Oxera

Bristol Water's efficiency

An assessment of relative operating expenditure efficiency for water services

An independent submission by Oxera to the Competition Commission

in association with Distinguished Professor Subal Kumbhakar

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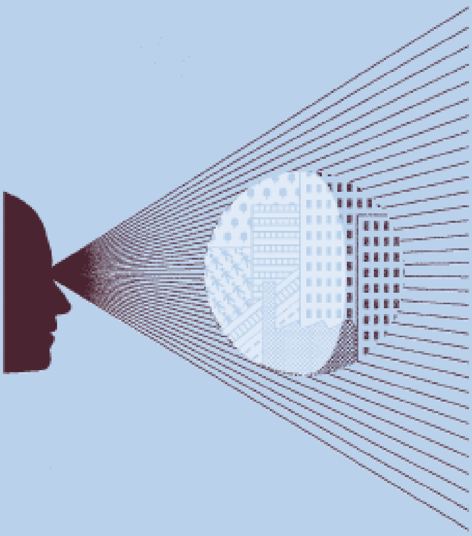

Executive summary

During the 2009 price control review in the water industry (PR09), Oxera and Distinguished Professor Subal Kumbhakar undertook an assessment of Ofwat's econometric modelling approach to estimating water companies' relative efficiency. This paper updates the analysis undertaken during PR09 and forms an independent Oxera submission to the Competition Commission in relation to the Bristol Water appeal against the price limit determinations. It is intended to assist the CC during its investigation.

Having reviewed Ofwat's approach to comparative efficiency, Oxera considers that many elements within the approach have much merit, including the following.

– There is a reasonably consistent dataset across companies and over time.

– A considerable amount of industry and regulatory knowledge is embedded within the models, as they have been developed over a long period of time.

– The models explain a reasonably large variation in costs.

As such, the modelling for this submission has been based very closely on that developed by Ofwat and the industry. However, three issues have been identified where improvements may be possible that could result in a more robust estimation of the relative efficiency of the companies within the industry.

1) As recommended by the CC[1] and as evidenced in Kumbhakar and Horncastle (2010),[2] a panel approach, rather than a year-by-year cross-section model, provides more data and improves the precision of the modelling.

2) Ofwat's modelling is undertaken using functional models for different cost areas. This requires that costs are separable across the different water activities and that cost allocation across the water companies is consistent. The original reason for such an approach was to include as many of the key cost drivers as possible within the confines of using cross-sectional data. Now that a panel dataset is available, the reason for using functional models is less persuasive. Indeed, it is now possible to include considerably more cost drivers using a panel dataset. Thus, Oxera considers that modelling at the aggregate level—for water services total operating expenditure (OPEX)—has a number of benefits, including removing the requirement for both cost separability and consistency in cost allocation, and allowing for the inclusion of multiple cost drivers. It may therefore potentially offer a more robust approach.

3) Ofwat's use of corrected ordinary least squares (COLS), together with the additional adjustments undertaken, does not correctly account for the noise in the modelling. Oxera considers that stochastic frontier analysis (SFA) is a superior method that does not require a subjective adjustment to account for such noise.[3]

This submission to the CC first shows that modelling with panel data is statistically valid and that this results in greater precision compared with Ofwat's approach, before going on to

[1] Competition Commission (2007), 'South East Water Limited and Mid Kent Water Limited: A report on the completed water merger of South East Water Limited and Mid Kent Water Limited', para 24.

[2] Kumbhakar, S. and Horncastle, A. (2010), 'Improving the Econometric Precision of Regulatory Models ', *Journal of Regulatory Economics* (forthcoming).

[3] Other approaches are also worth considering, such as data envelopment analysis; however, the focus in this report is SFA.

develop an econometric model for aggregate water OPEX and estimating the relative efficiency of Bristol Water using SFA. The results from this exercise indicate that Bristol Water is between 5.8% and 8.8% inefficient in 2008/09, depending on the distributional assumption in the SFA model, and compares with Ofwat's estimate of 8.68%[4] and Bristol Water's estimate of 5%.[5] The result from this analysis would place Bristol in Upper Band B and is consistent with Ofwat's Final Determinations in this respect.

[4] Bristol Water (2010), 'Competition Commission Price Determinations: Statement of Case', February 17th, paragraph 1153.
[5] Bristol Water (2010), op. cit., paragraph 1022.

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1 Introduction

During PR09, Oxera and Distinguished Professor Subal Kumbhakar undertook an assessment of Ofwat's econometric modelling approach to estimating water companies' relative efficiency. Ofwat and the water industry have developed this approach over more than 15 years, and the modelling presented in this submission to the CC inquiry is based very closely on the cost drivers developed by Ofwat and the industry. Oxera considers that many elements within the approach have much merit, including the following.

– There is a reasonably consistent dataset across companies and over time.

– A considerable amount of industry and regulatory knowledge is embedded within the models as they have been developed over a long period of time.

– The models explain a reasonably large variation in costs.

Nevertheless, three issues have been identified where improvements may be possible that could result in a more robust estimation of the relative efficiency levels of the companies within the industry.

1) As recommended by the CC,[6] and as evidenced in Kumbhakar and Horncastle (2009),[7] a panel approach, rather than a year-by-year cross-section model, provides more data and improves the precision of the modelling.[8] Oxera's analysis shows that modelling with panel data is statistically valid and that this results in greater precision.

