of household sanitation and domestic hygiene	establishment of appropriate decision-support systems to guide decision-makers	SIG and Statistical Analysis	empirical
Henriques and Catarino (2016)(37)	Portugal	14 wastewater treatment plants	secondary data from Portuguese Waters Company (ADP)	briefly evaluates waste water from the treatment process and identifies potentialities of the process energy improvements linked to eco-efficiency	same approach but types of toxicity-related parameters	Sustainable Value and Cleaner Production method developed by United Nations Environment Programme (UNEP)	empirical
Lee (2010)(46)	China	data from 1990s	secondary data from China Water Net	analyzes the transformation of urban water services, noting the interaction between government and the private sector	-	-	theoretical
Levidow, Lindgaard-Jørgensen, Nilsson, Skenhall and Assimacopoulos (2016) (47)	industrial water-service systems (freshwater and wastewater)	2 large manufacturing companies	relevant stakeholders and LCA databases (EcoWater Project)	analyzes the entire water service value chain through meso-level interactions among heterogeneous actors (process water users, suppliers and wastewater treatment companies)	-	EcoWater assessment of mesolevel eco-efficiency hybrid model	theoretical and empirical
Lorenzo-Toja, Vázquez-Rowe, Amores, Montserrat Termes-Rifé, Marın-Navarro, Moreira and Feijoo (2016) (50)	Spanish	22 wastewater treatment plants (WWTPs)	system database	provides an alternative scheme for analyzing the relationship between environmental impacts and costs	with decentralized systems should be analyzed in depth from an eco-efficiency standard	Life Cycle Assessment (LCA) and Life Cycle Costing (LCC)	empirical
Molinos-Senante, Gémar, Gomez, Caballero and Sala-Garrido (2016) (58)	Spanish	30 WWTPs	sistem database	provides an innovative and pioneering approach to assessing eco-efficiency	new studies which relationship the factors affecting individual inefficiency scores	weighted Russell directional distance model and a non-radial DEA model	empirical
Molinos-Senante, Hernández-Sancho, Mocholí-Arce and Sala-Garrido (2014) (60)	Valencia Region, Spanish	60 wastewater treatment plants (WWTPs)	secondary data from Entitat de Sanejament d'Aigües (EPSAR)	integrates the environmental impacts in the evaluation of the efficiency of the pure environmental performance indexes (PEEP) and mixed (MEPI) of the environmental performance estimators	perform a DEA analysis to identify and examine the variables that contribute to the environmental performance of the WWTP (PEPIs and MEPIs)	Data Envelopment Analysis (DEA) and Kruskal-Wallis test	empirical
Palme and Tillman (2008)(65)	Sweden	3 water sector	combination of literature and interviews	analyzes sustainable development indicators (SDIs) and what information is included in these indicators	to study the role of SDIs in planning and decision-making	-	theoretical
Renzetti and Dupont (2009)(70)	Ontario, Canada	64 Canadian water utilities in 1996	secondary data from water agencies	presents a multistage procedure that combines DEA and regression analysis to measure and evaluate relative technical efficiency, testing the influence of exogenous environmental factors	-	Data Envelopment Analysis (DEA)	empirical
Stanchev and Ribarova (2016)(72)	Bulgaria	5 representative residential districts	secondary data from National Statistical Institute (NSI) and Water Operator	provides reference values for twelve eco-efficiency indicators for urban water systems	The values of the calculated eco-efficiency indicators could serve as reference values in further research work as well as for decision makers	Economic Value from Water Use (EVU) and Energy efficiency indexes (EEI)	theoretical and empirical
Timmins (2002)(75)	California, USA	13 municipal water utilities	companies database	Prediction of a structural system of water supply and demand equations	-	Two-Stage Estimation Algorithm	empirical

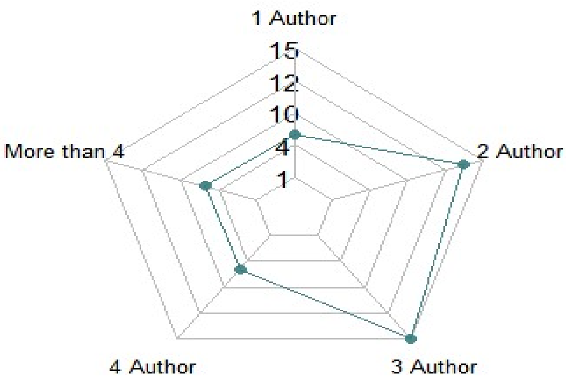
Considering the publication areas, shown in Figure 3, we considered four: business and administration, economics, econometrics and finance, engineering, and sciences [2]. We observed that of the 43 published articles, 16 are of the area of business and administration, 3 of economics, 1 of agriculture, 2 of medicine, with 11 and 10 in the areas of environmental sciences and engineering, respectively.

Figure 3: Areas of publication.



Regarding the authorship of the publications, we can see in Table 1, Table 2, Table 3 that some authors are present in more than one article. These authors are Sala-Garrido, Molinos-Senante, Haider, Sadiq, Aubert, Reynaud, Tesfamariam, Angelis-Dimakis, Arampatzis and Assimacopoulos. Besides that, most studies have 3 to 2 authors, according to Figure 4.

Figure 4: Authorship.

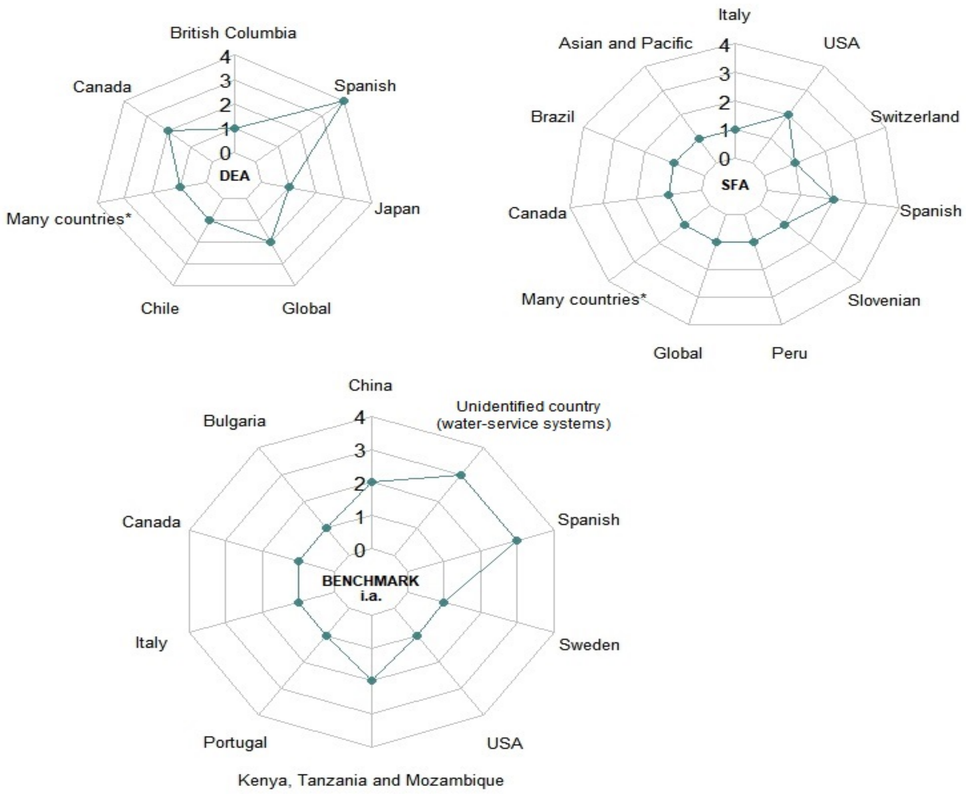


[2]The area of science and water technology according to the Scimago categorization.

We can also identify that even when searching for terms related to sewage, the studies obtain a relationship with Wastewater Treatment Plants (WWTPs). An analysis in the database suggests a higher of this relationship in the global scope and Spain, as presented in Figure 5. We also observed the presence of the countries Canada, Japan, Chile and Africa.

Thus, the studies presented in Figure 5 have the SFA methodology as a feature, have a local and diverse scope, carried out in Brazil, Peru, the USA, Asia, Italy, Africa, and Spain and secondary data from agencies and companies. The present characteristics of the articles, consist of a majority of empirical study, with data from sanitation companies, government entities, and regulatory agencies. The themes addressed in these studies were: benchmark, performance dashboard, performance, and efficiency indicators performed on WWTPs, industrial supply systems, and companies. The scope was local and diverse in countries like Spain, China, Africa, Sweden, Portugal, Canada, Bulgaria, and the USA.

Figure 5: Study countries.

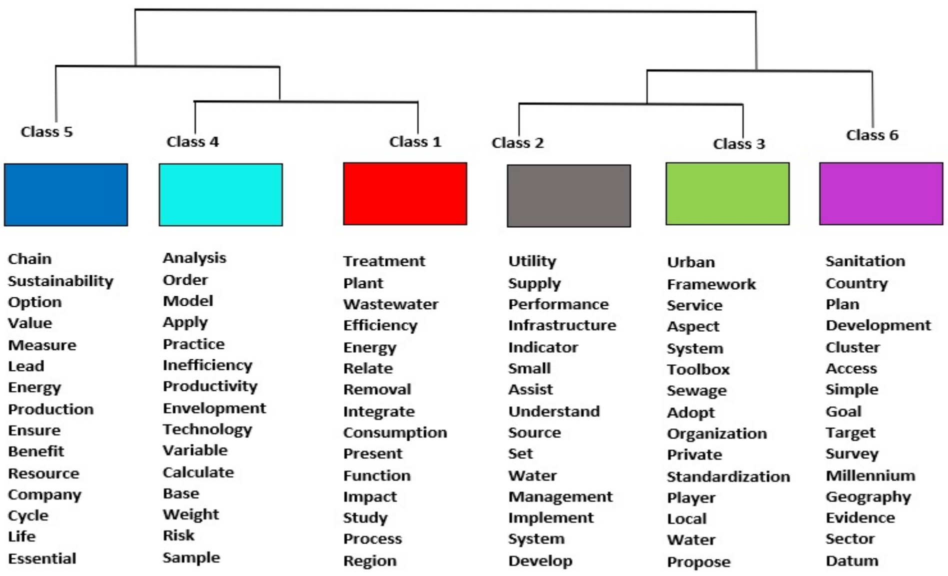


*Canada, Australia, United Kingdom, Wales, Asia, Arabia, Afica, South Africa, Armenia.

