PROFIT, PRODUCTIVITY AND PRICE PERFORMANCE CHANGES IN THE WATER AND SEWERAGE INDUSTRY: AN EMPIRICAL APPLICATION FOR ENGLAND AND WALES.

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Abstract

This paper aims to analyse the impact of regulation in the financial performance of the Water and Sewerage companies (WaSCs) in England and Wales over the period 1991-2008. In doing so a panel index approach is applied across WaSCs over time to decompose unit-specific index number based profitability growth as a function of the profitability, productivity and price performance growth achieved by benchmark firms, and the catch-up to the benchmark firm achieved by less productive firms. The results indicated that after 2000 there is a steady decline in average price performance while productivity improves resulting in a relatively stable economic profitability. It is suggested that the English and Welsh water regulator is now more focused on passing productivity benefits to consumers, and maintaining stable profitability than it was in earlier regulatory periods. This technique is of great interest for regulators to evaluate the effectiveness of regulation and companies to identify the determinants of profit change and improve future performance, even if sample sizes are limited.

Keywords: Profit Decomposition, Total Factor Productivity, Price Performance, Panel Index Numbers, Regulation, Water and Sewerage Industry.

1. INTRODUCTION

A firm's economic performance is commonly measured by its economic profitability (π). However, changes in profitability can be decomposed into changes in productivity and price performance (Chang et al., 2014). Total factor productivity (TFP) captures changes in performance attributable to increased physical production of outputs relative to inputs. In contrast, total price performance (TPP) captures the impact of changes in output prices relative to input prices. Comparing changes in TFP and TPP therefore allows determination of whether profit change is primarily explained by improvements in productivity or is attributable to an increase in output prices relative to input prices that has improved the firm's price mark up relative to actual costs.

The assessment of TFP and TPP changes is a key tool in business economics to improve the competitiveness of the evaluated sector (Lawrence et al., 2006). In many countries such as UK, Colombia, Argentina, Brazil or Portugal water industry was privatised and regulated and therefore water management and efficiency became subjects of utmost importance for researchers and decision-makers (Schuster and Edelman, 2003; Estache and Trujillo, 2003; Marques, 2008; Marques et al., 2011; Molinos-Senante et al., 2014a). In this context, benchmarking and TFP analysis in particular are essential since they allow to monitoring activity firms, i.e., assessing how the firm is doing over time and to comparing firm performance with respect of its main competitors (Epure et al., 2011). More specifically, in CPI-X price regulation, the assessment of the productivity change is even more important since X-factor reflects the degree to which the regulator believes the business can improve their productivity (Coelli et al., 2005). In CPI-X price regulation, the regulated business is allowed to increase its prices over a particular period by the change in the consumer price index (CPI) minus (or plus) an X factor. Such factor reflects the degree to which the regulator believes the business can improve their productivity, therefore, it is known as productivity offset.

Methods used to compute TFP and TPP could be categorised as frontier and non-frontier. The first approach uses the outputs and inputs data of the units evaluated to estimate the efficient frontier of production. A pitfall of frontier techniques is that a significant number of units are needed to perform the assessment (Carvalho and Marques, 2014). In other words, its application is limited by the requirement of having a sufficient number of freedom degrees to estimate a meaningful parametric or non-parametric frontier. The main advantage of non-frontier techniques such as the index number based approach is that they can be applied to decompose profitability growth regardless of the number of inputs and outputs specified, even in cases were the number of observations are extremely limited (Fox et al., 2003). This advantage is extraordinarily important in the framework of regulated industries where the number of companies operating at country level might be small. Moreover, while profit decomposition approaches with frontier techniques allow for the impact of differences in relative performance on the production side, it has not, to our knowledge, yet been extended to allow for differences between firms in price performance.

The index numbers may be used to quantify changes in time, space or both. Hence, the indexes are used to assess prices and quantities over time, i.e., TPP and TFP, as well as to gauge their differences among companies within the industry (Fox et al., 2003; Salerian, 2003; Lawrence et al., 2006). From a policy perspective, the assessment of the TPP and TFP change provides useful information about the effects of shifts in regulation, level of inputs used, price fluctuations and other factors on firm and industry performance.

The usefulness of the index number approach in the framework of regulated water industry was evidenced by Saal and Parker (2001) who decomposed the economic profitability change of the English and Welsh water and sewerage companies (WaSCs) into TFP change and TPP change. This paper illustrated how changes in regulatory policy of the UK industry influenced both the productivity and price performance of WaSCs. Despite the advantages of this methodological approach, the lack of any link between water companies´ indices makes it impossible to measure differences in the level of TFP, TPP and profitability across firms. The implication of this limitation is highlighted in the framework of the UK water industry since it is subject to price cap regulation in which price are set using a comparative yardstick regime that measures firm performance levels to other regulated water companies.

More recently, Maziotis et al. (2009), following Ball et al. (2001) and Fox et al. (2003) approaches, developed a cross sectorial (spatial) index number technique to allow for the measurement of changes in productivity, regulatory price performance and profitability across English and Welsh WaSCs. As well as Fox et al. (2003), in the index number approach computed by Maziotis et al. (2009) the performance of all firms was compared to the most profitable or productive firm, respectively. Hence, the limitation of these papers is that did not measure how the performance of less profitable/productive firms towards the best practice firm changed over time (catch-up) and changes in the performance of best practice firm over time (frontier shift). In the regulatory analysis of water industry, catch-up and frontier shift measures are of great significance (Coelli and Walding, 2006; Lawrence and Kain, 2012).

To overcome these limitations we follow the methodological framework suggested by Hill (2002, 2004) and further applied by Ball et al. (2001); Fox et al. (2003); Pierani (2009) to allow for quantity and price indexes that span both multiple firms a given time (multilateral spatial index) and a single firm over multiple periods (temporal indexes). The main advantage of the methodological approach proposed is that separate spatial and unit-specific profitability, TFP and TPP indexes are reconciled into a single index. Unlike Waters and Tretheway (1999), Han and Hughes (1999), Saal and Parker (2001) or Salerian (2003) our approach not only allows for indexes of unit-specific profitability, TFP and TPP changes but also allows spatially consistent measures in changes in these performance measures relative to other firms. The empirical application developed in this paper focused on English and Welsh water industry. Nevertheless, the methodology proposed could be applied to decompose profitability in other regulated industries.

The main aim of this study is to analyse the impact of regulation on the financial performance of WaSCs in England and Wales over the period 1991-2008. In doing so, the profit changes and their decomposition into TFP change and TPP change are computed. The decomposition of a firms´ performance changes is highly relevant in regulatory framework. Hence, the results of this study are expected to be of great interest to a wide range of professionals, including policy makers, water regulators, water companies´ managers and researchers since it provides sound scientific baseline information to better decision-making aimed to improve management and water industry performance.

This paper unfolds as follows. Section 2 discusses the potential application of index number techniques for measuring profitability, productivity and price performance in a binary context. Section 3, then considers the methodology necessary to empirically apply this approach in a multilateral setting, whereas section 4 discusses the data that were used in this study. The following section provides an application of this methodology followed by a discussion of empirical results. The last section offers some conclusions.

2. METHODOLOGY

2.1 Profitability, Productivity and Price Performance: A Theoretical Illustration with Bilateral Indices

Our analysis illustrates several theoretically related methods to measure and decompose financial performance across companies and over time. Firstly, we provide measures of temporal (unit-specific) profitability, productivity and price performance across time for each firm. Secondly, we allow profitability, productivity and price performance comparisons across companies at any given year (multilateral spatial comparisons). Thirdly, by reconciling together the temporal and spatial profitability, productivity and price performance into relative profitability, productivity and price performance measures, we provide a single index that consistently measures performance change between both firms and over time. Finally, the reconciliation of the spatial, temporal and relative profitability, productivity and price performance measures allows us to decompose the unit-specific index based number profitability growth as a function of the profitability, productivity, price performance growth achieved by benchmark firms, and the catch-up to the benchmark firm achieved by less productive firms.

