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Do Governance Arrangements Affect the Voluntary Adoption of Water Safety Plans? An Empirical Study of Water Utilities in Portugal

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Abstract

What factors influence the voluntary adoption of Water Safety Plans (WSPs) by water utilities? EU Directive 2015/1787, October 6th, on water quality for human consumption, mandates the implementation of a risk assessment process for all water utilities. The strategic approach present in WSPs may be decisive for this purpose, allowing utilities to pursue effective risk assessments with positive repercussions for public health and environmental protection, as well as for the governance of the water sector. This article investigates the factors influencing the voluntary adoption of WSPs by water utilities in Portugal prior to the change in the national regulatory framework. More specifically, it seeks to explore whether the governance arrangement of water utilities – in-house bureaucracies, municipal corporations, concessions to private firms or public-public partnerships – affects the likelihood of adoption of a WSP. The results indicate that governance arrangements can make a difference when it comes to the adoption of this methodology, suggesting that water utilities run by in-house bureaucracies are less likely to adopt WSPs. The dimension is also a relevant factor as utilities serving above 50,000 residents or 10,000 m^3/day are more prone to adopt WSPs. Moreover, water utilities with quality management systems in place are more predisposed to adopt WSPs. Broadly, the article urges all stakeholders, mainly water utilities and national regulators, to implement measures that lead to the best possible results considering that the implementation of WSPs is a major upgrade in water quality assurance.

Keywords Water Safety Plans · Water utilities · Water supply · Drinking water quality · Governance · Ownership

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1 Introduction

In 2010, the United Nations (UN) General Assembly declared access to safe drinking water and sanitation a human right, essential to the full enjoyment of life and all other human rights. This recognition that water quality at affordable prices for all is the key condition for the promotion of public health, environmental sustainability, and quality of life, entails an obligation for States to respect, protect and ensure that right.

Water quality for human consumption is, therefore, an issue of utmost importance for public health and the environment, and recent technical and scientific advances have led to new policy approaches. In addition to concentrating the obligation of compliance on essential quality parameters, the safe supply of water for human consumption requires rigorous and structured control action throughout the entire supply system, from catchment to consumer (Vieira and Morais 2005; WHO 2011).

Still, a distressing prevalence of water quality-related crises outbreaks remains in the developed world, with causes ranging from technical failures to institutional lapses and, in the extreme, negligence by operating and managerial staff (Hrudey and Hrudey 2004; Jetoo et al. 2015). On the one hand, water supply systems in urban areas may become faulty due to aging equipment and problems related to maintenance management, further jeopardized by significant increases in demand associated with population growth (Monte and Morais 2019). Furthermore, the costs of managing water resources are increasing due to present and prospective crises, such as urban and agricultural pollution, economic recession, and climate change (Pot 2019). Moreover, operating water delivery systems involves a large number of concerns that decision-makers must address simultaneously. Thus, the use of tools to support decision-making processes provides a better understanding of these problems and generates recommendations fitting the needs of decision-makers (Monte and Morais 2019).

In order to tackle these issues, the water sector has been formalizing and adopting explicit approaches to risk management that have formerly been implicit (Pollard et al. 2004, 2008). In the European Union, Directive 2015/1787, October 6th, explicitly refers to the adoption of WSPs as new tools to achieve comprehensive risk management of water supply for human consumption. Globally, much of the responsibility for providing drinking water is assigned to local governments and water utilities are at the center of this goal (WHO 2011).

Prior empirical studies have investigated the contextual factors influencing the adoption and implementation of WSPs. Several authors stress the lower rates of adoption and the challenges to their implementation in small size communities (Perrier et al. 2014; Kot et al. 2017; Oluwasanya and Carter 2017; Szpak and Tchórzewska-Cieślak 2019), whereas other studies underline the role of community readiness as a pre-condition for successful implementation (Kot et al. 2015). Communities lacking technical, financial, and human capacity are also likely to require simplified procedures to implement WSPs (String and Lantagne 2016). Prior experiences with water quality certification through hazard analysis and critical control points (HACCP) and international standards such as ISO 9001 and ISO 14001 are also associated with an increased likelihood of adoption of WSPs (Baum and Bartram 2017).

Yet, despite the importance of the implementation of WSPs in multiple countries across the globe, academic research on the role of water utility governance modes in the adoption of WSPs remains conspicuously absent. This article aims to fill this lacuna by investigating the factors influencing the adoption of WSPs in a single country. While this may entail some limitations in terms of the generalizability of the study, it has the advantage of controlling for institutional and contextual variation, given that water utilities in Portugal operate under the same national legislation and regulatory framework.

The recognition of the importance in securing the highest standards in drinking water quality for human consumption has led several water utilities in Portugal to voluntarily adopt and implement WSPs. Water supply in Portuguese municipalities is managed by water utilities with different governance arrangements, including direct provision by the municipality (in-house bureaucracy), municipal corporations, intermunicipal corporations, partnerships between the municipality and the national government (public-public partnerships), and concession contracts to private firms.

