Optimising the water sector market structure in Portugal
Rui Marques and Pedro Carvalho

ABSTRACT
This paper investigates the market structure of the water sector in Portugal through the application of distinct methods usually used in the literature (parametric and nonparametric methods). A sample of Portuguese water utilities was used to search for economies of scale and economies of scope in the period 2002–2008. High economies of vertical integration, economies of scale and economies of scope (both in the provision of water supply and wastewater services) were found. Therefore, there are advantages in water utilities merging by joining the retail and wholesale components and the water and wastewater services. The results show that amalgamation in the Portuguese water sector should be encouraged, creating vertically integrated water and wastewater utilities to supply more than 16 mm³/year of drinking water, corresponding to about 120,000 customers.

Key words | economies of scale, economies of scope, parametric and nonparametric methods, Portugal, water sector

INTRODUCTION
Drinking water supply and wastewater collection and treatment are vital services for the citizens’ welfare and public health. However, as they are generally provided in a monopolistic market structure, there is a great potential for efficiency improvement if one takes advantage of economies of scale and economies of scope (Garcia & Thomas 2001).

Economies of scale are defined as a measure that evaluates the increase in outputs due to an increase in all inputs. When an $\alpha$ per cent increase in all inputs produces a greater increase of the output percentage ($\alpha' > \alpha$), it is said that there are economies of scale or increasing returns to scale and, thus, it is advantageous for utilities to increase the level of production. Otherwise, it is said that utilities are operating under decreasing returns to scale and they should reduce the level of production. It can also happen that to an $\alpha$ per cent increase in all inputs corresponds the same $\alpha$ per cent increase in outputs. In this case, it is considered that the utility presents constant returns to scale and, therefore, it is operating at an optimal scale (Panzar & Willig 1981).

Sometimes, the literature refers to economies of scale when, in fact, it is dealing with economies of size (ESize) (Zoric 2006). These two concepts coincide only when the production technology meets some additional requirements (Chambers 1988). Economies of scale concern the output reaction as a result of an increase in all inputs, while ESize refer to the cost reaction caused by an increase in output (Chambers 1988). Furthermore, in network industries, some authors propose the inclusion of the number of customers (cu) and the mains length (len) (or service area) in the cost function to make the estimation of economies of output density (EOD), economies of customer density (ECD) and ESize possible (Caves et al. 1984; Roberts 1986; Filippini et al. 2008). EOD measure the relative increase in cost resulting from an increase in output, holding the number of customers and the mains length constant and are defined by

$$EOD = (\varepsilon_y)^{-1} = \left(\frac{\partial \ln C}{\partial \ln y}\right)^{-1}$$

(1)

where $C$ is the cost function, $y$ is the main output and $\varepsilon_y = \partial \ln C / \partial \ln y$ is the cost elasticity associated with the output $y.$

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ECD measure the relative increase in total cost resulting from a proportional increase in both the output and the number of customers, holding the mains length constant

\[
ECD = (\varepsilon_y + \varepsilon_{cu})^{-1} = \left( \frac{\partial \ln C}{\partial \ln y} + \frac{\partial \ln C}{\partial \ln cu} \right)^{-1}
\]  

(2)

Finally, ESize measure the reaction of costs when the output, the number of customers and the mains length increases proportionally and are defined as

\[
ESize = (\varepsilon_y + \varepsilon_{cu} + \varepsilon_{len})^{-1} = \left( \frac{\partial \ln C}{\partial \ln y} + \frac{\partial \ln C}{\partial \ln cu} + \frac{\partial \ln C}{\partial \ln len} \right)^{-1}
\]  

(3)

When these economies take values higher than the unit it is proved that there are EOD, ECD or ESize, respectively, and diseconomies otherwise.

Economies of scope exist when the costs of joint production of various goods produced by a single utility is lower than the costs of producing them separately by diverse specialised firms (Panzar & Willig 1981). In the case of the production of two outputs \(y_1\) and \(y_2\), if \(C(y_1, y_2) < C(y_1, 0) + C(0, y_2)\), where \(C(y_1, y_2)\) represents the total cost to a single firm producing the two outputs and \(C(y_1, 0)\) and \(C(0, y_2)\) represent the total cost of firms specialising in the production of outputs \(y_1\) and \(y_2\), respectively, there are economies of scope and diseconomies of scope otherwise. This may result, for example, in the sharing of resources in the joint production of various products or services, such as the joint delivery of both water supply and wastewater services (Fraquelli et al. 2004). In contrast, when economies of scope originate from joining several production stages in the production of a single good (e.g. joining bulk water production with water distribution in the drinking water service industry) they are called economies of vertical integration (Garcia et al. 2007).