2) Ofwat's modelling is undertaken using functional models for different cost areas. This requires that costs are separable across the different water activities and that cost allocation across the water companies is consistent. The original reason for such an approach was to include as many of the key cost drivers as possible within the confines of using cross-sectional data. Now that a panel dataset is available, the rationale for using functional models is less persuasive. Indeed, it is now possible to include considerably more cost drivers in an aggregate model using a panel dataset. Thus, Oxera considers that modelling at the aggregate level—for water services total OPEX—has a number of benefits, including removing the requirement for both cost separability and consistency in cost allocation, and allowing for the inclusion of multiple cost drivers. It may therefore have the potential to offer a more robust approach.

3) Ofwat's use of corrected ordinary least squares (COLS), together with the additional adjustments undertaken, does not correctly account for the noise in the modelling. Oxera considers that stochastic frontier analysis (SFA) is a superior method that does not require a subjective adjustment to account for such noise.[9] SFA can also be used to test for the presence of inefficiency.

As part of our assessment of Ofwat's approach, we developed alternative approaches and models to assessing operating expenditure efficiency in the water sector. This submission to the CC inquiry presents the models and results from this assessment, together with some recommendations for changes to the comparative efficiency methodology.

[6] Competition Commission (2007), 'South East Water Limited and Mid Kent Water Limited: A report on the Completed Water Merger of South East Water Limited and Mid Kent Water Limited', May, para 24.

[7] Kumbhakar, S. and Horncastle, A. (2010), 'Improving the Econometric Precision of Regulatory Models', *Journal of Regulatory Economics* (forthcoming).

[8] This is evident through the lower standard errors of the estimated coefficients. See Kumbhakar and Horncastle (2010), op. cit.

[9] Other approaches are also worth considering, such as data envelopment analysis; however, the focus of this study is SFA.

Based on this approach, in 2008/09 Bristol Water is estimated to be between 5.8% and 8.8% inefficient. This equates to an average of 7.3% and places Bristol Water in Upper Band B, which is consistent with Ofwat's Final Determinations. The lower value of the range places Bristol Water at the margin of Lower Band A.[10]

Extensions to the model and exploration of some of the issues raised by Bristol Water in its submission to the CC (eg, the use of a two-sided wage adjustment instead of the one-sided adjustment applied by Ofwat) have not been explored in this report and may affect the results of the analysis.

The remainder of this submission is structured as follows.

– Section 2 discusses the data and methodology used to obtain the inefficiency estimates.

– Section 3 examines the precision of the Oxera modelling compared with that of Ofwat.

– Section 4 presents the econometric and inefficiency results from the Oxera models.

– Section 5 concludes.

[10] The special factors included in this analysis for 2007/08 are based on data provided in the 2007/08 Relative Efficiency Assessment, which Oxera understands were subsequently amended in the PR09 Draft Determinations. The regional wage adjustment in the 2007/08 Relative Efficiency Assessment was also subsequently amended in the Draft Determinations. The regional wage adjustment used in this analysis was provided by Thames Water, but is understood to be based on Ofwat's approach and produces similar results. The 2007/08 adjustments used in the Draft Determinations were not available at the time of this analysis, and the results from this analysis are subject to change once this data becomes available, although it is unlikely that this will have a significant impact on the 2008/09 inefficiency estimates.

2 Methodology

Ofwat and the water industry have developed their approach to assessing relative efficiency over more than 15 years. Hence, the starting point taken here is Ofwat's current approach.

2.1 Ofwat's approach and implications for the Oxera modelling

In assessing water companies' OPEX efficiency, Ofwat uses a suite of econometric models originally constructed for the 1994 price review, which have since been continually reviewed and developed. This is a key strength of the regime—in particular, embedded within it is a significant amount of industry knowledge about what constitute the key drivers of operating costs.

The models use OLS regression techniques to determine, at the company level, the relationship between costs and a key set of explanatory factors for a single year. For this purpose, Ofwat employs a sub-model approach—ie, the different functions undertaken by water companies are deemed to be separable. The models are summarised below and, as a result of our assessment, this has led us to four key principles.

2.1.1 The models

Ofwat's functional models are summarised in Table 2.1.

Table 2.1 Water OPEX sub-models, 2008/09

	Dependent variable	Explanatory variables		Fit of the model, R^2
Resources and Treatment (R&T)	R&T functional expenditure (£m) less Power expenditure (£m), less service charges (£m), divided by resident winter population (m)	Number of sources divided by distribution input (Ml/day)	Proportion of supplies derived from boreholes	0.416 (0.903)[1]
Distribution	ln(Distribution functional expenditure, less Power expenditure (£m), divided by number of properties connected at year end ('000s))	ln(Length of main (km) divided by number of connected properties at year end ('000s))		0.154 (0.940)[1]
Power	ln(Power expenditure (£m))	ln(Distribution input (Ml/d) multiplied by average pumping head)		0.983
Business Activities	ln(Business Activities expenditure (£m) including doubtful debts (£m))	ln(number of billed properties ('000s))		0.970

Note: ln denotes natural logarithm. [1] R&T and Distribution models appear to have relatively low R^2 values, but this is because the dependent variable is formulated in unit cost terms. Oxera has calculated the value in brackets by using costs as the dependent variable in the model. This demonstrates that these two models also have reasonably high R^2 values.
Source: Ofwat (2009), 'Relative Efficiency Assessments 2007-08 – supporting information', January 29th; Oxera calculations.

Table 2.1 shows that the models are relatively straightforward, with only one to three explanatory variables.[11] Yet the models are, in most cases, able to explain a relatively large proportion of the variation in costs.[12]

[11] Three explanatory variables exist in the R&T model (including the scale factor).

