Science of the Total Environment 544 (2016) 574–586

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Estimating size and scope economies in the Portuguese water sector using the Bayesian stochastic frontier analysis

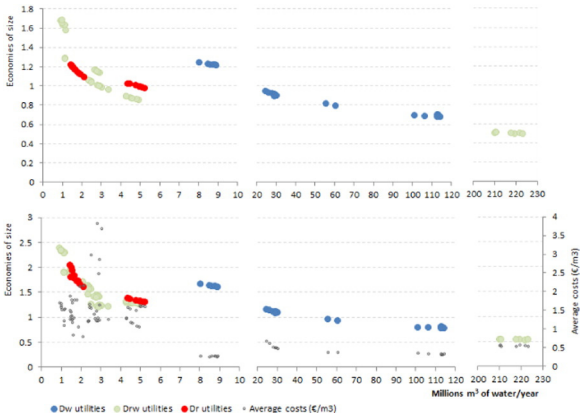
Pedro Carvalho [a,b,*], Rui Cunha Marques [b]

[a] Computational Modelling in Engineering and Geophysics Laboratory (LAMEMO), Department of Civil Engineering, COPPE, Federal University of Rio de Janeiro, Av. Pedro Calmon - Ilha do Fundão, 21941-596 Rio de Janeiro, Brazil
[b] Center for Urban and Regional Systems (CESUR), CERIS, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, 1049-001 Lisbon, Portugal

HIGHLIGHTS

- This study aims to search for economies of size and scope in the water sector;
- The usefulness of the application of Bayesian methods is highlighted;
- Important economies of output density, economies of size, economies of vertical integration and economies of scope are found.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 12 August 2015
Received in revised form 24 November 2015
Accepted 29 November 2015
Available online xxxx

Editor: Simon Pollard

JEL classification:
L100
C110

Keywords:
Bayesian stochastic frontier analysis
Economies of size
Economies of scale
Economies of scope
Water utilities
Portugal

ABSTRACT

This study aims to search for economies of size and scope in the Portuguese water sector applying Bayesian and classical statistics to make inference in stochastic frontier analysis (SFA). This study proves the usefulness and advantages of the application of Bayesian statistics for making inference in SFA over traditional SFA which just uses classical statistics. The resulting Bayesian methods allow overcoming some problems that arise in the application of the traditional SFA, such as the bias in small samples and skewness of residuals. In the present case study of the water sector in Portugal, these Bayesian methods provide more plausible and acceptable results. Based on the results obtained we found that there are important economies of output density, economies of size, economies of vertical integration and economies of scope in the Portuguese water sector, pointing out to the huge advantages in undertaking mergers by joining the retail and wholesale components and by joining the drinking water and wastewater services.

* Corresponding author at: Computational Modelling in Engineering and Geophysics Laboratory (LAMEMO), Department of Civil Engineering, COPPE, Federal University of Rio de Janeiro, Av. Pedro Calmon - Ilha do Fundão, 21941-596, Rio de Janeiro, Brazil.
E-mail addresses: pedrocarv@coc.ufrj.br (P. Carvalho), pedro.c.carvalho@tecnico.ulisboa.pt, rui.marques@tecnico.ulisboa.pt (R.C. Marques).

http://dx.doi.org/10.1016/j.scitotenv.2015.11.169
0048-9697/

1. Introduction

Although drinking water supply and wastewater treatment are essential services for the welfare and public health of the communities, they are, in most cases, provided in a monopoly environment. This happens because, in general, the provision of these services in a particular region is more cost advantageous when it is supplied by only a single company rather than by multiple companies (natural monopoly) (Nauges and van den Berg, 2007). This situation associated with large capital costs and existence of economies of size (ESize), scale and also economies of scope (ScE) together hamper the entry of new companies in the sector (barriers to entry). As a result, these services do not feel the pressure of market competition and, therefore, they tend to be inefficient. This inefficiency is transferred to the customer in the form of higher prices and/or a poor quality of service. However, this may be mitigated, for instance, by exploiting the existing ESize and ScE (Fabbri and Fraquelli, 2000). ESize (or economies of scale, as it is often referred to in the literature) concern the dimension of production that leads to the lower (unit) average cost and ScE are related to savings coming from the joint production of different goods. There are ScE when the costs of production of different goods or services provided together by a single firm are lower than the costs of providing them separately by different specialized firms (Panzar and Willig, 1981).

