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Ownership, Productivity Change in the Australian Urban Water Sector: a Bootstrap Malmquist indices approach.

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Abstract

This paper provides a comprehensive productivity analysis of 53 Australian water service providers during the period 2006-2012. Pressures for sector reform have stimulated interest in identifying and understanding the factors that can contribute to improve the performance of Australian water utilities. The aim is to provide to the policy-makers quantitative-evidences that allow to identify the best interventions, in relation to the alternative forms of ownership that characterize the water utilities in the different territories\states of Australia, to obtain productivity gains.

Keywords: Australian water utilities, DEA, bootstrap, kernel density, ownership.

1. Introduction

The purpose of this study is to analyze the relative performance of water utilities in Australia to identify best performers and areas of weakness in the sector. The results can help decision-makers better direct investment funds into projects that will further develop the water sector in the country. Water users in Australia can be divided into two groups: (i) agricultural and (ii) residential and industrial. The businesses that supply water to the latter group of consumers can also be divided into two groups: (i) businesses that primarily supply water to small regional towns and rural communities, and (ii) larger businesses that generally supply water to the state capital cities and larger regional cities. The latter group of large businesses are the focus of the present study. This is for two reasons. First, these large businesses are generally owned by state governments or territories and their prices tend to be regulated by independent regulatory agencies, while the smaller businesses are usually owned by local town councils, without formal independent price regulation (Coelli and Shannon, 2005).

Regulation of the water utilities has become increasingly important in the Australian economy. Since the early 1990s a number of reforms have been implemented in the water industry with the aim to obtain a more commercial configuration of the utilities, which generally remains in government ownership. The key changes (Maddock, 1996) introduced concern : (i) a corporate structure of management; (ii) a fair rate of return on capital invested; and (iii) prices set by an independent regulatory authority. Each state and territory has a regulatory authority that is in charge for regulating prices. The different state regulators use similar but not identical methods in regulating water prices. Moreover, the existence of a regulation mechanism affects the productivity evolution of the water utilities (Coelli and Walding, 2005). So in this framework DEA is a particularly powerful tool for assess the effect that the regulation mechanisms have on productivity. Various approaches have been used in the literature to deal with efficiency. One of the most widely known, and accepted, is DEA where the frontier, constructed using linear programming, is the benchmark against which the relative performance of the decision making units (DMU), that is the hospitals in our analysis, is measured. DEA is a non-parametric methodology that constructs an efficiency frontier based on the production units which use the least inputs to produce a certain output or alternatively produce the most output for a given inputs. The production units that lie on the frontier are called efficient. Then, the efficiencies of the other production units are defined relative to these efficient production units. As highlighted by Simar and Wilson (1998) the efficiency calculated by DEA, is an estimate of the true (and unknown) production frontier, conditional on observed data resulting from an underlying data-generating process. As a consequence, DEA efficiencies are biased by construction and are sensitive to the sampling variations of the obtained frontier. So, to overcome this problem, Simar and Wilson (1998) proposed a bootstrap procedure to approximate the sampling distribution of the efficiency scores and to make inferences. The consistency of this procedure was established by Kneip et al. (2011). Most empirical applications of DEA have investigated the efficiency in different fields: utilities (Coelli and Walding, 2005), hospitals (Grosskopf and Valdmanis, 1993; Grosskopf et al., 2001, 2004; Ferrier et al., 2006; Djema and Djerdjouri, 2012; De Nicola et al., 2012; De Nicola et al. 2013a, 2013b), cross country economic growth (Ceccobelli et al., 2011, 2012) and airports (Curi et al., 2008, 2011; Gitto and Mancuso, 2012a, 2012b, De Nicola et al. 2013c). From our search of the published literature, we were unable to identify any studies that have applied these new developments of DEA on Australian water supply businesses. The study is organized as follows. In Section 2, the methodology is described. Section 3 examines the empirical results. Section 4 concludes

