



The Evolution of Ofwat's Approach to Efficiency Analysis

John Hargreaves, Matt Parr, Helen Lay and Melvyn Weeks

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Indepen Consulting Ltd
Diespeker Wharf, 38 Graham Street, London N1 8JX
T +44 (0) 20 7324 1800 F +44 (0) 20 7253 4949 www.indepen.co.uk

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Executive Summary

In 2005 Ofwat asked an Independent Steering Group¹ to review the 2004 Periodic Review. One of the Group's principal recommendations was that *"In view of the widespread industry dissatisfaction with Ofwat's efficiency methodology, and the large number of studies carried out in this area, we recommend instituting a joint industry review of efficiency studies and econometric approaches with the aim of developing a common industry approach for the 2009 review."*²

This report seeks to provide clarity over Ofwat's approach to assessing efficiency and its application in price setting and to review the evolution of Ofwat's approach given the significant literature in this area. It also captures the views of academics that work in this area.

The study has been sponsored by four water companies: Anglian Water; South East Water; Thames Water; and Yorkshire Water. At all stages we have worked closely with our sponsors, Ofwat and Water UK. Each of the parties has been involved in scoping the review and has had an opportunity to review and comment on our findings.

RPI-X price cap regulation is widely regarded as having provided strong incentives for companies to become more efficient. However, the act of setting price limits is not simple and regulators need to combine the results of analysis with judgement. Judgements should reflect the context within which price limits are set including the objectives of regulation, the incentive effects of the regime, the information available, a wide range of technical considerations and the acceptability to stakeholders of the outcomes. In addition, better regulation stipulates that regulatory processes and decisions should be transparent, replicable and well understood.

Ofwat seeks to determine the overall scope for efficiency improvement and also to set company specific X factors. We have found that Ofwat's approach to assessing efficiency and its application in price setting is multi-stage and the results are modified by several important regulatory judgements. It appears to be reasonably transparent to water company practitioners but can be somewhat counter-intuitive and overly-complicated to water company executives that do not have time for detailed study of Ofwat's approach. Amongst other things this may lead to a lack of trust in the approach.

Defining Key Terms

The RPI reflects productivity growth and input prices in the economy as a whole. The RPI-X formula aims to index the increase in output prices in the water sector to the increase in the efficiency of the sector. It is unclear exactly how Ofwat applies this intention. It has not clearly distinguished between efficiency and productivity and there may be inconsistencies. It would be helpful if Ofwat were to publish its definitions and confirm they are consistent with the academic conventions.

Key Decisions

A number of key decisions are required in order to implement price cap regulation and are present in the case of Ofwat's approach to PR04. They include

- how to identify relevant comparators
- how to select and apply the most appropriate analytical and statistical methods
- for the parametric methods, how to specify the independent variables (cost drivers) and the relationships to be analysed

¹ Report into the Conduct of the 2004 Ofwat Periodic Review. A report commissioned by Ofwat from the Independent Steering Group, August 2005.

² Ibid, p.9.

- how to collect and validate relevant data (typically volumes and values of inputs and outputs and the conditions in which the entities operate), particularly important given the significance of cost attributions in the water industry
- what separability assumptions are viable. For example, using company or sub-company data, taking all a company's services together (thereby avoiding cost attribution problems) or considering individual services separately
- how to combine the results based upon analytical methods with a relatively large number of qualitative regulatory judgements
- what inferences can be drawn from the results of the analysis.

In responding to these issues and the circumstances in the sector, Ofwat has developed a complex approach to price setting. This may be characterised by a base methodology centred upon an econometric model, in combination with the application of a number of regulatory interventions. Our principle views of this approach are

- The complexity stems from by pragmatism rather than theoretical considerations or evaluation of the benefits that complexity brings. The approach has evolved and it is not clear that if you started again you would end up here.
- The complexity precludes the approach from being transparent or readily understood by those who are not closely involved at a technical level.
- The incentive properties of the complexities and the overall approach are not obvious.

Regulatory Judgements

An important component of this complexity is the substantial number of judgements. The number and nature of the judgements that Ofwat makes detract from the objectivity that we might expect of a soundly based statistical analysis. These judgements include

- Judgements by the regulator about company specific factors. These stem from data limitations and subsequent follow dialogue between the companies and the regulator. Such judgements are an important determinant of the extent to which unexplained differences in costs are assumed to reflect inefficiency. However, the impact of company specific factors on final inefficiency factors is not transparent.
- How to identify the benchmark against which to judge the efficiency of the individual entities. Under Ofwat's PR04 approach, uncertainty attaching to the benchmark company is ignored and prices are set as if the position of the benchmark company were known with certainty. Since the selection of the benchmark company is based on estimates, this should be reflected in the analysis.
- How to evaluate the performance of each entity relative to the benchmark and decide what part, if any, of the difference between actual performance and the benchmark, reflects an efficiency difference.
- What assumption to make about the speed with which and the extent to which those companies judged to be inefficient can catch-up with the best performers.

