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The Luenberger productivity indicator in the water industry: An empirical analysis for England and Wales

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ABSTRACT

We innovate in the field of water companies' performance with an application of the directional distance function and the Luenberger productivity indicator (LPI) to the assessment of water companies' productivity growth. The advantage of our approach is that it takes into account both input contractions and output expansions. The analysis covered 22 water companies from England and Wales using data over the period 2001–2008. To the best of our knowledge, there are no prior studies applying the Luenberger productivity indicator to the water industry in England and Wales or other countries. For the sake of comparison, the traditional Malmquist productivity index (MPI) was also estimated. The results indicate that on average, a declining trend for the productivity change was evident in the English and Welsh water sector based on both the LPI and the MPI approach. However, the latter approach overestimated the productivity changes as its measures were higher than those obtained by the LPI approach. Unlike the assessment based on the average LPI values, an analysis at the company level allowed us to identify that the primary driver of the decline in water companies' productivity was the negative shift in the production frontier. Taking into account that new water prices were introduced in England and Wales in 2000 and 2005, our study also provides some insights into the relationship between productivity change and the regulatory cycle.

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1. Introduction

Benchmarking is a tool that is widely used in various countries and sectors to provide both utility managers and regulatory authorities with information and incentives (Stapenhurst, 2009). The water industry has not escaped this trend and a significant number of studies have been developed with the aim of assessing the efficiency and productivity growth of water utilities or companies using benchmarking procedures (Berg and Marques, 2011; Berg, 2013).

Within the water industry, there are many reasons why organizations benchmark. From the utilities' point of view, benchmarking allows the identification of best practices based on output/input ratios. Hence, benchmarking is a useful tool to identify cost-saving opportunities (Molinos-Senante et al., 2014). On the other hand, assessing the performance of water utilities provides regulators with valuable information to enhance the design of public policies (Mbuvi et al., 2012). Moreover, in countries or regions where water services are regulated, benchmarking has special relevance. Marques et al. (2011) analyzed the use of benchmarking in more than 50 countries/states in the regulatory context. They concluded that 72% of the regulators applied benchmarking either service quality regulation or economic regulation. For example, in England and Wales, the economic regulator (the Water Services Authority – Ofwat) has been using a benchmarking procedure for the review of water prices (Allan, 2006).

Privatization and regulatory reforms in the English and Welsh water industry have stimulated interest in benchmarking tools for evaluating the effectiveness of reforms. In this context, several studies have assessed the productivity change of the private water companies. On the one hand, some studies have focused on analyzing the impact of privatization on the efficiency and productivity of companies (Ashton, 2000; Saal and Parker, 2000, 2001; Marques, 2008). Other studies have evaluated the impact of regulation on productivity growth (Saal and Reid, 2004; Erbetta and Cave, 2007; Saal et al., 2007; Bottaso and Conti, 2009; Portela et al., 2011).

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The productivity growth of English and Welsh water companies has been evaluated using both parametric and non-parametric techniques.[1] Within the latter approach, Portela et al.'s (2011) study was the only one in which productivity change over time was computed through a Malmquist index framework. In particular, they used a meta-Malmquist index to measure the productivity change of English and Welsh companies from 1993 to 2007. This index can be decomposed into circular components of efficiency change and technical change (Portela and Thanassoulis, 2008). The two main advantages of this index are easy manipulation of the data and the feasibility of problems for computing the index under variable returns to scale (Tohidi et al., 2012). Despite such advantages, Portela et al. (2011) used productivity change models based on constant returns to scale technology.

In other countries, studies on the productivity growth of water utilities have also been carried out using the Malmquist productivity index (MPI) (e.g. Lin and Berg, 2008; Hernández-Sancho et al., 2011; De Witte and Marques, 2012). Despite the wide application of the MPI in the literature, a significant drawback is that it requires a choice between an output and an input orientation (Williams et al., 2011). Making use of the shortage function developed by Luenberger (1992, 1994), Chambers et al. (1996) introduced the Luenberger productivity indicator (LPI) as a generalization of the MPI. The LPI can account simultaneously for output expansion and input contraction. Moreover, the LPI can also specialize in an output or an input-oriented perspective corresponding to revenue-maximization or cost-minimization. According to Chambers (2002, cited in Epure et al., 2011), "these Luenberger indicators are novel because they are based on a translation (not radial) representation of the technology and, thus, are all specified in difference (not ratio) form." Boussemart et al. (2003) demonstrated that the MPI overestimates the productivity change, as opposed to the LPI, concluding that the LPI encompasses the MPI. Subsequently, empirical applications (Managi, 2003; Briec and Kerstens, 2004; Boussemart et al., 2006) verified that the ratio-based productivity index (MPI) overestimates productivity change compared with the productivity indicator (LPI).