Descending Hierarchical Classification – DHC

DEA methodology presented DHC analysis (Figure 6) in 299 (83.28 %) segments, 6315 occurrences (words, forms, or words) emerged, with 1601 distinct words and 854 with a single occurrence, which presented six classes. Class 1 has 41 segments of text (ST) (16.5 %), the most frequent words within the class were: treatment, plant, and wastewater. Class 4 had 33 ST (13.5%); in this class, the most frequent words were: analysis, order, and model. The abstracts present in these classes (1 and 4) are related to the theme of eco-efficiency, efficiency, and DEA modeling. Class 5 presented 37 ST (14.9 %), with the most frequent words: series, sustainability, and option, shown in Figure 6. Like the study of Cetrulo et al., (2020) that in their bibliometric survey on efficiency in sanitation companies, observed the DEA methodology (evaluating the performance of the providers of this service") as the preferred method. From our sample (46 abstracts) 54.4 % employ this methodology.

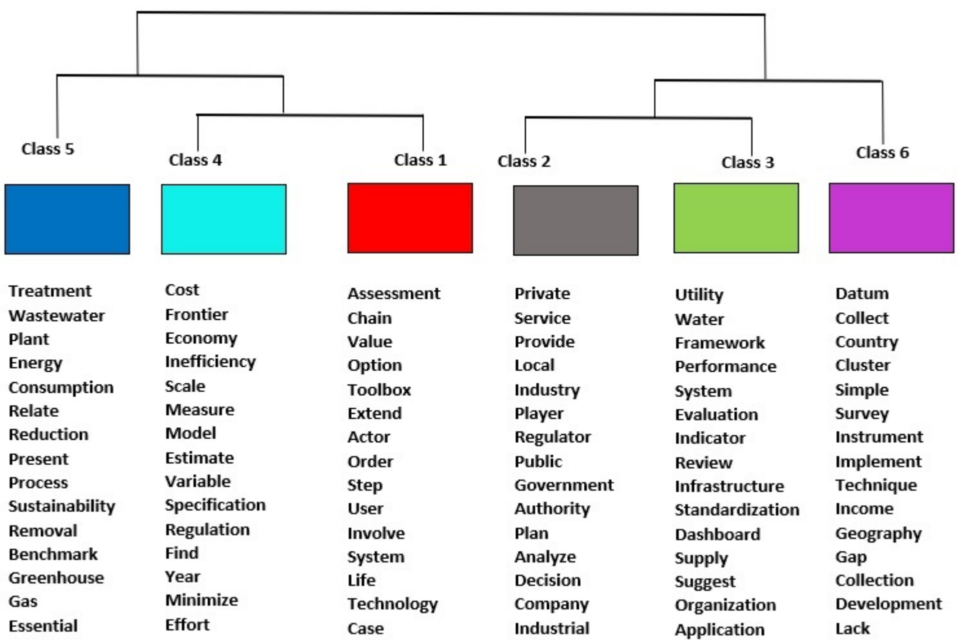
Figure 6: Descending hierarchical classification, DEA methodology.



Class 2 showed 49 ST (19.7 %), being the words that obtained a higher frequency: utility, supply, and performance; characterized by summaries related to DEA modeling, indicators, and management tools. In class 3, the themes of the abstracts addressed the theme of privatization, eco-efficiency, public-private partnership, and management tools. This class presented 41 ST (16.5 %), being the most used words: urban, structure, and service. With 48 ST (19.3 %), class 6 addressed the theme of efficiency, spatial analysis, indicators, and DEA modeling. In this class, the most used words were: sanitation, country, and plan, shown in Figure 6. The use of indicators is not limited only to water supply, studies on the sewage system and wastewater, also make use of them as a management tool and are mainly linked to issues of efficiency and sustainability (Palme et al., 2005; Balkema et al., 2002; Ashley and Hopkinson, 2002; Henriques and Catarino, 2017).

For the SFA methodology, the DHC analysis is shown in Figure 7 and it presents that in 265 (84.53%) segments 5566 occurrences emerged (words, forms, or terms), with 1232 distinct words and 819 with a single occurrence, presented six classes. Class 1 has 36 TS (16.1%), being the most frequent words within the class: treatment, wastewater, and plant. Class 4 had 45 TS (11.6 %); in this class, the most frequent words were: cost, frontier, and economy. The abstracts present in these classes (1 and 4) are related to the theme of eco-efficiency, efficiency, and SFA modeling. Also, in a bibliometric survey, CETRULO2019372, (2020)on sanitation services observed that the SFA methodology, analyzing the performance of providers, in 46 abstracts only 39.1 % use this methodology.

Figure 7: Descending hierarchical classification, SFA methodology.



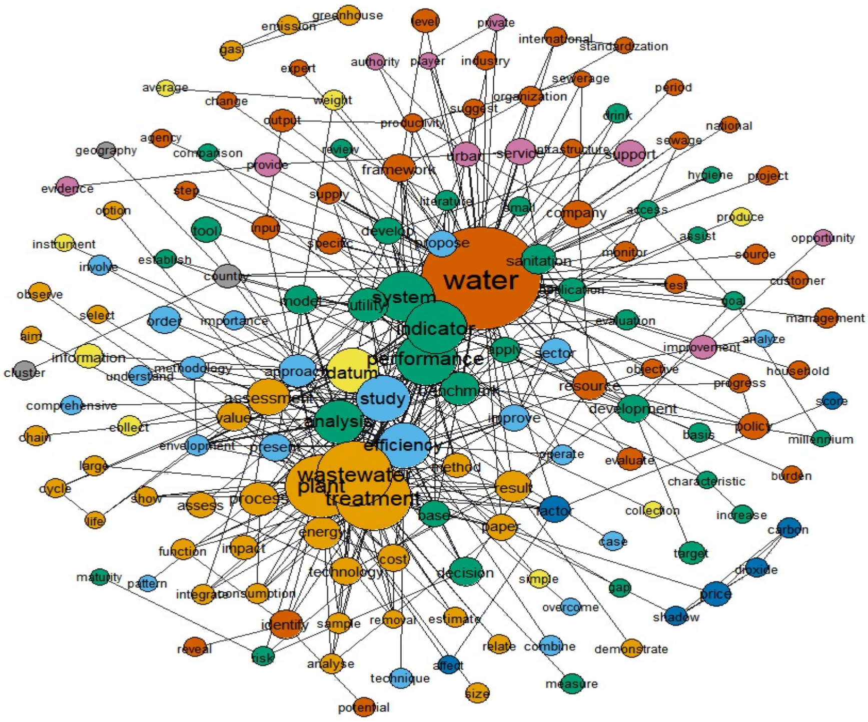
Class 6 presented 45 TS (20.1 %), with the most frequent words: access, series, and value. The abstracts present in this class are related to eco-efficiency and CO_2 estimation. For issues related to sustainability and sanitation as a whole, the focus of the studies are related to impacts on the environment, distribution and access (Longo et al., 2016 and Agudelo-Vera et al., 2011). Class 3 showed 26 TS (11.6 %) and the words that obtained a higher frequency were: private, service and supply, characterized by abstracts related to SFA modeling, efficiency, eco-efficiency, privatization, and public-private partnership, shown in Figure 7. In class 2, the themes of the abstracts addressed the theme of indicators, eco-efficiency, efficiency, SFA modeling, and management tools. This class presented 45 TS (20.1 %), with the most used words: utility, water, and structure. In a review study on indicators in water supply systems (WSS) Haider et al., (2013) found that these consist of tools for performance analysis and are related to system management. Around the world, agencies and organizations develop detailed performance evaluations. These evaluations include various indicators to cover all aspects of the system.

With 26 TS (11.6 %), class 3 addressed the theme of eco-efficiency, privatization efficiency, public-private partnership, and SFA modeling. In this class, the most used words were: private, service, and supply. In class 5, the themes of the abstracts addressed the theme of spatial analysis and indicators. This class presented 46 TS (20.5 %), with the most used words: datum, collection, and country. In the classes definition, studies on sanitation services have their divisions, in which issues related to sanitation and water supply are generally not addressed in the same article (Giné-Garriga et al., 2013; Onda et al., 2014; Iribarnegaray et al., 2015).Most of the times, they are connected to water supply related to indicators, water resources management and system performance and in regards to sewage they are related to efficiency, energy, and nutrient removal.

Similarity analysis

In the similarity analysis of the DEA methodology shown in Figure 8, it is possible to identify the occurrences between the words and indications of the connection between them, serving as an aid in identifying the structure of the content of a textual corpus. There are eleven words highlighted: "water", "indicator", "performance", "system", "study", "datum", "analysis", "wastewater", "treatment", "pant" and "efficiency". From these words, ramifications occur, of which the word water is the central point.

Figure 8: Similarity analysis, DEA methodology.