Consideration of the regulatory judgements involved brings into focus the robustness of the final distribution of X factors and how to account for the various dimensions of uncertainty that underlie the final estimates of inefficiency. Uncertainties stem from the type of econometric model used, the nature of the regulatory adjustments, and from the small number of comparators.

Changing Context

Ofwat has been reasonably consistent in its approach to assessing companies' relative efficiency. For example, since the 1994 Periodic Review Ofwat has used only one methodology (Ordinary Least Squares (OLS)) to determine relative operating efficiency for the purpose of setting prices. Although Ofwat has examined other techniques (considered in this report) that can be used to assess efficiency, these have not been used in price setting.

It is open for discussion whether Ofwat's approach has adequately evolved to reflect the changes observed in the industry. Since privatisation the industry has made significant efficiency improvements, there appears to have been a convergence in efficiency and the number of separate water companies has fallen from 39 to 22. There is also evidence that the significant driver of efficiency since privatisation has been technical change (i.e. frontier shift) rather than catch-up between companies. Despite these changes and a good historical data set to examine these issues, there is not common agreement between Ofwat and the industry over these changes or the current industry context.

Recommendations

Indepen supports the Baker review in calling *a joint industry review of efficiency studies and econometric approaches with the aim of developing a common industry approach for the 2009 review*. We believe that the current UKWIR initiative is a step in the right direction.

We believe that there needs to be a common understanding of the evolution of the industry and that there is a good time series of data to examine these issues. Once this has taken place can the industry start to develop a common agreed approach for the next Review.

Clearly technical experts have a clearer understanding of this area of regulation than generalists but efficiency is so central to the price setting regime that it needs to be widely understood and accepted in order to create the right incentives. We believe that it is desirable to involve senior industry executives on the steering committee of the UKWIR project.

The primary consideration should be the incentive consequences of designing the regime in different ways.

1 Introduction

This introductory section provides the context for this report; sets out some of the issues with the treatment of efficiency in regulation; describes the terms of reference and structure of the report and thanks those who supported the project.

1.1 Context for this report

1.1.1 Origins of Ofwat's approach

At the time of privatisation there were large differences in companies' unit costs. Ofwat made the fundamental decision that it should make company specific efficiency assumptions based on an analysis of comparative performance and that these should result in different price limits for the companies.

The considerations in comparing possible efficiency approaches would be

- the relative information burden of the two approaches
- the incentives that each approach creates and how these support or conflict with the other incentives in the regime and
- the likely net effects on productive and allocative efficiency.

The comparative approach is challenging as it requires the regulator to know what is the right level of efficiency. The basis of Ofwat's approach is an explicit recognition that, as well as possibly reflecting efficiency differences, differences between companies' costs result from differences in circumstances and in constraints on available resources. Unfortunately, the information contained in the feasible set of cost drivers imperfectly captures these differences.

The regulator has sought to move on from unit cost comparisons precisely because these make no allowance for the effect of differences (observed and unobserved) between companies' operating environments. If these differences are not accurately measured, this will call into question the validity of inferences on efficiency. Estimates, purportedly of comparative efficiency, will be contaminated by other unmeasured differences.

As a consequence of these problems, it would be desirable to consider an approach that used a single efficiency improvement number for all companies, this being the obvious counterfactual to Ofwat's comparative approach. As it would not be necessary to compare the levels of efficiency of the companies, the information requirements would be less challenging. Ofwat already seeks to establish the frontier shift or continuing efficiency assessment.

As far as we are aware, Ofwat did not consider alternatives to its comparative approach nor did it at the time it made the decision or subsequently publish any appraisal of the benefits that comparative analysis would provide. Even so, it began the significant programme of data collection and analysis to implement the comparative approach.

1.1.2 Developments up to PR04

During the 1990s, water companies substantially outperformed Ofwat's efficiency assumptions. As well as the windfall tax, the late 1990's saw a significant tightening of the regulatory regime in water. This manifested itself in a number of ways

- Requests for companies to return money to customers (through cash rebates or K deferrals)
- Increased monitoring of companies' inputs and activities

- Requirements that companies explain differences from Ofwat's assumptions
- Increased specification at Price Reviews of inputs and outputs

Ofwat made more challenging efficiency assumptions at the 1999 Periodic Review.

Ofwat's approach to efficiency did not change markedly for the 2004 Periodic Review and while the final determination as a whole was regarded as being better balanced, elements of Ofwat's approach, including the treatment of efficiency, remained contentious.

1.1.3 Challenges to Ofwat's approaches

The opportunities to review and challenge the regulator's policies and decisions are as follows

- Regulated companies can require referral to the Competition Commission of any licence modifications proposed by Ofwat (including price limits). Referrals have been few, however, and none of the water companies required their PR04 price limits to be referred to the Commission.
- From time to time, parliamentary committees and the National Audit Office scrutinise the activities of regulators but they have not looked in detail at the efficiency question in water.
- There has been no judicial review of Ofwat's approach to efficiency.