2. Methodology

Bootstrap-DEA

We employ DEA to compute the Malmquist productivity index (Färe et al., 1992). We use an input-orientated model because producers are required to meet market demand and can freely adjust the input usage (Lovell, 1993). Following the papers by Simar and Wilson (1998, 1999), we analyze the productivity evolution of water utilities in an inferential setting. In fact, as noted by the two authors, the traditional DEA estimator is biased by construction and is affected by the uncertainty resulting from sample variation. In a deterministic setting, the Malmquist index for each airport, or Decision Making Unit (DMU), is obtained by solving four DEA problems. (See Thanassoulis et al. (2008) and Simar and Wilson (2008) for details.) The DEA basic model, which assumes constant returns to scale everywhere, measures the distance $\Delta_{i,t}(y_{i,t}, x_{i,t})$ of DMU *i,* at time *t,* relative to technology existing at the same period and it is always greater than one. Computing the Malmquist index requires additional distance functions to be defined: $\Delta_{i,t+1}(y_{i,t}, x_{i,t})$ is the distance of DMU *i* at time *t*, relative to technology at the period *t+1*.

The Malmquist input-oriented index between periods *t* and *t+1*, can be defined as (Färe et al. 1992, 1995):

$$M_i^{t,t+1} = \frac{\Delta_{i,t+1}(y_{i,t+1}, x_{i,t+1})}{\Delta_{i,t}(y_{i,t}, x_{i,t})} \times \left(\frac{\Delta_{i,t}(y_{i,t+1}, x_{i,t+1})}{\Delta_{i,t+1}(y_{i,t+1}, x_{i,t+1})} \frac{\Delta_{i,t}(y_{i,t}, x_{i,t})}{\Delta_{i,t+1}(y_{i,t}, x_{i,t})} \right) = Effch_i^{t,t+1} \times Techch_i^{t,t+1} \quad (1)$$

where $Effch_i^{t,t+1}$ and $Techch_i^{t,t+1}$ represent the efficiency change and technological change, respectively. Efficiency change identifies the movements toward the frontier, whereas technological change measures the shift of the frontier. Values of $M_i^{t,t+1}$, $Effch_i^{t,t+1}$, $Techch_i^{t,t+1}$ or less (or greater) than one indicate productivity growth (or decline) for the DMU *i (i=1,2,…,n)* between period *t* and *t+1*. However, relation (1) does not allow us to determine whether changes in productivity, efficiency, or technology are real or merely artifacts of the fact that we do not know the true production frontiers and must estimate them from a finite sample (Simar and Wilson, 1999). Thus, we employ a consistent bootstrap estimation procedure for correcting and obtaining confidence intervals for the Malmquist index and its components two components. The idea underlying the bootstrap is to approximate the sampling distributions of the Malmquist index by simulating the data generating process (DGP). In other terms, given the estimates $\widehat{M}_i^{t,t+1}$of the unknown true values of $M_i^{t,t+1}$ we generate through the DGP process a series of pseudo datasets to obtain bootstrap estimate $\widehat{M}_*^{t,t+1}$. Simar and Wilson (1998) discussed the problems that arise for bootstrapping in DEA models and they suggested the use of a smooth bootstrap procedure. In addition, the Malmquist index uses panel data, with the possibility of temporal correlation. For this reason, Simar and Wilson (1999) modified the bootstrap algorithm for efficiency scores to preserve any temporal correlation present in the data by applying a bivariate smoothing procedure.

The bias-corrected estimates of the Malmquist index, are obtained from:

$$\widetilde{M}_i^{t,t+1} = \widehat{M}_i^{t,t+1} - \widehat{bias}_i = 2\widehat{M}_i^{t,t+1} - B^{-1} \sum_{b=1}^{B} \widehat{M}_{i,b*}^{t,t+1} \quad i=1,\dots,n \quad (2)$$

However, the correction of the bias introduces additional noise, which increase the variance of the estimator. Thus, as rule of thumb, Simar and Wilson (1999) recommended that one not correct for the bias unless $|\widehat{bias}_i| > \sqrt{3}\widehat{std}(\widehat{M}_{i,b*}^{t,t+1})$, where $\widehat{std}(\widehat{M}_{i,b*}^{t,t+1})$ is the sample standard deviation of the bootstrap values. The construction of the confidence intervals is obtained sorting the values $\{\widehat{M}_{i,b*}^{t,t+1} - \widehat{M}_{i}^{t,t+1}\}_{b=1}^{B}$ in increasing order and deletes the $\left(\frac{\alpha}{2}\cdot 100\right)$-percent of the elements at either end of the sorted list. Then, for setting $-\hat{a}_{\alpha}^{*}$ and $-\hat{b}_{\alpha}^{*}$ (with $\hat{a}_{\alpha}^{*} < \hat{b}_{\alpha}^{*}$), which is equal to the endpoints of the sorted array, the estimated $(1-\alpha)$-percent confidence interval for the productivity index is:

$$\widehat{M}_{i}^{t,t+1} + \hat{a}_{\alpha}^{*} \leq M_{i}^{t,t+1} \leq \widehat{M}_{i}^{t,t+1} + \hat{b}_{\alpha}^{*} \quad (3)$$