Principle 1: The Oxera modelling is based very closely on the cost drivers developed by Ofwat and the water industry.

Given the success of Ofwat's modelling in explaining companies' costs and the inclusion of industry knowledge in the development of the models, it is sensible to use these cost drivers (and some other potential drivers) in the construction of the Oxera models. The additional drivers might be able to improve further the fit of the models.

As well as the cost drivers, a further point worth noting is that Ofwat models operating costs across different functions. The original aim of this approach was to incorporate more cost drivers in the modelling. Modelling water OPEX at a disaggregated level using functional models for different cost areas requires two conditions to hold: that costs are separable across the different water activities; and that cost allocation across the water companies is consistent. However, it may be that neither of these conditions is met. For example, for General & Support functions, these costs are currently allocated across the Distribution and R&T models.

The ultimate focus of Ofwat's comparative efficiency regime is total OPEX efficiency. So, even when the functional models are taken as the starting point, their outcome needs to be aggregated in order to establish companies' total OPEX relative efficiency levels. That is, predicted costs from the functional models are used to obtain total predicted costs for each company (as well as for the industry). While it is not complicated to compute predicted total costs (at the company as well as the industry level)—they are simply the sum of predicted costs from each functional model—the problem is in computing the associated uncertainty (measured by the standard error of predicted cost). Uncertainty associated with predicted cost for each functional model cannot simply be summed to obtain the uncertainty for the aggregate model. Since the functional models are estimated separately, there is no simple way to compute the uncertainty for the total predicted cost. Aggregation also causes a problem for the computation of aggregate inefficiency and the associated confidence interval. The implicit assumption in estimating the functional models is that the error terms (both noise and inefficiency) across different functional models are uncorrelated, which is unlikely be the case, especially for inefficiency. That is, inefficiency in a functional model is likely to be correlated with inefficiency in other models. Such correlations are difficult to capture. However, both of these problems can be avoided if an aggregate model is used.

Principle 2: The Oxera modelling focuses on water services total OPEX.

By modelling at the aggregate level, the Oxera modelling is able to avoid issues of separability of the cost functions and differences in cost allocations across companies.

2.1.2 The dataset

One of the strengths of Ofwat's comparative regime is its regulatory accounts (June Returns), which provide a wealth of financial and non-financial indicators. Available over the period from 1992/93 to 2008/09, these are reasonably consistent both across companies and over time, especially in later years.

However, Ofwat's current econometric models are estimated using cross-sectional data for a given year. The limited number of cost drivers per model, discussed above, is due to this relatively small dataset: with 21 companies, the number of explanatory factors that can be included is very limited in these econometric models; more explanatory variables could be included if more observations were available. This issue is summarised in a measure known

[12] The R^2 value shows how much of the variation in costs is explained by the cost drivers. As shown in Table 2.1, this is the case for at least 90% of the variation.

as the ‘degrees of freedom’ of the model, which is simply the number of observations less the number of parameters to be estimated.

Principle 3: In order to increase the number of observations for modelling, a panel dataset is used.

Panel data analysis is a natural extension to Ofwat’s current cross-sectional OLS approach. In contrast to this approach, pooled/panel techniques employ data on companies both across the industry and over time, enabling more observations to be used in the regressions, and thereby increasing the degrees of freedom in the modelling and potentially improving the robustness of the results. Thus, with N companies and T years of data, $N \times T$ observations would be available in a panel data framework.

The key advantage of using panel data is therefore that the sample size is significantly larger, allowing for a more precise estimation of coefficients, and strengthening the power of the test statistics. (In other words, it increases the probability of correctly detecting a difference and rejecting a null hypothesis, given that it is false).[13] In addition, company-specific and/or industry time trends or dummies can be included to capture changes in efficiency over time, and particular panel data techniques can control for ‘unobservable’ effects.

Another advantage of panel data is that, while cross-sectional data provides only a snapshot of producers and their efficiency, panel data provides more reliable evidence on their performance because it allows the performance of each producer to be tracked through a sequence of time periods. Thus, panel data also enables any atypical performance in one year to be checked and accounted for. For example, owing to luck, the frontier company may have had an atypically low-cost year, which would represent an unfair benchmark for the rest of the industry. Panel data would enable such atypical performance to be readily identified and accounted for.

Indeed, in the 2007 merger inquiry, the CC stated that panel data warranted further investigation:[14]

> We found there to be scope for exploring the use of both sub-company data and, in particular, panel data. There might also be scope to ensure that Ofwat made the maximum use of the available data from other sources, and to use alternative techniques (such as stochastic frontier analysis (SFA) and data envelopment analysis (DEA)) to validate the results of Ofwat’s existing econometric models where possible.

The Oxera analysis presented here is based on June Returns data for 2003/04 to 2008/09, giving 131 observations (five years’ worth of data, each with 22 companies, and one year, 2008/09, with 21 companies).[15]

[13] A potential shortcoming of this approach arises from the fact that the data points are not independently distributed over time. This *may* lead to bias or inconsistent results when applying OLS techniques, which can be remedied by allowing the regression intercepts (or even coefficients) to change over time using dummy variables. Therefore, alternative panel data models that take into account the nature of the data are generally more suitable for analysing panel data than the application of the pooled OLS technique. However, as shown below, this is of no concern for the data analysed in this submission.