The novelty of this article is twofold. First, the research investigates whether the governance mode is associated with the likelihood of adopting a WSP while controlling for other key enablers, such as size, prior experience with water quality certification, and the perception of the role played by the national regulator of the water sector. Despite the outmost importance of the topic, these factors have not been investigated as determinants of the application of the WSPs methodology. Second, the research has important implications for water policy since it highlights the role of water governance models in accomplishing the highest standards of water for human consumption.

After this introduction, section two presents an overview of WSPs, focusing primarily on prior empirical works studying the factors influencing their adoption and implementation and the gap in investigating the role of ownership and governance mode. Section three introduces the key hypotheses of this research. Section four describes the research context. Section five introduces the methodology employed in this research and section six presents the results of the analysis. Section seven discusses the findings and policy implications for managing the water sector. The last section identifies the limitations of the investigation and the opportunities for future research.

2 Background on the Implementation of Water Safety Plans

Since 2004, WSPs have been recommended for preventive management of water supply in the WHO Guidelines for Drinking Water (WHO 2004). The application of WSPs has been advocated by the International Water Association (IWA), launching the Bonn Charter for Safe Drinking Water with the overall goal of assuring "good safe drinking water that has the trust of the consumer" (IWA 2004). The IWA Bonn Charter stresses that governments need to define roles and responsibilities through legal and institutional arrangements, preventive management, cooperation between all stakeholders, and communication of risk and water quality to consumers (Gunnarsdottir et al. 2015).

Data on the worldwide application of WSPs is unclear. Recent data suggests that over 90 countries have implemented WSPs, but widespread uptake is still uncertain due to the limited reporting of outcomes and impacts (String and Lantagne 2016). More recently, the WHO and the IWA published a report stating that 93 countries have implemented WSPs. This report indicates that 46 countries have policy or regulatory instruments in place to promote or require WSPs, with such instruments under development in an additional 23 countries (WHO and IWA 2017). Countries where the implementation of WSPs is mandatory include Australia, Iceland, New Zealand, Serbia, Switzerland, Uganda, and the United Kingdom (Gunnarsdottir et al. 2015), while other countries have promoted technical recommendations for preventive risk management.

The WHO report (2017) presents a broad range of benefits, including improvements in operations and management, institutional knowledge, and water quality. The analysis of several case studies worldwide suggests that the implementation of WSPs varies across countries, but highlights some commonalities (Roeger and Tavares 2018, 20): (1) the systematic identification of risks and the definition of formal procedures and activities to minimize/mitigate them; (2) a greater focus on monitoring and reporting across the supply system as a whole; (3) better external communication and increased stakeholder satisfaction, especially end users; and, lastly, (4) the need for a stronger commitment of leadership and more effective inter-agency work.

In contrast, an IWA survey discusses a range of barriers that have prevented water suppliers from implementing WSPs effectively, such as lack of skills, knowledge, and financial capacity, poor institutional arrangements, and uncertainty over how to best implement them (Zimmer and Hinkfuss 2007). This uncertainty may result in an unwillingness to invest in the development of WSPs. Reasons for this resistance include more work-hours for staff, competition with other projects, resistance to change/cultural barriers, cost and time constraints, and the absence of upfront investment due to the lack of demonstrable outcomes (Zimmer and Hinkfuss 2007).

The significant variation in the adoption and implementation of WSPs, both between and within countries, justifies a closer inspection of the motives leading to such variation. This research extends prior efforts aimed at uncovering the factors enabling WSPs (see Baum and Bartram (2017) for a recent review) by investigating the role played by the governance mode and ownership of water utilities.

3 Hypotheses

The aim of this research is to investigate the factors influencing the voluntary adoption of WSPs by water utilities. More specifically, it seeks to explore whether the governance arrangement of water utilities affects the likelihood of adoption of WSPs. In order to answer this research question, the literature review serves as a source of information for elaborating a set of key hypotheses. Besides this main goal, we are also interested in whether the factors mentioned as constraints in the empirical literature apply to the context of water utilities in Portugal. This section develops these hypotheses.

The implementation of WSPs requires significant investments in human and technical capacity, particularly if the plans are to be implemented in their complete format. While financial outcomes in the form of cost savings have been reported in the literature (String and Lantagne 2016), there is also evidence that the costs entailed by the preventive measures included in the WSPs are highest at the beginning phase of implementation (Chang et al. 2013). As a result, water utilities relying on external funding, either through private firms or partnerships with other public sector organizations, may be in a better position to successfully adopt WSPs.

Private firms are better able to secure bank loans or issue debt bonds in financial markets. They benefit from specialization and do not have to compete for budget allocations as water utilities run by in-house bureaucracies. The same applies to municipally owned corporations, since the widespread corporatization of water utilities in the 1990s replaced politics with professionalism (Grossi and Reichard 2008; Bourdeaux 2013; Voorn et al. 2017) with clear efficiency gains (Pérez-López et al. 2015). Lastly, water utilities are often managed as partnerships, either with the national government or with other municipalities. Utilities run as partnerships, in particular, are more likely to benefit from scale economies and additional revenue sources, and may be better equipped to deal with the financial pressures associated with the initial investment in WSPs (Bel and Warner 2015).

Given the arguments advanced above, it is expected that:

H1: The mode of governance of water utilities affects the likelihood of adoption of a WSP.