All elements of price setting, including efficiency, are subject to challenge by the regulated businesses as part of the periodic review process, but companies are not impartial and, in any event, this challenge is usually in private. In practice, therefore, Ofwat's approach has not been subject to independent scrutiny that is on the record.

Following the 2004 Periodic Review, Ofwat asked an Independent Steering Group to examine the way Ofwat had carried out PR04. The group's report, known as the Baker Report,³ had as one of its principal recommendations

"In view of the widespread industry dissatisfaction with Ofwat's efficiency methodology, and the large number of studies carried out in this area, we recommend instituting a joint industry review of efficiency studies and econometric approaches with the aim of developing a common industry approach for the 2009 review."

This review will shortly be commissioned by UKWIR.

1.2 Background to the regulatory assessment of efficiency

In this section, we provide background on

- various efficiency concepts
- approaches to comparing efficiency
- the incentive implications of the various approaches.

1.2.1 Measures of efficiency

The literature on the topic of efficiency is extensive and often confusing. The following are some of the causes of this

- Economists attach different adjectives to efficiency to give a range of different meanings. In the statements of regulators and companies it is not always clear which sort of efficiency they mean.

³ Report into the Conduct of the 2004 Ofwat Periodic Review. A report commissioned by Ofwat from the Independent Steering Group, August 2005.

- Efficiency is a ratio of outputs to inputs and this means that for the definition to be clear it must be qualified. For example, an increase in efficiency can occur if there is an increase in output while inputs diminish, remain the same or even increase but less than proportionately with output. Reducing output can also be efficient if inputs diminish by more.
- If the production of goods or services involves multiple outputs or inputs or both, then we can define a plethora of partial measures.
- Efficiency is not directly observable and as such we must infer it from differences in things that can be. This entails many different approaches.

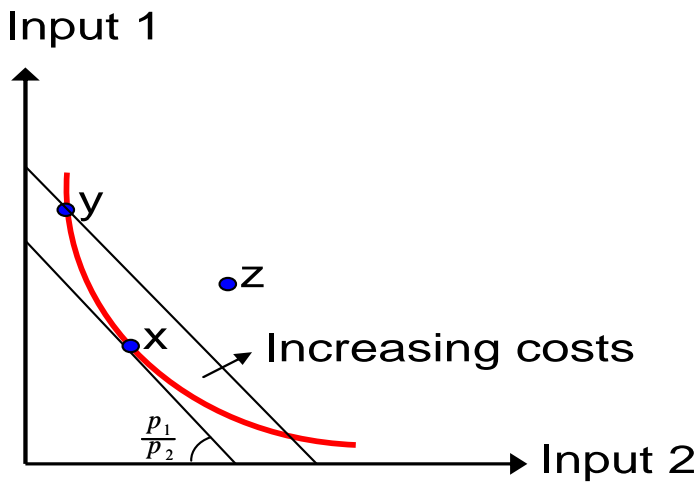
Some frequently used efficiency concepts are as shown in Table 2.1.

Table 1.1 – Concepts of efficiency

Concept	Definition	Related concepts
Productive efficiency	This refers to the efficient production of a given set of outputs, sometimes characterised as being on the production possibility or efficiency frontier. For a firm, this is achieved when it combines factors of production so that the ratio of the marginal products of any pair of factors is equal to the ratio of their prices.	Engineering efficiency – a partial measure, the ratio of output to the input of a single factor (e.g. miles per litre of petrol). Technical efficiency – the ratio of output to the physical amount of all factors involved in production. Economists also call this “X efficiency”. Economic efficiency - the ratio of output to the value of all the inputs. A firm is efficient if there is no way of using a lower value of inputs.
Allocative efficiency	Reflects an efficient choice between positions on the efficiency frontier. The economy or a company is efficient in allocative terms if, as well as being on the efficiency frontier, the marginal cost of producing any product is equal to its price.	Producing the right outputs in the right way – allocative efficiency means that the sum of consumers' and producers' surplus is a maximum. The output in a market with perfect competition is allocatively efficient.
Dynamic efficiency	The system produces desirable process and product innovations and flexible responses to changes in demand.	Other things being equal, regulation limits dynamic efficiency.
Comparative efficiency	A regulatory term referring to a range of techniques to used to compare regulated entities and use the best performer as the standard for achievement by the others – See 1.2.2	Absolute efficiency – meaningless in this context Comparative competition – the way in which companies respond to the incentives introduced when regulators publish performance league tables Catch-up – the extent to which the laggards catch up with the leaders in comparative competition

Figure 1.1 illustrates the concepts of productive and allocative efficiency in a simple example where there are two inputs and a single output. Firms X and Y are productively efficient as they are on the efficiency frontier. Firm Z is not as, in comparison with firm X, it uses more of both inputs. Only firm X is allocatively efficient, however, as Firm Y has higher costs for the same output.

Figure 1.1 – Productive and allocative efficiency



If regulators were seeking to maximise welfare (the sum of consumer and producer surplus) they would focus on allocative efficiency. Ofwat has developed the use of estimates of long run marginal cost (LRMC) in a number of decision areas in the interest of promoting allocative efficiency.