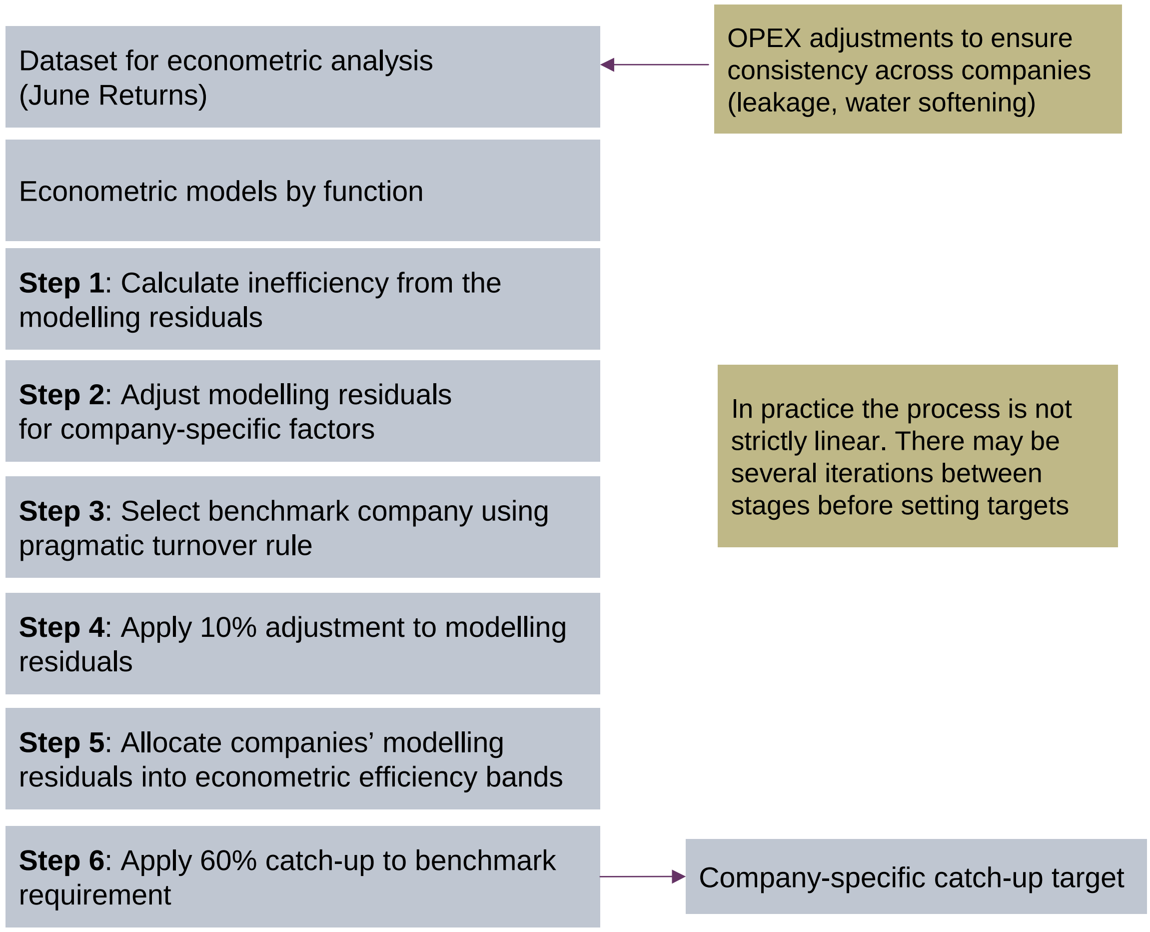
[14] Competition Commission (2007), op. cit., para 24.

[15] At the time of this analysis, data was not available on the special factors and regional wage adjustment for the 2007/08 data as applied in the Draft Determinations. Therefore, this submission to the CC inquiry uses the 2007/08 special factors published alongside Ofwat’s Relative Efficiency Assessment in January 2009. (Ofwat, ‘Relative Efficiency Assessment 2007-08, Supporting Information’, January 29th 2009.) These are understood to have been amended subsequently. A different one-sided regional wage adjustment to that published in the Relative Efficiency Assessment is also applied to the cost data since this is believed to reflect Ofwat’s current wage adjustment more closely than the adjustment published in January 2009. This adjustment was provided by Thames Water during PR09 and is similar to that of Ofwat in terms of the methodology and results. The provision of the special factor and regional wage adjustments used by Ofwat in 2007/08 may slightly alter the results of the

2.1.3 Modelling errors

The steps in Ofwat's approach to establishing company-specific operating cost-reduction targets for the water companies are summarised in Figure 2.1.

Figure 2.1 OPEX modelling for water services



Source: Oxera, adapted from Ofwat (2009), 'Relative Efficiency Assessments 2007–08—supporting information', January 29th.

In each model, companies' relative efficiency is calculated by comparing actual costs with those predicted from the model. Companies with costs lower than those predicted by the model (ie, with a negative efficiency estimate) are judged to be more efficient than those with higher costs than predicted by the model (ie, with a positive efficiency estimate). For each company, the results are aggregated across the four sub-models (ie, *total* observed costs are compared with *total* predicted costs).

Using Ofwat's approach, the efficiency of each company is therefore assumed to be captured by the *residuals* in the models—ie, that part of a company's costs that cannot be explained by the relationship postulated between the explanatory variables (which capture various aspects of geography and demographics) and costs. However, one issue with this approach is that the residuals contain both inefficiency and statistical noise (omitted cost drivers, incorrect functional form, data measurement errors, etc).