Compared to water utilities run by the municipality's own bureaucracy:

H1.1: Water utilities managed by private sector operators are more likely to adopt a WSP.
H1.2: Water utilities run as municipal corporations are more likely to adopt a WSP.
H1.3: Water utilities managed by public-public partnerships are more likely to adopt a WSP.

The challenges faced by water utilities serving smaller communities is well documented in the literature (Kot et al. 2017; Szpak and Tchórzewska-Cieślak 2019). On one hand, smaller communities lack the technical capacity required to develop a comprehensive WSP. Utilities in rural and less populated communities face human resource limitations preventing specialization and a high degree of professionalization of water utility officials and staff, making them less likely to have full time staff allocated to the implementation of a WSP (Kot et al. 2017). On the other hand, less population served also means higher costs per capita, which discourages WSP implementation. In addition, smaller communities are also less likely to keep detailed records to allow mapping of the water system, making it more costly to overcome the initial risk assessment (Perrier et al. 2014). In contrast, water utilities in urban areas are more likely to secure the human and technical capacity needed to enable the adoption of WSPs.

For all the reasons stated above, it is expected that:

H2: Water utilities serving more population are more likely to adopt a WSP.

Preventive risk management practices have not started with the adoption of WSPs. In fact, many water utilities around the world have invested in risk management since the early 2000s by following guidelines and standards promoted by international organizations. Hazard analysis and critical control points (HACCP) was adopted by the food industry since the late 1960s (Baum and Bartram 2017) and, by suggestion of Havelaar (1994), imported by water utilities to manage risks associated with the supply of drinking water. Similarly, international standards such as ISO 9001 and ISO 14001 underline the importance of quality control and certification at every step of the water supply system, in stark contrast to earlier practices of end-product testing (Baum and Bartram 2017). Experience with these practices contributed to change the organizational culture of water utilities (Kot et al. 2017) and to create an enabling environment for the successful implementation of WSPs (Baum and Bartram 2017). Thus,

H3: Water utilities with prior experience in water quality certification and international standards are more likely to adopt a WSP.

The literature reports situations where the water sector regulator acts as an external auditor of the components of WSPs (Bartram et al. 2009). Conversely, lack of support from the national regulator is likely to cause delays in the diffusion of WSPs across the water utility sector (Gunnarsdottir et al. 2012, 2015). Moreover, having a positive perception of the role played by the national regulator is perhaps as important as the provision of financial and regulatory incentives to the implementation of WSPs. The adoption and implementation of WSPs as a national goal is likely to contribute to instill a preventive risk management culture and produce the desired effects on water utilities. Hence,

H4: Water utilities with a positive perception about the role of the national regulatory body are more likely to adopt a WSP.

Next, these hypotheses are tested using data from water utilities in Portugal. The following section describes the water utility sector in Portugal, with a special emphasis on the adoption and implementation of WSPs.

4 The Water Utility Sector in Portugal

In order to understand the adoption of WSPs in Portugal, it is important to characterize the Portuguese water sector. Water utilities have shown a positive evolution in terms of preventive strategies in recent years, as evidenced by their gradual convergence towards the national objectives defined by the 2007–2013 national strategic plan. Significant investment efforts accompanied by a stable regulatory framework and co-financing by European funds led to a 95% coverage of the country's population by public water supply systems in 2011 (ERSAR 2018).

The Portuguese Water and Solid Waste Regulatory Authority (ERSAR) has been a major player in the water sector in Portugal and fulfills its mission by developing a quality service evaluation system for water utilities based on the use of indicators. The system seeks to develop quantitative measures of efficiency and effectiveness of water services. The output of this process is an annual report summarizing the most relevant information related to the quality of water for human consumption. The 2017 annual report concluded that Portugal reached the target of 99% compliance with the parametric values of water quality set in the Strategic Plan for Water Supply and Sanitation of Waste Water 2014–2020 (RASARP 2018). Since the EU deliberated that the value of 99% is compliant with Directive 98/83/EC, this represents the standard of excellence for the quality of water intended for human consumption. The achievement of this goal indicates that water at the consumer's tap corresponds to high quality levels (Fig. 1).

In terms of water sector operators, systems are classified as *upstream* and *downstream*, depending on the activities carried out by water utilities (ERSAR 2018). This classification comprises multi-municipal systems, mainly responsible for providing services to municipalities who serve as shareholders (*upstream* systems) and water utilities serving the population through municipal systems (*downstream* systems) providing water and sanitation services.

Currently, nearly all water utilities that supply *upstream* services are of a corporate nature and concessions are the governance mode that clearly dominates the sector. As of December 31, 2017, these utilities represented about 72% of the population and 79% of the number of municipalities in mainland Portugal. Multi-municipal concessions are the predominant governance mode in the *upstream* business, covering 174 out of 308 municipalities and more than 5.1 million inhabitants (out of a total population of 10 million).

Additionally, a single company (EPAL) under delegation from the national government serves 25 municipalities with approximately 1.8 million inhabitants. In another set of municipalities, supply is vertically integrated, performing water collection and treatment as well as distribution to end-users (*upstream* and *downstream*). In mainland Portugal, this governance mode covers 120 municipalities and a total of 3 million inhabitants, mainly in the north and center of the country. Lastly, partnerships between the State and the municipalities provide water services to approximately 250.000 inhabitants, covering about 21% of continental Portugal in very low-density areas (Fig. 2).