There are, however, theoretical, methodological and practical problems estimating LRMC and using it when setting price limits. There are questions about the incentive properties of Ofwat's price controls and whether they encourage companies to respond in a way that maximises welfare. These are not the subject of this review but given the significance of incentives to the success of the regulatory regime, these considerations are relevant to the review that UKWIR is commissioning in response to the Baker Report's recommendation on efficiency.

In the remainder of this review we are concerned mainly with comparative, technical efficiency.

1.2.2 Techniques for comparing efficiency

The simplest comparison focuses on unit costs. This will only be helpful if certain restrictive assumptions are met. An inference that the entity with the lowest unit cost is the most efficient ignores

- possible economies or diseconomies of scale
- possible economies or diseconomies of scope
- any effect on cost of differing operational conditions - an entity that operates in an expensive area is not necessarily inefficient even if it has relatively high unit costs
- A comparison that allows for these factors is inevitably more technical and comes with additional data requirements. The economic regulation of water, and other regulated industries, in the UK has tended to move in this direction. As a consequence it entails a number of judgements and decisions for the regulator to make all of which should have regard to the complexity illustrated in Table 2.1.

The methods used by regulators to facilitate efficiency comparisons fall into three main groups

- judgemental approaches, such as best practice comparisons, process benchmarking and comparisons of standard costs
- non-parametric methods

- parametric statistical methods.

The first of these is outside the scope of this review. The others are in scope and we describe them briefly below and consider their pros and cons. We also describe panel data approaches that can be used with both parametric and non-parametric methods.

Non-parametric methods

These include

- ratio comparisons
- the use of indices or growth accounting approaches
- Data Envelopment Analysis (DEA), a technique based on linear programming.

DEA depends on the notion that an entity producing the same output with fewer inputs is more efficient. It does not depend on the specification of a cost or production function: the location and shape of the efficiency frontier are derived from linear segments that join up the firms with the highest ratios of outputs to inputs.

Parametric methods

Parametric methods entail the specification and estimation of an equation that describes the way in which inputs are converted into outputs, allowing for the estimated effects of a range of cost drivers. The parametric approach identifies a variable (known as the dependent variable) to be explained by one or more independent variables. The relationship between the dependent and independent variables is described by parameters, also known as coefficients. For technical efficiency the dependent variable would be output and for economic efficiency it would be input cost (definitions as in Table 1.1).

The parametric approach specifies a set of independent variables that are likely to explain differences in the dependent variable. It then applies statistical methods to the data for the companies to estimate the best relationship between the dependent and independent variables. The difference between an actual data point for any company and the value implied or predicted by the estimated relationship is known as the residual.

The most widely used parametric approach is known as Ordinary Least Squares (OLS). This method estimates the coefficients so that the relationship minimises the sum of the squares of the residuals, in other words it estimates the line of best fit. Entities with a positive residual have higher than expected costs, and vice versa.

One interpretation of the results is to assume that at least one entity in the sample is on the efficiency frontier. For a cost function this would be the company with the largest negative residual. This interpretation has obvious relevance to comparative efficiency.

A variation on the basic OLS method is known as Corrected OLS or COLS. The correction shifts the OLS relationship so that it passes through the position of the frontier company and the performance of the other entities is judged relative to this. Ofwat has made extensive use of COLS.

Another parametric method is Stochastic Frontier Analysis (SFA) under which a cost or production function is specified in the same way as in OLS but the residual is explicitly defined. The residual has two elements: a random error that can be positive or negative, and a non-negative element that measures the inefficiency. The basis of the additional assumptions required is often questioned.

Panel data

The term panel data is used to describe a data set that includes more than one observation from each entity, for example a data set which includes observations at different points in time or on disaggregated parts of each company at one point in time. Ofwat's sewerage operating expenditure models (sewerage networks and large treatment works) are examples of the latter.

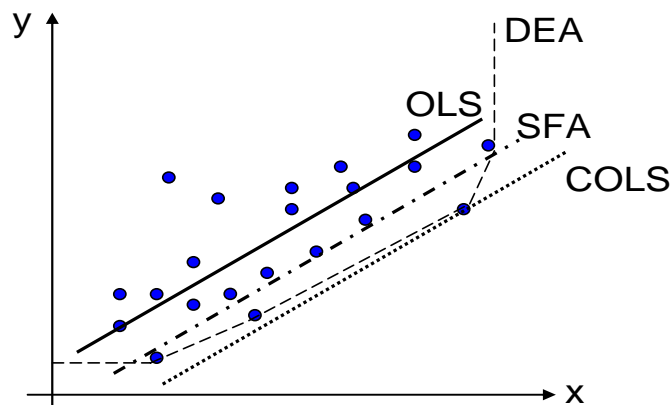
Each of the main techniques discussed above (OLS, SFA and DEA) can be adapted to use panel data. If there is consistent time series data for each entity, these techniques can distinguish between the relative efficiency of the different companies and efficiency improvements over time.