In the literature, mainly two groups of methods have been adopted to search for economies of scale (or size) and economies of scope: parametric and nonparametric methods (Saal et al. 2015). Both methods have strengths and weaknesses (Murillo-Zamorano 2004; Fried et al. 2008). However, as the parametric methods come from the discipline of economics, they have a more statistical nature. Yet, they require the assumption of a functional form to represent the cost or production function and require too many other assumptions. Conversely, the nonparametric methods, with origin in operational research, have a more mathematical nature. Although they do not require the adoption of a functional form or the consideration of many assumptions, they are more sensitive to outliers and extreme data. For these reasons, in this study, two types of methods were applied in order to gather results from different viewpoints and, thus, to draw conclusions as robust as possible on the water sector market structure in Portugal.

This study has several aims. First, it intends to provide advice to support national decisions on the reform of the Portuguese water sector so that it becomes more efficient and sustainable, as millions of euros have unnecessarily been spent because no one knows what the most efficient market structure is, particularly concerning the vertical integration of water services. Second, it intends to evaluate whether the application of different methodologies leads to different results, contrary to what is usually done in the literature where only one estimation method and a single model are adopted. It also intends to explore the advantages and disadvantages of each methodology and simultaneously to obtain robust results concerning the Portuguese water sector market structure.

The Portuguese sample consists of utilities that operate exclusively in the wholesale segment and of utilities that operate mainly in the retail segment in the 2002–2008 period. The wholesale subsample comprises 19 utilities covering the entire mainland national territory while the retail subsample includes 55 utilities.

The current research is organised as follows. After this introduction, the next section provides an overview of the literature on economies of scale and economies of scope in the water sector. The following section describes the case study and the models adopted, followed by a section which presents and discusses the results. Finally, the main conclusions are drawn.

**LITERATURE REVIEW**

The first study to investigate scale economies in the water sector was published in the 1960s (Ford & Warford 1969).
It tried to identify an appropriate specification of the cost function for water utilities in the UK and argued that their amalgamation would not necessarily lead to a lowering of average costs. In the following two decades (1970s and 1980s), several US and UK studies were published. For example, Fox & Hofler (1985) found economies of scale in water distribution and diseconomies of scale in the production of water in the USA. It was during that period that the first studies examining scope economies appeared (Berg & Marques 2011).

In the 1990s and 2000s, the number of market structure studies published about water services, including cost or production functions, more than doubled. For example, Stone Webster Consultants (2004) concluded that the biggest water and wastewater companies in England and Wales presented diseconomies of scale and the remaining small water-only companies showed economies of scale. For the USA, Torres & Morrison (2006) found economies of scale for small utilities but diseconomies of scale for the largest utilities. Similar results were obtained for other countries, including Italy (Fraquelli & Moiso 2005), France (Garcia & Thomas 2001) and Japan (Mizutani & Urakami 2001). Economies of scale were also found in Portugal (Martins et al. 2006; Correia & Marques 2011), Germany (Sauer 2005) and Canada (Renzetti 1999) in the provision of water services.

Regarding economies of scope, the literature results are mixed. Of the studies examining economies of scope in the joint supply of water and wastewater services, a large proportion found economies of scope (e.g. Fraquelli et al. 2004; Martins et al. 2006), although some of them conclude that the savings are greater for small companies than for large ones. Nevertheless, there are other studies which concluded the opposite (Stone Webster Consultants 2004). There are also several studies quantifying economies of scope in multi-utilities, including water, electricity, urban waste or gas services. For example, Piacenza & Vannoni (2004) identified significant economies of scope for Italian multi-utilities. Other studies found economies of scope in joint retail and wholesale segments (economies of vertical integration) (Stone Webster Consultants 2004; Torres & Morrison 2006). Conversely, Garcia et al. (2007), using a sample of US utilities, concluded that separation may be beneficial in some situations, and that economies of vertical integration are not significant, except for the smallest utilities.