Ofwat's formula for calculating cost inefficiency (ie, percentage increase in cost due to inefficiency) for the ith company is based on the OLS residuals, and is calculated as follows.

$$(q_i - \min(q))/(100+q_i) \qquad \text{Equation 2.1}$$

econometric model, but is unlikely to have a significant effect on the 2008/09 inefficiency results. All other special factors applied in this analysis are taken from the Relative Efficiency Assessment in each year.

where q is the OLS residual in percentage terms. In contrast, the corrected OLS (COLS) approach uses the numerator of this equation only—ie, the cost inefficiency is defined as the difference between the OLS residual and the minimum OLS residuals (measured in percentages).

Thus, if the best-performing company (with the maximum negative OLS residual) happens to be the best because it got a lucky draw (a high negative value), all the other companies will look more inefficient than they actually are. This is potentially a serious problem. Ofwat seeks to control for this, to some extent, by considering the frontier company as the benchmark when that company's output is more than 2–3% of the total industry output (**Step 3**).

Ofwat acknowledges that, as with all modelling, its modelling is imperfect, and that the residual term also captures modelling errors and local factors that have not been captured by the econometric models. It partly addresses this issue by considering, in **Step 2**, companies' special factor claims—ie, those factors that increase a company's costs relative to other companies, but that are not captured in the modelling.

The modelling residuals—the difference between predicted and actual costs—not only represent inefficiency, but also include noise, introduced in the form of data collection errors, discrepancies in accounting conventions or modelling errors. In recognition of this, in **Step 4**, Ofwat adjusts the residuals resulting from its water models by 10%. This adjustment appears to be subjective. It is worth noting that noise is assumed to have a zero mean—ie, it is positive for some companies and negative for others. Thus, using a 10% adjustment for all companies is not necessarily the correct way to adjust for noise. This adjustment does not reflect the actual uncertainty in the modelling. For example, this adjustment does not discriminate between companies in terms of the degree of uncertainty about their predicted expenditure. Yet, in OLS regression, the further a company is from the mean value on the explanatory variables, the greater is the uncertainty about its predicted expenditure.

Instead of using the actual company-specific catch-up factor, in **Step 5** Ofwat allocates companies into five bands (A to E) according to their distance from the frontier (0–5%, 5–15%, 15–25%, 25–35%, and over 35%). These are then sub-divided into upper and lower bands, such that the bands represent estimates of inefficiency from the frontier of 0% (ie, the frontier), 0–5% (lower A), 5–10% (upper B), 10–15% (lower B), etc. Ofwat then sets cost-reduction targets based on the midpoint of each band (0%, 2.5%, 7.5%, 12.5%, etc). A company's estimated inefficiency is therefore increased or decreased depending on whether it is closer to the upper or lower bound of its allocated band. This implies a further regulatory adjustment.

Ofwat's banding approach suggests that it believes that its modelling can determine company inefficiency only within an accuracy of 5% over five years, or 1% per annum. Thus, a company with an inefficiency of 15.1% would be placed in Upper Band C (ie, 15–20%), and its cost-reduction target would be based on the midpoint of 12.5%. In practice, Ofwat also examines borderline cases and exercises some discretion in its final bandings.

Since a company can be estimated to be efficient simply because its inefficiency is confounded with noise, it is essential to separate noise from inefficiency. A more appropriate, transparent and objective way to adjust for uncertainty can be achieved by using SFA.

Principle 4: To reduce the subjectivity, Oxera uses SFA, which takes into account symmetric errors/noise in efficiency modelling. The only additional adjustment undertaken by Ofwat that is also considered in the Oxera modelling is step 2 (special factor claims). This is because SFA accounts for symmetric noise only, while special factors are asymmetric.

When companies are not fully efficient and the objective is not only to estimate the parameters but also to predict cost inefficiency, OLS is not the most appropriate approach to use. Under certain assumptions, the OLS slope coefficients are unbiased but not the intercept (which is biased upwards). Thus, the predicted cost and associated standard error are not correct because the OLS estimates fail to take inefficiency into account. The problem stems from the fact that the OLS residuals contain both noise and inefficiency, and there is no way of separating inefficiency from noise, given the OLS residuals.

With the objective of Ofwat's modelling being to estimate an efficient cost level for each company, a technique is needed that is capable of estimating not only the parameters of the cost function, but also the inefficiency of each company. In other words, a technique is needed that can separate inefficiency from noise. One main reason for using SFA is to provide this separation.

SFA is an econometric method that estimates the parameters of a production, cost, profit or revenue function *and* the inefficiency for each observation. The separation of inefficiency from the residuals is achieved with the help of the distributional assumption made on the noise and inefficiency components. Since inefficiency might be associated with many unobserved company-specific factors, it is modelled as a random variable. If the factors affecting inefficiency are observed, it is also possible to include them in the model as determinants of inefficiency, and to compute the marginal effect of each determinant on cost. Thus, the application of SFA allows for the noise element and true inefficiency components, and would therefore reduce the amount of judgement required in Ofwat's current approach.[16]

Indeed, in the 2007 merger inquiry, the CC was also of the opinion that SFA warranted further investigation:[17]

> We found that alternative approaches, including in particular SFA and DEA, might have some value in validating the results of the Ofwat's existing models. Together with alternative data sources … , we thought that these should be kept under review by Ofwat in the future.

2.2 Summary of the Oxera approach

The results presented here are based on an econometric model for total water services, estimated using several years of data. SFA is then employed to benchmark the water companies. This approach has a number of advantages, as detailed below.