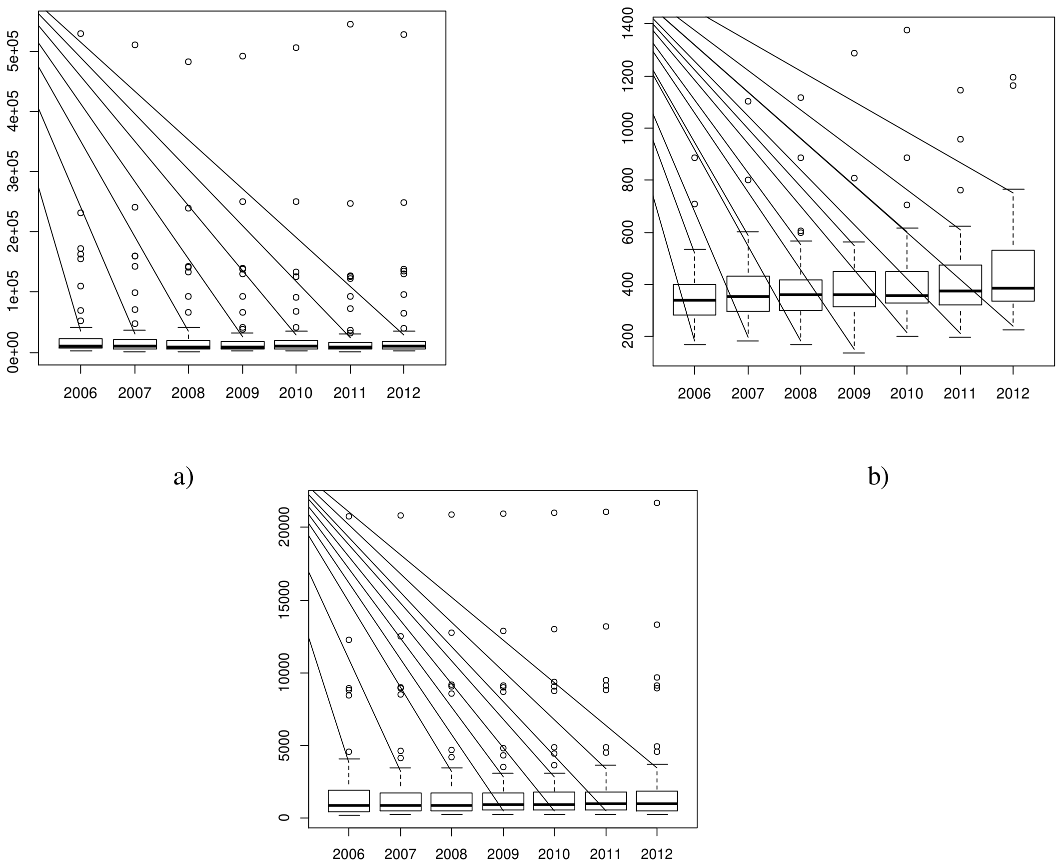
Relations (2) and (3) are similarly computed for the two components of the productivity index: efficiency change and technological change. With the obtained confidence interval for Malmquist index and its components, it is possible to determine whether productivity improvement (or decline) is significant at the established confidence level.

Testing the difference in Malmquist distributions

The main questions of the present paper concern the evaluation of the impact of several environmental variables on Malmquist productivity. To address these questions and to complete the previous analysis, we test for the statistical significance of differences between distributions. We use the test proposed by Li et al. (2009): the null hypothesis states that the two distributions can be considered equal.

3. Data

We consider a balanced panel data of 53 Australian water utility between 2006 and 2012. Our sample includes the main water utility characterized by different ownerships and operational characteristics. Data has been collected from the national performance report (Australian Government -National Water Commission-, 2006-2012). In the computation of the Malmquist index we employ one output, the total urban water supplied *(tuv)* and two inputs: length of water main pipelines *(lwm)* and operating cost *(oc)*. In Figure 1 the boxplots related to the three variables employed in the analysis is shown.



a) b)

c)

Figure 2. Boxplots of the output and inputs. In panel a), the volume of water supplied (ML). In panels b) and c) the operating costs and the length of water main pipelines, respectively, are shown.