Pros and cons of the methods

The methods are illustrated in Figure 1.2 for the case of a single input (x) and a single output (y). Features of the different approaches include

- The OLS technique estimates a line through the data points.
- The COLS adjustment shifts the line vertically downwards to go through the data point that represents the entity unit with the biggest negative residual.
- SFA assumes that a certain proportion of the residual is due to random errors with the remainder being inefficiency. The residual for observations below the SFA line is attributed to random error (since the inefficiency component cannot be negative).
- DEA finds a line that wraps around the observations.

Figure 1.2 – Illustration of different techniques for efficiency assessment



Parametric methods require a number of decisions, such as the form of the function to be estimated, which variables should be included (inputs, outputs, and environmental factors) and the distribution of the residuals. The inefficiency estimates may be sensitive to these assumptions and it is possible to apply non-parametric methods alongside econometric assessments.

It is not possible to say generally which is the most appropriate technique: each has strengths and limitations.

Table 1.2 summarises some of the pros and cons of the methods.

Table 1.2 – Pros and cons of efficiency assessment techniques

	Pros	Cons
Non-parametric approaches		
Simple ratios	Simple to understand Easy to compute	Does not take into account factors that lead to valid differences across companies
Index/growth accounting approach	Widely used for estimating productivity Useful with few observations	Not designed for comparative analysis Problem of defining and measuring aggregate inputs and outputs
Data Envelopment Analysis (DEA)	No explicit functional form imposed Can cope easily with multiple inputs and outputs	Assumes no measurement errors or noise In small samples, can suggest that all firms are efficient Sensitive to choice of inputs and outputs Sensitive to outliers
Parametric approaches		
Ordinary least squares (OLS) and Corrected Least Squares (COLS)	Robust Works with finite samples, although robustness increases with sample size Can cope with multiple inputs and outputs, e.g. through simultaneous equations	Assumes a specific functional form COLS assumes that at least one company is efficient, that there are no measurement errors and that the marginal effects of the cost drivers is the same for the frontier company as for the average (i.e. COLS is a vertical shift of the OLS line - the gradient of the function is unchanged)
Stochastic frontier analysis (SFA)	Defines a frontier	Requires assumption about distribution of residuals Works best with large samples
Panel data		
Sub-company panel data	Can be used with parametric and non-parametric methods Estimates company efficiency without additional assumptions	Requires consistent cost allocation policies between sub-company components for all companies
Time series panel data	Can be used with parametric and non-parametric methods Provides indication of changes over time	Requires knowledge of how the cost structure has changed over time A firm at different points in time is assumed to represent unrelated observations

There is a tension between the need to have a large number of comparators in the interest of the precision of the estimates and the biases that fundamental differences between the comparators might introduce. An issue for the OLS method favoured by Ofwat is the fact that there are currently 10 water and sewerage companies and 12 water only companies. This means that there are 10 sewerage and 22 water comparators at company level and places a premium on panel data. Ofwat has responded to this by using sub-company data on the sewerage side. It has not done the same for the water service nor has it adopted time series panels at periodic reviews.

1.2.3 Efficiency and incentive mechanisms

To illustrate the effects of the efficiency methodology on incentives, it is instructive to consider two contrasting approaches to efficiency assessment. The approaches are

- a comparative efficiency modelling exercise which uniquely determines a set of inefficiency scores for each company

and

- efficiency scores determined following consultation with the individual companies.

In the former there is an explicit recognition of the existence of an efficiency frontier, that efficiency levels across a set of industries are comparable, and that there exists the potential for catch-up.

In terms of the latter, efficiency is evaluated based on a detailed analysis of each company, A disadvantage of this approach is that it is intrusive, difficult to replicate and, given that each company is compared with itself, would place a ceiling on the potential for efficiency savings. Although a comparative approach embodies, in principle, better incentive properties in explicitly recognising a distribution of efficiencies across the industry, there is a greater information burden. In addition, the realised incentives of such an approach depend on the appropriateness of the comparators, measurement of the appropriate set of cost drivers and the extent to which the process involves other regulatory interventions.

It is also important to consider the nature of the regulator's loss function. In the consideration of and adjustment for company specific factors, Ofwat adjusts residuals (firm level differences between actual and predicted costs) in one direction only. Namely, adjustments are only made which improve the measurement of firm inefficiency. Subsequently, it would appear that the regulator's loss function is asymmetric given the way in which company specific circumstances which are not measured by an observable set of cost drivers, are used to generate a set of inefficiency scores which then, in part, determine prices.

1.3 Terms of reference and structure of this report

In discussion with the companies and Ofwat, we concluded that there would be value in reviewing how Ofwat's approach to efficiency had developed since its inception in the light of the considerable body of literature that the topic has spawned.

Our terms of reference focused on Ofwat's comparative econometrics and did not encompass the cost base approach. Nor did they refer to the fundamental issue, raised in 1.1.1 above, of whether comparative efficiency assessment produces better results than other approaches.