In contrast with *upstream* services, *downstream* water supply services are highly fragmented, as evidenced by the large number of utilities, most with an intervention area equal to, or less than the area of the municipality. In-house bureaucracies stand out, covering 70% of all municipalities and approximately 52% of the population in mainland Portugal.

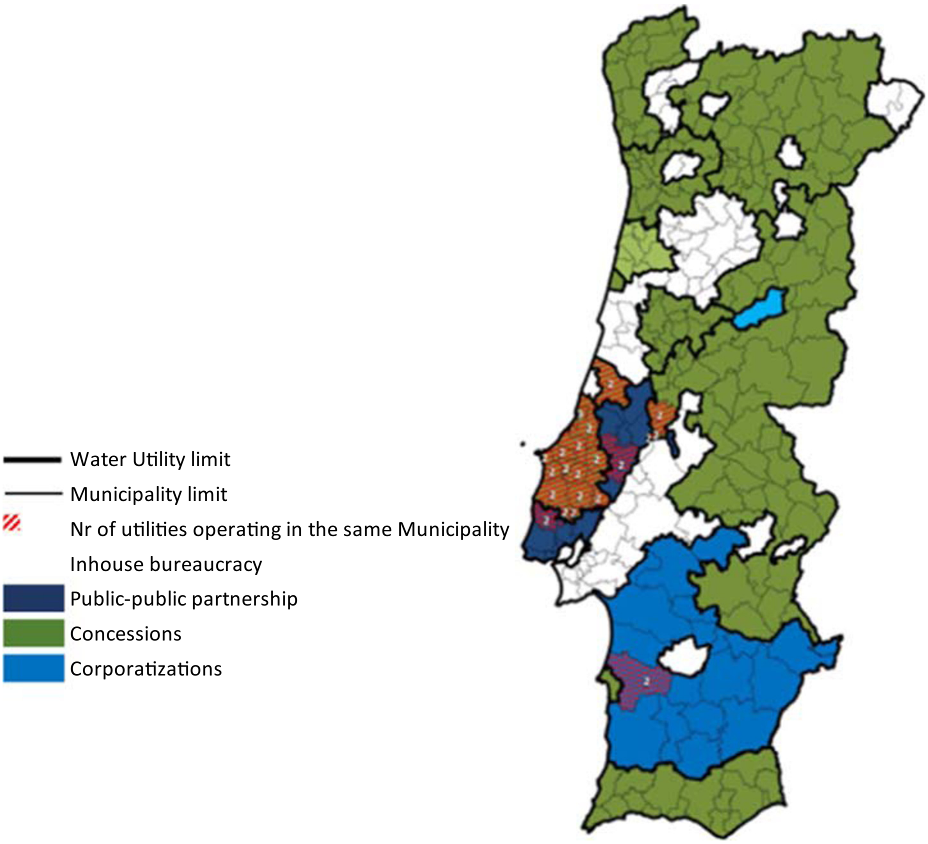

Fig. 1 Geographical distribution of water utilities that supply *upstream* services. (Source: RASARP 2018)

In the densely populated urban area of Lisbon, the governance mode is one of State delegation, as in the *upstream* service, serving approximately 500.000 inhabitants. Private concessions and municipal or intermunicipal companies are also governance modes with a significant share of the *downstream* water supply sector.

In-house bureaucracies dominate *downstream* water supply. However, in the last two decades there has been a trend towards increased corporatization in the water sector. In the first decade of the 21st century, the governance modes of private contracting and municipal corporations represented only 20% of the population, whereas currently they represent almost half, more than doubling their weight in the sector. This trend is also witnessed in Europe – the UK, France, Spain, and Italy have all been involved in privatization processes, with diverse results (ERSAR 2018; Abbott and Cohen 2009; Berg and Marques 2011).

4.1 Water Safety Plans in Portugal

Beginning in 2003, a multi-municipal company implemented a WSP highly praised by the national regulator, which recommended this risk management methodology to other water utilities (Vieira 2011). This initiative also sparked the launching of a pilot project (2008–2010) in ten water utilities of different sizes and governance modes, but the results of this project were never formally published (Roeger and Tavares 2018).