From the analysis of Figure 1, panel a), it can be noticed that the total volume of water supplied rose slightly from 2010 to 2012 after a period of steadily decline. Looking at the two inputs, the box-plots in panel b) reveal a progressive increase of the operating cost, especially since 2009 when the dispersion has increased. In other terms the rise of operative costs has not been homogeneous among the 53 water utilities. Finally, panel c) indicates a moderate increase in the length of water main pipelines. One of the most interesting aspects of the Australian water industry is the existence of a alternative approaches, in each state/territory, to the management of the water services in terms of form of ownership and degree of government intervention (i.e. service delivery model and regulatory agencies). In what it follows we classify the 53 water municipality in three groups according to the type of ownership and the degree of state and local government intervention:

1) State Owned utilities servicing entire urban area (SO)
2) Private Integrated utilities (PI)
3) Local Government utilities (LG)

Table 1 shows the distribution of the 53 Australian water utilities by the form of ownership.

Ownership form	Frequency
SO	12
PI	18
LG	23
TOT	53

Table 1. The distribution of the Australian water utilities by ownership form. *SO*= State Owned utilities; *PI*= Private Integrated utilities; *LG*=Local Government utilities.

4. Empirical results

4.1 Preliminary analysis: TF, Effch and Techch

As noticed in the previous section the input and output show an high level of the dispersion over the considered time period. So, the measurement of the TFP should be carefully carried in order to avoid a biased analysis of the productivity evolution. In the present work the choice of the time period to consider to evaluate the performance of the water utility in Australia has been driven by the utilization of three statistical tests. The tests allow to identify if the differences between the TFP and its two component, *Effch* and *Techch*, calculated in two different time periods are statistically significant. In Figure 2 and Table 2 the results of the analysis of the distributions related to two sub-periods, 2006-2009 and 2009-2012, are respectively shown.