Although the literature is not consensual about the optimal size of water utilities or the existence of economies of scope among various activities, it is generally agreed that small water utilities providing only one service or that are not vertically integrated have significant scale and scope economies. In contrast, large or vertically integrated utilities seem to have scale and scope diseconomies. The literature reports a wide range of a maximum number of connections where economies of scale were not exhausted. The results pointed out in the literature show more consistency regarding economies of density and, in general, the studies point both to the existence and the importance of this kind of economies.

Concerning the Portuguese water sector and regarding the economies of scale, most studies of the national literature advocate the existence of economies of scale (size) in the water sector in Portugal (Martins et al. 2006, 2012; Correia & Marques 2011; Marques & De Witte 2011). Regarding economies of scope, the results are not as consistent among the studies of the national literature. Most of them have shown the existence of economies of scope in the joint supply of water and wastewater services (Martins et al. 2006, 2012; Carvalho & Marques 2014b). However, other studies have found no evidence of the existence of economies of scope in the joint supply of these two services (Correia & Marques 2011; Marques & De Witte 2011). Conversely, regarding economies of vertical integration, there are few studies in the national literature researching this kind of economies. Nevertheless, these few studies have found evidence of economies of vertical integration in the water sector in Portugal (Carvalho & Marques 2014a).

**THE WATER SECTOR IN PORTUGAL**

The municipalities are responsible for the water utilities (water and wastewater) in Portugal, as in most European countries. However, the Portuguese management model is quite different from other countries in Europe, like France or Spain, since water and wastewater sectors are not vertically integrated. As a rule, there are different actors...
supplying the ‘wholesale’ segment (intake, treatment and transportation in water and transportation and treatment in wastewater) and the ‘retail’ segment (water distribution and wastewater collection). Besides, there is a sector-specific regulator, an atypical situation in Europe (Marques 2010).

In the ‘wholesale’ segment, there are 21 water utilities (mostly water and wastewater utilities – 12 utilities) which encompass 233 municipalities (in 278 from the mainland country; in the islands there are no vertically disintegrated utilities only responsible for the provision of wholesale services). From these, one is a private concessionaire (contractual type of public private partnership (PPP)) and the remaining are public concessionaires (a partnership between a state-owned company and municipalities). In the retail segment there are 279 retail companies, including private concessionaires (contractual PPPs), a state-owned company (EPAL in Lisbon), municipal companies (with private participation or not), public-public partnerships between the State and municipalities, semi-autonomous utilities (municipality bodies which have some administrative and financial autonomy) and municipal services (without autonomy) (Carvalho & Marques 2011).

In addition to the regulation and unbundling of the water services, two other noteworthy features should be highlighted. The first one is related to the importance of the Central State as player in the water sector, controlling almost all the wholesale segment, and having a relevant position in the retail segment. The second one refers to the growing importance of the private sector participation. Currently 23% of the population is already supplied by private operators.

In Portugal, there are utilities that provide only water and others that provide both water and wastewater. Furthermore, some utilities also include urban waste and some also provide other activities, such as transportation, gardening and swimming pools. The predominant model is the water and wastewater utility. However, for several years it has been discussed what the optimal market structure is, thus acknowledging the importance of economies of scale and scope. In 1993 the water sector was reformed and was unbundled (separating the production from the distribution in water and collection from treatment in wastewater) spending millions of euros to specialise the utilities. In 2001 the sector was reformed again and from then on the strategy recommended was to amalgamate the utilities and not to specialise them. Again millions of euros were spent. Recently, the last government has announced the reform (again) of the water sector market structure, aiming at its optimisation (see Marques (2010) for a detailed analysis of the Portuguese water sector). Successive advances and retreats of strategies over the past few years in the sector have led to the misuse of thousands of millions of euros. Furthermore, the sector still continues to present several efficiency and sustainability problems, for example, with an inadequate cost recovery, especially in the wastewater service, as happens in many developing countries (Seppälä & Katko 2003).