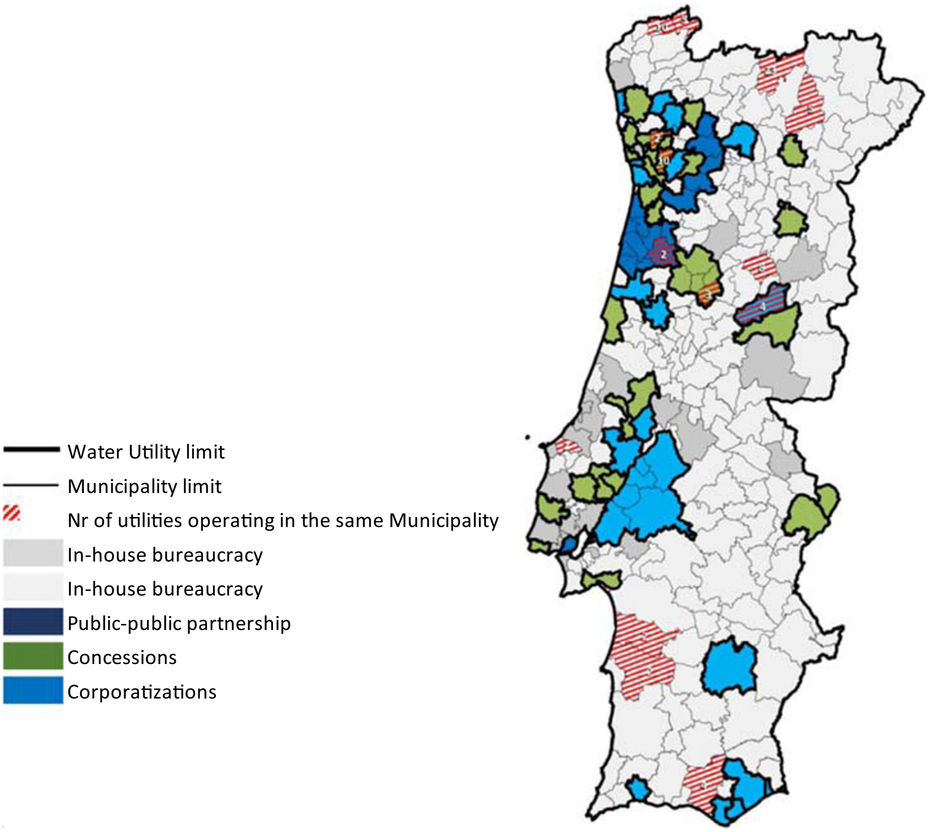

Fig. 2 Geographical distribution of water utilities that supply *downstream* services. (Source: RASARP 2018)

According to ERSAR (2018), several water utilities in Portugal have been voluntarily developing and implementing the WSP methodology in line with the recommendations of the WHO and the IWA. However, this has been done in an uncoordinated manner, since the national legislation on the quality of water for human consumption has only recently included this approach. With the publication of Law-Decree 152/2017, this risk management approach became mandatory and it is now based on European and international standards, in particular EN 15975-2, and the structure of the WSP approach promoted by the WHO.

5 Data and Methods

The main goal of this research is to investigate the determinants of the voluntary adoption of WSPs. Assessing these factors should allow authorities in Portugal (and elsewhere) to identify and remediate potential shortcomings in water utilities not implementing WSPs. Gathering all information about the voluntary implementation of WSPs in Portugal was vital to fulfill this goal. For that purpose, a survey targeted at Portuguese water utilities was conducted with the direct support of the ERSAR. The empirical analysis relies on cross-sectional data collected from Portuguese water utilities in 2016/2017 using this survey questionnaire. An email with the link to an open source survey tool was sent to all water utilities with the collaboration of the ERSAR.

The sample targeted 258 water utilities out of a total of 319 (*upstream, downstream*, and both *upstream and downstream*) that comprise all water utilities in mainland Portugal (ERSAR 2018). The survey was not sent to 61 water utilities as they supply water to less than 1,000 inhabitants each. We received responses from 179 utilities, representing 69.4% of the 258 utilities in the targeted sample. Thirty-five utilities reported having voluntarily implemented a WSP, which represents about 20% of the responses. Almost two-thirds of the 35 utilities have only been implementing this tool since 2014, and 25 water utilities reported having a WSP under development and expected to approve it soon.

In order to test the hypotheses stated above, we employ probit regression analysis with the coefficients estimated through maximum likelihood. Probit models are appropriate when the dependent variable is a binary outcome (Long 1997). In this particular case, the dependent variable is the adoption of WSPs by water utilities and is coded "1" if the water utility has adopted a WSP and "0" otherwise. Probit models use maximum likelihood estimation to characterize the probability of observing outcomes via a 'model' of a vector of independent variables, **X**, estimated corresponding coefficients, β, normally distributed error, ε, and an unobserved binary dependent variable, y_i^*. Thus, the latent variable y_i^* is linearly related to the observed x's through the structural model:

$$y_i^* = \mathrm{X_i}\beta + \varepsilon_\mathrm{i} \tag{1}$$

And the latent variable y_i^* is linked to the observed binary variable y_i by the measurement Eq. (2):

$$y_i = \begin{matrix} 1 & \text{if } y_i^* > \tau \\ 0 & \text{if } y_i^* \leq \tau \end{matrix} \tag{2}$$

Where τ is the threshold or cutpoint (Long 1997).

The equation to be estimated is:

$$\Pr(\mathrm{wsp} = 1 \mid \mathrm{x}) = \Phi(\beta_0 + \beta_1\mathrm{con} + \beta_2\mathrm{cor} + \beta_3\mathrm{pup} + \beta_4\mathrm{inh} + \beta_5\mathrm{qct} + \beta_6\mathrm{ect} + \beta_7\mathrm{sst} + \beta_8\mathrm{oth} + \beta_9\mathrm{size} + \beta_{10}\mathrm{aud} + \beta_{11}\mathrm{tec} + \beta_{12}\mathrm{fin} + \beta_{13}\mathrm{dow} + \beta_{14}\mathrm{sup}) \tag{3}$$

Where Pr (wsp = 1 | x) is the probability of observing a *wsp* for a given independent variable, Φ is the normal cumulative distribution function for the probit model, and the β are the coefficients of the independent variables to be estimated through maximum likelihood (see Table 1 for variable codes).