The favourable features of the estimation of productivity change using the LPI instead of the MPI can be summarized as follows. First, the use of the directional distance function instead of the Shephard function means that it is not necessary to choose between input and output orientation, but it allows the simultaneous evaluation of the input savings and the output improvements (Chambers et al., 1996). Second, unlike the MPI, the LPI takes economic issues into account, since the directional distance function is the transposition into production theory of Luenberger's "benefit function" in a consumer context (Luenberger, 1992; Färe et al., 2008). Third, the LPI comes closest to characterizing total factor productivity growth, while the MPI presents an upwardly biased estimate (Boussemart et al., 2003). Hence, Luenberger indicators are more general than Malmquist indices.

The LPI has been used to compute the productivity growth of a wide variety of organizations and services, such as airlines (Barros and Couto, 2013); touristic resorts (Peypoch, 2007; Goncalves, 2013); seaports (Barros and Peypoch, 2012); hydroelectric dams (Briec et al., 2011); and banks (Epure et al., 2011; Williams et al., 2011), among others. This study estimates productivity growth by employing a productivity indicator that has a more generalized form than the commonly used productivity measurement.

This manuscript contributes to the current strand of literature in several respects. First, to the best of our knowledge, there are no prior studies applying the LPI to the water industry in England and Wales or other countries. Hence, we innovate in the field of utility performance studies with an application of the LPI to evaluate the productivity change of the English and Welsh water industry at the company level over the period 2001–2008. Second, the results of the LPI and the MPI for the water sector are compared for the first time. Finally, taking into account that new water prices were introduced for England and Wales in 2000 and 2005 (i.e., following the 1999 and 2004 price reviews[2]), our study also provides insight into the relationship between productivity change and the regulatory cycle. Beyond their academic interest, the findings of this paper are very useful from a policy perspective. The decomposition of both the LPI and the MPI into efficiency change and technical change is particularly relevant since it allows water utility managers and regulators to identify the primary contributor to the productivity change over time. Subsequently, different strategies could be adopted to improve productivity depending on the values of the catching-up index and the frontier productivity index (both of which are described below).

The paper unfolds as follows. Section 2 presents the methodology employed in this study, followed by a discussion of the sample data in Section 3. Section 4 presents the main findings and the final section concludes.

2. Methodology

To determine the productivity growth of the English and Welsh water companies, the conventional MPI and the alternative LPI were computed. Both approaches follow the non-parametric data envelopment analysis (DEA) method for evaluating the performance of decision-making units (DMUs) (i.e., water companies). DEA is a linear programming technique that neither requires a predetermined functional form nor demands the user to set weights for each input and output (Cooper et al., 2000).

One of the merits of the MPI and the LPI is that they can be decomposed into two components: efficiency change (ECH) and technical change (TCH) (Chen et al., 2008). Hence, it is possible to identify the factor that contributes most to productivity change and, consequently, utility managers can act to improve productivity.

The ECH, also known as the catching-up index, reflects the relative change in efficiency between time periods. In terms of water companies, this concept involves their capacity to be managed in accordance with best operational practices (i.e., so that the utility operates on the efficient frontier). The efficiency gains due to the catching-up effect can mainly be attributed to the managerial capacity of water companies' response to changes in scale efficiency and their ability to adjust to input factors in a timely manner (i.e., changes in pure technical efficiency). The contribution of the ECH represents the change of the production factors relative to the minimum inputs that still produce the outputs (efficient frontier) in the time interval considered (Simoes and Marques, 2012).

The TCH, also known as the frontier productivity index, measures the change in frontiers between two periods (Hernández-Sancho et al., 2011). It can be induced by an increase (or decrease) of the rate of transformation of inputs into outputs (Simoes and Marques, 2012). Effective long-term strategic planning and timely capital investment are needed to improve the technical efficiency. For the water utility sector, institutional reforms to

[1] It is not the aim of the paper to discuss the advantages and disadvantages of the parametric and non-parametric approaches. In the English and Welsh context, parametric techniques were used by Ashton (2000), Saal and Parker (2000), Saal and Reid (2004) and Saal et al. (2007) and non-parametric techniques were used by Thanassoulis (2000), Saal and Parker (2001), Erbetta and Cave (2007), Maziotis et al. (2009, 2012) and Portela et al. (2011).

[2] The water prices were also reviewed in 2009.

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