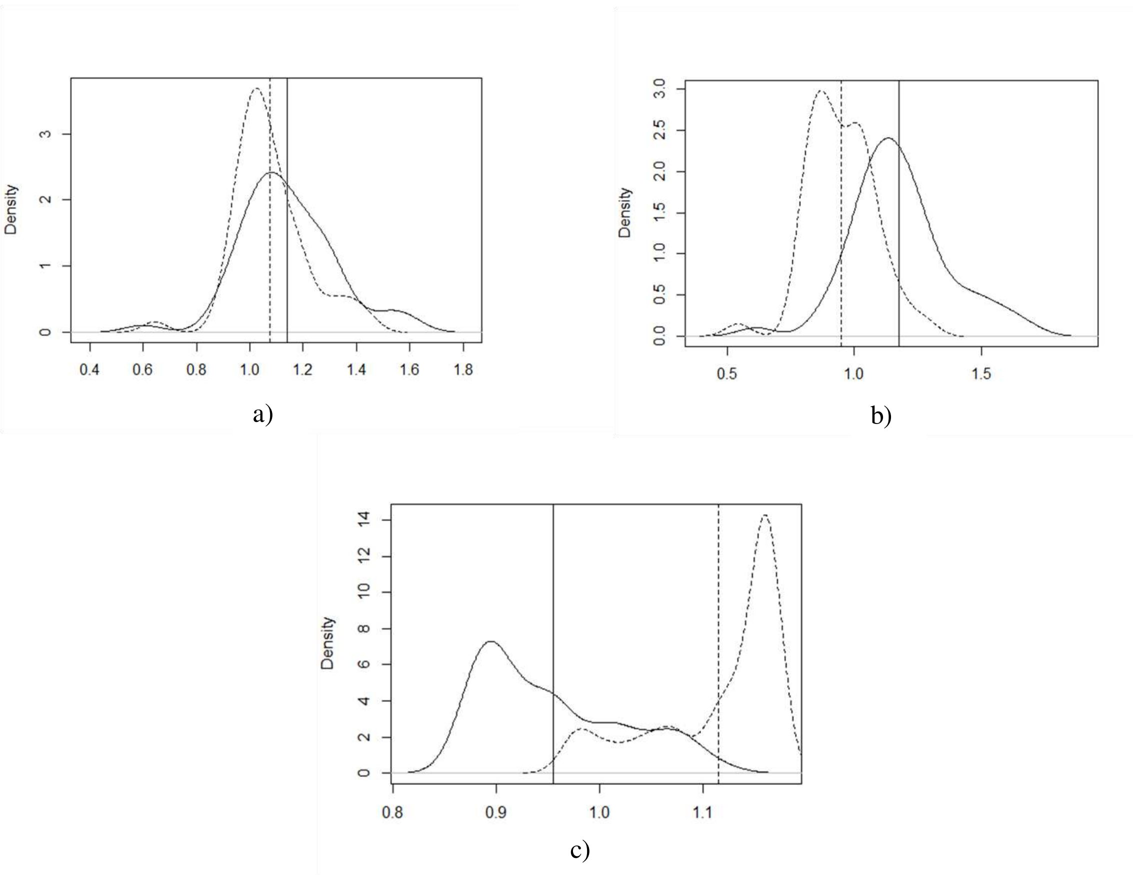


Figure 2. Distributions of TFP, Effch and Techch. The solid line refers to the period 2005-2009, and the dashed line to the period 2009-2012.Vertical lines represent means. In panel a),the TFP distribution are described. In panels b) and c) the distributions of Effch and Techch ,respectively, are shown.

Li's Test			
H_0: equality of distributions	Test Statistic	P-Val	Decision
f(TFP(2006-2008))=f(TFP(2008-2012))	2.629	0.023	H_0 rejected
f(Effch(2006-2008))=f(Effch(2008-2012))	21.466	0.000	H_0 rejected
f(Techch(2006-2008))=f(Techch2008-2012))	12.178	0.000	H_0 rejected
Kolmogorov Smirnov test			
f(TFP(2006-2008))=f(TFP(2008-2012))	0.2453	0.082	H_0 rejected
f(Effch(2006-2008))=f(Effch(2008-2012))	0.6981	0.000	H_0 rejected
f(Techch(2006-2008))=f(Techch(2008-2012))	0.6038	0.000	H_0 rejected
Wilcoxon rank sum test			
Rank(TFP(2006-2008))= Rank(TFP(2008-2012))	1759	0.025	H_0 rejected
Rank(Effchch(2006-2008))= Rank(Effchch(2008-2012))	2412	0.000	H_0 rejected
Rank(Techch(2006-2008))= Rank(Techch(2008-2012))	165	0.000	H_0 rejected

Table 2. Li's Test, Kolmogorov Smirnov Test and Wilcoxon rank sum test.

Figure 2 and Table 2 reveal that in order to obtain a reliable analysis of the productivity evolution of the Australian water utilities the total factor productivity should be separately computed in the two periods: 2006-2009 and 2009-2012. Moreover, the analysis highlights that the main factor that contributes to generate the difference in productivity evolution, between the two periods, is the technological change (see Figure 2, panel c)).

In Figure 3 the evolutions of the TFP, Effch and Techch for the whole time horizon (2006-2012) and the two sub-periods, 2006-2008 and 2008-2012, are shown.