– **Panel data**. Ofwat's current approach is based on a single year of data. The analysis presented in this submission to the CC inquiry is based on data covering several years. This has the advantage that it increases the number of observations available, allowing more explanatory variables to be included in the model than when cross-sectional data is used, and improving the statistical validity of the models. The use of panel data has been shown to substantially improve the precision of the estimated coefficients compared with cross-sectional data.[18]

– **Aggregate water model**. Ofwat currently models water OPEX at a disaggregated level using functional models for different cost areas. The results are then aggregated up to estimate the overall relative efficiency of each firm. The analysis presented here is based on an econometric model for total OPEX for water activities. Modelling at an aggregate, rather than a functional model, level has the advantage that it avoids the

[16] Some degree of judgement is still necessary since an assumption needs to be made about the distribution of inefficiency, which, in practice, is unknown. However, this is different from, for example, adjusting the residuals for all companies by 10% or treating the company with the lowest residual as fully efficient.

[17] Competition Commission (2007), op. cit., para 6.21.

[18] This is evident through the lower standard errors of the estimated coefficients. See Kumbhakar and Horncastle (2010), op. cit.

issue of whether costs are separable across the different water activities. Furthermore, it reduces the impact of differences in cost allocation mechanisms across the water companies. The aggregate model used to estimate the relative efficiency of water companies is identified from a limited number of variables (although this dataset does include all the cost drivers used by Ofwat in its functional modelling, as well as several others).

– **SFA**. Ofwat's current approach uses COLS to estimate the relative efficiency of the water companies. One of the main weaknesses of such an approach is that it assumes than any difference between a company's observed costs and the regression line (ie, the residual) reflects inefficiency. It does not account for any stochastic error or noise in the model (eg, measurement error) which may affect the residual. COLS may therefore impose harsh targets when the stochastic error element of the residual is large. By assuming a distribution for the inefficiency and the random error components of the residual,[19] SFA is able to decompose the residual term into inefficiency and noise, and thereby identify the relative inefficiency of each firm in the sample. It can also be used to test for the presence of inefficiency. SFA models developed by Professor Subal Kumbhakar also allow for extensions to the standard SFA model to account for heteroscedasticity (ie, the residuals do not have a constant variance) in the inefficiency or noise terms of the model and exogenous determinants of inefficiency (eg, complex water treatment procedures for particular companies or a high volume of burst pipes). Ignoring these issues may lead to biased inefficiency estimates.[20] However, one of the disadvantages of SFA is that it often requires large datasets (although this is the case for any econometric model to obtain precise estimates). The availability of June Returns data for a number of years now enables this approach to be applied.

[19] The stochastic error component of the residual is assumed to be normally distributed. The inefficiency component may be half-normal, truncated or exponentially distributed.

[20] For more detail, see Kumbhakar, S. and Knox Lovell, C.A. (2000), *Stochastic Frontier Analysis*, Cambridge University Press, March.

3 Appropriateness and precision of the Oxera modelling

This section demonstrates that modelling with panel data is more robust than Ofwat's current models, which rely on cross-sectional data. The purpose is to show that approaches that use panel data are:

– **statistically valid**—the nature of the data in the UK water industry is such that it is valid to adopt approaches that use panel data rather than having to rely on cross-sectional data (section 3.1);

– **superior** to Ofwat's current econometric approach (section 3.2)—the accuracy of the modelling compared with Ofwat's current models is increased such that there is less need to rely on as many regulatory judgements as at present.

We then show, in section 4, that models can be developed which make use of panel data that is already available and which are statistically valid.

3.1 Poolability

In section 4, a number of models are developed using panel data; however, the starting point is to ensure that such an approach is statistically valid.

Within a panel data framework, various models are possible. The appropriateness of each is dependent on the data and can be tested for. In the first instance, it can be tested whether the data can be pooled (poolability hypothesis) against the alternative that coefficients vary cross-sectionally. If not, cross-sectional regressions can be run by year to examine the temporal behaviour of the regression. However, if the estimators do not change much from year to year, the error variance can be estimated more precisely (which will lessen the predictive uncertainty) by pooling the data.

To be able to pool the data, the parameters should not change over time, which can be econometrically tested by performing the standard Chow test. If this crucial assumption is satisfied, panel data analysis can be used to increase significantly the number of observations, and the OLS estimates from the pooled model will be more precise (ie, the standard errors will be smaller). Moreover, the model will have higher degrees of freedom than cross-sectional OLS. However, since pooling is based on the restrictive assumption that all the parameters (including the intercept) and the error variance are unchanged over time, as well as across cross-sectional units (in this case, companies), the first step is to test the appropriateness of the poolability hypothesis. If this hypothesis is rejected (ie, some or all of the parameters are either not the same for all companies or are not stable over time), the pooled OLS results are biased (and might be inappropriate).

The statistical tests (performed in the Oxera modelling of total OPEX and total OPEX less special factors) are based on running unrestricted models where the coefficients on the explanatory variables are allowed to change over time, and comparing the results to restricted models where the coefficients are assumed to be constant over time. If the unrestricted model provides a better fit than the restricted model, this would suggest that a cross-sectional OLS modelling strategy is more appropriate. The idea is therefore to test the restrictions statistically. The test statistics depend on formulation of the restricted and the unrestricted models. Since cost, given everything else, is likely to change over time, in specifying the unrestricted model there is the option to allow intercepts and/or slopes to differ over time.