CASE STUDY

The sample

The sample analysed included 74 water utilities which operated in mainland Portugal and in the islands for the period 2002–2008. The water utilities served about 5 million people in the retail segment (almost 50% of the Portuguese population) and about 9.8 million people in the wholesale segment (about 97% of the total population). Figure 1 shows the observations, according to the services provided, in the retail (left graph) and in the wholesale (right graph) segments. The capital letters WS and WW refer to the water supply and wastewater collection and treatment, correspondingly, and the lowercase letters r and w designate the retail and the wholesale segments, respectively. Thus, for instance, the WSwr-WWr utilities provide both water and wastewater services, providing drinking water supply in the wholesale and retail segments but only wastewater services in the retail segment.

Model specification

As mentioned above, this study did not adopt a single methodology, as is normally done in most studies in the literature, but several different methodologies (parametric and non-parametric methodologies), in order to gather results from different views and also to draw conclusions as robust as possible on the Portuguese water sector.
Within each of these methodology groups there was a selection of the methods with the highest potential. In the group of parametric methodologies and within the non-frontier methods, the nonlinear seemingly unrelated regression (NLSUR) was used. In the frontier methods group, we applied the stochastic frontier analysis (classical and Bayesian), and in the group of nonparametric methodologies, the ones applied were the traditional full frontier methodologies (data envelopment analysis) and the recent and robust partial frontier nonparametric methodologies (order-α and order-m).

Regarding the functional form chosen for the cost functions, in the application of the parametric methodologies, the generalised translog functional form was selected, since it was proved to be the most appropriate to the sample (Carvalho & Marques 2014b), having the following expression:

\[
\ln C = a_0 + \sum_{i=1}^{q} a_i y_i^{(x)} + \frac{1}{2} \sum_{i=1}^{q} \sum_{j=1}^{q} a_{ij} y_i^{(x)} y_j^{(x)} + \sum_{i=1}^{q} \sum_{k=1}^{p} \beta_{ik} y_i^{(x)} \ln w_k + \sum_{k=1}^{p} \beta_{k} \ln w_k + \frac{1}{2} \sum_{k=1}^{p} \sum_{l=1}^{p} \gamma_{kl} \ln w_k \ln w_l \tag{4}
\]

where \( C \) is the cost function, \( y_i \) are the outputs, \( w_k \) are the price of inputs, \( p \) is the number of inputs that the utilities use to produce \( q \) outputs, \( a_x, \beta_x, \pi \) and \( \pi \) are the parameters to be estimated, where the last parameter \( \pi \) corresponds to a Box-Cox transformation (see, for example, Piacenza & Vannoni 2004).

Total cost was chosen as the dependent variable in the parametric methods, since it can be assumed that the water utilities choose their inputs so as to minimise the long-run cost of production to a given level of output. The outputs considered were the amount of drinking water supplied (retail and wholesale), the amount of collected and treated wastewater, in m³, the number of customers and the mains length and sewers length (in kilometres). The inputs used were the labour cost, capital cost and other operational cost. In the application of parametric methods, the input prices adopted were the labour price (defined as the ratio of the annual labour cost to the total number of employees, in €/employee), the capital price (which was estimated dividing the capital cost by the mains length and sewers length, in €/km) and the prices of other costs, a global price that reflects the price of energy, material and external services (computed dividing other costs by the sum of the total volume of water distributed and the collected and treated wastewater volume, in €/m³). All the data were obtained from the annual account reports published by the water utilities and from the regulator annual reports.

In the application of nonparametric methods, an input orientation was adopted, since the aim of the water utilities is to reduce the inputs consumed for a given level of outputs delivered. The search for economies of scale (size) and economies of scope was performed separately for each of the two groups of utilities considered: the group of utilities that provide only water and the group of utilities that provide both drinking water and wastewater services.

RESULTS AND DISCUSSION

According to the results obtained from the various methods, there is evidence of the existence of economies of scale
(size), economies of scope and economies of vertical integration to explore in the water sector in Portugal. Parametric methods highlight also EOD. These results indicate that there are advantages and potential for mergers of the water utilities.

