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Computing economies of vertical integration, economies of scope and economies of scale using partial frontier nonparametric methods

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ABSTRACT

So far, in the nonparametric literature only full frontier nonparametric methods have been applied to search for economies of scope and scale, particularly the data envelopment analysis method (DEA). However, these methods present some drawbacks that might lead to biased results. This paper proposes a methodology based on more robust partial frontier nonparametric methods to look for scope and scale economies. Through this methodology it is possible to assess the robustness of these economies, and in particular to assess the influence that extreme data or outliers might have on them. The influence of the imposition of convexity on the production set of firms was also investigated. This methodology was applied to the water utilities that operated in Portugal between 2002 and 2008. There is evidence of economies of vertical integration and economies of scale in drinking water supply utilities and in water and wastewater utilities operating mainly in the retail segment. Economies of scale were found in water and wastewater utilities operating exclusively in the wholesale, and in some of these utilities diseconomies of scope were also found. The proposed methodology also allowed us to conclude that the existence of some smaller utilities makes the minimum optimal scales go down.

1. Introduction

Scale economies refer to the relationship between outputs and inputs, measuring the way the outputs produced change with an increase in inputs. Scale economies exist when an expansion in an output can be achieved with less than a proportionate increase in all inputs, whereas scope economies are related to savings originating from the joint production of different goods or services (Panzar & Willig, 1981). The concept of natural monopoly is associated with the latter kind of economies. In the simple case of single-output production, there is a natural monopoly when a single firm can produce a good or service at a lower cost than several firms that produce the same good or service separately, or when the cost function is subadditive, in other words, when $C(Y) < \sum_{i=1}^{k} C(y_i)$, where $\sum_{i=1}^{k} y_i = Y$ and k is the number of producers (Baumol, Panzar, & Willig, 1988). However, when the production involves more than one type of output, economies of scope may be observed. For economies of scope to occur the cost function has to be subadditive, but it is also necessary that orthogonality between the output vectors of the different (specialised) firms exists, that is, $y_i \cdot y_j = 0, i \neq j$. This means that there are scope economies when the costs of production of two or more goods produced together by the same firm are lower than the costs of producing them separately by several different specialised firms (Baumol et al., 1988).

Scope economies may be derived, for example, from the sharing of resources (especially important in the network industries where usually there are high short-run fixed costs) or negotiation power. However, these benefits may not be sufficient, and therefore it might be more advantageous to separate production (specialisation). In these cases there are diseconomies of scope. Usually this happens with large institutions, where the provision of services is already too complex (for example, due to the network complexity (Abbott & Cohen, 2009)) and where bureaucracy might be relevant.

Generally scope economies refer to savings originating from the joint production of different kinds of services (for example, water supply and wastewater services). However, when economies of scope originate from joining various production stages in the production of a single good or service in an industry characterised by several successive production stages they are called economies of vertical integration. For example, in the drinking water service industry, if a single vertically integrated utility (in charge of activities from bulk water production to water distribution) is able to provide water at a lower cost than several vertically disintegrated firms, there are economies of vertical integration. Economies of this type may occur if there are strong technological interdependencies between production and distribution stages and if there are considerable needs for coordination and adaptation across

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stages, as in the case of network industries (e.g., water, electricity and gas industries) (Garcia, Moreaux, & Reynaud, 2007). In these cases, vertical integration avoids duplication of fixed costs and enables better coordination across stages, bringing benefits for customers, either within the final product quality or the price level. However, vertical integration may also lead to negative situations. For example, utilities may take monopoly positions in the region where they operate because they have no direct competitors or no incentives to improve. In such situations, vertical disintegration may be beneficial because it may promote competition between upstream and downstream stages.

For the purpose of this research we investigated the economies of scope and scale in the Portuguese water sector, which presents a very enriched sample with audited data by a regulator. In addition, in Portugal there has been a divergent scenario with respect to the vertical integration of water utilities. In 1993 the water sector was reformed and the guidelines were in the direction of unbundling, meaning that production should be separated from distribution in drinking water activity and collection from treatment in wastewater activity. Some years later, in 2001 the sector was reformed again but the orientations then were towards the merger of utilities, spending millions of Euros for such a purpose. Recently, the government has announced the reform of the water sector market structure, aiming at its optimisation (see Marques (2010) for a detailed analysis of the Portuguese water sector). Therefore, searching for economies of scope and economies of scale in the water sector in Portugal is not only necessary but also urgent if the aim is to move towards an optimal market structure rather than facing advances and retreats.