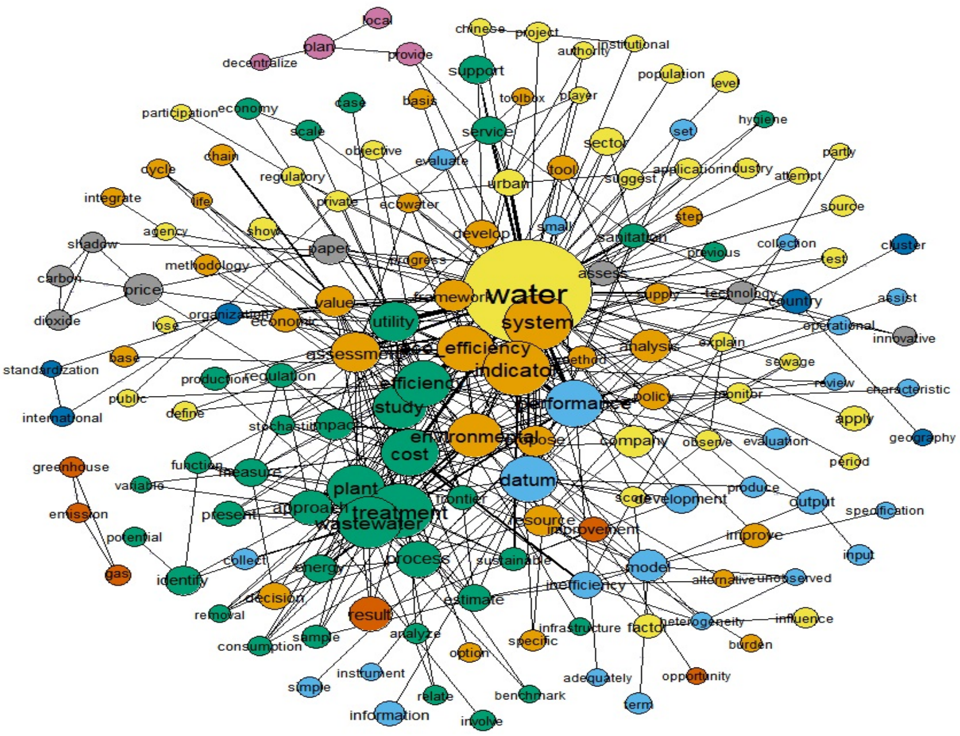


Note the relationship between "indicator" and "support", "performance" and "method", "system" with "policy", "datum" and "information", "analysis" with "apply", "study" and "decision". With that, we observe that the studies that deal with indicators have a focus on analyzing the system to improve performance and decision making. In a content analysis of two full years of articles published in a water-related magazine, Chenoweth (2012) noted the dissemination of articles that addressed topics related to water policy issues.

The relationship between "wastewater" and "assess," "treatment" and "energy," "plant" and "factor" was also observed. Therefore, the studies related to wastewater have the objective of verifying the impact, technologies, analysis of Life Cycle. Walter et al., (2009) analyzed studies that address efficiency in water supply systems and they concluded that the supply sector is increasingly subject to studies related to efficiency, which develop new models and methodologies. Further, they verified that the data availability and its quality are critical.

Figure 9 shows the similitude analysis of SFA methodology, in which we can observe eight words highlighted: "water", "indicator", "performance", "system", "cost", "wastewater"," treatment", and " plant ". Seeking to distinguish the success in sanitation through a bibliographic survey, Davis and Tobin (2016)verified the frequency of words through clouds. They also verified a greater mention of the words "sanitation," "water," " service, "and" management”. From these eight words, branches occur, which the word water is the central point. It is also important to note the relationship between "indicator" and "performance" with "tool", "treatment" with "propose", "system" with "policy" and "decision", "cost" with "estimate", "paper" with "technology", "service" with "plan".With that, he can affirm that the studies seek to propose an alternative treatment related to wastewater.

Figure 9: Similarity analysis, SFA methodology.



Most of them are studies characterized by presenting cost estimation models, performance analysis with indicators, and other tools. In an analysis of the talk on sustainable development, using the word cloud as a tool, Araújo et al., (2018) observed the use of the words "develop," "energy," "policy," " technology, "access "and" water "more often. . Humphry et al., (2011) in social and cultural research on water, also found a greater presence of the words: "water", "urban", "policy", "technology", "approach", "sector" and "sanitation".

With a slightly different approach, developing indicators for wastewater, Palme et al., (2005) found that the use of indicators is often not considered in this type of study, with its most common use related to water supply studies. They point out that this tool has a variety of applications as used in drapery, control, formulation of goals and support for decision making, as well as serving as a support for choosing technologies to improve the system.

Observed trends and gaps

As established by the SDG, one of the objectives is to make water and sanitation available for all. It is evident by the focus of the studies that there was an advance in the water availability to the population, which in developed countries is an established reality. The current concern in this service is the management through indicators, which served as a decision making support, seeking to monitor this service. However, regarding sanitation, we found that these studies focus on technological development. They show that the universalization of this service is still a gap since the focus at first was to provide water to the population. We observed that the studies focused only on the urban area, only the study by Cumming et al., (2014) carried out an analysis in the urban and rural areas.

In a critical review on universal access to drinking water and sanitation, Tortajada and Biswas (2018) also noted this gap. They also pointed out that many regions, with a high poverty rate and in development, still need many improvements for access to quality water and sanitation. Also through a review, but with a systematic focus on assessing the impact of sanitation, the studies by Garn et al., (2017) and Freeman et al., (2017) noted significant deficiencies in sanitation efforts in low-income countries to mitigate the selected diseases from these services. They also found that most interventions had only a modest impact on increasing service coverage. Accordingly, the latest reports on updates to the Joint Monitoring Program (JMP) confirm the disparities in coverage of access to sanitation services, in which the urban population has more access to these essential services compared to the rural population (WHO, 2017).

Carter (2019) analyzing urban-rural inequality in access to these services, stresses that the implications of access to sanitation in rural areas are related to difficulties in maintaining and repairing the service in communities as well as the financing of these services. However, he also verified that several initiatives are underway. To reach these areas and in some countries, private operators are extending their reach to surrounding areas. In other cases, the provision of this service occurs promptly under a single social enterprise or private operator. Furthermore, he concludes that what is needed is a systematic and strategic approach to rural services, considering the demographic projections specific to the context, continuing capital investment in new infrastructure, carrying out asset planning, and providing subsidies directed at significant repairs and replacements.

Conclusions

Through this review of sanitation services, with a focus on analytical frontier methods, there was a trend in studies and they primarily occurred in Europe, mainly in the urban region. Only one study was found that deals with urban and rural areas. It was possible to identify the focus of these researches, following a quantitative and qualitative approach. According to the observed characteristics of the created database, we can verify that studies related to the deterministic frontier have a higher occurrence in WWTPs, and to the analytical methods of the frontier to studies in water supply and water utilities. The studies about benchmark approaches, performance dashboards, performance, and efficiency indicators used hybrid models, data envelopment analysis, geographic information systems, and statistical analyzes.

We also found that for the DEA method, indicators are a tool for performance analysis, system, and decision making. In the SFA method, they seek to propose an alternative treatment related to wastewater, characterized by presenting estimation models cost analysis, performance analysis with indicators, and other tools.

These differences in the applications of the methods are related to aspects of methodologies following different approaches: parametric (SFA) and non-parametric (DEA). The SFA needs to define a function a *priori*, so the studies that use these techniques must have accurate data, allowing to test hypotheses through statistical tests. In the DEA technique, there is no need to define a function, so it is more flexible approach, allowing to detect discrepancies in the data sample. In this sense, the methods can be designed more as complements than as substitutes.

With that, we point out that advances are still needed related to water supply and sanitation services, mainly in low-income locations and developing countries. It is also up to the academy to contribute to the challenges established through more realistic and efficient analysis methodologies to estimate the performance of these services. The present research contributes to the literature presenting in its results the approaches given by the studies that correlate WWTPs with DEA and SFA with water utilities and water supply.

The study also highlights the results obtained, that the systems related to water supply have advanced in their services and how they focus on the management of these systems through efficiency analysis tools. For studies related to sewage service, it is evident the use of efficiency analysis in the search for more robust technologies, and the concern about management of these systems are still not the focus of many studies.

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CAPÍTULO 2

Sanitation and water services: Who is the most efficient provider public or private? Evidences for Brazil

Abstract

The present study analyzes the performance of water supply and sewage services in the 95 largest Brazilian cities, using two techniques for analyzing the efficiency boundaries, DEA and SFA. Indicators were used to estimate the efficiency score between the years 2013-2018, collected through the National Sanitation Information System. The results showed that for both techniques used, private providers are more efficient when compared to public providers in the water supply service. For the sewage service, public and private providers do not present significant differences. The results demonstrated an increase in the scores obtained for the sanitary sewage service as well as some declines, over the period of analysis, which reveals an attempt to make progress in the sewage sector. In the water supply sector there was no increase, but a decline in the scores obtained, that is, there was no improvement in the efficiency of this service across the analyzed period. We could verify that even though the public providers presented better averages in their data related to water and sewage, this did not show an impact on the estimated efficiency between 2013-2018. As investments in both systems by the private sector occurred in a more similar way than in the public and the extension of the network in the private sector in both services is superior. The study suggests the absence of incentives for efficiency, requiring the creation of instruments that promote the incentive to a better performance, through the regulatory structure of these services.

Keywords: Data envelopment analysis (DEA), Efficiency analysis, Stochastic frontier analysis (SFA), Water and sanitation services.

Introduction

The lack of sanitation and water supply infrastructure is a public health problem. Investments in these services ensure several externalities that impact quality of life, health and the environment. These services are often provided by a single provider, so they can be considered a natural monopoly. Investments in this type of market are high and costs very low, with little rivalry. Therefore, it is essential to have some sort of regulation that protects the balance of service quality and costs.

One of the tools that allows obtaining information to improve performance and ensure the uniformity and sustainability of these services in a transparent manner, is the performance assessment based on efficiency. The most common methods for determining efficiency are boundary models, such as the Data Envelopement Analysis (DEA) and the Stochastic Frontier Analysis (SFA). These two types of techniques are frequently used in boundary analysis, one being a nonparametric approach based on mathematical programming (DEA) and the other a parametric approach based on econometric principles (SFA).

These methodologies for analyzing efficiency in water supply and sewage services are being applied in several countries such as Mexico, Australia, Chile, Malaysia, Peru, Africa and Italy (Anwandter et al., 2002; Estache and Rossi, 2002 ;Molinos-Senante et al., 2016;Munisamy, 2009; Lin and Berg, 2008; Mbuvi et al., 2012; Mugisha, 2014; Romano et al., 2017). In these studies, the objective was to evaluate and estimate efficiency, comparing service providers and associating the modeling variables to know their weight in estimating the level of efficiency.