According to Han and Hughes (1999), Waters and Tretheway (1999), Saal and Parker (2001) and Salerian (2003), the unit specific profitability can be decomposed in productivity and price performance. Economic profits of firm i at the base year 1, $\Pi_{i,1}$ are defined as a ratio of total revenues, $R_{i,1}$ and total costs in year 1, $C_{i,1}$. Total revenues of a firm i at period $1, R_{i,1}$, are defined as $R_{i,1} = P_{i,1} \times Y_{i,1}$, where $P_{i,1}$ and $Y_{i,1}$ respectively represent the output price index and the aggregate output index at period 1. Similarly, $C_{i,1} = W_{i,1} \times X_{i,1}$ It can be defined and decomposed a unit-specific index of economic profitability for firm i at period t relative to the base period 1, $\pi_{i,t}^{US}$, as follows:

$$\pi_{i,t}^{US} = \frac{\Pi_{i,t}}{\Pi_{i,1}} = \frac{\frac{R_{i,t}}{C_{i,t}}}{\frac{R_{i,1}}{C_{i,1}}} = \frac{\frac{P_{i,t}Y_{i,t}}{W_{i,t}X_{i,t}}}{\frac{P_{i,1}Y_{i,1}}{W_{i,1}X_{i,1}}} = \frac{TFP_{i,t}}{TFP_{i,1}} \times \frac{TPP_{i,t}}{TPP_{i,1}} = \frac{\frac{Y_{i,t}}{Y_{i,1}}}{\frac{X_{i,t}}{X_{i,1}}} \times \frac{\frac{P_{i,t}}{P_{i,1}}}{\frac{W_{i,t}}{W_{i,1}}} = \frac{Y_{i,t}^{US}}{X_{i,t}^{US}} \times \frac{P_{i,t}^{US}}{W_{i,t}^{US}} = TFP_{i,t}^{US} \times TPP_{i,t}^{US} \quad (1)$$

As $TFP_{i,t}^{US} = Y_{i,t}^{US} / X_{i,t}^{US}$ and $TPP_{i,t}^{US} = P_{i,t}^{US} / W_{i,t}^{US}$ these indices can be further decomposed as functions of the unit-specific output ($Y_{i,t}^{US} = Y_{i,t} / Y_{i,1}$), input ($X_{i,t}^{US} = X_{i,t} / X_{i,1}$), output price ($P_{i,t}^{US} = P_{i,t} / P_{i,1}$) and input price ($W_{i,t}^{US} = W_{i,t} / W_{i,1}$) indices.

We next consider the relationship between profits, productivity and price performance for firm i relative to a base firm b at time t, which we call a spatial index. We define the economic profits of the base firm b at time t, $\Pi_{b,t}$, as a ratio of its total revenues, $R_{b,t}$ and total costs, $C_{b,t}$, at time t. Thus, $R_{b,t} = P_{b,t} \times Y_{b,t}$ and $C_{b,t} = W_{b,t} \times X_{b,t}$, where $P_{b,t}$ and $Y_{b,t}$ present the output price index and the aggregate output index respectively and $W_{b,t}$ and $X_{b,t}$ denotes the input price index and the aggregate input index respectively of the base firm at year t. Similarly, we can define economic profits of any firm i at period t, $\Pi_{i,t}$ as a ratio of its total revenues, $R_{i,t}$ and its total costs, $C_{i,t}$. We can thus define and decompose a spatial economic profitability index for any firm i relative to the base firm b at period t, $\pi_{b,t}^{S}$ as follows:

$$\pi_{i,t}^{S} = \frac{\Pi_{i,t}}{\Pi_{b,t}} = \frac{\frac{R_{i,t}}{C_{i,t}}}{\frac{R_{b,t}}{C_{b,t}}} = \frac{\frac{P_{i,t}Y_{i,t}}{W_{i,t}X_{i,t}}}{\frac{P_{b,t}Y_{b,t}}{W_{b,t}X_{b,t}}} = \frac{TFP_{i,t}}{TFP_{b,t}} \times \frac{TPP_{i,t}}{TPP_{b,t}} = \frac{\frac{Y_{i,t}}{Y_{b,t}}}{\frac{X_{i,t}}{X_{b,t}}} \times \frac{\frac{P_{i,t}}{P_{b,t}}}{\frac{W_{i,t}}{W_{b,t}}} = \frac{Y_{i,t}^{S}}{X_{i,t}^{S}} \times \frac{P_{i,t}^{S}}{W_{i,t}^{S}} = TFP_{i,t}^{S} \times TPP_{i,t}^{S} \quad (2)$$

As $TFP_{i,t}^{S}=Y_{i,t}^{S}/X_{i,t}^{S}$ and $TPP_{i,t}^{S}=P_{i,t}^{S}/W_{i,t}^{S}$ these indices can be further decomposed as functions of the spatial output ($Y_{i,t}^{S}=Y_{i,t}/Y_{b,t}$), input ($X_{i,t}^{S}=X_{i,t}/X_{b,t}$), output price ($P_{i,t}^{S}=P_{i,t}/P_{b,t}$) and input price ($W_{i,t}^{S}=W_{i,t}/W_{b,t}$) indices.

By definition spatial indices estimate firm *i*'s performance relative to any potential base firm *b,* and therefore should have potential applications in regulatory settings on this basis alone. However, spatial measures also contain information on relative performance across firms, which unit-specific indices do not. Spatial performance indices can therefore also be employed to measure catch up in relative performance. Thus, if we have access to data for the base year 1 and any other year t, we can define and decompose an index of economic profitability catch up for any firm i at time t and relative to the base firm b at period t, $\pi_{i,t}^{C}$,as follows:

$$\pi_{i,t}^{C}=\frac{\pi_{i,t}^{S}}{\pi_{i,1}^{S}}=\frac{TFP_{i,t}^{S}}{TFP_{i,1}^{S}}\times\frac{TPP_{i,t}^{S}}{TFP_{i,1}^{S}}=\frac{\dfrac{Y_{i,t}^{S}}{Y_{i,1}^{S}}}{\dfrac{X_{i,t}^{S}}{X_{i,1}^{S}}}\times\frac{\dfrac{P_{i,t}^{S}}{P_{i,1}^{S}}}{\dfrac{W_{i,t}^{S}}{W_{i,1}^{S}}}=\frac{Y_{i,t}^{C}}{X_{i,t}^{C}}\times\frac{P_{i,t}^{C}}{W_{i,t}^{C}}=TFP_{i,t}^{C}\times TPP_{i,t}^{C} \tag{3}$$

As $TFP_{i,t}^{C}=Y_{i,t}^{C}/X_{i,t}^{C}$ and $TPP_{i,t}^{C}=P_{i,t}^{C}/W_{i,t}^{C}$ these indices can be further decomposed as functions of catch up indices for outputs ($Y_{i,t}^{C}=Y_{i,t}^{S}/Y_{i,1}^{S}$), inputs ($X_{i,t}^{C}=X_{i,t}^{S}/X_{i,1}^{S}$), output prices ($P_{i,t}^{C}=P_{i,t}^{S}/P_{i,1}^{S}$) and input prices ($W_{i,t}^{C}=W_{i,t}^{S}/W_{i,1}^{S}$). This decomposition of profitability catch up highlights that a firm's catch up in profitability can be explained not only by improving its productivity performance relative to the base firm, but also by improving its price performance relative to the base firm. Thus, evidence of improved relative profitability cannot be taken as definitive evidence of improved productivity performance.

Subsequently, we define the relationship between profits, productivity and price performance for any firm i at any time *t* relative to a base firm b at the base time 1. As by construction these indices are measured relative to a constant base for all t and all i, they therefore capture differences in both the spatial and the temporal dimensions for any given firm at any given time.

We define the economic profits of the base firm b at year 1, $\Pi_{b,1}$, as a ratio of its total revenues, $R_{b,1}$ and total costs, $C_{b,1}$, at year 1. Thus, $R_{b,1} = P_{b,1} \times Y_{b,1}$ and $C_{b,1} = W_{b,1} \times X_{b,1}$, where $P_{b,1}$ and $Y_{b,1}$ present the output price index and the aggregate output index respectively and $W_{b,1}$ and $X_{b,1}$ denotes the input price index and the aggregate input index respectively of the base firm at year 1. We can thus define and decompose a relative index of economic profitability change at time t for firm i relative to the base firm b at time 1, $\pi_{i,t}^{R}$, as follows:

$$\pi_{i,t}^{R} = \frac{\Pi_{i,t}}{\Pi_{b,1}} = \frac{\frac{R_{i,t}}{C_{i,t}}}{\frac{R_{b,1}}{C_{b,1}}} = \frac{\frac{P_{i,t}Y_{i,t}}{W_{i,t}X_{i,t}}}{\frac{P_{b,1}Y_{b,1}}{W_{b,1}X_{b,1}}} = \frac{TFP_{i,t}}{TFP_{b,1}} \times \frac{TPP_{i,t}}{TPP_{b,1}} = \frac{\frac{Y_{i,t}}{Y_{b,1}}}{\frac{X_{i,t}}{X_{b,1}}} \times \frac{\frac{P_{i,t}}{P_{b,1}}}{\frac{W_{i,t}}{W_{b,1}}} = \frac{Y_{i,t}^{R}}{X_{i,t}^{R}} \times \frac{P_{i,t}^{R}}{W_{i,t}^{R}} = TFP_{i,t}^{R} \times TPP_{i,t}^{R} \tag{4}$$

Thus, for firm i at time t, the relative economic profitability index, $\pi_{i,t}^{R}$ can be expressed as a function of an index of relative total factor productivity for firm i at time t relative to the base firm *b* at time 1, $TFP_{i,t}^{R}$,and an index of total price performance for firm i at time t relative to the base firm *b* at time 1,, $TPP_{i,t}^{R}$. As $TFP_{i,t}^{R} = Y_{i,t}^{R} / X_{i,t}^{R}$ and $TPP_{i,t}^{R} = P_{i,t}^{R} / W_{i,t}^{R}$ these indices can be further decomposed as functions of the relative output ($Y_{i,t}^{R} = Y_{i,t} / Y_{b,1}$), input ($X_{i,t}^{R} = X_{i,t} / X_{b,1}$), output price ($P_{i,t}^{R} = P_{i,t} / P_{b,1}$) and input price ($W_{i,t}^{R} = W_{i,t} / W_{b,1}$) indices.