The pooled OLS model is first tested against the alternative that slope coefficients differ over time (ie, the coefficients are year-specific). The unrestricted model allowed both the slopes and intercepts to be year-specific. This is a standard F test and the test result rejects the null hypothesis at the 5% level of significance (for each model). The results of the poolability tests for the aggregate models discussed here are reported in Table 3.1. The values of the test statistics for each of these models are reported in column 1, while column 2 reports the critical values and column 3 the acceptance/rejection decision. Further details of the aggregate models are provided in section 4.

Table 3.1 Test results on the stability of the aggregate model over six years, 2003/04–2008/09

Model	Value of test statistics	Test probability	Implication
Total OPEX			
Pooled OLS	0.31	0.99	Cost function is stable
Total OPEX less special factors			
Pooled OLS	0.64	0.90	Cost function is stable

Note: The test checks whether the year-specific (dummy × coefficient) coefficient is equal to 0.
Source: Oxera calculations.

In both models, the hypothesis that there is structural change is rejected—ie, the pooled OLS model is accepted. Given the stability of the slope parameters, the above tests are repeated on intercept dummies for each year. The F test does not reject the null hypothesis that the intercept is time-invariant. On close scrutiny it was found that only one or two of these year effects are statistically significant and only in the model excluding special factors. The classical pooling model was therefore used, but with a slight modification to allow for some year effects.

3.2 Precision

Having demonstrated the statistical validity of using pooled OLS, the next step is to test whether this approach provides more precise estimates.[21]

One way of establishing the gain in accuracy from using the expanded dataset is by comparing the confidence interval around the predicted cost resulting from the two models. As discussed above, confidence intervals depend critically on the properties of the data: the deviation of the explanatory variables from their respective means; residual variance; and sample size. All else equal, from the statistical point of view, a larger sample size will reduce the standard error of the parameters, thereby tightening the confidence intervals (for a given level of significance).

Table 3.2 compares the sum of the 95% confidence intervals across the 21 companies' predicted values for the cross-sectional models against pooled models using the latest available data.

[21] The following is based on Kumbhakar and Horncastle (2010), op. cit.

Table 3.2 Comparison of confidence bands around predicted costs in models based on cross-sectional data and panel data

Year	Cross-sectional data, 2008/09	Panel data, 2003/04 to 2008/09
Total OPEX (£m)	360.1	125.1
Total OPEX less special factors (£m)	265.3	92.0
Number of observations	21	131

Note: The figures are the sum of the difference between the £m value of the upper and lower confidence interval bounds (95% confidence) for each company's predicted cost in 2008/09.
Source: Oxera analysis.

Table 3.2 shows that the confidence intervals using the panel dataset are almost a third of the confidence intervals when using one year of data—ie, precision is greatly improved by using the panel dataset.

3.3 Summary

As shown in Table 3.1, a pooled econometric approach is statistically valid as the cost functions have not significantly altered over the timeframe considered. Additionally, as shown in Table 3.2, using a pooled dataset results in far greater precision when predicting companies' costs.

4 Results

Oxera and Professor Subal Kumbhakar have estimated an econometric model for water services total OPEX based on a sub-set of the data provided in the June Returns.

4.1 Estimated model

As the Oxera modelling is based around that of Ofwat, very similar cost drivers and similar functional forms and transformations of the variables are used. The resulting model is shown in Table 4.1.

Table 4.1 Aggregate water model: total OPEX

ln(length of mains/number of properties)	–0.33***
	(–4.25)
Number of sources/distribution input	1.52***
	(5.73)
Proportion of distribution input from boreholes	–0.31***
	(–4.31)
ln(total number of billed properties)	0.96***
	(75.34)
Proportion of distribution input requiring W3 or W4 treatment	0.21*
	(2.50)
Constant	–1.87***
	(–7.21)
N	131
Adjusted R^2	0.986

Note: t-statistics in parenthesis. *** significant at 0.1%, ** significant at 1%, * significant at 5%.
Source: Oxera analysis.

Based on this model, Bristol Water is estimated to be in Lower Band B. However, this model does not account for special factors and cannot statistically identify the presence of inefficiency, possibly because of the inclusion of special factors in modelled costs.

4.2 Special factors

The SFA modelling presented in this section seeks to remove the effect of symmetric noise from estimated inefficiency. Company-specific factors may, to some extent, be symmetric and thus be contributing to this noise. So, the modelling in this section partly accounts for these issues.

Within its comparative efficiency framework, Ofwat accounts separately for special factors. These represent company-specific effects outside management control that increase a company’s costs relative to those of other companies, and should not be estimated as part of inefficiency. If special factors are not removed, as is the case in this section, inefficiency estimates will be biased upwards.

The modelling of this section is repeated but with operating costs less special factors. Although the special factors are removed in a similar way as is done by Ofwat, this happens before the modelling, whereas Ofwat does it afterwards. However, in general, companies claim special factors only when they result in increased cost. Thus, the special factors deduct something positive from company-specific effects. In other words, the company-specific effects are not completely eliminated by the removal of special factors. This holds in both Ofwat's and Oxera's modelling. In the latter, this will not lead to biased inefficiency estimates if the company-specific effects are similar (after special factors are removed) so that they are absorbed in the intercept terms and do not affect inefficiency. However, as the effect is unclear, the approach taken here is to consider the modelling both with and without special factors removed from the modelled costs.

The special factors and regional wage adjustment included in this analysis is based on data provided in the Relative Efficiency Assessment in each year.[22] The regional wage adjustment used here is one-sided. The use of a two-sided adjustment may affect the results.

The resulting model is shown in Table 4.2.