Concerning economies of scale (size), the results obtained show that there are large economies of scale (size) either for the utilities that provide both drinking water and wastewater services or for the utilities that provide only water. For utilities that provide only water the results point to large global ESize for small and median utilities, demonstrating optimal scales for supplies of 20–60 Mm³/year of water, corresponding to providing about 140,000–400,000 customers (according to the results obtained from frontier parametric methods) or for supplies of 12–18 mm³/year of drinking water associated with a range between 90,000 and 125,000 customers (according to the results obtained from non-frontier parametric methods) (Figure 2). For utilities that provide both drinking water and wastewater services, the results show the existence of global ESize for small, median and large utilities, showing optimal scales for dimensions larger than a supply of 16 mm³/year drinking water corresponding to providing close to 120,000 customers (according to the results obtained from frontier parametric methods) or for supplies of 8–12 mm³/year of water corresponding to a supply of about 60,000–90,000 customers (according to the results obtained from non-frontier parametric methods), or even a supply of more than 24 mm³/year of water (close to 180,000 customers). As can be seen in Figure 2, there is much potential for increases in the size of utilities since most of them (represented by dots: WS in a lighter colour and WS-WW in a darker colour) currently have dimensions considerably below the optimal scale (represented in shaded colour). According to these results we also noted that the frontier parametric methods tend to provide higher optimal scales compared with the non-frontier parametric methods and with the nonparametric methods. This may be related to the simultaneous imposition to parametric frontier methods of a continuous function to the cost function (or production function) which meets a series of conditions and simultaneously this cost function (or production function) envelops all data to constitute a frontier. Thus, these frontier parametric methods may be less likely to smaller local optimum dimensions as happens with the non-frontier parametric methods and with the nonparametric methods.

Regarding the economies of vertical integration, all approaches lead to the conclusion that there are significant economies of vertical integration in the water sector in Portugal, especially important in the wastewater activity. This means that there are advantages in the sector to join the wholesale and retail components, especially in the wastewater activity (that is, in jointly operating wastewater collection and treatment). This conclusion for the water sector in Portugal is entirely in line with the literature, according to which there is strong evidence of economies of vertical integration in the water sector (Carvalho et al. 2012) and can be explained by the existence of strong

![Figure 2](https://iwaponline.com/aqua/article-pdf/63/4/303/400872/303.pdf)
technological interdependencies between production and distribution stages and by a great need for coordination and adaptation across stages.

Concerning economies of scope, all methodologies reveal the existence of these economies in the joint supply of water and wastewater activities. This is in line with most studies in the literature and can be justified by the sharing of resources between activities, such as staff, machinery and savings in fixed costs. The results also show that there are some cases of diseconomies but only in the wholesale segment.

Thus, the water sector in Portugal must evolve to exploit these economies, that is, carry out mergers and join the retail with wholesale in order to become more cost efficient. Moreover, this should be encouraged or even imposed by the government or the regulator. One way to speed up this process could be to somehow enable more active involvement of the private sector in the Portuguese water sector.

CONCLUSIONS

From the application of distinct methods we found that there are EOD, economies of scale (size), economies of scope and economies of vertical integration to explore in the water sector in Portugal, especially for small and median utilities. Thus, there are advantages for mergers, joining water and wastewater activities and the wholesale and retail components in the Portuguese water sector. This can be justified because the sector is characterised by being too fragmented compared with other European countries, especially in the retail component. This is because, first, contrary to what happens in most European countries, in Portugal the utilities are not vertically integrated (when considerable evidence for the existence of economies of vertical integration exists in the literature for the joint supply of upstream water production and distribution, Saal et al. (2013)). Secondly, because in the retail segment each utility usually covers only one municipality (more than 80% of municipalities have less than 50,000 inhabitants and more than 90% of municipalities have less than 100,000 inhabitants), contrary to what happens in other countries in Europe, like France or Spain, where the participation of private companies in the management of these services is large and there are savings with the existence of economies of scale (size) and economies of scope in the sector by the private companies, even though they operate several small utilities.

According to these results, vertically integrated utilities that provide both water and wastewater services should be formed so that the sector may become more efficient. In a first phase, mergers should take place to reach dimensions exceeding 16 mm$^3$/year supply of water, corresponding to a provision of more than about 120,000 customers. The mergers must be conducted solely within watersheds, since this is a situation that leads to less wastefulness and follows the guidelines of the European Union regarding the management of watersheds. To make that possible, it is essential that the regulator or policy makers intervene through incentives or other mechanisms to lead the industry to move towards a market structure with these characteristics and simultaneously to decrease the inefficiency levels, estimated in this study to be 30%.

REFERENCES


Torres, M. & Morrison, C. 2006 Driving forces for consolidation or fragmentation of the US water utility industry: a cost function approach with endogenous output. J. Urban Econ. 59, 104–120.