Our terms of reference required us to document how the regime has developed to where it is now and what has been tried in terms of approaches, methods, specifications and data. In doing this we were to have regard to the literature to see what conclusions have been reached on

- the feasibility of various approaches and solutions to technical problems including functional form and level of aggregation
- issues to do with the availability and interpretation of the data
- how Ofwat has developed its approach over time
- the way Ofwat has used its approach in setting price limits.

The structure of this report is as follows

Section 2 discusses the concept of efficiency and introduces the analytical techniques

Section 3 describes Ofwat's approach to making the efficiency assumptions it used when determining price limits at PR04

Section 4 describes the evolution of Ofwat's approach within the changing context of the industry

Section 5 contains our conclusions and recommends areas for future consideration.

1.4 Acknowledgements

We offer our thanks to

- Anglian Water, South East Water, Thames Water and Yorkshire Water who sponsored the project and their representatives who played an important part in informing and commenting on our work
- Ofwat's efficiency and capital maintenance teams for assistance with documents and interpretation and their constructive participation in the review
- Water UK for input and support
- Dr. David Saal and Professors David Parker, Mark Stewart, Emmanuel Thanassoulis and Tom Weyman-Jones who have undertaken academic work in this area and who have made time to engage with us on a range of technical matters.

This is Indepen's report. The views expressed are ours as is the responsibility for any errors of omission or commission.

2 Ofwat's approach at PR04

2.1 Summary

Ofwat views the scope for improvement as having three components

- the rate at which efficiency improves in the whole economy, as reflected in RPI
- the extent of change in the efficiency frontier – known variously as the continuing efficiency improvement or the frontier shift)
- the extent to which individual companies that have been judged to be less efficient can catch-up with those judged to be more efficient.

Ofwat makes forward-looking estimates of the scope for efficiency improvements by comparing actual performance with a benchmark. The assessment relates to four categories of expenditure

- water opex
- water capital maintenance
- sewerage opex
- sewerage capital maintenance

and combines the assessments with assumptions about how quickly companies can become more efficient.

At PR04, Ofwat assessed the scope for continuing efficiency improvement having regard to the fact that in the previous price control period, the companies that had been judged most efficient had still managed to meet their efficiency targets. Additionally, the best performing companies had indicated that that they could continue to improve.

Ofwat used two methods to analyse comparative levels of efficiency: econometrics and standard costing. The latter is known as the cost base exercise. It compares elements of the cost of the investment programme, such as the cost of replacing a length of water main, with the standard cost of doing this based on cross sector information and professional review. Ofwat's application of these techniques at PR04 was as in Table 2.1.

Table 2.1 - Ofwat methods for determining catch-up factors in PR04

	Operating expenditure		Capital expenditure	
	Base	Enhancement	Maintenance	Enhancement
Method of assessment	Econometric models Unit cost	Econometric models (from base opex)	50% econometric / unit cost 50% cost base	Cost base

In the rest of this section we consider the following key elements in Ofwat's approach

- assessing the overall scope for efficiency improvement
- the use of the service and sub-service models for opex and capital maintenance
- the techniques used for assessing efficiency

- adjustments made to company data
- selection of the benchmark
- making catch-up assumptions.

Our terms of reference did not include consideration of the cost base analysis or its interaction with capital maintenance econometrics.

2.2 Overall scope

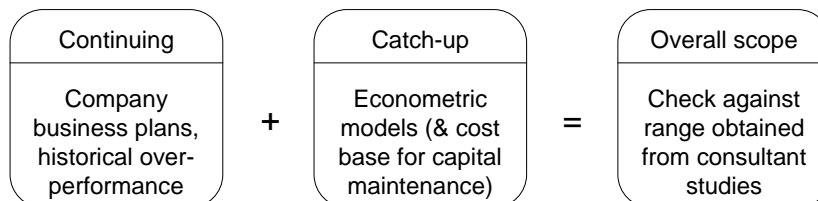
Ofwat wished to assess the overall scope for efficiency improvement in the sector and it commissioned Europe Economics, London Economics and Stone & Webster to look at efficiency trends and how they might develop in the future. It also considered NERA's report for Water UK, company commissioned reports, including those by Oxera and Frontier Economics, and CEPA's report to Ofgem in connection with the electricity distribution price review.

The conclusion from these reports was

"range of industry productivity growth forecasts has emerged, from 0.4% per annum (NERA) to 2.6% per annum (CEPA)".⁴

In the absence of any consensus, Ofwat decided not to choose a number from within the range. Instead it decided to investigate whether the companies that had delivered the greatest efficiency improvements in AMP3 might be expected to continue to do this into the future. As an estimate of the prospective frontier shift, it looked at what the companies currently on the frontier were indicating in their business plans. It combined this with its other evaluations in the way shown in Figure 3 and this represents a combination of industry views and internal discussions.

Figure 2.1– Ofwat PR04 actual approach



Ofwat revisited its assessment of total scope for efficiency improvements in the light of the companies' responses to the draft determinations. It conclude that the total scope for efficiency improvements for base operating expenditure in PR04 was 2.4% (this was down from the original estimate of 2.6%) per annum for water and 2.3% (down from 3.9%) per annum for sewerage.