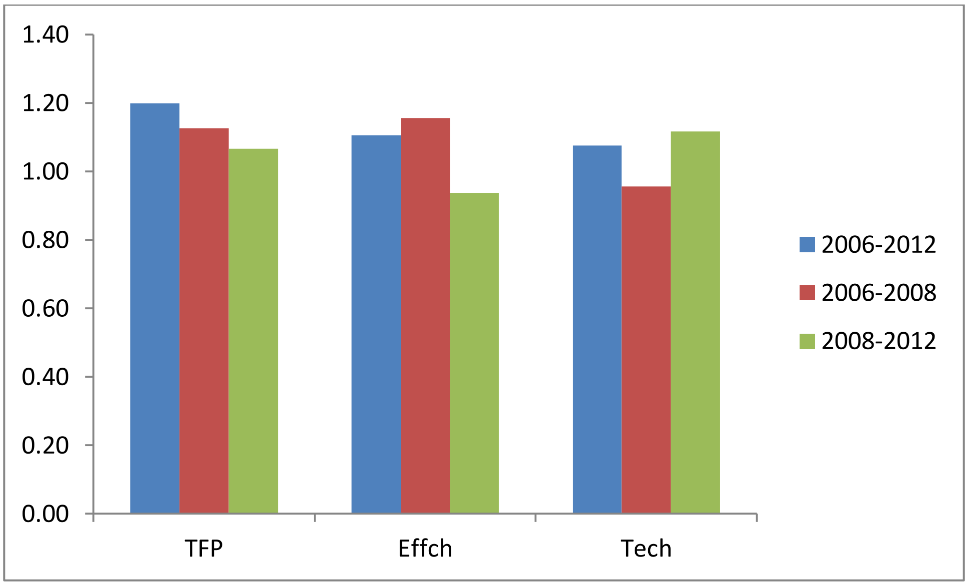


Figure 3. TFP, Effch and Tech evolutions.

Looking at the table it can be noticed that the total factor productivity of the Australian water sector has experienced a decline in productivity of about 20% over the period 2009-2012. However, the decline has been higher in the first period (2006-2009) than in the second one. Moreover, the main source of the productive slowdown is clearly different in the two periods. In fact, while during the first three years the efficiency change is the main cause of the decline in the TPP the opposite has occurred from 2009 to 2012 when technological change has had a negative effect on the productivity evolution of the Australian water utilities.

4.2. The effect of ownership

After obtaining the estimates of the TFP, Ecch and Techch, we use the kernel density estimator to evaluate if the alternative forms of ownership result in differential impacts on the productivity evolution and its main components. The analysis has been conducted separately for the two sub-periods. For the period 2006-2009 the results are shown in Figure 4 and Table 3.