Given the binary definition of $\pi_{i,t}^{R}$ and its components these relative performance estimates are theoretically equivalent to the separate binary performance estimates provided by the unit-specific and spatial performance measures. Thus, as $\pi_{i,t}^{US} = \pi_{i,t}^{R} / \pi_{i,1}^{R}$, $TFP_{i,t}^{US} = TFP_{i,t}^{R} / TFP_{i,1}^{R}$, $TPP_{i,t}^{US} = TPP_{i,t}^{R} / TPP_{i,1}^{R}$, $Y_{i,t}^{US} = Y_{i,t}^{R} / Y_{i,1}^{R}$, $X_{i,t}^{US} = X_{i,t}^{R} / X_{i,1}^{R}$, $P_{i,t}^{US} = P_{i,t}^{R} / P_{i,1}^{R}$ and $W_{i,t}^{US} = W_{i,t}^{R} / W_{i,1}^{R}$ it is straightforward to demonstrate that $\pi_{i,t}^{US}$ can be estimated and fully decomposed as a function of relative performance measure estimates.

$$\pi_{i,t}^{US}=\frac{\pi_{i,t}^{R}}{\pi_{i,1}^{R}}=\frac{\frac{Y_{i,t}^{R}}{Y_{i,1}^{R}}}{\frac{X_{i,t}^{R}}{X_{i,1}^{R}}}\times\frac{\frac{P_{i,t}^{R}}{P_{i,1}^{R}}}{\frac{W_{i,t}^{R}}{W_{i,1}^{R}}}=\frac{TFP_{i,t}^{R}}{TFP_{i,1}^{R}}\times\frac{TPP_{i,t}^{R}}{TPP_{i,1}^{R}} \tag{5}$$

Similarly:

$$\pi_{i,t}^{S}=\frac{\pi_{i,t}^{R}}{\pi_{b,t}^{R}}=\frac{\frac{Y_{i,t}^{R}}{Y_{b,t}^{R}}}{\frac{X_{i,t}^{R}}{X_{b,t}^{R}}}\times\frac{\frac{P_{i,t}^{R}}{P_{b,t}^{R}}}{\frac{W_{i,t}^{R}}{W_{b,t}^{R}}}=\frac{TFP_{i,t}^{R}}{TFP_{b,t}^{R}}\times\frac{TPP_{i,t}^{R}}{TPP_{b,t}^{R}} \tag{6}$$

Estimates of $\pi_{i,t}^{C}$ can then be constructed with the underlying relative profitability indices, and can in fact be constructed as the ratio of either unit specific or spatial indices as defined in (5) and (6). This also clearly demonstrates that the catch up index is, at its core, simply a ratio of unit specific profitability growth rates.

$$\pi_{i,t}^{C}=\frac{\pi_{i,t}^{S}}{\pi_{i,1}^{S}}=\frac{\frac{\pi_{i,t}^{R}}{\pi_{b,t}^{R}}}{\frac{\pi_{i,1}^{R}}{\pi_{b,1}^{R}}}=\frac{\frac{\pi_{i,t}^{R}}{\pi_{i,1}^{R}}}{\frac{\pi_{b,t}^{R}}{\pi_{b,1}^{R}}}=\frac{\pi_{i,t}^{US}}{\pi_{b,t}^{US}} \tag{7}$$

Moreover, by rearranging (7) and decomposing the profitability index we can write:

$$\pi_{i,t}^{US}=\pi_{i,t}^{C}\times\pi_{b,t}^{US}=\left(TFP_{i,t}^{C}\times TFP_{b,t}^{US}\right)\times\left(TPP_{i,t}^{C}\times TPP_{b,t}^{US}\right) \tag{8}$$

The temporal economic profitability of a firm i over time, $\pi_{i,t}^{US}$ can be decomposed as a function of the profitability growth of the base firm b, $\pi_{b,t}^{US}$ and the profitability catch-up of the firm i relative to the base firm between year 1 and t, $\pi_{i,t}^{C}$, e.g. profit performance of any firm can be decomposed into a measure capturing the profit change of a reference firm, and the given firm's performance change relative to that reference firm. If $\pi_{i,t}^{C}>1$, then firm i improved its economic profitability relative to the base firm over time, whereas $\pi_{i,t}^{C}<1$ implies that relative profitability of firm i has declined relative to that of the base firm. Moreover, as Eq. (8)

demonstrates, $\pi_{i,t}^{US}$ can be further decomposed to measure not only the relative contributions of unit specific measures of price performance and productivity to profitability, but also to measure these unit specific changes relative to change in TFP and TPP for the base firm.

Equation (8) highlights the strong potential to apply this index based approach to regulatory settings such as water industry where it is desirable to not only measure firm performance, but also to judge that performance relative to a base firm, normally defined as a "best practice" or "benchmark" firm. The decomposition of the unit specific profitability change in Equation (8) can be visualized in Figure 1. Temporal economic profitability change can be expressed as a function of the profitability growth of the benchmark firm and the profitability catch-up relative to the benchmark firm. Moreover, unit specific economic profitability change can be further decomposition into a unit specific productivity and price performance change. The former can be expressed as a function of a function of the productivity growth of the benchmark firm and the productivity catch-up relative to the benchmark firm, whereas the latter can be expressed as a function of the price performance growth of the benchmark growth and the price performance catch-up relative to the benchmark firm.

INSERT FIGURE 1

2.2. Multilateral Productivity, Price Performance and Profitability Computations in Practice

In this section we calculate chained unit-specific profitability, productivity and price performance growth following Han and Hughes (1999), Waters and Tretheway (1999) and Saal and Parker's approach (2001). We thus measure these performance measures for any firm between two time periods by using a temporal Fisher index number approach.

Temporal Fisher output and input indexes between two time periods 1 and t, where 1 is the base period in the case of m outputs and n inputs for a firm i are respectively, $Y_{i,t}$ and $X_{i,t}$, :

$$Y_{i,t} = [\frac{\sum_{m=1}^{M} P_1^m Y_t^m}{\sum_{m=1}^{M} P_1^m Y_1^m} \times \frac{\sum_{m=1}^{M} P_t^m Y_t^m}{\sum_{m=1}^{M} P_t^m Y_1^m}]^{\frac{1}{2}} \qquad X_{i,t} = [\frac{\sum_{n=1}^{N} W_1^n X_t^n}{\sum_{n=1}^{N} W_1^n X_1^n} \times \frac{\sum_{n=1}^{N} W_t^n X_t^n}{\sum_{n=1}^{N} W_t^n X_1^n}]^{\frac{1}{2}} \qquad (9)$$

where Y_t^m and Y_1^m denote the quantities for the mth output for periods t and 1 respectively, whereas X_t^n and X_1^n present the quantities for the nth inputs for periods t and 1 respectively. Moreover, P_t^m and P_1^m are the prices for mth output, while W_t^n and W_1^n denote the input prices. A temporal Fisher productivity index, $TFP_{i,t}$ is then constructed as a ratio of Fisher output index relative to Fisher input index, which takes the value 1 in the year 1:

$$TFP_{i,t} = \frac{Y_{i,t}}{X_{i,t}} \tag{10}$$

A temporal Fisher productivity index can be used in the unchained form denoted above or in a chained form where weights are more closely matched to pair-wise comparisons of observations (Diewert and Lawrence, 2006). The unit-specific output and input indices are thus chained indices, $Y_{i,t}^{CH}$ and $X_{i,t}^{CH}$ between observations 1 and t which are given by:

$$Y_{i,t}^{CH} = 1 \times Y_{i,1,2} \times Y_{i,2,3} \times \ldots \times Y_{i,t-1,t} \qquad X_{i,t}^{CH} = 1 \times X_{i,1,2} \times X_{i,2,3} \times \ldots \times X_{i,t-1,t} \tag{11}$$