Three variables are included in the regression models to assess the first hypothesis: the choice of governance arrangement influences the likelihood of adopting a WSP. The first dichotomous variable indicates whether the water utility is run as a concession (*con*) to a private firm (yes = 1). If the water utility is part of the local corporate sector (*cor*), a second dichotomous variable takes the value of "1". This governance arrangement includes both municipal corporations with 100% of the shares owned by the local government and inter-municipal corporations with the capital shared by two or more municipalities. Lastly, the third dichotomous variable takes the value of "1" if the water utility is a partnership between the municipality and the national government (*pup*). The direct management governance arrangement – water utilities run by in-house bureaucracies – is the omitted category.

In order to test the effect of water utility size, the analyses include a dichotomous variable (*size*) that takes the value of "1" if the organization serves a population above 50,000 residents or over 10,000 m^3 of daily water supply. The third hypothesis states that water utilities with

Table 1 Descriptive statistics

Variable (code)	Obs.	Cases (N = 179)	Proportion	Stand. Dev.	Min.	Max.
Water Safety Plans (wsp)	179	35	0.20	0.40	0	1
Concessions (con)	179	22	0.12	0.33	0	1
Corporatization (cor)	179	24	0.13	0.34	0	1
Public-public partnership (pup)	179	7	0.04	0.19	0	1
In-house bureaucracy (inh)	179	126	0.70	0.46	0	1
Quality certification (qct)	179	52	0.29	0.46	0	1
Environmental certification (ect)	179	29	0.16	0.37	0	1
SST certification (sst)	179	27	0.15	0.36	0	1
Other certification (oth)	179	16	0.09	0.29	0	1
Any certification (any)	179	120	0.33	0.47	0	1
Size (> 50000 inhabitants or > 10000 m3) (size)	174	35	0.20	0.40	0	1
Auditing (ERSAR) (aud)	179	38	0.21	0.41	0	1
Technical support (ERSAR) (tec)	179	154	0.86	0.35	0	1
Financial support (ERSAR) (fin)	179	41	0.23	0.42	0	1
Downstream system (dow)	179	98	0.55	0.50	0	1
Supply áreas (sup)	179	-	15.68	22.04	1	149

prior experience with quality or environmental certification are more likely to engage in WSPs. In order to assess this, the first model specification (column (1) in Table 2) includes a dichotomous variable taking the value of "1" if the water utility received at least one type of certification (*any*). As an alternative specification (column (2) in Table 2), the second model specification includes four dichotomous variables taking the value of "1" for each type of certification: quality certification (*qct*) (ISO 9001 or similar), environmental certification (ect) (ISO 14001), safety and security certification (*sst*) (SST), and other certification (*oth*) (HACCP, ISO 22000 and company manual). No prior certification is the omitted category.

The fourth hypothesis states that water utilities with a positive perception of the role played by the national regulatory authority are more likely to adopt a WSP. In order to assess this assertion, the models include three dichotomous variables indicating positive perceptions of the auditing (*aud*), technical (*tec*), and financial (*fin*) support provided by the ERSAR. Positive coefficients are expected for all the variables.

Lastly, both model specifications include two control variables. The first is a dichotomous variable for water utilities managing only *downstream* services (*dow*), whereas the second is a count variable of the number of supply areas managed by the water utility (*sup*). Table 1 displays the descriptive statistics and codes for all the variables included in the empirical analyses.

6 Findings

Thirty-five water utilities have voluntarily implemented a WSP, representing 20% of the 179 respondents. In slightly over 60% of the cases, utilities state they adopted WSPs for innovation reasons and in about 40% in order to achieve a better knowledge of their system. 83% of water utilities implementing WSPs have seen improvements in the knowledge of their systems, 63% stated better capacity for emergency response, 53% saw improvements in teamwork and better trained staff, and 43% have registered improvements in internal and external communication. None of the respondents identified lower costs associated with WSPs and only 3.5% of the respondents fail to see any benefits in this methodology.

Table 2 Probit regression analysis (Dependent variable: Water Safety Plans (1 = Yes))

Variables	(1)	(2)
Concession	1.15997***	1.38818***
	(0.408)	(0.458)
Corporatization	1.37911***	1.43772***
	(0.372)	(0.398)
Public-public partnerships	0.58222	0.07218
	(0.945)	(1.319)
Size	1.08946***	1.08444***
	(0.355)	(0.387)
Certification	0.77535**	----
	(0.308)	
Quality certification	----	0.47752
		(0.432)
Environmental certification	----	5.69381
		(330.207)
SST certification	----	-5.66734
		(330.207)
Other certification	----	1.54161***
		(0.558)
Auditing (ERSAR)	-0.43842	-0.90596*
	(0.367)	(0.464)
Technical support (ERSAR)	-0.15230	-0.11477
	(0.419)	(0.457)
Financial support (ERSAR)	0.44893	0.34909
	(0.369)	(0.417)
Downstream system	0.50322	0.34692
	(0.330)	(0.345)
Supply areas	0.00619	0.00694
	(0.009)	(0.009)
Constant	-2.41860***	-2.34219***
	(0.573)	(0.616)
Observations	174	174
LR chi^2 (13)	75.15	85.63
Prob > chi^2	0.000	0.000
Pseudo R^2	0.453	0.516