In the Brazilian scope, studies related to efficiency in the water supply and sanitation sector, mostly use only one analysis technique, either DEA or SFA, and focus on verifying the association between provider and efficiency, not separating services of water supply and sewage collection and treament. Many consider only the service related to water supply and sewage (Faraia et al., 2005; Carvalho et al., 2015; Da Silva e Souza et al., 2007; Faria et al., 2008; Barbosa et al., 2016), while others analyze only the provider of these services (Ferro et al., 2014; Barbosa and Brusca Alijarde, 2011; Oliveira and Carrera-Fernandez, 2004; da Motta and Moreira, 2006; Sabbioni, 2008; Grigolin, 2008).

In this sense, the study sought to fill this gap, performing an analysis of the performance in the water supply and sewage sector in Brazil, using the DEA and SFA techniques. Further, the analysis considered separating water and sewage services, in order to check for differences between companies, at the provider's organizational level between public and private.

Evolution of the Brazilian water supply and sanitation sectors

In 1971, the first milestone in sanitation policy took place in Brazil, when the military government instituted the National Sanitation[3] Plan (Planasa). As a result, investments in sanitation related to the expansion of access to drinking water began, serving the urban population. The control of this service was the responsibility of the State and the Union, with the support of some institutions such as the World Bank, Inter-American Development Bank (IDB) and the United States Agency for International Development (USAID) and others (Leoneti et al., 2011; Parlatore, 2000).

With the economic crisis in the 1980s, changes in the government culminated in the publication of the Magna Carta in 1988, in which it was established that responsibilities for sanitation policies should be changed from the Union to the municipal sphere. Then, with this modulation, the sanitation investment system lost strength and as a consequence Planasa was extinguished. Additionally, the Magna Carta considered water as a Union's good, and the Union was then responsible for lakes, and rivers that surround more than one State, and serve as limits with other countries. Also, surface and groundwater were the States' responsibility (Sousa and Costa, 2016).

The National Water Resources Policy (PNRH in Portuguese) was enacted in Law No. 9,433 in 1997, and it defines how the Brazilian State will take over and take charge of managing national water resources. The instituted objectives of the PNRH were: to guarantee water availability for the present and future generations; rational and integrated use of water resources; and defend and prevent possible hydrological events in the country. In order to comply with the objectives and guidelines of the PNRH, the National Water Agency and Basic Sanitation (ANA in Portuguese) was created in 2000, to regulate access and use of water resources through grants, monitoring the rivers together with the Union, coordinating the implementation of PNRH and preparation and participation in studies at the municipal, state and federal levels (Brasil, 1997; Brasil, 2000).

[3]In Brazil, sanitation refers to the services of water supply, wastewater collection and treatment, urban cleaning and solid waste management, and rainwater drainage management.

In 2007, Law No. 11,445/07 known as the Basic Sanitation Law, established guidelines for the sanitation sector, covering water supply, sewage services, solid waste management and urban rainwater services. The law assigned the Federal Government the responsibility for drafting the National Basic Sanitation Plan (Plansab) and set the goal of making services universal. In 2010, the United Nations (UN) General Assembly decided that access to drinking water and basic sanitation are essential human rights. And after that, in 2012, Plansab was approved, constituting a central axis for basic sanitation in the Country, carrying out the national articulation for the implementation of the guidelines of the Sanitation Law. In addition, short, medium and long term goals were established for universal sanitation services by 2033 (Leoneti et al., 2011; Parlatore, 2000)

In 2019 the law project (PL 4162/2019) updated the legal framework for basic sanitation. It attributed to the National Water and Basic Sanitation Agency (ANA) the competence to edit reference standards for the regulation of public basic sanitation services. Created the Interministerial Committee on Basic Sanitation and improved the structural conditions of basic sanitation. Established deadlines for the proper final disposal of tailing. Extended the scope of the Metropolis Statute to micro-regions. It also authorized the Union to participate in the fund with the sole purpose of financing specialized technical services, with the objective of supporting the structuring and development of concession projects and public-private partnerships of the Union, the States, the Federal District and the municipalities (Brasil, 2019).

Regulation and Management Models of Sanitation Services

Since the establishment of Plansab, the regulation of sanitation services' regime is based on the service's cost, in which the values are entirely of incurred operating costs and investments. In this scenario, the provider applies a capital return and regulates the setting of tariffs. The regulation model must be aligned with the national guidelines and national basic sanitation policy, Federal Law No. 11,445/07 (Madeira, 2010; Junior et al., 2009).

Sanitation services in Brazil have a historical relationship with the performance of public and private institutions. At first, the public sector began to operate in this sector between the 19th and 20th centuries, working on the implementation of sanitary structures for the collection of domestic sewage. This institution has a universal character in relation to sanitation, as it is organized in the form of state companies operating autonomously in the municipalities. In contrast, private companies started to move forward in the 1990s due to neoliberal policies. These companies are made up of consortia by national or foreign capital (De Oliveira, 2005).

According to the National Sanitation Information System (SNIS in Portuguese), sanitation management has a regional, micro-regional and local scope, classified according to the legal organization: direct administration, autarchy, mixed-capital company, public company, private company and social organization. There is a predominance of direct administration, followed by autarchy, private company, mixed capital company, public company and on a smaller scale social organization (SNIS, 2018).

The National Sanitation Information System (SNIS)

SNIS consists of a database of information on the sanitation sector, linked to the National Sanitation Secretariat (SNS) of the Ministry of Regional Development. This secretariat aims to become a tool to assist: planning and execution of public sanitation policies, resources' application, knowledge and assessment of the sector and service providers, management improvement, regulatory activities and inspection, and exercise of social control (SNIS, 2018).

This database contains information and indicators on the provision of water, sewage services, urban solid waste management and stormwater drainage and management, which are provided annually by service providers. Indicators and information have an operational, managerial, financial and quality character regarding the provision of services. All data are public and updated annually (SNIS, 2018).

Methods

Efficiency and estimation methodologies

Efficiency estimation methodologies make it possible to evaluate a company in order to encourage its development and improvement. Lovell et al. (1993) states that when this evaluation is carried out, it is common to characterize the company's performance making a distinction between a more efficient and a less efficient company. The techniques for determining the level of efficiency are segregated in two approaches, Bottom-Up and

Top-Down. The Bottom-Up approach allows for the calculation of operating costs and an efficiency assessment is carried out from them. At Top-Down, a survey is performed on the operating costs of a group of companies, using variables that determine them, such as indicators (Berg, 2007).

From these data collection approaches, mathematical or statistical models are developed. These models allow to relate these costs and find the levels of efficient operation (Guimarães et al., 2013). Thus, this efficiency analysis corresponds to a comparison between the values observed as optimum inputs and outputs.

Data Envelopment Analysis (DEA)

This methodology allows Top-Down approach and combines estimation with a measure of efficiency, integrating two basic concepts: i) definition of the performance standard (model) and the analysis tool, and ii) model validation and analysis (Bogetoft and Otto, 2010). It provides a mathematical programming method for estimating the efficiency frontier with different data sets, known as Decision Making Units (DMUs). DMUs are the individuals to be analyzed, formed commonly by indicators of the system to be assessed, through inputs and outputs with different units of measure, which form a production frontier that represent the efficiency frontier (Bogetoft and Otto, 2010).

Traditional models are based on scientific research, mathematical programming, as well as they are related to econometrics concepts. The most common models are: CCR (Charnes, Cooper and Rhodes) and BCC (Banker, Charnes and Cooper), in which CCR works with feedback constant, so a variation in the input is proportional to the output, as shown in Equation 1.

$$\begin{gathered} Eff_o = \text{Max} \frac{\sum_{r=1}^{s} u_r y_{rj_0}}{\sum_{i=1}^{m} v_r x_{ij_o}} \\ \text{s.t. } \frac{\sum_{r=1}^{g} u_r y_{rj_o}}{\sum_{i=1}^{m} v_i x_{ij_o}} \leq 1 \\ v \geq 0, u \geq 0, j = 1, 2, \ldots n \end{gathered} \tag{1}$$

In the BCC, the input variation may promote an proportional or not increase in the output, or even a decrease (Cooper et al., 2001), according to Equation 2.

$$Eff_o = \text{Max}\,\frac{\sum_{r=1}^{s} u_r \cdot y_{r_0}}{\sum_{i=1}^{m} v_r \cdot x_{i_0}}$$

$$\text{s.a}\ \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1,\ j = 1,2,\ldots,n \tag{2}$$

$$u_r \geq 0, r = 1,2,\ldots,s$$

$$v_i \geq 0, i = 1,2,\ldots,m$$

Where x_{it} is the input quantity per DMU_j (the j-th DMU), y_{rj} the output r quantity produced by DMU_j, v_i, vi is the weight of the input i, u_r is the weight of the output r, n is the total number of DMU_s (the plural form of DMU), m is the total number of inputs, s is the total number of outputs, and 0 is the unit evaluated for an optimization run. y_{r0} and x_{r0} are the technological coefficients of the input and output data matrices. In the case of $Eff_{o=1}$, the $DMU_0$is considered efficient when compared to the other units considered in the model, and if $Eff_o < 1$, this DMU is considered inefficient.

Stochastic Frontier Analysis (SFA)

This technique was developed by Aigner et al. (1977) and Meeusen and van Den Broeck (1977). It allows the approach like DEA, but it differs as it possibilitate measuring technical inefficiency, based on the error term. This error term is composed of two parts, a unilateral component, and a symmetric component. The unilateral component captures the effects of border-related inefficiency, and the symmetrical component captures the effects of measurement errors between random variations between the border and individuals. The efficiency established by Cobb-Douglas considering the error term in the production function is expressed in Equation 3.

$$lny_{it} = \beta_0 + \sum_n \beta_n \ln x_{nit} + v_{it} - u_i$$

$$i = 1,\ldots,N \tag{3}$$

$$t = 1,\ldots,T$$

$$u_i \geq 0$$

Where y_{it} is the output quantity of the i-th DMU, x_{it} the quantity of input in the year t, t, u_i represents the random time-invariant non-negative variables that capture invariant technical inefficiency, v_{it} are variables of the i-th unit in year t, reflecting the effect of statistical noise.