The unit-specific productivity of a firm i over time can be similarly calculated as a chained index, although it can be equivalently calculated as a ratio of the chained unit-specific output and input indices over time, $Y_{i,t}^{CH}$ and $X_{i,t}^{CH}$:

$$TFP_{i,t}^{CH} = \frac{Y_{i,t}^{CH}}{X_{i,t}^{CH}} \tag{12}$$

To derive TPP index we firstly express unit-specific turnover at period t relative to the base year 1 as $R_{i,t}^{US} = R_{i,t} / R_{i,1}$. The chained unit-specific aggregate output price index, $\left(P_{i,t}^{CH}\right)$ is then calculated as $P_{i,t}^{CH} = R_{i,t}^{US} \big/ Y_{i,t}^{CH}$. Similarly, we express unit-specific nominal economic costs at period t relative to the base year 1 as $C_{i,t}^{US} = C_{i,t} / C_{i,1}$. The chained unit-specific aggregate input price index, $\left(W_{i,t}^{CH}\right)$ is then calculated as $W_{i,t}^{CH} = C_{i,t}^{US} \big/ X_{i,t}^{CH}$. Finally, a chained unit-specific TPP index for any firm *i* over time, $\left(TPP_{i,t}^{CH}\right)$ can be obtained as:

$$TPP_{i,t}^{CH} = \frac{\dfrac{R_{i,t}^{US}}{Y_{i,t}^{CH}}}{\dfrac{C_{i,t}^{US}}{X_{i,t}^{CH}}} = \frac{P_{i,t}^{CH}}{W_{i,t}^{CH}} \qquad (13)$$

The next step is to derive a multilateral Fisher index to measure profitability, productivity and price performance across companies at any given year (multilateral spatial comparisons). When the price and quantities across different companies are compared, it is important that such comparisons are undertaken for every pair of companies being considered (multilateral comparisons) (Ball et al., 2001; Rao et al., 2002; Coelli et al., 2005; Balk, 2008; Pierani, 2009). However, in order to achieve consistency between all the pairs of comparisons we need to derive multilateral indexes that fulfill the property of circularity (Diewert, 1999; Fox et al., 2003; Coelli et al., 2005; Pierani, 2009). Internal consistency (circularity) implies that a direct comparison between two firms gives the same result when comparing indirectly these two firms through a third firm (Rao et al., 2002; Coelli et al., 2005).

Bilateral Fisher output and input indexes between two firms i and j in the case of m outputs and n inputs are respectively, $Y_{i,j}$ and $X_{i,j}$:

$$Y_{i,j} = \left[\frac{\sum_{m=1}^{M} P_j^m Y_i^m}{\sum_{m=1}^{M} P_j^m Y_j^m} \times \frac{\sum_{m=1}^{M} P_i^m Y_i^m}{\sum_{m=1}^{M} P_i^m Y_j^m}\right]^{\frac{1}{2}} \qquad X_{i,j} = \left[\frac{\sum_{n=1}^{N} W_j^n X_i^n}{\sum_{n=1}^{N} W_j^n X_j^n} \times \frac{\sum_{n=1}^{N} W_i^n X_i^n}{\sum_{n=1}^{N} W_i^n X_j^n}\right]^{\frac{1}{2}} \qquad (14)$$

where Y_i^m and Y_j^m denote the quantities for the mth output for firms i and j respectively, whereas X_i^n and X_j^n present the quantities for the nth inputs for firms i and j respectively. Moreover, P_i^m and P_j^m are the prices for mth output, while W_i^n and W_j^n denote the input prices. The bilateral Fisher productivity index is then constructed as a ratio of the Fisher output index relative to Fisher input index:

$$TFP_{i,j} = \frac{Y_{i,j}}{X_{i,j}} \qquad (15)$$

Eq. (15) can be applied directly when we are only interested in making comparisons between two firms. However, when we are interested in making meaningful comparisons between more than two firms, the multilateral nature of spatial comparisons creates some difficulties, which arise from the fact that more than two firms are compared at the same time. Firstly, the number of comparisons may be quite large depending on the number of companies that we have in our sample so the calculation of productivity index can be quite difficult (Coelli et al., 2005). Secondly, we need consistent comparisons between all firms such that the relative comparisons between any two firms are consistent with other comparisons (circularity) (Rao et al., 2002). These binary Fisher indices can be converted into multilateral consistent transitive indices by applying the EKS method developed by Elteto-Koves (1964) and Szulc (1964) to derive transitive Fisher indices (see for example Balk, 2003 and 2008; Ball et al., 2001; Fox et al., 2003; Hill, 2004; Lawrence et al., 2006; Pierani, 2009 for a discussion on multilateral transitive indices).

We therefore derive circular Fisher output and input indices using the EKS method, which is equivalent to taking the geometric mean of the *I* possible direct and indirect (through any possible 3rd firm *k*) binary Fisher comparisons of firms *i* and *j*. The resulting Fisher output and input indices, Y_{ij}^S and X_{ij}^S therefore fulfill the circularity property:

$$Y_{ij}^S = \prod_{k=1}^{I} \left[Y_{ik} \times Y_{kj} \right]^{\frac{1}{I}} \qquad X_{ij}^S = \prod_{k=1}^{I} \left[X_{ik} \times X_{kj} \right]^{\frac{1}{I}} \tag{16}$$

Multilateral EKS-type indexes satisfy circularity and minimize the distance from the binary Fisher comparisons (Rao and Banerjee, 1984; Pienari, 2009). Adopting the terminology of the index literature (Hill, 2002; 2004) we refer to these multilateral output and input indices as spatial indices, as they provide spatially consistent measures across all firms.

The spatial total factor productivity Fisher index for a firm i relative to firm j, $TFP_{i,j}^S$, can then be constructed as the ratio of the spatial Fisher output index relative to spatial Fisher input index:

$$TFP_{ij}^{S} = \frac{Y_{ij}^{S}}{X_{ij}^{S}} \tag{17}$$

If spatial comparisons are available for each of T time periods indexed by t, and we assume the same base firm in all years, we can define the spatial productivity of firm i relative to firm b at time t as:

$$TFP_{i,t}^{S} = \frac{Y_{i,t}^{S}}{X_{i,t}^{S}} \tag{18}$$

We now turn our discussion to the construction of the spatial total price performance index, $\left(TPP_{i,t}^{S}\right)$. Firstly, we express turnover of a firm *i* relative to the base firm as $R_{i,t}^{S} = R_{i,t} / R_{b,t}$. The spatially consistent aggregate output price index, $\left(P_{i,t}^{S}\right)$ is then calculated as $P_{i,t}^{S} = R_{i,t}^{S} / Y_{i,t}^{S}$. Similarly, we express nominal economic costs of a firm *i* relative to the base firm as $C_{i,t}^{S} = C_{i,t} / C_{b,t}$. The spatially consistent aggregate input price index, $\left(W_{i,t}^{S}\right)$ is then calculated as $W_{i,t}^{S} = C_{i,t}^{S} / X_{i,t}^{S}$. Finally, a spatially consistent TPP index of any firm *i* relative to the base firm at any given time t, $\left(TPP_{i,t}^{S}\right)$ can be obtained as:

$$TPP_{i,t}^{S} = \frac{\frac{R_{i,t}^{S}}{Y_{i,t}^{S}}}{\frac{C_{i,t}^{S}}{X_{i,t}^{S}}} = \frac{P_{i,t}^{S}}{W_{i,t}^{S}} \tag{19}$$

Therefore, a spatial economic profitability index at time t, $\pi_{i,t}^{S}$ is calculated as the product of an index of spatial total factor productivity for firm *i* relative to the base firm *b*, $TFP_{i,t}^{S}$ and a spatial index of total price performance between firm *i* and the base firm *b*, $TPP_{i,t}^{S}$.

In order to simultaneously measure and decompose the profitability growth of any firm in the sample across time and relative to other firms, in practice it is necessary to reconcile the spatial profitability measures defined above with the underlying unit-specific chained profitability of each firm. Hill (2002, 2004) demonstrated that it cannot be derived, in practice, multilateral measures of the productive change of any firm i relative to the base firm, which can satisfy both spatial and temporal consistency.[1] Hence, we have chosen to pursue measures of relative productivity change over time that guarantee spatial consistency, as this approach is most consistent in the regulatory application. Thus regulators in comparative or yardstick regulatory regimes typically employ cross section techniques to measure differences in productivity or efficiency across firms.