Table reports unstandardized coefficients from Probit regression. Standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

While a WSP approach is considered the best method for achieving safe drinking water, the potential impact of such an approach is often overshadowed by implementation challenges (Kot et al. 2015). A similar conclusion can be drawn from the results obtained in our study, as 91% of Portuguese water utilities recognize the importance of a WSP, but only about 20% of those surveyed have voluntarily implemented it. In fact, half of the water utilities that implemented a WSP resorted to consulting and, among the difficulties identified by non-implementers are the scarcity of human resources (31%), the costs involved (28%) and, as the main motive, the fact that implementation was not yet compulsory (36%).

Of the 179 respondents, five are *upstream* systems, of which three have implemented a WSP. Seventy-six water utilities have both *upstream* and *downstream* systems and, of these, 15% adopted a WSP. As for the 98 *downstream* water facilities, 12.5% implemented a WSP. About 70% of the water utilities are run as in-house bureaucracies, of which more than half (55%) are *downstream* systems. The majority of water utilities classified as private concessions and municipal corporations are *downstream* systems (nearly 60%). 53% of concessions and municipal corporations have implemented WSPs and that includes *upstream systems*, both *upstream* and *downstream systems*, and *downstream systems* (respectively 11%, 25% and 64%). Only about 5,5% of water utilities under the direct management model report the implementation of a WSP, of which 43% are both *upstream* and *downstream systems* and 57% *downstream systems*. Fourteen private companies report adopting WSPs, five of which serve less than < 50,000 inhabitants or < 10.000 m3/day.

Less than 10% of water utilities supplying < 50,000 inhabitants or < 10.000 m3/day have voluntarily implemented a WSP. Water utilities serving more than 50,000 inhabitants or 10.0000 m3/day embody 20% of the respondents and 55% of these have implemented WSPs. Thirty percent have implemented quality management systems (ISO 9001) and approximately 20% have safety health and environment management systems (namely OHSAS 18001 and ISO 14001). In total, 69% of water utilities that have voluntarily implemented a WSP also have implemented some quality management system.

Table 2 reports the results of the probit regression analysis of the determinants of the adoption of WSPs by water utilities in Portugal. Both models perform very well, with an overall significance of 99.9% and pseudo-R^2 of 0.453 and 0.516, respectively.

The first hypothesis receives empirical support. Both *con* and *cor* are positive and statistically at the 99% confidence level. Water utilities run as concessions to private firms (H1a) or as municipal corporations (H1b) are more likely to adopt WSPs than in-house bureaucracies are. This confirms the idea that governance arrangements can make a difference when it comes to the adoption of this methodology. In contrast, the public-public partnership mode does not appear to be associated with an increased likelihood of adopting WSPs compared to in-house bureaucracies. These results also suggest that water utilities run by in-house bureaucracies (the omitted category) are less prone to adopt WSPs.

The empirical analysis also confirms the second hypothesis. Water utilities serving populations above the 50,000 residents or 10,000 m^3/day threshold are more likely to adopt WSPs. *Size* displays a positive and highly significant coefficient, indicating an increase in likelihood of adoption.

Regarding the third hypothesis, the results are a bit more mixed. The first specification (column 1 in Table 2) uses a single dichotomous variable indicating whether a water utility has received at least one certification (*any*). The results of this specification suggest that certification is an important pre-condition for the adoption of WSPs as *any* displays statistical significance at the 95% confidence level. The second specification (column 2 in Table 2) breaks down certification by type and the findings are less convincing. All the certification variables miss statistical significance with the exception of the *oth* variable (HACCP, ISO 22000, and company manual).

Lastly, the analysis does not provide empirical support to the fourth hypothesis of this research. In general, all coefficients associated with the role played by the national regulator (ERSAR) appear to be unrelated to the adoption of WSPs. One exception is the negative coefficient obtained for the *aud* variable in the second specification, suggesting that a positive perception of the auditing function of the regulator reduces the likelihood of adoption of WSPs.

7 Discussion

The results show a clear difference between water utilities that have a governance model of concession or corporatization and those run by in-house bureaucracies of local governments.

The latter are mainly represented by *downstream systems* or *upstream* and *downstream systems* of a smaller dimension, with fewer resources and less professional staff required to implement a WSP project. This finding is quite robust, since the multivariate analysis indicates that the differences in the likelihood of implementation between concessions/municipal corporations and in-house bureaucracies still hold after controlling for size. In other words, the choice of governance arrangement influences the adoption of WSPs, irrespective of the effect of the *size* variable.

Less than 10% of water utilities supplying < 50,000 inhabitants or < 10.000 m^3/day have voluntarily implemented a WSP. The size of the water utility is, therefore, a significant factor in the voluntary implementation of a WSP and this finding is fully confirmed in the multivariate analysis. Small water utilities are less predisposed to that commitment, presumably due to limited resources. When designing the new legal framework, and specifying the enforcement criteria and fines, this finding requires careful attention in order to secure compliance. Moreover, water utilities pointed out the lack of experience and human resources dedicated exclusively to the project as the main difficulties in the implementation of a WSP. These results confirm the findings for small and medium-sized municipalities in Austria: financial and personnel resources are usually of very limited availability (Mayr et al. 2012).