Table 4.2 Aggregate water model: total OPEX less special factors

ln(length of mains/number of properties)	–0.22***
	(–3.64)
Number of sources/distribution input	1.42***
	(6.91)
Proportion of distribution input from boreholes	–0.36***
	(–6.47)
ln(total number of billed properties)	0.97***
	(98.03)
Proportion of distribution input requiring W3 or W4 treatment	0.08
	(1.18)
Year dummy in 2008/09	0.08***
	(3.19)
Constant	–2.20***
	(–10.85)
N	131
Adjusted R^2	0.992

Note: t-statistics in parenthesis. *** significant at 0.1%, ** significant at 1%, * significant at 5%.
Source: Oxera analysis.

The average inefficiency estimate for Bristol Water resulting from this model is 7.3% in 2008/09. This places Bristol Water in Upper Band B and is consistent with Ofwat's Final Determinations. The model provides a range of inefficiency estimates of 5.8% (exponential distribution) to 8.8% (half-normal distribution). The lower range of the results places Bristol Water at the margin of Lower Band A. The model is able to differentiate statistically between noise and inefficiency in the model.

[22] The 2007/08 adjustments used in the Draft Determinations differ from those published in the 2007/08 Relative Efficiency Assessment and were not available at the time of this analysis.

4.3 Model diagnostics

The estimated coefficients make intuitive sense and are in line with industry knowledge and comparable to those estimated by Ofwat. In particular:

- the coefficient on length of main per property is negative, as per Ofwat's Distribution model. This variable captures the density or urbanisation of a company's network. The more urban or dense a network, the cheaper it is to maintain;
- the coefficient on the number of sources per distribution input is positive, as per Ofwat's R&T model. This variable takes into account economies of scale at the source level (costs will be lower if fewer sources are used);
- the coefficient on the proportion of distribution input from boreholes is negative, as per Ofwat's R&T model. This variable takes into account the difficulty of treatment (borehole supplies will generally be cheaper to treat than other sources);
- the number of billed properties is the scale driver of the model. The estimated coefficient of 0.97 suggests that economies of scale exist. This is consistent with Ofwat's modelling, which estimates economies of scale in Business Activities and Power, and constant returns to scale in Distribution and R&T;
- the coefficient on the proportion of distribution input requiring W3 or W4 treatment is positive and captures the extra cost associated with this level of treatment. As such, there may be some overlap with the proportion of distribution input from boreholes. However, the two variables are not highly correlated with each other, so it was considered worth including both cost drivers. The t-test on this variable fails at 10% statistical significance, but has an intuitive coefficient and is believed to be an important cost driver. An alternative representation (not examined in this submission) would be to consider an extension of the SFA model. (This is discussed in more detail below);

a dummy variable for 2008/09 was included in the model (this variable was not statistically significant in the total OPEX model). The coefficient on this variable indicates that costs were 8% higher on average across the industry in 2008/09 than in previous years. To test whether the slope coefficients vary over time, time dummies were added, as well as their interactions with the cost drivers. As demonstrated in section 3.1, the standard F test based on the OLS model fails to reject the null hypothesis that the slope coefficients are the same over time. Conditional on the slope coefficients being the same, a joint test for no year effects in the intercept was also undertaken. The F test does not reject the null hypothesis that the intercept is time-invariant.

Statistical tests also show the presence of heteroscedasticity in the model. We return to this point below. The model fails the Ramsey Reset test for correct functional specification. However, the modelling also tests whether the functional form is consistent for the entire dataset by using quantile regression to examine whether the coefficients across the quantiles are the same. The test shows that this is the case.

Heteroscedasticity has been identified in the SFA models. Extensions to the standard SFA model using techniques and models developed by Professor Subal Kumbhakar can control for this heteroscedasticity, which may be biasing the efficiency estimates. In previous work, Oxera has shown that the inclusion of company-specific additional variables in the extension to the SFA model (eg, complexity of treatment or burst rate) can result in more robust efficiency estimates, and can provide an objective estimate of the cost of these additional factors. In this submission, extensions to the SFA model have not been explored using the latest available data or for issues raised by Bristol Water in its submission to the CC.

5 Conclusion

Having examined Ofwat's approach, the Oxera modelling has followed similar principles. It uses very similar functional forms and cost drivers, but based on a pooled dataset over the period 2003/04 to 2008/09, with SFA applied to aggregate water cost functions. These three alterations to Ofwat's approach improve the robustness of the estimated inefficiency because:

– using a panel approach, rather than a year-by-year cross-section model, provides more data and improves the precision of the modelling;

– modelling at the aggregate level—ie, for water services total OPEX—removes the requirement for cost separability and consistency in cost allocation, while allowing for the inclusion of multiple cost drivers;

– SFA is a superior and more objective approach to account for modelling errors/noise, compared with COLS and additional subjective adjustments.

This submission to the CC inquiry has first shown that modelling with panel data is statistically valid and that this results in greater precision, before presenting an econometric model for aggregate water OPEX and estimating the relative efficiency of water companies using SFA.

The analysis presented here suggests that Bristol Water should be placed in Upper Band B, and is consistent with Ofwat's assessment in the Final Determinations. The model results in a range of inefficiency estimates of 5.8–8.8%, depending on the distributional assumptions used in the SFA model.

Further analysis is required to examine the impact of using a two-sided wage adjustment, and to extend the SFA model to account for the heteroscedasticity present in the model, including the impact of accounting for issues raised by Bristol Water in its submission to the CC. These adjustments to the model may affect the results of the analysis.

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