According to Hill (2002, 2004) firm i's relative productivity change over time ($TFP_{i,t}^{R}$) is determined as the geometric average of the *I* alternative potential estimates of relative productivity, as derived by employing the chained time trends and spatial productivities of all the *I* firms in the sample:

$$TFP_{i,t}^{R} = \left[\prod_{j=1}^{I} \left[(TFP_{j,t}^{CH} \times TFP_{j,1}^{S}) \times \frac{TFP_{i,t}^{S}}{TFP_{j,t}^{S}} \right] \right]^{\frac{1}{I}} \tag{20}$$

Thus, when i = j, $TFP_{i,t}^{R}$ can be simply expressed as the product of the firm's own chained productivity index and its spatial productivity measure in year 1: $TFP_{i,t}^{R} = TFP_{i,t}^{CH} TFP_{i,1}^{S}$. In contrast, for the alternative *I*-1 estimates when, $i \neq j$. $TFP_{i,t}^{R}$ can also be expressed as a function of any other firm *j*'s relative productivity index calculated as $TFP_{j,t}^{R} = TFP_{j,t}^{CH} TFP_{j,1}^{S}$, and the spatial productivity of firm i relative to firm j, which given the definition of our spatial productivity measures, can be expressed as $\frac{TFP_{i,t}^{S}}{TFP_{j,t}^{S}}$. Thus, rather than relying on a single one of these potential estimates, the definition of $TFP_{i,t}^{R}$ in Eq. (20) employs all available spatial and chained productivity estimates to provide an arguably superior geometric average estimate of $TFP_{i,t}^{R}$. We can similarly derive measures of the relative output and input indices over time, $Y_{i,t}^{R}$ and $X_{i,t}^{R}$.

[1] Spatially consistency implies that each year's relative productivity measures do not depend on the other years in the comparison and temporal consistency implies that each firm's productivity estimates do not depend on the number of observations in the time series

Construction of consistent price, and TPP indices can therefore be accomplished by firstly expressing turnover of firm *i* relative to the base firm at the base year 1 as $R_{i,t}^{R} = R_{i,t} / R_{b,1}$. The relative aggregate output price index over time is then calculated as $P_{i,t}^{R} = R_{i,t}^{R} / Y_{i,t}^{R}$. Similarly, we express nominal economic costs of a firm *i* relative to the base firm at the base year 1 as $C_{i,t}^{R} = C_{i,t} / C_{b,1}$. The relative aggregate input price index over time is then calculated as $W_{i,t}^{R} = C_{i,t}^{R} / X_{i,t}^{R}$. Finally, a relative TPP index of any firm *i* relative to the base firm at the base year 1 can be obtained as:

$$TPP_{i,t}^{R} = \frac{\dfrac{R_{i,t}^{R}}{Y_{i,t}^{R}}}{\dfrac{C_{i,t}^{R}}{X_{i,t}^{R}}} = \frac{P_{i,t}^{R}}{W_{i,t}^{R}} \qquad (21)$$

As a result, a relative economic profitability index, $\pi_{i,t}^{R}$ can be calculated as the product of an index of relative total TFP *i* relative to the base firm *b* at base year 1, $TFP_{i,t}^{R}$ and a relative index of TPP between firm *i* and the base firm *b* at the base year 1, $TPP_{i,t}^{R}$.

In order to achieve our ultimate goal of decomposing unit specific profit growth in the multilateral context, we must finally derive unit specific indices which are consistent with the relative indices developed in equations (20) and (21). We therefore calculate a consistent measure of unit-specific productivity over time, which can be obtained as $TFP_{i,t}^{US} = \dfrac{TFP_{i,t}^{R}}{TFP_{i,1}^{R}}$. Similarly, consistent measures of unit-specific output and input growth are respectively $Y_{i,t}^{US} = \dfrac{Y_{i,t}^{R}}{\mathrm{Y}_{\mathrm{i},1}^{\mathrm{R}}}$ and $X_{i,t}^{US} = \dfrac{X_{i,t}^{R}}{\mathrm{X}_{\mathrm{i},1}^{\mathrm{R}}}$. In an analogous manner, consistent measures of unit-specific TPP output price, input price and economic profitability indexes are respectively, $TPP_{i,t}^{US} = \dfrac{TPP_{i,t}^{R}}{TPP_{i,1}^{R}}$, $P_{i,t}^{US} = \dfrac{P_{i,t}^{R}}{\mathrm{P}_{\mathrm{i},1}^{\mathrm{R}}}$, $W_{i,t}^{US} = \dfrac{W_{i,t}^{R}}{\mathrm{W}_{\mathrm{i},1}^{\mathrm{R}}}$ and $\pi_{i,t}^{US} = TFP_{i,t}^{US} TPP_{i,t}^{US}$.

Given our modeling decision to maintain spatial consistency at the cost of temporal consistency, and the subsequent employment of the geometric average of the I alternative potential relative indicators as appropriate unit specific relative productivity, output and input indices, we must note that the unit-specific chained temporal indexes will, by construction, not be perfectly consistent with the unit specific temporal indexes constructed from the multilateral relative indices. Nevertheless, it can be readily mathematically demonstrated that the geometric average of the I chained unit specific temporal indices and those derived from the relative indices detailed in equations (20) and (21) are equal.

3. SAMPLE AND DATA DESCRIPTION

The water and sewerage industry in England and Wales was privatized in 1989. Before privatization there were 10 Regional Water Authorities responsible for the water and sewerage supply and 29 Statutory Water companies, which were already privatized companies that were only responsible for the supply of water. After 1989, the 10 Regional Water Authorities were privatized and formed the WaSCs and the 29 Statutory Water Companies became water only companies (WoCs). Today, there are 10 WaSCs whose duties include the supply of water in areas that are not supplied by the WoCs, and the collection, treatment and disposal of sewerage in all areas. The WaSCs supply drinking water to 80% of the population in England and Wales with WoCs supplying the rest.

Our empirical application focuses on the 10 English and Welsh WaSCs for the period 1991-2008. Water connected properties and sewerage connected properties are the proxies for water and sewerage output and are drawn from the "June Returns for the Water and Sewerage Industries in England and Wales" published by Ofwat each year at its webpage. Finally, aggregate output price indices were constructed as the ratio of relative aggregate turnover in nominal terms to this aggregate output index.

Regarding inputs, three variables namely capital stock, labor costs and other inputs are considered. The physical capital stock measure is based on the inflation adjusted Modern Equivalent Asset (MEA) estimates of the replacement cost of physical assets contained in the companies' regulatory accounts. MEA values for previous years based on net investment are also systematically calculated as is necessary given the periodic substantial revisions of the companies' MEA values (Saal and Parker, 2001; Maziotis et al., 2009; 2012).

We subsequently employed a user-cost of capital approach, to calculate total capital costs as the sum of the opportunity cost of invested capital and capital depreciation relative to the MEA asset values, and construct the price of physical capital as the user cost of capital divided by the above MEA based measure of physical capital stocks (Maziotis et al., 2009).

The average number of full-time equivalent (FTE) employees is available from the companies' statutory accounts. Firm specific labour prices were calculated as the ratio of total labour costs to the average number of full-time equivalent employees. Other costs in nominal terms were defined as the difference between operating costs and total labour costs[2]. Given the absence of data allowing a more refined break out of other costs, we employ the UK price index for materials and fuel purchased in purification and distribution of water, as the price index for other costs, and simply deflate nominal other costs by this measure to obtain a proxy for real usage of other inputs. Finally, economic profits are calculated as the difference between turnover and calculated economic costs.

Table 1 presents average revenues, costs, inputs and outputs for the WaSCs for selected periods of study.

INSERT TABLE 1

4. RESULTS AND DISCUSSION

The spatial and relative profitability, productivity and price performance measures were defined relative to the base firm in the sample. However, if the base firm is defined as the firm with the highest productivity in the sample, then each firm's productivity, prices and profits will be relative to this best practice or benchmark firm[3]. It should be noted that our approach

[2] While it would be particularly desirable to disaggregate other input usage data further and in particular to allow for separate energy and chemical usage inputs, the data available at company level from Ofwat's regulatory return does not allow a further meaningful decomposition of other input usage.