Bootstrap test

This test was applied in order to verify the differences in efficiency scores between public and private providers. The bootstrap is equivalent to an alternative to the t-test and the hypothesis test. It consists of statistical, computational resampling technique, introduced by Efron and Tibshirani (1997) in 1979, to obtain information on the distribution. The principle of the test is to sample observations with substitutions of a data set, thereby creating a new set of data called random, with the same size as the original. Through this data set it is possible to calculate the necessary statistics, called replicas, and this process is repeated to create a sample of replicas. Based on this new sample, information related to the distribution of data set can be understood in the analysis. The standard test algorithm is described below (Bogetoft and Otto, 2010):

1. Select B independent bootstrap samples x_1, x_1, ..., x^B, that is, a sample taken with replacement of our data set.

2. Calculate the estimate for each bootstrap sample with Equation 4.

$$t\left(x^b\right)(b = 1,\ldots,B) \tag{4}$$

3. Estimate the standard error using the sample B standard error of replications.

$$\widehat{s_B} = \sqrt{\frac{1}{B-1}\sum_{b=1}^{B}\left(t\left(x^b\right)-t\right)^2} \tag{5}$$

Where $\bar{t} = \frac{1}{8}\sum_{b=1}^{B} t\left(x^b\right)$

Influence of variables on efficiency scores

In order to verify the indicators' weight in the estimation of the efficiency level in both systems and techniques used in the study, a multivariate linear regression analysis (MLR) and analysis of variance (ANOVA) were performed. The MLR analysis, shown in Equation 6, allows to find a regression equation, which predicts the response variable based on the combination of the explanatory variables (HAIR et al., 2005).

$$y = \beta_0 + \beta_1 x_1 + ... + \beta_n x_n + \varepsilon \tag{6}$$

Where y is the response or dependent variable and x_i (i = 1, 2, 3 ... n) explanatory or independent variables. β_0 represents the y value when the independent variables are null, and β_i are the regression coefficients. The forecast error (ε) is the difference between the real and the predicted values of the dependent variable.

In the analysis of variance (ANOVA) it was verified the source of variation by the sum of squares, between the means (treatment), trying to verify the representation of the deviation of each group mean in relation to the global average and within the samples (error). Besides, portraying the deviation of each element in relation to the group average, according to Equations 7 and 8 (Clark and Downing, 2011):

$$SQTR = n \sum_{j=1}^{m} (\bar{x}_j - \bar{x})^2 \tag{7}$$

$$SQER = n \sum_{i=j}^{n} \sum_{j=1}^{m} (\bar{x}_i j - \bar{x})^2 \tag{8}$$

In the study, the response variable employed was the efficiency score obtained by the DEA and SFA techniques in both systems and the variables responses to inputs and outputs.

Description and data collection

For the study, panel data was used between the years 2013-2018, from the 95 largest Brazilian municipalities ($>$ 300,000 inhabitants) according to the Trata Brazil Institute[4]. These

[4]This institute is an OSCIP - Civil Society Organization of Public Interest, formed by companies with an interest in the advances in basic sanitation and in the protection of the country's water resources. One of its studies

95 providers consist of the DMUs to be analyzed, in which 43 water supply and sewage companies are present, of which 9 are private and 34 are public.The provision of these services does not occur centrally in the public power, as there are variations in governance arrangements. The database consists of approximately 50% of representatives from the Southeast region, followed by around 14% and 20% from the South and Northeast regions, and finally with less than 10% from the North, Central west and Federal District, as shown in Table 4.

Table 4: Brazilian geographic areas of the selected companies.

Geographic area	N. of cities	% representative of the region
North	7	7.37
Federal Distrit	1	1
Northeast	20	21.05
Mid-West	6	6.32
South	14	14.74
Southeast	47	49.47

The information related to the description of the indicators was taken from the glossary of water and sewage information of the 2018 service diagnosis (SNIS, 2018). The data related to the water supply system (Table 5) are:

- Volume of water produced: that comprises the annual volume of water, available for consumption captured and imported raw, measured or estimated at the exit of the Water Treatment Station (WTS) or Simplified Treatment Unit (STU), as well as untreated water, measured at the entrance of the distribution system.
- Extension of the water network: represents the total length of the distribution network, including pipelines, sub-pipelines and distribution networks and excluding building extensions.
- Number of connections: includes active and inactive water connections to the public network, whether or not provided with a hydrometer.
- Volume of treated water: corresponds to the water subjected to the treatment, including the raw and imported raw water, measured or estimated at the exit of the WTS.

carried out since 2018 is the Basic Sanitation Ranking. Information on the size of the municipalities was extracted from this study.

- Water volume billed: refers to the annual volume of water charged to the total savings (measured and unmeasured), for billing purposes.

Table 5: Indicators used in the study

Indicators	Measure unit
Water production	1.000 m^3/year
Total length network	km
Number of connections	un
Volume of water treated	1.000 m^3/year
Billed water volume	1.000 m^3/yearano
Operating expenditure (OPEX)	R$/year
Provider's investment in the system	R$/year
Billed sewage volume	1.000 m^3/year
Volume of sewage collected	1.000 m^3/year
Volume of treated sewage	1.000 m^3/year

With regard to the sewage system (Table 5), the existing data, on this service are:

- Collected sewage volume: it refers to sewage discharged into the collection network, with 80% to 85% of the volume consumed in the same economy, not including the volume of imported raw sewage;

- Treated sewage volume: that corresponds to sewage subjected to treatment, measured or estimated at the entrance to the sewage treatment plant (STP), not including raw sewage imported and exported at the importer's premises;

- Number of connections: which refers to active and inactive connections to the public network; extension of the sewage network, which comprises the total sewage collection network, including collection networks, trunk collectors and interceptors and excluding building extensions and settlement outlets, operated by the service provider;

- Volume of billed sewage: which expresses the sewage charged to the total number of households, for billing purposes.

And both services (Table 5) are:

- Operating expenditure (OPEX): depict the annual amount of expenses incurred for the exploration of services, comprising expenses with personnel, chemicals, electricity, third-party services, imported water, exported sewage, tax or tax expenses computed in OPEX, in addition to other operating expenses.

- Investments: made by the service provider, and it represents the investment made directly or through contracts, in equipment and installations incorporated into the systems, accounted for in construction in progress, in fixed assets or in intangible assets.

Input and Output selection

An important factor in the modeling stage is the selection of inputs and outputs. In the literature, studies on water supply and sewage systems related to efficiency employ several indicators, as suggested by Alegre et al. (2016). Many of the studies include variables such as network length, number of employees, volume produced (Suárez-Varela et al., 2017; Brettenny and Sharp, 2018; Cetrulo et al., 2019), as well as indicators related to operating expenses (Güngör-Demirci et al., 2017; Coelli et al., 2005). Table 6 shows the input and output variables used in this study, considering the literature and data availability.

Table 6: Input and output variables.

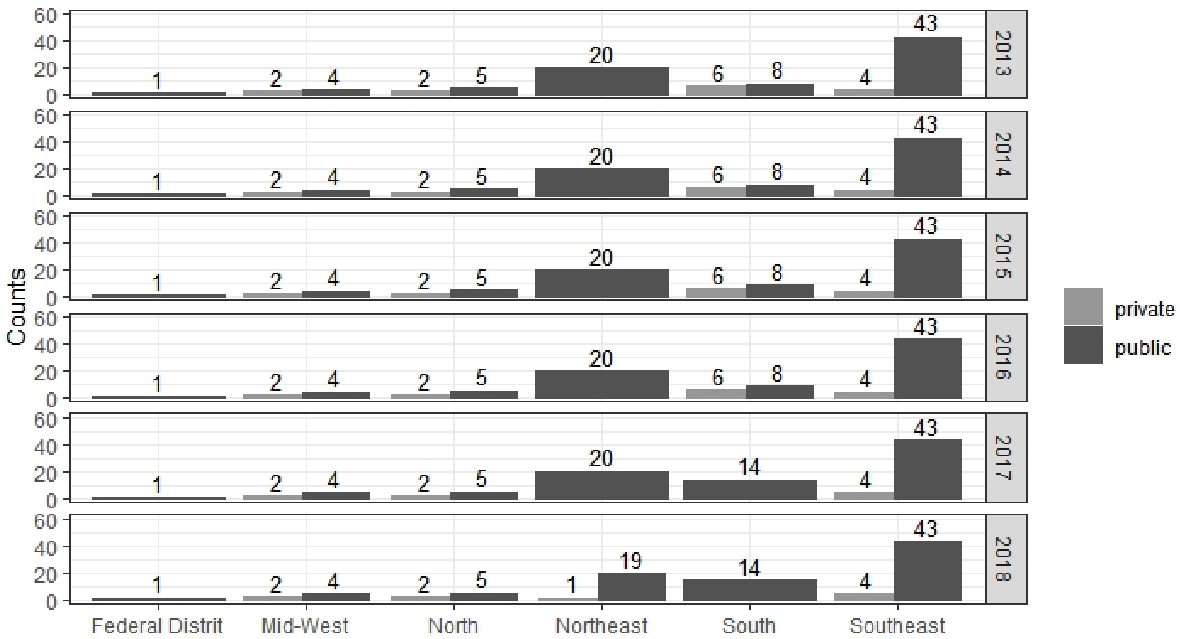
Inputs	Outputs
Water supply	
· Total length network	· Billed water volume
· Number of connections	
· Volume of water treated	
· Operation expenditure (OPEX)	
· Provider's investment in the system	
· Water production	
Sanitary sewer system	
· Total length network	· Billed sewage volume
· Number of connections	
· Volume of treated sewage	
· Operating expenditure (OPEX)	
· Provider's investment in the system	
· Volume of sewage collected	

Results

System characteristics

Figure 10 presents the results related to the type of provider of water supply and sewage services. In general, we can see that from the 95 largest Brazilian cities 81 have public providers and only 14 private ones. We were able to observe that in the Federal District the provision by the public sector was constant in the period from 2013 to 2018. In the Mid-West region, we found that there is also a constancy in the provision, with 2 private and 4 public providers. As in the North region, where the provision was also constant by 2 providers from the private sector and 5 from the public sector. In the Northeast, these services were supplied only by the public sector (20 providers) in the period from 2013 to 2017, and in 2018 the service was provided by 1 private and 19 public. As for the Southeast region, we also observed a consistency in the provision of water supply and sewage in the years 2013 to 2018, with 4 private and 43 public providers.