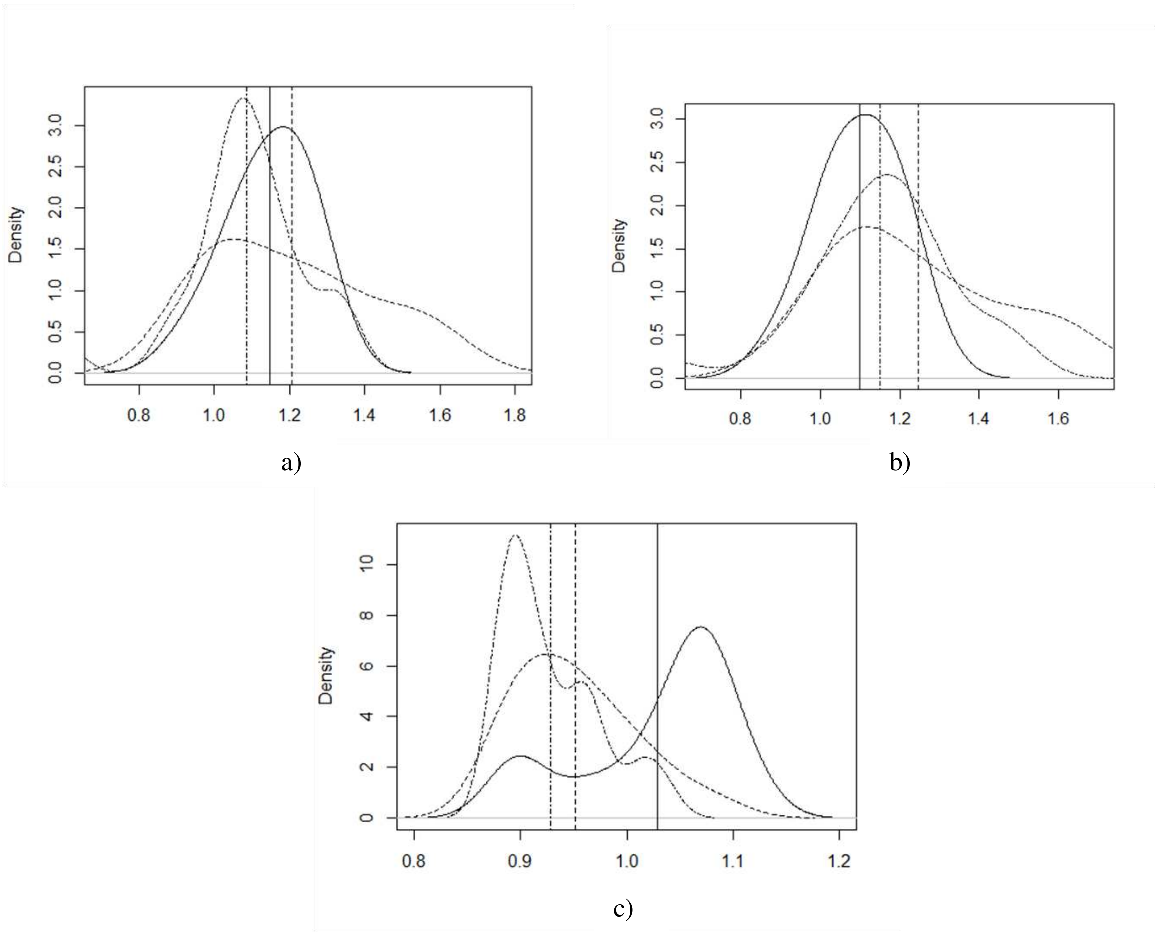


Figure 4. Distributions of TFP, Effch and Techch in the period 2006-2009. The solid line refers to the State owned utilities, the dashed line to the private integrated utilities and the dash dotted line to the local government utilities. Vertical lines represent means. In panel a), the TFP distribution are described. In panels b) and c) the distributions of Effch and Techch, respectively, are shown.

Li's Test			
H_0: equality of distributions	Test Statistic	P-Val	Decision
f(TFP(of=SO)=f(TFP(of=PI))	0.782	0.017	H_0 is not rejected
f(TFP(of=SO))=f(TFP(of=LG))	0.246	0.263	H_0 is not rejected
f(TFP(of=PI))=f(TFP(of=LG))	-0.198	0.222	H_0 is not rejected

f(Effch(of=SO)=f(Effch(of=PI))	0.285	0.171	H_0 is not rejected
f(Effch(of=SO))=f(Effch(of=LG))	-0.339	0.258	H_0 is not rejected
f(Effch(of=PI))=f(Effch(of=LG))	0.652	0.648	H_0 is not rejected
f(Techch(of=SO)=f(Techch (of=PI))	3.205	0.005	H_0 rejected
f(Techch(of=SO))=f(Techch(of=LG))	5.90	0.003	H_0 rejected
f(Techch(of=PI))=f(Techch(of=LG))	2.301	0.451	H_0 rejected

Table 2. Li's Test on TFP, Effch and Techch. *of*=ownership form; *SO*= State Owned utilities; *PI*= Private Integrated utilities; *LG*=Local Government utilities. Time period 2006-2009.

The results reported in the Figure 4 and the Table 3 highlights that while there are not significant differences in the TFP and in the Effch among the three alternative forms of governance. On the contrary we can conclude that the State owned utilities servicing entire urban area have been characterized, on average, by a significant technological decline. Taking into consideration the second period, 2009-2012 (Figure 5 and Table 4), further insight can be obtained.