[3] The same firm is consistently found to have the highest spatial productivity estimates in all years, and is therefore modelled as the benchmark most productive firm in each year of our study.

assumes constant returns to scale and it doesn't allow for further decomposition of profitability change into scale efficiency change. However, this assumption is line with previous traditional productivity and efficiency measure techniques (see for instance Portela et al. 2011; Molinos-Senante, 2014b).

Figure 2 illustrates the decomposition of unit-specific economic profitability change into unit-specific productivity and price performance change over the period 1991-2008. The results indicate that between 1991 and 2008, average economic profitability increased by 5.9%, which was attributed to an improvement in TFP of 22.9% and a reduction in TPP of 13.9%. On average there was a stable increase in TFP over time, while TPP followed an upward trend until 1994, which was interrupted in 1995, but was again followed by a substantial increase between 1999 and 2000. We note that during the years 1991-1994, average economic profitability increased due to increases in TPP which was substantially greater than TFP growth. As documented in previous studies, Ofwat's tightening of price caps in the 1994 price review decreased the growth in real output prices and therefore resulted in a downward trend for both TPP and economic profitability until 1998, while TFP continued to rise steadily. Our finding therefore confirms Saal and Parker's (2001) study, which found that during 1991-1999, positive changes in economic profitability were mainly attributed to changes in TPP rather in TFP. However, Figure 2 extends their study by including results for unit-specific profitability, productivity and price performance changes until 2008.

INSERT FIGURE 2

These results demonstrate that after 2000, reduced output prices caused TPP to dramatically decline, and its value remained consistently below unity after 2000. This indicates that regulatory price changes implemented after 2000, caused the price performance of firms to fall substantially below its level in 1991. Moreover, average unit-specific TPP followed a downward trend except for 2006, when output prices were allowed to momentarily rise in the first year of the 2006-2010 regulatory period. Unsurprisingly, given the dramatic fall in price performance after 2000, average economic profitability also substantially declined, even though TFP continued to follow a steady upward trend, which was only momentarily interrupted in 2007.

Thus, in the post 2000 period, trends in temporal economic profitability continued to follow the trend of TPP, indicating that changes in price performance continue to be the main determinant of changes in economic profitability.

Nevertheless, while TPP fell below 1991 levels after 2000 average economic profitability did not, thereby implying that on average profitability in the industry remained moderately higher than in the immediate aftermath of privatization. This is because of the significant and continuing gains in TFP between 1991 and 2000 that more than offset the dramatic tightening of regulated output prices in 2001. Thus, the immediate impact of the 1999 price review in 2001 is consistent with an interpretation emphasizing that Ofwat chose to pass considerable accumulated past productivity improvements to consumers. Moreover, the steady decline in average price performance, gains in TFP and relatively stable economic profitability that have characterized the 2001-2008 period, suggests that Ofwat is now more focused on passing productivity benefits to consumers, and maintaining stable profitability than in the earlier regulatory periods.

Given that Ofwat operates a system of yardstick regulation which is designed to encourage catch up to benchmark firm performance, the results shown in Figure 2 are particularly relevant. Thus, we should expect that the performance improvement of laggard firms should exceed that of benchmark firms. This is because the price caps set for benchmark firms should only require them to continue improving their performance through technical change, while price caps for non benchmark firms will also require them to catch up to the benchmark firm. Thus, the multilateral models develop above can be used to illustrate the contribution of benchmark performance and average catch-up to average firm performance.

Figure 3 illustrates that average economic profitability increased significantly until 1994 by 23.4% and that this exceeded benchmark economic profitability growth (19.6%) allowed an average catch-up to benchmark profitability of 3.1%. The tightening of price caps from 1994 resulted in a downward trend for average and benchmark economic profitability. Thus, during the years 1995-1998, the average firm did not improve its economic profitability relative to the benchmark but this was once again interrupted during 1998-2000, when average economic profitability increased more than benchmark profitability, allowing average catch-up of 2.4%. The substantial reduction in output prices due to the tightened 1999 price review resulted in a significant reduction in average and benchmark economic profitability for the subsequent years which showed an upward trend only in 2002 and in 2006. We note that benchmark firm realized significant decline in its economic profitability in 2001, and despite an improvement in 2002, further declines meant that its profitability in 2005 was only 0.04% of its level in 1991. Despite an uptick of benchmark profitability to 1.115 in 2006, by 2008 benchmark profitability was only 97.9% of its 1991 level. In contrast, while average economic profitability was also considerably lower after 2000, it has never declined below average 1991 levels. As a result, average firm showed high levels of catch-up in profitability relative to the benchmark after 2001. However, this is mainly explained by the relative decline in the economic profitability of the benchmark firm. Thus, over the 1991 to 2008 period the average company caught-up to benchmark economic profitability by 8.1%, but this was mainly attributable to a decline in benchmark profitability of 2.1%.

INSERT FIGURE 3

The decomposition of average unit-specific productivity growth into productivity change of the benchmark firm and average productivity catch-up relative to the benchmark firm is depicted in Figure 4. Until 1995 there were negative productivity catch-up as the productivity improvements for the average company amounted to 3.9%, while the benchmark company improved its productivity by 4.4%. This finding suggests that the price caps set at privatization encourage neither average or benchmark firms to achieve high productivity levels. This trend was interrupted after 1995 when both average and benchmark productivity performance significantly improved. We note that during the years 1996-2000 when price caps were first tightened, average companies should have had stronger incentives to catch-up to benchmark, while the benchmark company should also have been incentivized to continue to improve its productivity. By 2000, average cumulative productivity increased by 12% and this growth exceeded that of the benchmark firm, which achieved cumulative improvement of 10.2%, thereby indicating total catch-up in productivity of 1.1% between 1991 and 2000. Moreover, significant productivity gains for the average firm relative to the benchmark firm also continued after 2000. Thus, our results suggest that the implementation of even tighter price caps in 1999 further encouraged less productive firms to improve their performance relative to the benchmark, even though the benchmark firm continued to improve its performance. Thus, by 2004, the cumulative measures of productivity change since 1991 indicate that average company improved its productivity by 16.8% catching up to the benchmark productivity by 2.1%, while the benchmark firm improved its productivity by 14.5%. During 2004 price review period, average productivity growth again substantially exceeded the productivity growth of the benchmark firm, resulting in high levels of productivity catch-up between 2005 and 2008, although this is largely explained by substantial declines in benchmark productivity after 2006.

In conclusion, over the entire 1991-2008 regulatory period, average productivity improved by 22.9%, while benchmark productivity improved its productivity by 16.6% allowing an average productivity catch-up of 4.7%. Moreover, our results suggest that all of this catch-up can be attributed to the post 1995 period, after Ofwat first tightened price caps, and most of it can be attributed to the post 2000 period, following the even more stringent 1999 price review.

INSERT FIGURE 4

The decomposition of average unit-specific economic price performance change into the price performance change of the benchmark firm and average price performance catch-up relative to that firm over time is displayed at figure 5. The results indicated that until 1994 when price caps were relatively lax, both average and benchmark price performance significantly increased by 19.9% and 15.1% respectively. Average TPP growth exceeded benchmark TPP growth allowing an average catch-up in price performance of 4.1%. The tighter 1994 price review, led to a substantial downward trend in average and benchmark TPP until 1998. We note that during the years 1996-1998 benchmark TPP growth exceeded average TPP growth and therefore there were not any price performance catch-up gains on average. After 1998, average TPP increased more than benchmark TPP but by 2000, there was a broad convergence in average and benchmark TPP as the respectively demonstrated cumulative increases of 18.4% and 17.5% since 1991. However, the dramatic impact of the 1999 price review obliged the companies to reduce their output prices significantly and after 2000 there was a significant decline in average and benchmark TPP, except for the year 2006 when relatively looser price caps were introduced. We notice that during the years 2001-2004, there was little or no difference between average and benchmark TPP, while during the years 2005-2008 average TPP exceeded benchmark TPP showing the highest levels of price performance catch-up in 2006 and in 2008. By 2008, average TPP had been reduced by 13.9% relative to 1991 levels, while benchmark TPP had been reduced even more by 16.5%, thereby allowing an average catch-up in price performance of 3.2%. Thus, figure 5 clearly illustrates that in the post 1999 price review period, the price performance of all firms is substantially lower than in the first 10 years after privatisation.