Figure 10: Characteristics of sample systems.



DEA and SFA

Water supply

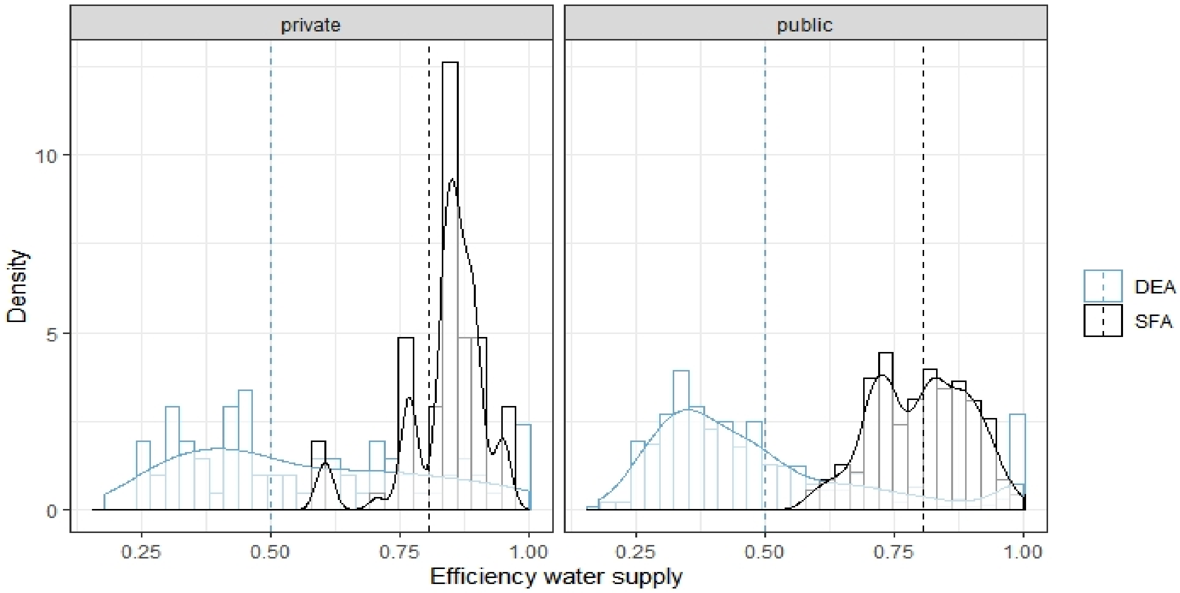
Table 7 shows the average, minimum and maximum efficiency scores per year obtained by the SFA and DEA techniques for water supply. It shows that the SFA methodology obtained a variable average from 0.810 to 0.807. The maximum and minimum values found for SFA were 0.985 to 0.984 and 0.595 to 0.590, respectively. We verified a pattern of decrease for the average, minimum and maximum values. For DEA the mean values ranged from 0.522 to 0.476 as the maximum and minimum values verified were from 1 (maximum) and between 0.244 to 0.180 (minimum). There was also a pattern in these results, in which the average and the minimum value tended to increase and decrease. The studies by Saal et al.(2007) and Ferro and Mercadier(2016) presented maximum efficiency scores similar to our study, which were between 0.995 and 0.985, in an analysis of water and sanitation companies.

Table 7: Water supply efficiency scores.

Year	Obs		Mean	Std.Dev.	Min	Max		Mean	Std.Dev.	Min	Max
2013	95	SFA	0,810	0,091	0,595	0,985	DEA	0,522	0,219	0,197	1
2014		SFA	0,809	0,091	0,594	0,985	DEA	0,504	0,222	0,180	1
2015	95	SFA	0,809	0,091	0,593	0,985	DEA	0,514	0,207	0,244	1
2016		SFA	0,808	0,091	0,592	0,985	DEA	0,498	0,221	0,199	1
2017	95	SFA	0,808	0,092	0,591	0,984	DEA	0,476	0,203	0,198	1
2018		SFA	0,807	0,092	0,590	0,984	DEA	0,510	0,224	0,222	1

Figure 11 presents an analysis of the efficiency scores considering the techniques applied in the study as well as the provision of the water supply service by the private and public sectors. Through the histogram, we could examine the peaks, dispersions and adjustments of the data distribution, as well as verify if they have any type of symmetry (data pattern). We can point out that for DEA and SFA both providers are asymmetric, which shows that for DEA many public and private providers had efficiency scores below or close to the variable average of 0.522 to 0.476. In the SFA, these scores from both providers occurred close to or above the variable average of 0.810 to 0.807. In addition, there were many peaks in the efficiency score in private providers, which shows that private providers can present a more variable pattern in the water supply provision services than public ones.

Figure 11: Water supply DEA and SFA efficiency scores over the years.



In the distribution adjustment, we could observe that for public providers there was a good adjustment in both techniques, as the distribution line was very close to the bars, so we can say that these providers are more similar in their provision of services related to water supply. From this, it appears that there are differences between the results obtained by these two techniques (DEA and SFA), with many providers achieving higher efficiency scores in SFA than in DEA. However, these scores are below 1, which is seen as a maximum value in DEA. These differences observed in the techniques occur due to the fact that the SFA technique estimates the score using the *posteriori* average, and as a consequence, the DMUs that reach 1 in the DEA presented lower scores in the SFA. An alternative to overcome this limitation is to use the maximum efficiency value in DEA and SFA as the final efficiency, as suggested by Agrell et al. (2017).

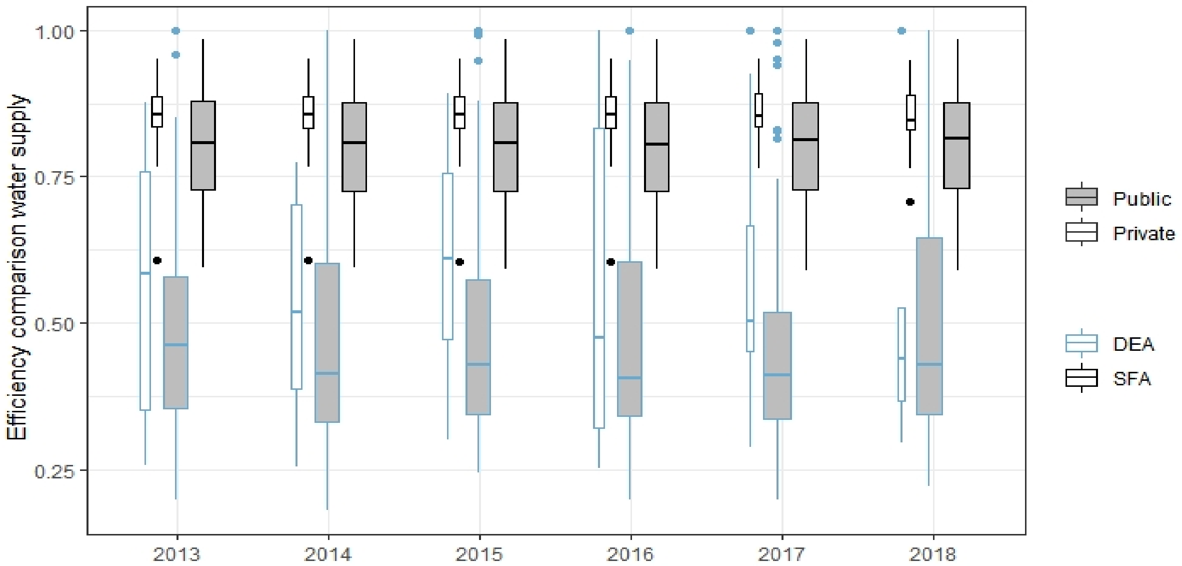
In order to verify whether this difference between the efficiency scores by public and private providers is significant, Table 8 presents the p-values for the Bootstrap, Wilcoxon and Kolmogorov- Smirnov difference tests. This difference between the types of providers is assessed based on the average efficiency score values, within each group and tested whether these values are statistically equal using these techniques. Thus, we can see that the sample differences were significant (p-value <0.05), proving that there are indeed differences in the provision of water supply services between the public and private sectors using both techniques.

Table 8: Group difference test results, water supply p-values.

	Bootstrap	Wilcoxon	Kolmogorov-Smirnov
SFA (public $\neq$ private)	1,00E-04	7,52E-02	3,70E-05
DEA (public $\neq$ private)	0,00E+00	6,52E-03	9,91E-03

Considering the providers and the DEA and SFA techniques Figure 12 shows the behavior of the efficiency scores over the analyzed period.The numerical analysis revealed that the majority of private providers achieved better efficiency, with values above the minimum (0.180 and 0.590, respectively) and close to the maximum (0.985 and 1) for SFA and DEA. In public providers, most of these providers had values close to the minimum (0.180 and 0.590) and the maximum (0.985 and 1) for DEA and SFA, respectively. In both techniques, for the years 2013 to 2017, private providers showed higher values than public ones. And in 2018, this type of provider did not show a higher efficiency than public, for DEA.

Figure 12: Comparison of the behavior of DEA and SFA efficiency scores by provider, water supply.