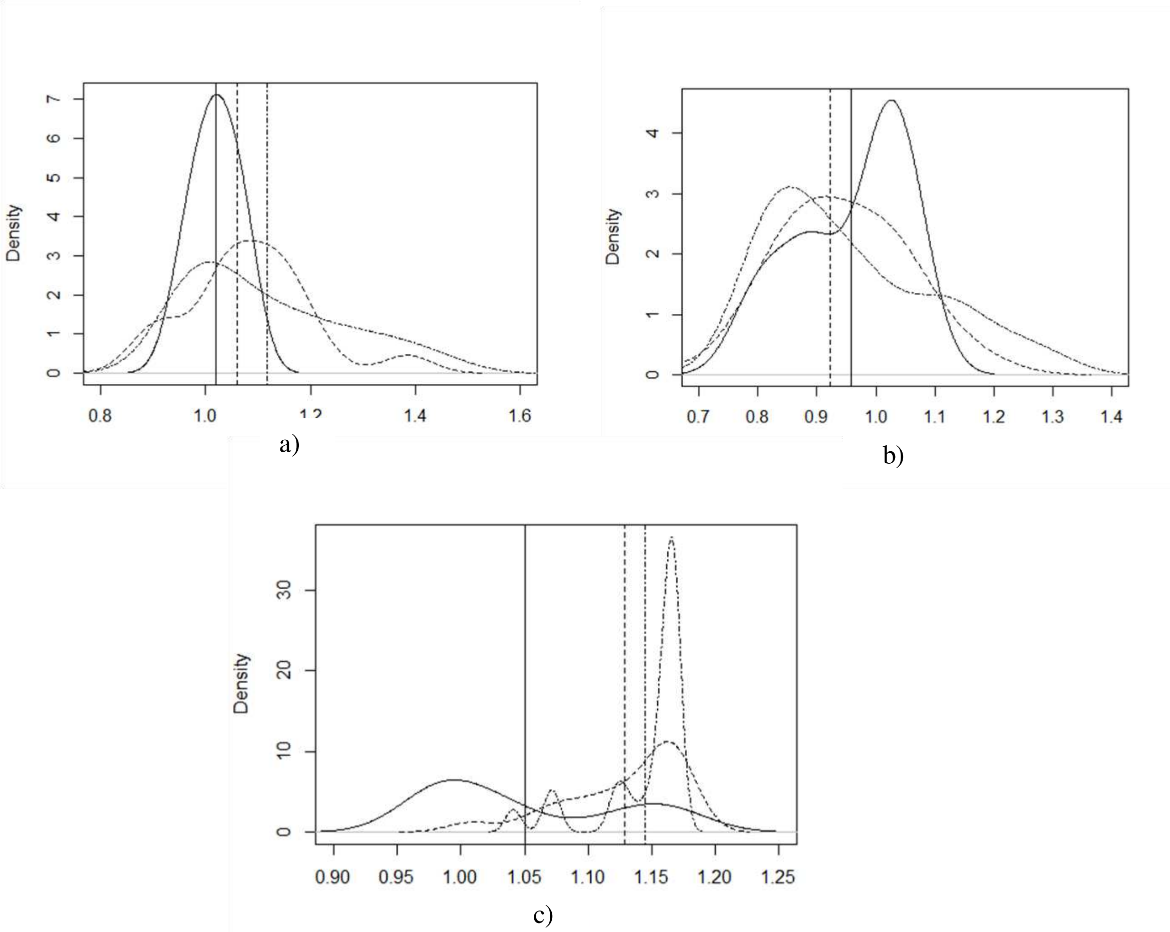


Figure 5. Distributions of TFP, Effch and Techch in the period 2009-2012. The solid line refers to the State owned utilities, the dashed line to the private integrated utilities and the dash dotted line to the local government utilities. Vertical lines represent means. In panel a), the TFP distribution are described. In panels b) and c) the distributions of Effch and Techch, respectively, are shown.

Li's Test			
H_0: equality of distributions	Test Statistic	P-Val	Decision
f(TFP(of=SO)=f(TFP(of=PI))	1.640	0.009	H_0 is not rejected
f(TFP(of=SO))=f(TFP(of=LG))	0.893	0.041	H_0 is not rejected
f(TFP(of=PI))=f(TFP(of=LG))	0.770	0.648	H_0 is rejected
f(Effch(of=SO)=f(Effch(of=PI))	-1.099	0.047	H_0 is rejected
f(Effch(of=SO))=f(Effch (of=LG))	1.478	0.036	H_0 is not rejected
f(Effch(of=PI))=f(Effch (of=LG))	1.105	0.547	H_0 is not rejected
f(Techch(of=SO)=f(Techch(of=PI))	2.375	0.008	H_0 is not rejected
f(Techch(of=SO))=f(Techch(of=LG))	7.004	0.000	H_0 is not rejected
f(Techch(of=PI))=f(Techch(of=LG))	4.399	0.195	H_0 is rejected

Table 4. Li's Test on TFP, Effch and Techch. *of*=ownership form; *SO*= State Owned utilities; *PI*= Private Integrated utilities; *LG*=Local Government utilities. Time period 2009-2012.

The analysis of the TFP distributions, panel a), and the Li' tests reveal that in the period from 2009 to 2012 the State owned utilities have exerted an productive performance which is statistically better than those achieved by the private integrated and local government utilities. Moreover, all the water utilities have obtained productivity gain trough a better input-output configuration, see panel b). Finally the distributions of the Techch, panel c), indicate a technology decline which is higher for private integrated and local government utilities than State owned ones.

5. Conclusion

The present paper employing a bootstrapped DEA techniques to estimate TFP and its two main components, efficiency and technical change, offers an interesting analysis on the relation between the productive evolution and the forms of governance of 53 Australian water utilities over the period 2006-2012. The paper highlights as the water industry as steadily declined its efficiency especially during the two last year of the considered time horizon. Under a political perspective the empirical analysis highlights as the Government utilities as has marked the highest slowdown in the productivity evolution mostly lead by a technological regress.

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