2.3 Ofwat's service models

Ofwat considers operating expenditure and capital maintenance separately for water and for sewerage services. It considers several areas of expenditure under each, giving 18 models in total. The expenditure data are derived from the June Return.⁵

Table 2.2 presents the functional form and scale variable for each model.

⁴ p.146, "Future water and sewerage charges 2005-10. Final Determinations", Ofwat, December 2004

⁵ For the Final Determinations Ofwat used 2003-04 data to estimate the models. 2002-03 data were used for the Draft Determinations.

Table 2.2– Summary of operating cost and capital maintenance models, 2003 04

	Method/dependant variable	Scale variable
Water service opex		
Resources and treatment	Unit cost comparison	Resident winter population
Distribution	Log unit cost	Resident winter population
Power	Log cost	(APH*distribution input)
Business activities	Log cost	Number of billed properties
Sewerage service opex		
Sewerage network	Log unit cost	Total sewer length
Large sewage treatment works	Log cost	Total load
Small sewage treatment works	Unit cost comparison	BOD5/day
Sludge treatment and disposal	Unit cost comparison	Thousand tonnes of dry solids
Business activities	Unit cost comparison	Number of billed properties

Water service capital maintenance		
Distribution infrastructure	Log unit cost	Length of mains
Distribution non-infrastructure	Log unit cost	Pumping station capacity
Management and general	Log unit cost	Billed properties
Water resources and treatment	Unit cost comparison	Total connected properties
Sewerage service capital maintenance		
Sewerage infrastructure	Log unit cost	Total sewer length
Sewage treatment	Log unit cost	Total load received
Sewerage non-infrastructure	Unit cost comparison	Number of pumping stations
Sludge treatment and disposal	Unit cost comparison	Total weight of dry solids
Management and general	Unit cost comparison	Billed properties

2.4 Estimation methods

Figures 2.2 and 2.3 depict Ofwat's combinations of econometric modelling and judgements for operating expenditure and capital maintenance. The processes are similar but not identical. In the remainder of the section for simplicity we have tended to focus on the opex process.

Figure 2.2– Econometric approach to operating expenditure assessment

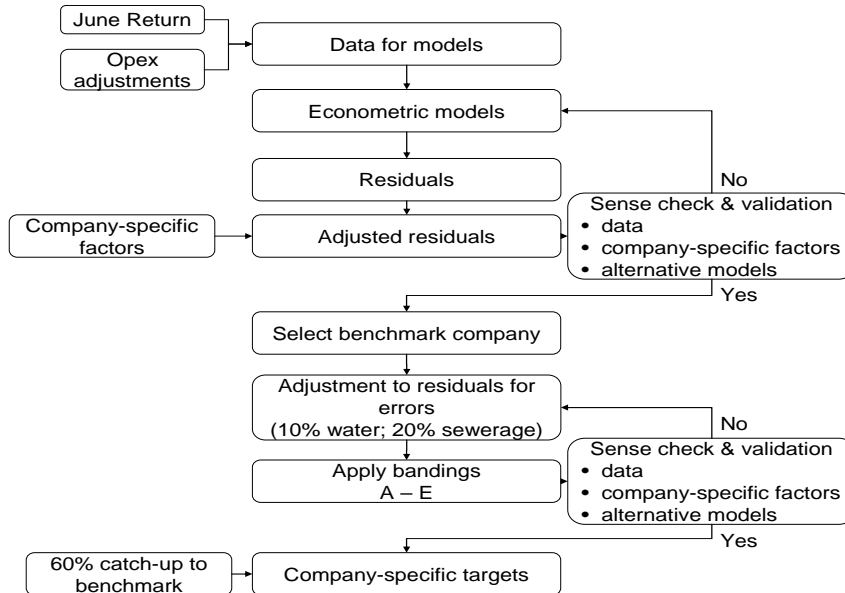
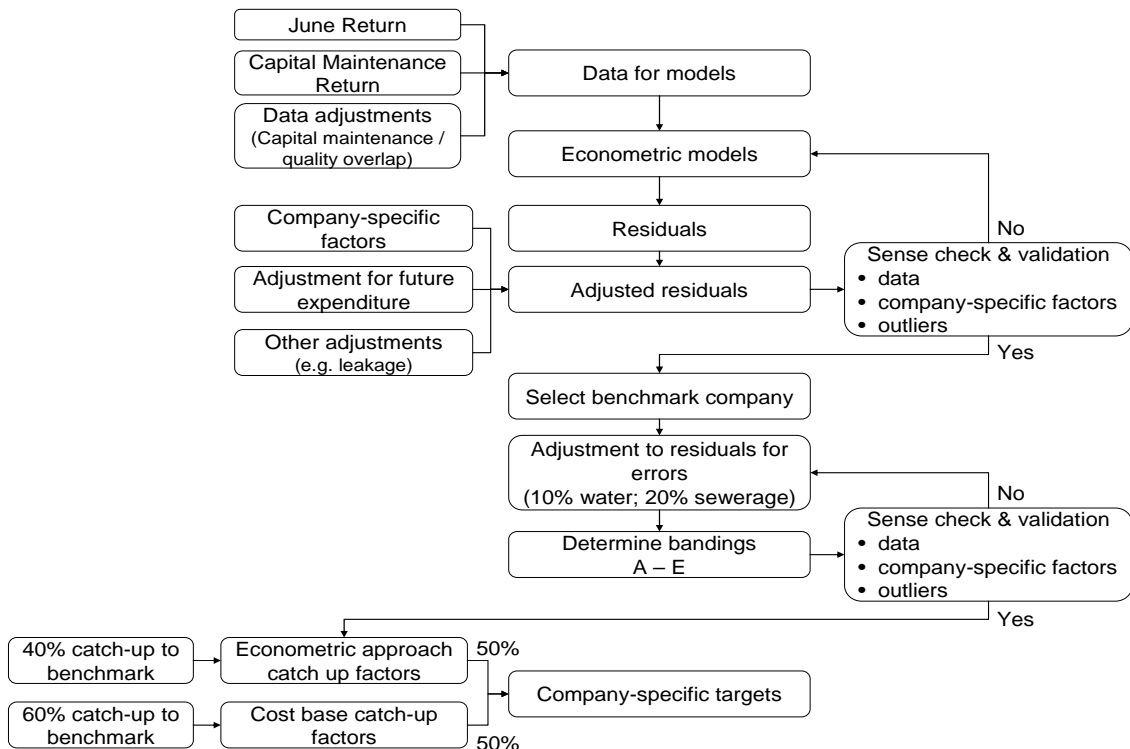