We also observed that, as in the previous results, the SFA technique presented high scores when compared to DEA and this occurred in all the evaluated years. Ferro et al.(2014) also performed a study based on efficiency analysis in Brazilian water and sanitation services, but only through the SFA technique, and they verified that the companies with the best efficiency were the private ones. Carvalho et al. (2015) through also a single technique, the DEA, and only in water companies, found a better performance in private providers likewise. This study brings a different approach, as we sought to establish a comparison not only between providers, as in the mentioned studies, but between performance analysis techniques as well.

We also verified the presence of outliers, as they consist of data values that are distant from other values, that is, they are values that deviate from the behavior pattern. These outliers were checked for SFA for the private providers, where the efficiency score is well below the minimum (0.180). In the DEA, this same occurrence was verified in the years 2017 and 2018 in the maximum value (1) in the private providers, and in the years 2013, 2015, 2016 and 2017 in maximum values (1) and above the variable average (0.522 to 0.476) in public providers.

Sewage system

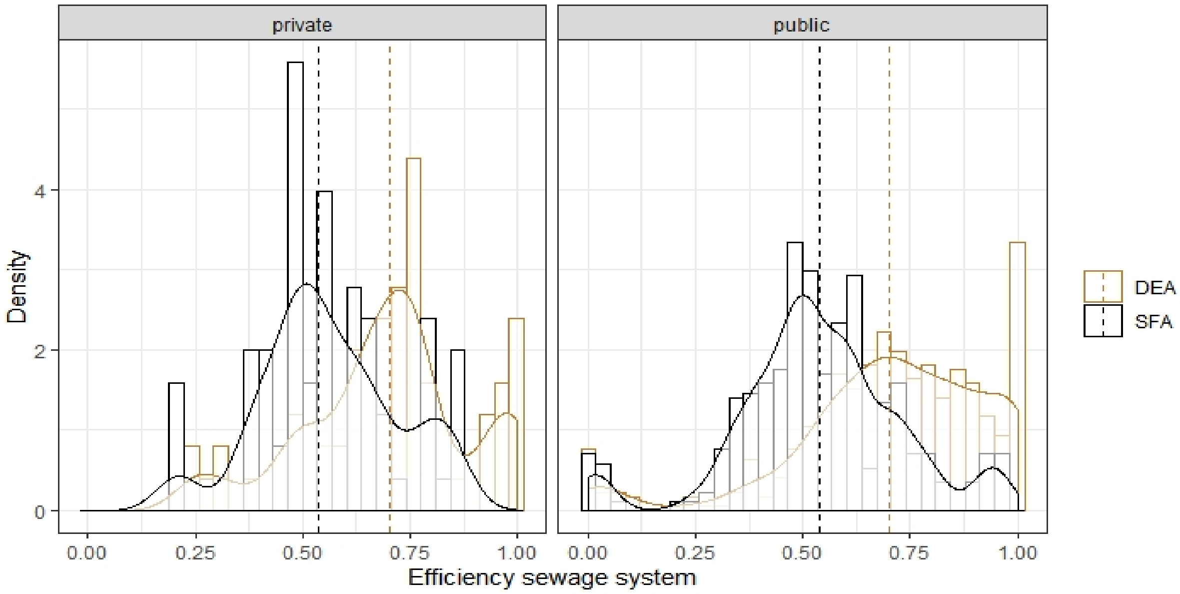
Table 9 presents the average, minimum and maximum annual scores for the sewage system in the period of 2013-2018. We find it important to note that the SFA methodology obtained a variable average of 0.532 to 0.541. The maximum values verified were 0.963 to 0.965 and minimum 0.001 and 0.002. We also noticed a pattern of growth in the values obtained from average, minimum and maximum. Considering the DEA, the average scores obtained were between 0.673 to 0.732, as the minimum values were 0.001, 0.002, 0.004, 0.010 and 0.011, and the maximum value was 1. An upward and downward trend could be observed. Tupper and Resende (2004) estimated the productivity for the Brazilian sanitation sector, in which they found efficiency scores between 0.663 to 1 through the DEA at state-owned operators. Further, Ferro et al. (2014) also estimated the efficiency in Brazilian sanitation, but using SFA, and found the average efficiency values from 0.648 to 0.695.

Table 9: Sewage system efficiency scores.

Obs		Mean	Std.Dev.	Min	Max		Mean	Std.Dev.	Min	Max
95	SFA	0,532	0,192	0,001	0,963	DEA	0,673	0,218	0,002	1
	SFA	0,534	0,192	0,001	0,964	DEA	0,690	0,222	0,001	1
95	SFA	0,535	0,192	0,001	0,964	DEA	0,689	0,217	0,004	1
	SFA	0,537	0,192	0,001	0,964	DEA	0,704	0,223	0,010	1
95	SFA	0,539	0,192	0,001	0,964	DEA	0,711	0,227	0,011	1
	SFA	0,541	0,191	0,002	0,965	DEA	0,732	0,241	0,002	1

The analysis of the efficiency scores in the sewage service, considering the DEA and SFA techniques, as well as public and private providers, was verified through the histogram in Figure 13. In the Figure we can determine that both providers in the DEA technique presented their data asymmetric, shown at the right side. Thus, we can also observe that the majority of public providers reached efficiency scores close to and above the variable average of 0.673 to 0.732 for this technique, and private providers obtained scores close to average for DEA.

Figure 13: Sewage system DEA and SFA efficiency scores over the years.



In the SFA technique, the data from both providers tended to align to the left, so we observed that these providers achieved efficiency scores close to the variable average of 0.532 to 0.541. We also noted that public providers presented a better distribution adjustment in their data, but both have many peaks, which indicates that the provision of services related to sanitation has a variable pattern in both public and private sectors.

In this way, we noticed that there were differences between the results obtained by these two techniques (DEA and SFA), as well as in the previous analysis. However, related to the water supply, many providers reached efficiency scores in the SFA higher than in the DEA, and these scores are below the maximum value for the DEA. As explained earlier, this is due to the SFA technique estimating the score using the *posteriori* mean. Nonetheless, we verified that in the sewage service both providers presented similar efficiency scores, mainly considering the SFA technique

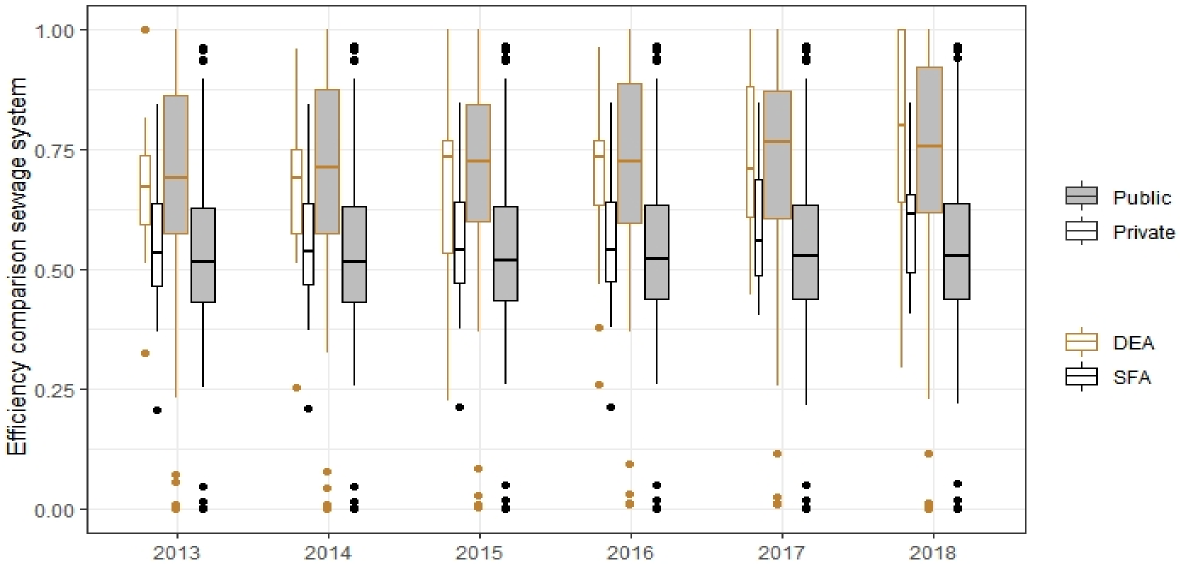
Table 10 shows the p-values, calculated in the group difference tests, in order to check if there are differences in the provision of services related to sanitation between public and private providers. The tests performed were the Bootstrap, the Wilcoxon and Kolmogorov-Smirnov tests, which considered the average values of efficiency scores. From the results shown, we can see that the sample differences were not very significant (p-value> 0.05).

Table 10: Group difference test results, water supply p-values.

Method	Bootstrap	Wilcoxon	Kolmogorov-Smirnov
SFA (public $\neq$ private)	3,15E-01	3,60E-01	2,20E-16
DEA (public $\neq$ private)	3,73E-01	3,06E-01	6,02E-02

In a temporal analysis of the providers over the 2013-2018 period (Figure 14), considering the DEA and SFA techniques, we could see a similarity between the scores obtained in both techniques for both providers. However, considering the period from 2013 to 2016, the public initiative performed better, with providers reaching scores above the average of 0.673 to 0.732 for DEA. In 2017 and 2018, private providers showed a better performance.

Figure 14: Comparison of the behavior of DEA and SFA efficiency scores by provider, sewage system.



Regarding the SFA technique in the period from 2013 to 2016, both providers obtained efficiency scores above the average of 0.532 to 0.541.In the years 2017 and 2018, many of the public providers maintained, scores above the average SFA and many of the private ones only in 2017.

In 2018, private providers reached scores below the average for the technique. Analyzing performance in the Brazilian sanitation sector, Da Silva e Souza et al.(2007) did not observe significant differences between public and private providers, through SFA, as well as da Motta and Moreira (2006) through DEA. Thus, it appears that, regardless of the performance analysis methodology, the sewage service does not present differences in the provision of its services comparing public and private. In the same way as Trujillo et al.(2005) did not verify a very high efficiency of private sanitation operators, in an analysis with 80 studies that also presented providers from developing countries.