INSERT FIGURE 5

5. CONCLUSIONS

This paper analyzed the impact of regulation on the financial performance of water and sewerage companies (WaSCs) in England and Wales over the period 1991-2008. We employed a panel index number technique to decompose profits into total factor productivity (TFP) and total price performance (TPP), and demonstrated several different but theoretically related methods to link productivity, price performance and profitability. From a methodological point of view, it should be highlighted that we not only estimated and decomposed unit-specific profitability of each firm over time, but also illustrated a multilateral spatial Fisher index that allowed multilateral spatial measures between all the pairs of companies included in the analysis at any given year. To estimate profitability, productivity and price changes the spatial and temporal results were linked. This approach involves a significant advantage from the regulator perspective since it allows us to express the unit-specific profitability of any firm as a function of the profitability growth of the benchmark firm and actual catch-up to the benchmark firm. In spite of the usefulness of the index number methodology applied, a limitation of it is that it does not allow us to as readily take into account differences in operating characteristics and the quality of service that may affect relative measures of productivity or price performance (Simoes and Marques, 2012). This is attributed to the fact that observed price data for operating characteristics and the quality of service are not available.

Results for the English and Welsh water industry indicated that during the years 1991-2008, on average there was a stable increase in TFP, while TPP followed an upward trend until 1994, due to the lax price caps set at privatization, but was interrupted in 1995 due to the tightened 1994/95 price review and was followed by a substantial increase in 1999 and 2000. After 2000, average TPP and economic profitability followed the same trend, whereas average TFP increased steadily. Average TPP and profitability significantly declined due to the tightened 1999/00 price review and followed a downward trend except for the years 2002 and 2006. Thus, after 2001, the steady decline in average price performance, gains in TFP and relatively stable economic profitability suggested that Ofwat was more focused on passing productivity benefits to consumers, and maintaining stable profitability than in the earlier regulatory periods.

Focusing on economic profitability results it is concluded that average economic profitability exceeded benchmark economic profitability during the years 1991-1994 and 1998-2008, showing high levels of catch-up relative to benchmark economic profitability after 2001. With respect to the productivity performance of the less productive and benchmark firms, it is concluded that until 1995 average and benchmark firms did not have strong incentives to achieve high productivity levels. Significant productivity gains for the average firm relative to the benchmark also continued after 2000. Thus, our results suggested that when Ofwat's tight price reviews in 1995 and especially in 1999/00 incentivize the companies to improve their productivity performance. Also, looking at the average and benchmark price performance we concluded by 2000 there had been a convergence in average and benchmark TPP. During the years 2001-2004, there was little or no difference between average and benchmark TPP and during the years 2005-2008 average TPP exceeded benchmark TPP showing the highest levels of price performance catch-up in 2006 and in 2008. Our results suggested that in the post 1999 price review period, the price performance of all firms was substantially lower than in the first 10 years after privatisation.

From a policy perspective, the index number decompositions provided a backward-looking approach with respect to the impact of price cap regulation on the profitability, productivity and price performance of less productive and benchmark firms. They indicate that after privatization on average companies did not have any strong incentives to improve their productivity as regulated prices were lax. So gains related to privatization were apparent more on the revenue side rather than on costs. The findings also suggest that the regulatory change can result in productivity shocks among firms but firms can adjust rapidly to such changes (Fox et al. 2003). This was apparent the period after tight price reviews where the regulator was more focused on passing productivity benefits to consumers, and sustaining stable profitability than in earlier periods. Moreover, our methodology provides a useful tool for policy makers to assess benchmark across firms at any point. It can identify the components that contribute to profits and suggest improvements in firms' management and industry performance. Most importantly, our method can be applied for any industry regardless of type of regulatory scheme employed to assess economic performance and impact of regulatory cycle especially when the number of available observations (water companies) was extremely limited. Finally, this methodology can be further used to aid regulators in setting X-factors under price cap regulation for regulated firms (forward-looking). Since X-factor requires the measurement of efficiency change (catch-up) and frontier shift (technical change), our approach provides evidence for catch-up (efficiency) in productivity by less productive firms based on the consistent spatial productivity measures across companies at any given year and also provides evidence for the productivity growth of the benchmark firm (technical change).

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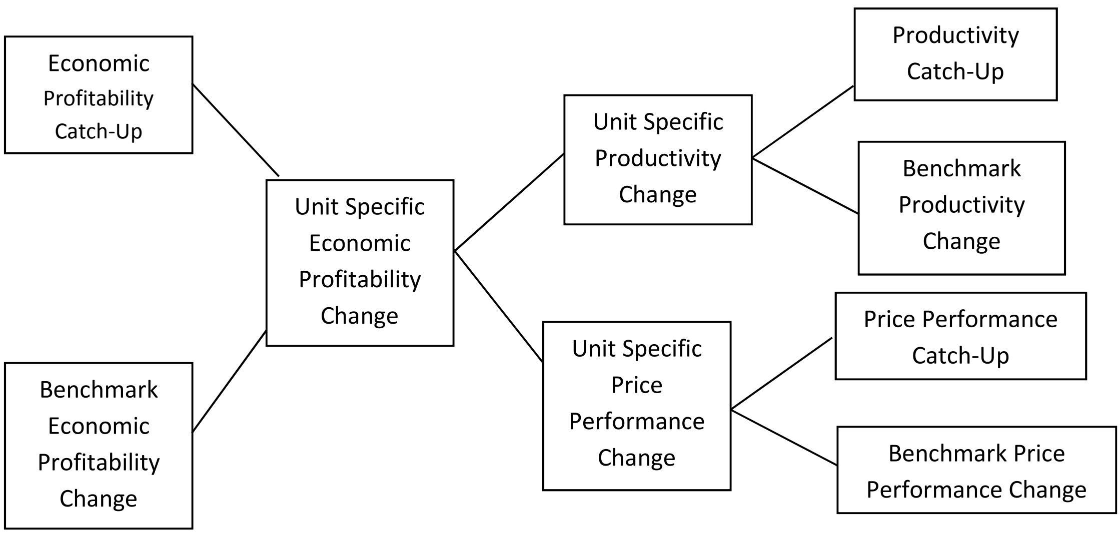
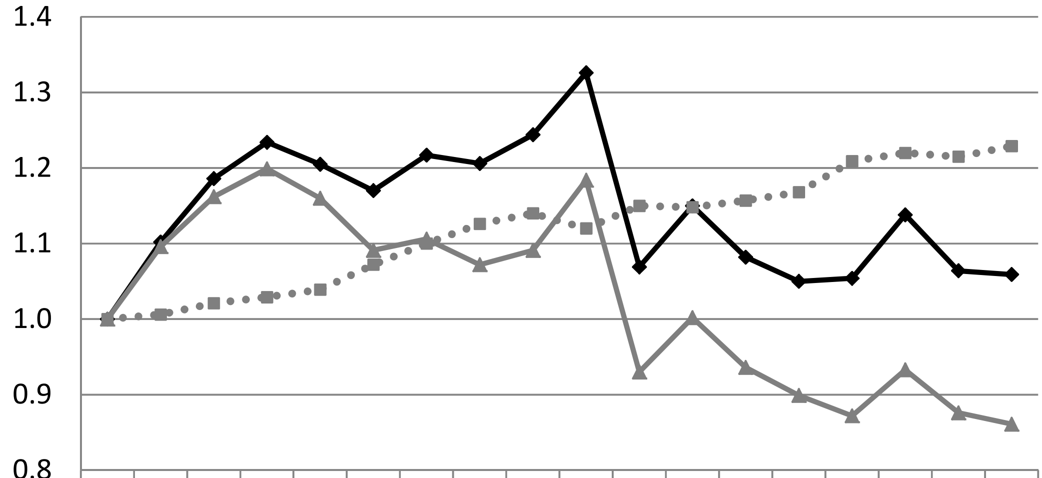
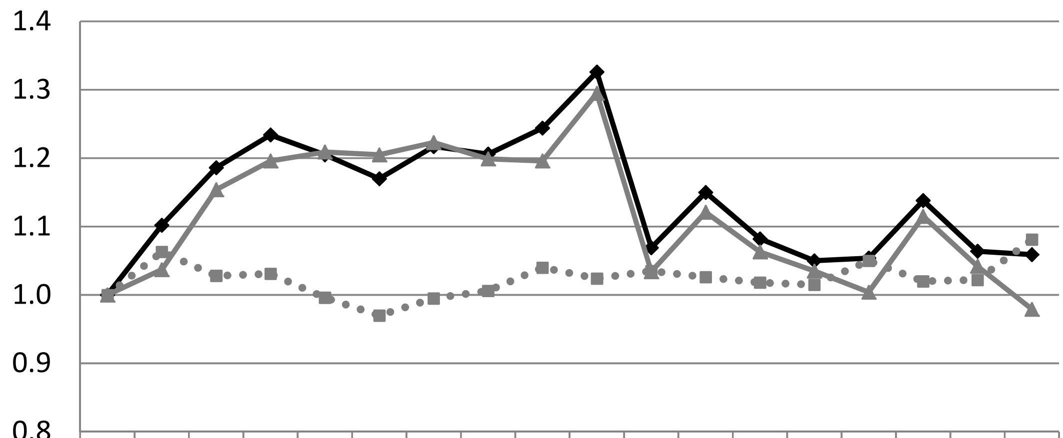