Where water suppliers already have quality management programs in place, the shift to a WSP approach may be seen as redundant. In a study of five German water utilities, Schmoll et al. (2011) found between 70% and 90% of their current practices aligned with those suggested by the WSP framework. While this did not create a barrier to a WSP integration *per se*, the authors noted that the utilities expressed concern that transitioning to a WSP might be both a financial and a time burden. More generally, utilities may perceive WSPs as a burden in terms of having to "step up their game" in response to some of the more rigorous aspects inherent in a WSP approach (Summerill et al. 2010; Mayr et al. 2012). Our results indicate that additional costs and the need to hire qualified human resources are two of the main problems, but they also show that 69% of water utilities that have voluntarily implemented a WSP also have a quality management system in place, which can be a trigger to the voluntary implementation of a WSP. The multivariate results partially confirm this assessment, even if the positive coefficients for quality and environmental certification fail to reach statistical significance at conventional levels.

Water suppliers may view a WSP approach as creating additional work for already overburdened water operators and managers (Williams and Breach 2012). For example, utilities already meeting water quality regulations may feel less motivated to adopt a WSP, seeing little incentive in proactively seeking out new or additional potential risks (Zimmer and Hinkfuss 2007; Mayr et al. 2012). In contrast with these findings, only 3.5% of Portuguese water utilities regard WSPs as having no benefit to the organization. This may be due to the relevant role the ERSAR plays in raising awareness among all water sector stakeholders. Ferrero et al. (2019) highlight a similar point. National authorities play both regulating and facilitating roles with respect to WSPs, and create an enabling environment by setting the legislative framework and developing health-based targets.

While 35 national water utilities have adopted WSPs, in *upstream systems* the percentage reaches 60%. These results suggest that *upstream systems* were readier to implement a WSP voluntarily. The reasons to explain this tendency are the dimension of the water utilities, as well as the fact that all companies belong to the *Águas de Portugal Group* (AdP). The AdP is a holding company that operates nationwide providing services to the municipalities that are simultaneously shareholders in the companies managing the multi-municipal systems (*upstream systems*) and directly serving their populations through municipal level services (*downstream systems*) for water supply and sanitation. The AdP has procedures in place that recommend the adoption of WSPs and a long history of implementation. The first study in this matter was conducted in 2003 in *Águas do Cávado*, one of the *Águas de Portugal* most dynamic companies in the water sector, and the replication in other companies within the same Group became the norm at that time.

8 Conclusions and Recommendations

This research sought to understand what factors influence the voluntary adoption of WSPs by water utilities. Three main conclusions stand out after the descriptive and inferential analyses. First, governance arrangements can make a difference when it comes to the adoption of this methodology, suggesting that water utilities run by in-house bureaucracies are less prone to adopt WSPs. Second, the dimension of water utilities is an important determinant, as utilities serving above 50,000 residents or more than 10,000 m^3/day are more likely to implement WSPs. Lastly, the results also suggest that certification is an important pre-condition for the adoption of WSPs, even though the type of certification is not determinant.

In order to meet the requirements of Directive (EU) 2015/1787 on risk assessment and to underline all aspects to be taken into consideration in the implementation of the new legal diploma at the national level, we include a series of recommendations as the outcome of the research.

First, the implementation of a risk assessment methodology is a priority to promote safe drinking water policies and is required by law. National regulator should define the implementation of WSPs as a key performance indicator for benchmarking purposes.

The second recommendation relates to the capacity and level of professionalization of water utilities. The implementation of WSPs requires sufficient technical capacity to attain in-depth knowledge of the supply chain, as well as a strong involvement by working teams and management bodies. In order to secure the means to implement a risk assessment methodology like a WSP, it is necessary to provide technical documentation and to invest in educational programs and training, particularly for small and midsize utilities. Financial incentives should also be considered to accomplish these goals. Water utilities run by the municipalities' workforce should be primary targets for these policies as they are the most resistant to change due to capacity limitations.

A third recommendation focuses on the certification of quality, environmental, and health management systems. Prior experience with certification facilitates the implementation of risk assessment methodologies. While making certification mandatory for all utilities may be impossible to mandate at this time, these practices should be incentivized in order to highlight the benefits of risk assessment processes and produce the organizational buy-in, as emphasized in Bartram et al. (2009).

Lastly, national regulators play a crucial role in the dissemination of WSPs. The implementation of management systems, as well as of WSPs, requires effective inter-agency work and engagement by the ERSAR in Portugal and other national water regulatory agencies elsewhere. In order to make inter-agency work effective, national regulators and health and environmental organizations should have specific responsibilities and mandatory procedures to accomplish, including the publication of benchmarking reports. Although the analysis does not provide empirical support to associate the adoption of WSPs to perceptions about the national regulator, it suggests that the auditing function of the regulator negatively affects the implementation of WSPs. This should alert the regulator for the need to implement different approaches regarding this role towards water utilities by focusing on more collaborative and training strategies.

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Compliance with Ethical Standards

Conflict of Interest None.

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