And once again the presence of outliers was verified in relation to sanitary sewage. These outliers were verified for SFA for the private providers, where the efficiency score has a value well below the minimum (0.001) between the years 2013 to 2016 and for public providers with values above the maximum (0.965) and much below minimum throughout the analysis period. In the DEA, this same occurrence was verified in the years 2013 to 2018 for the minimum value (0.002) for this technique in public providers, and in the years 2013, 2014, 2016 in private providers.

Influence of Indicators on efficiency scores

This influence occurs by observing the p-values obtained in the regression by ANOVA, and the variable with a p-value> 0.05 is said to be significant and of great weight in the estimation of this efficiency score. Table 11 presents the results for the water supply system, where we can see that the indicator operating expenses was significant in the DEA and SFA models, and public providers presented these expenses 42% above the average of private providers.

Table 11: Influence of indicators on water supply efficiency.

Indicators	p-value		Mean values		$\neq$
	DEA	SFA	Mean public	Mean private	
Total length network (km)	0.16	0.23	2103.03	2174.63	-3%
Water production (1000m^3/year)	0.59	0.77	69221.08	59499.73	16%
Volume of water treated (1000m^3/year)	0.01*	0.41	59486.89	52550.81	13%
Billed water volume (1000m^3/year)	0.49	0.60	55380.31	36938.97	50%
Number of connections (un)	0.18	7.73e-05*	228458.62	186308.70	23%
Operating expenditure (OPEX) (R$/year)	0.00*	0.02*	196892026.79	138486857.40	42%
Provider's investment in the system (R$/year)	0.26	0.27	32574559.00	22150673.37	47%

* Significant value (p-value<0.05).

In the DEA modelling, another significant indicator was the treated water volume, in which the public providers were on average 13% higher than the private sector. Regarding SFA, another significant indicator was the number of connections, with public providers with average values 23% higher than private ones. And for the other indicators, except the length of the network (-3%), the public providers presented averages higher than the private ones, such as: volume of water produced (16%), billed volume (50%), investments (47%). Ferro et al. (2014) also observed that the costs of private companies were lower than the costs of public companies.

However, we verified that even public providers presenting better averages in their water-related data, that is, producing, treating, investing more, these have a lower efficiency than private providers, as shown in the previous analysis. For Ferro et al. (2014) this is linked to the independency of companies, as private companies are more independent and public ones are dependent. Public providers have milder budget restrictions and can use other government resources without paying for them, and this favors them in the availability of this service, but it does not guarantee an efficient service.

Regarding the sewage service results, Table 12 shows that for DEA and SFA most of the indicators used were significant, except for the provider's investments in the DEA and operating expenses in the SFA. We could find evidences that, except for network length (-1%), in both services, public companies presented their indicators with higher averages such as: collection (45%), treatment (17%), billed volume (54%), number of connections and OPEX (42%), and investment (13%). The network length may be related to the budgetary issues of public provider, due to the ease in using government resources, for improvements in the system. We observed the relationship between collected and treated sewage. Public companies had an average rate of 78% of sewage collected and treated, and private companies 97%. In an audit report by the Federal Audit Court (Brasil, 2015), it was verified that the release of sewage in natura is the main cause of pollution of water bodies, in cities.

Table 12: Influence of indicators on sewage efficiency.

Indicators	p-value		Mean values		
	DEA	SFA	Mean public	Mean private	$\neq$
Total length network (km)	0.00*	0.01*	1269.91	1280.32	-1%
Volume of sewage collected (1000m^3/year)	< 2e-16*	< 2e-16*	34033.04	23469.64	45%
Volume of sewage treated (1000m^3/year)	0.00*	0.00*	26634.01	22802.53	17%
Billed sewage volume (1000m^3/year)	1.70e-06*	3.18e-08*	37427.52	24316.34	54%
Number of connections (un)	7.84e-05*	9.93e-06*	158634.49	111716.16	42%
Operating expenditure (OPEX) (R$/year)	0.02*	0.12	196892026.78	138486857.40	42%
Provider's investment in the system (R$/year)	0.07	0.01*	21343184.15	18905864.54	13%

* Significant value (p-value<0.05).

Regarding investments, the water supply service revealed them higher than those made in sanitary sewage. As well, investments in both systems by the private sector took place more similarly between US$5 and US$4 million and in the public US$ 6 and US$4 million, for water and sewage respectively. Nonetheless, according to data from Trata Brasil (2019), many investments are still needed to universalize these services, and they report that public companies lack a balance between revenues and expenses, while private companies have a good financial balance.

Conclusions

In this study, the efficiency of public and private providers in the water supply and sewage services was analyzed, using performance analysis techniques. This efficiency was measured from service indicators and calculated through Data Envelopment Analysis (DEA) and the Stochastic Frontier Analysis (SFA). Therefore, we sought to improve the understanding of the performance of these providers, and thereby serve as an aid to policy makers.

There was a predominance of public initiative in the provision of water supply and sewage services in Brazil. In the water supply service, there are differences between providers, as there are cases of services provided that perform better than others. Over the analysis period (2012-2018), there was no increase, but a decline in the scores obtained, that is, there is no improvement in the efficiency of water-related services. However, this service was the one that received most investments by public and private providers.

In the sewage service, there were no significant differences between providers, yet public providers had higher scores in the DEA. In SFA the scores obtained were similar for both providers. We evidenced an increase in the scores obtained for the sewage service as well as some declines, over the period of analysis, which demonstrates attempted advances in the sewage sector. This is proved by the investments in these services, which are lower than in the water supply service. We also found that private providers had a better relationship between the volume of sewage collected and treated, which were higher than for the public ones.

We concluded then, that for both techniques for performance analysis, private providers are more efficient when compared to public providers in the water supply service. For the sewage service, public and private providers did not present significant differences. Evidence found in this study suggests that the absence of incentives for efficiency, drive providers to dissipate their productivity potential. The regulatory framework should focus on creating instruments to generate efficiency incentives. The new regulatory framework for basic sanitation (PL 4,162/2019), a project already analyzed by the Chamber, may help the regulatory environment and reduce costs for attracting investors in this sector, and thus provide the sustainable and solid expansion of the coverage of these services.

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CONSIDERAÇÕES FINAIS

O estudo proporciona uma avaliação do abstecimento de água e esgotamento sanitário brasileiro contribuindo com os prestadores desses serviços e reguladores. Buscou-se preencher uma lacuna observada nas pesquisas que realizam a análise de desempenho nos serviços de abastecimento de água e esgotamento sanitário. Muitos desses estudos utilizam por conveniência as técnicas de modelagem DEA ou SFA, que possibilitam efetivar esse tipo de análise, e consideram apenas estudos similares para justificar tal escolha. Com isso, realizam somente a aplicação desses modelos em seu ambiente de estudo, sem desenvolvimento científico.

Mediante a isso, a primeira etapa do estudo consistiu de um levantamento bibliográfico baseado em mineração de dados, em pesquisas científicas que utilizam a análise de desempenho como ferramenta para acompanhamento e gestão do setor de água e saneamento, focado nas técnicas DEA e SFA, afim de verificar o objetivo desses estudos ao utilizar essas modelagens. Com os resultados obtidos desse levantamento, pode ser observado avanços relevantes na disponibilidade de água para a população e a preocupação atual é a gestão, que é desenvolvida por meio de indicadores de desempenho. Considerando o esgotamento sanitário os resultados demontraram que o gerenciamento ainda não é bem explorado, e foco desse serviço no uso dessas modelagens é o desenvolvimento de tenologias para tratamento de efluentes .

Os resultados obtidos demostraram também que os estudos relacionados à DEA têm maior ocorrência nas estações de tratamento de águas residuárias, e à SFA em abastecimento e serviços de água, e isso deve-se ao fato da metodologia DEA não necessitar que os dados sejam muito precisos para seu uso, sendo assim uma modelagem mais flexível. Com isso os estudos que aplicaram essa técnica concentram-se na implementação de novas tecnologias relacionados ao esgoto sanitário, esses estudos são caracterizados por uma abordagem experimental. Na metodologia SFA necessário que os dados possuam uma melhor precisão, com isso uma modelagem menos flexível, e o uso dessa técnica ocorreu em estudos com indicadores relacionados ao abastecimento de água, apresentando uma abordagem relacionada a gestão e tomada de decisão. Mesmo com essas diferenças em suas aplicações, as técnicas DEA e SFA devem ser utilizadas como complementares não como substitutivas.

A segunda etapa consistiu do desenvolvimento da técnica, efetuando a estimação da pontuação de eficiência dos sistemas de abastecimento de água e esgotamento sanitário das 95 maiores cidades brasileiras, por meio da DEA e SFA. Os resultados demonstraram que para ambas as técnicas utilizadas, os provedores privados são mais eficientes quando comparado aos provedores públicos no serviço de abastecimento de água. Para o serviço de esgotamento sanitário, os provedores públicos e privados não apresentam diferenças significativas.

Ficou demonstrada uma elevação dos scores obtidos para o serviço de esgotamento sanitário como também alguns declínios, ao longo do período de análise, revelando uma tentativa de avanços no setor de esgotamento sanitário. No abastecimento de água não houve elevação, mas sim um declínio nos scores obtidos, ou seja, não há melhoria na eficiência desse serviço.

Pode ser verificado também, que mesmo os provedores públicos apresentando melhores médias em seus indicadores relacionados à água e esgoto, isso não demostrou impacto na eficiência estimada. Como também, os investimentos em ambos os sistemas pela inciativa privada ocorreram de forma mais similar do que nas públicas e a extensão da rede na iniciativa privada em ambos os serviços é superior.

Com isso esse estudo salienta que as pesquisas relacionadas ao saneamento ainda precisam incorporar uma discussão sobre o gerenciamento e uso de indicadores para tornar mais eficiente a prestação do serviço. Bem como sugere a ausência de incentivos à eficiência, sendo necessária a criação de instrumentos que promovam o incentivo a uma melhor performance, por meio da estrutura regulatória desses serviços.