In the water sector literature there is no consensus regarding the optimal scale for water utilities or in relation to the existence of economies of scope in the joint provision of different kinds of services or across stages (vertical economies). So, while some studies found economies of scale in the provision of water services (e.g., Nauges & Berg, 2008), economies of scope between water supply and wastewater services (e.g., Fraquelli & Moiso, 2005), or between other activities in multi-utilities (such as electricity, urban waste or gas services: e.g., Piacenza & Vanonni, 2004) or even economies of vertical integration (e.g. Torres & Morrison Paul, 2006), other studies concluded the opposite (diseconomies of scope: e.g., Correia and Marques (2010) and diseconomies of scale: e.g., Baranzini and Faust (2009)) (see further on, for example, Abbott and Cohen (2009) and Carvalho, Marques, and Berg (2012)). Although these findings are not surprising since the researches are related to different countries or regions with different operating conditions (different topographical, hydrological and geographical circumstances, or legal frameworks, among other aspects), it can be concluded that generally small water utilities providing only one service or that are not vertically integrated have significant scale and scope economies and that large or vertically integrated utilities have scale and scope diseconomies (Carvalho et al., 2012).

In the literature, two main approaches have been followed in the study of economies of scope and economies of scale: the parametric and nonparametric approaches (e.g., Sahoo & Tone, 2012). The parametric approaches (e.g., stochastic frontier analysis – SFA) estimate cost or production functions based on the econometric theory while the nonparametric ones, like Data Envelopment Analysis (DEA) (Charnes, Cooper, & Rhodes, 1978), use linear programming to estimate the deterministic production (or cost) frontier (see, for example, Fried, Lovell, and Schmidt (2008) for an overview of parametric and nonparametric approaches). Even though the parametric methodologies have been more often applied in the literature, they have faced some controversial issues, such as choosing a functional form to represent the cost or production functions, which may lead to biased results and severe policy implications when such a form is not appropriate (Giannakas, Tran, & Tzouvelekas, 2003). Nonparametric methodologies do not suffer from this problem and present advantages such as not requiring so many assumptions and being easy to compute. Nevertheless, the nonparametric methodologies applied so far in the literature to search for scale and scope economies have basically been the full frontier methodologies (DEA and the non-convex free disposal hull – FDH (Deprins, Simar, & Tulkens, 1984)), which also have some limitations. They are particularly sensitive to extreme data and outliers and suffer from the problem of the “curse of dimensionality”. Several recent studies have used bootstrapping methods to mitigate some of these drawbacks, but a few problems remain.

For this reason, in the current study we propose the use of new nonparametric methodologies (partial frontier nonparametric methodologies) to assess scope and scale economies. These partial frontier methodologies use only part of the sample to estimate the production frontier, therefore they are less sensitive to extreme data and outliers and do not suffer from the problem of the “curse of dimensionality”. In addition, they allow for evaluating scope and scale economies for various partial frontiers, enabling us to understand how these economies behave as we approach the full frontiers and to evaluate their consistency as they will incorporate possible outliers in the sample. Therefore, they are far more robust than full frontier methodologies.

After an overview of the nonparametric methodologies and their application in the literature, Section 2 describes the proposed methodology. Section 3 presents the case study and the model adopted and Sections 4 and 5 display and discuss the results obtained. Finally, Section 6 draws the main conclusions.

2. Economies of scope and their computation by nonparametric methods

Economies of scope have been examined through nonparametric methodologies, primarily through DEA. Most studies in the literature are based on the idea of Färe (1986) and Färe, Grosskopf, and Lovell (1994), which consists of computing scope economies by estimating the frontier of multiproduct firms and the frontier of firms constructed from the sum of specialised firms and by evaluating which of these frontiers is the most efficient. There are several examples of studies in the literature that have applied the full frontier nonparametric methodologies, as is the case, for example, of Grosskopf and Yaisawarng (1990) in the provision of municipal public services; Ferrier, Grosskopf, Hayes, and Yaisawarng (1993) in the banking sector; Fried, Schmidt, and Yaisawarng (1998) and Lee, Chun, and Lee (2008) in hospitals; Cummins, Weiss, and Zi (2003) and Berger, Cummins, Weiss, and Zi (2000) in the insurance; Growitsch and Wetzel (2007) in the railways; Arocena (2008) in the electricity; Cherchye, De Rock, and Vermeulen (2008) in universities and De Witte and Marques (2010) in the water sector.

The DEA is a full frontier nonparametric method (Charnes et al., 1978) which allows estimating the production (or cost) frontier and evaluating the technical efficiency for each observation (or decision making units – DMU). In an input orientation context, DEA estimates the frontier from observations which use a minimum of inputs to produce a given level of outputs. The frontier and technical efficiencies are estimated from the following linear programming problem (when a variable returns to scale (VRS) technology is assumed) (Fried et al., 2008):

$$
\begin{aligned}
\min_{\theta,\lambda} \quad & \theta_i^{VRS} \\
\text{s.t.}: \quad & y_i \leqslant Y\lambda \\
& \theta_i^{VRS} x_i \geqslant X\lambda \\
& I'\lambda = 1 \\
& \lambda \geqslant 0
\end{aligned}
\qquad (1)
$$