One of the first studies in the literature that sought to identify ESize in the water sector dates back to the 1960s (Ford and Warford, 1969). Ford and Warford attempted to estimate a cost function for water utilities in the UK and finally they concluded that the mergers of utilities would not necessarily lead to the average cost reduction. From then on, many other studies followed mainly in the US and the UK. Many of these studies also address issues related to ownership, trying to understand whether the kind of ownership (public or private) have influence on the performance of utilities. Nevertheless, only in the last twenty years has the number of studies investigating ESize and ScE in the water sector increased significantly and proliferated in the rest of the world (see, for instance, Carvalho et al., 2012; Abbott and Cohen, 2009; Ferro et al., 2010, for an outline of the literature review on the water sector). The literature is not conclusive concerning the definition of an optimal size of water utilities which leads to maximum efficiency, or in other words, which leads to the lower (unit) average costs. This is because the context and operational environment in which utilities operate is different throughout the world, varying from country to country, from region to region and also over time (Nauges and van den Berg, 2007). Nonetheless, the literature is consistent in the inference that, in general, the small water utilities have significant ESize and ScE and conversely large utilities exhibit scale and scope diseconomies (Abbott and Cohen, 2009).

Concerning the methodologies used in literature, the estimation of ESize and ScE, so far (in the literature the search for ESize and ScE) has been made mainly by using non-frontier methods, such as seemingly unrelated regressions (SUR) and ordinary least squares (OLS) or by frontier methods, such as stochastic frontier analysis (SFA) (Kumbhakar and Lovell, 2003). Although the SUR non-frontier method is attractive, as it enables the estimation of cost functions along with their derivatives (cost shares) and, therefore, more accurate cost functions are obtained, the frontier methods, such as SFA, enable to assess best practices (the best-practice frontier technology) and the inefficiency levels of firms (e.g. Farsi and Filippini, 2004). The SFA method has been widely applied in the water sector literature but, in most cases, only through classical statistics (see, for instance, Abbott and Cohen, 2009 for a more complete literature review concerning the methodologies used in the water sector).

As a contribution to the literature, this paper aims to prove the usefulness and advantages of using Bayesian statistics in SFA over traditional SFA (hereafter referred to as classical stochastic frontier analysis — CSFA). The use of Bayesian statistics to make inference in SFA models (hereafter referred to as Bayesian stochastic frontier analysis — BSFA) has huge advantages over CSFA. The application of Bayesian statistics allows the easy incorporation of prior information and restrictions (such as regularity conditions imposed by the economic theory) on the parameters of the cost functions and the inference on efficiencies on small samples (Van den Broeck et al., 1994). The use of BSFA also allows overcoming problems in the estimation of cost functions that often occur when using CSFA, such as problems related to the bias in small samples and with the correct skewness of residuals. For example, in CSFA the skewness of residuals must necessarily be positive for the cost frontiers (or negative in the production frontier cases), which often does not happen. As far as the authors are aware, only one study was found in the literature applying BSFA to the water sector (Cosmo, 2009). This study investigates the impact of financial leverage on the efficiency of a sample of 65 Italian water utilities. The author estimated a translog cost function using the BSFA approach and found economies of scale for small water companies. It was also found that the firm's leverage level is one of the inefficiency sources and that ownership does not seem to influence the performance of utilities. Other frontier methods have been applied in the literature, as is the case of nonparametric methods (e.g. data envelopment analysis - DEA), but they are deterministic and sensitive to outliers and extreme data (Daraio and Simar, 2007).

A further aim of this study is to use this powerful tool (BSFA) to estimate ESize and ScE in the water sector in Portugal, which is a sector in restructuring and discussion and with characteristics almost unique in the world.

This study is organized as follows. After this introduction, Section 2 describes the water sector in Portugal, Section 3 explains the methodology applied and Section 4 outlines the case study. Sections 5 and 6 display the results and discuss them. And finally, Section 7 draws the main conclusions.

2. The water sector in Portugal

The water supply and wastewater industry in Portugal presents a market structure with characteristics almost unique in the world. For instance, this industry is split up in two different markets: the wholesale market and the retail market. This only happens in a few countries, such as Belgium, Holland and Romania (Carvalho et al., 2012). In addition, in Portugal, the retail market is characterized by excessive fragmentation (Saal et al., 2013) and therefore this market structure is not the most efficient one (Marques and De Witte, 2011).

Over the last decades, the lack of knowledge regarding the market structure that is closest to the ideal has led to constant strategy changes concerning the water market structure in Portugal and to millions of euros spent in advances and retreats in strategic options (Marques, 2010). One of the changes that took place was related to the merger/separation of the wholesale and retail components of the water supply and wastewater activities. Until 1993 the management and operation of the water services in Portugal was carried out by the municipalities. The water services were generally vertically integrated, i.e., each municipality was responsible for both the production of water (the wholesale component) and the water distribution to customers (the retail component). Simultaneously, although the country was not fully covered by wastewater infrastructure at that time, each municipality was also responsible for wastewater treatment and transportation (activities which comprise the wholesale component in the wastewater services) and the wastewater collection (the retail component). However, the provision of these water services was very precarious with moderate coverage levels since only part of the population had access to these services. Before such a scenario, in 1993, a law was published promoting the creation of regional companies with the aim of endowing the country with adequate coverage levels. At the same time, the unbundling of the wholesale and retail components was also encouraged. Thus, several regional companies were created with responsibilities only in the wholesale segment while the retail component remained with the