Figure 1. Decomposition of Unit Specific Economic Profitability Change



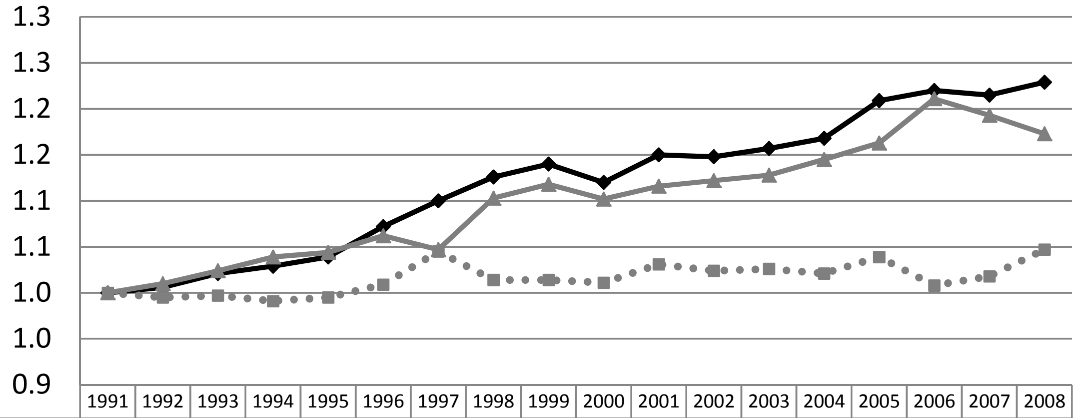
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Economic profitability	1.0000	1.1020	1.1860	1.2340	1.2050	1.1700	1.2170	1.2060	1.2440	1.3260	1.0690	1.1500	1.0820	1.0500	1.0540	1.1380	1.0640	1.0590
TFP	1.0000	1.0060	1.0210	1.0290	1.0390	1.0720	1.1000	1.1260	1.1400	1.1200	1.1500	1.1480	1.1570	1.1680	1.2090	1.2200	1.2150	1.2290
TPP	1.0000	1.0960	1.1620	1.1990	1.1600	1.0910	1.1060	1.0720	1.0910	1.1840	93000	1.0020	93600	89900	87200	93300	87600	86100

Figure 2. Decomposition of average unit-specific profitability into average unit total factor productivity (TFP) and total price performance (TPP).



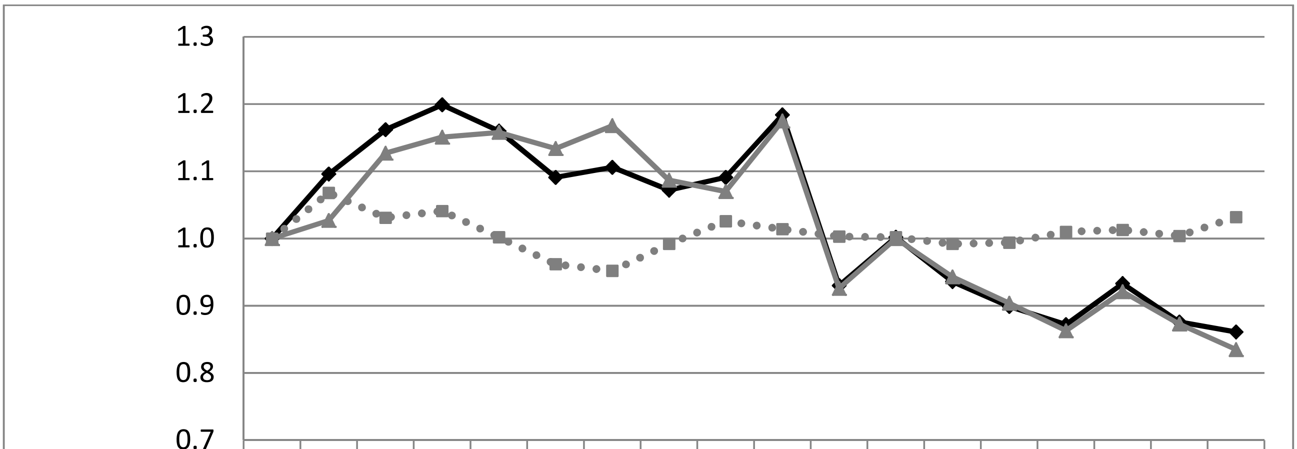
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Unit-Specific	1.000	1.102	1.186	1.234	1.205	1.170	1.217	1.206	1.244	1.326	1.069	1.150	1.082	1.050	1.054	1.138	1.064	1.059
Catch-up	1.000	1.063	1.028	1.031	.9960	.9700	.9950	1.006	1.040	1.024	1.035	1.026	1.018	1.015	1.050	1.020	1.022	1.081
Best	1.000	1.037	1.154	1.196	1.209	1.205	1.223	1.199	1.196	1.295	1.034	1.121	1.063	1.035	1.004	1.115	1.042	.9790

Figure 3. Decomposition of average unit-specific profitability into average profitability catch-up and profitability of the benchmark firm.



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Unit-Specific	1.0000	1.0060	1.0210	1.0290	1.0390	1.0720	1.1000	1.1260	1.1400	1.1200	1.1500	1.1480	1.1570	1.1680	1.2090	1.2200	1.2150	1.2290
Catch-Up	1.0000	0.9950	0.9970	0.9910	0.9950	1.0090	1.0450	1.0140	1.0140	1.0110	1.0310	1.0240	1.0260	1.0210	1.0390	1.0080	1.0180	1.0470
Best	1.0000	1.0100	1.0240	1.0390	1.0440	1.0620	1.0470	1.1030	1.1180	1.1020	1.1160	1.1220	1.1280	1.1450	1.1630	1.2110	1.1930	1.1730

Figure 4. Decomposition of average unit-specific TFP change into benchmark TFP change and average catch-up to the benchmark firm.



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Unit-Specific	1.0000	1.0960	1.1620	1.1990	1.1600	1.0910	1.1060	1.0720	1.0910	1.1840	0.9300	1.0020	0.9360	0.8990	0.8720	0.9330	0.8760	0.8610
Catch-Up	1.0000	1.0680	1.0310	1.0410	1.0020	0.9620	0.9520	0.9920	1.0260	1.0140	1.0030	1.0020	0.9920	0.9940	1.0100	1.0130	1.0040	1.0320
Best	1.0000	1.0270	1.1270	1.1510	1.1580	1.1340	1.1680	1.0870	1.0700	1.1750	0.9260	1.0000	0.9430	0.9040	0.8630	0.9210	0.8730	0.8350

Figure 5. Decomposition of average unit-specific TPP change into benchmark TPP change and average catch-up to the benchmark firm.

	Units	1991	1994	1995	2000	2001	2005	2006	2008
Revenues	10^6£ (2008)	366.99	478.79	507.35	627.88	581.54	672.89	753.72	849.46
Economic Costs	10^6£ (2008)	401.71	422.25	461.81	559.59	631.38	727.18	757.90	906.09
Water Connected Properties	10^3s	1,634	1,666	1,690	1,830	1,930	1,982	1,997	2,006
Sewerage Connected Properties	10^3s	2,098	2,130	2,148	2,212	2,227	2,302	2,346	2,380
Capital	10^6£ (2008)	18,488	19,229	19,441	20,660	20,817	21,325	21,436	21,692
Number of employees	FTE	3,938	3,813	3,774	2,969	2,785	2,720	2,755	2,952
Other Inputs	10^6£ (2008)	113	100	100	97	96	82	82	78
Price for a Water Connected Property	10^3£ (2008)	0.105	0.133	0.139	0.148	0.137	0.153	0.172	0.197
Price for a Sewerage Connected Property	10^3£ (2008)	0.102	0.136	0.145	0.182	0.158	0.180	0.197	0.219
Price for Capital	£ (2008)	0.012	0.012	0.013	0.015	0.018	0.022	0.022	0.028
Price for Labour	10^3£ (2008)	0.018	0.022	0.022	0.027	0.027	0.034	0.035	0.037
Price of Other Inputs	Price index	0.379	0.498	0.514	0.609	0.619	0.799	0.881	1.000

Table 1. Average revenues, costs, outputs, and inputs