Figure 2.3– Econometric approach to capital maintenance expenditure assessment



2.4.1 Data adjustments

The outputs from the econometric models are point estimates of the efficiency of each company. Ofwat then moderates these estimates by making a number of regulatory judgements before arriving at its efficiency assumptions for the companies

- standard data adjustments including adjustments to capital maintenance for future expenditure
- adjustments for company specific factors
- selection of the benchmark company
- decision on the extent to which companies judged to be less efficient should be able to catch up with the benchmark company.

We discuss these below.

Standard data adjustments

Prior to estimating the operating expenditure equations, Ofwat adjusts the June Return data.

- It excludes water softening costs from water treatment expenditure.
- It excludes British Waterways Board charges from the sewerage network model.
- It excludes Environment Agency, local authority and third party costs.
- It adjusts leakage costs to a common basis. This should not be necessary in future as the companies have agreed to align their approaches with Ofwat's.

Company specific adjustments

Comparative efficiency depends on the notion that there exists a distribution of efficiency levels within the water industry. To ascribe differences in costs as attributable to differences in efficiency requires all other influences on costs to be equal; otherwise the comparisons will be misleading. Ofwat recognises that there are circumstances, outside the control of the companies that affect costs but are not included in the econometric work as cost drivers and allows for a number of company-specific factors, such as water softening activity and the effect of traffic congestion. Ofwat applies the company-specific factors to the total of predicted costs for the water and sewerage services.

All of the company specific factors are such as to increase a company's costs. Ofwat does not consider special factor adjustments that might reduce a company's costs.

For each company, Ofwat checks the data submitted in the June Return and reviews the difference between the adjusted predicted costs and the actual costs, known as the "adjusted residuals". It has regard for how companies' residuals have moved since the previous year and how the residuals compare across the companies. It reconsiders the factors requested by each company but not accepted and considers estimates of the residuals from alternative models (opex only).

Ofwat does not consider alternative models for capital maintenance although this possibility was mooted in consultation in April 2003. The companies attended a workshop to discuss the interpretation of the cost drivers and models and this was followed by detailed joint consideration of alternative models at working level but little change ensued.⁶

Once Ofwat is satisfied with the results for all companies, the residual (expressed in percentage terms) for each company is calculated as

⁶ This might be due to the fact that the workshop was held after the companies had submitted their Capital Maintenance Econometric Return. This limited the extent to which new explanatory factors could be considered and tested.

$$\text{Residual} = (\text{Adjusted actual cost} - \text{Predicted cost}) / \text{Predicted cost}$$

2.4.2 Benchmark selection

Ofwat considers whether the company with the lowest residual would be appropriate as a benchmark and adopts it as such if, in its view

- there are no concerns about the data for the company
- the company has no special characteristics that are outside the control of the management and which might significantly reduce its costs relative to the industry norm
- a reasonable proportion of the industry will be able to achieve benchmark performance.

Ofwat believes that no company with deteriorating asset serviceability can be the capital maintenance benchmark.

At the 2004 Periodic Review the benchmark company for water service opex was Wessex, although Portsmouth and South Staffordshire had lower residuals. For the sewerage service, Thames was the benchmark company in the draft determinations but subsequently Ofwat concluded that Thames' performance had been unduly affected by its unusually large treatment works and that the adjustments for factors relating to its specific operating conditions made it unsuitable. In the final determinations, Yorkshire was the benchmark company. This change made a material difference to the catch-up improvements for sewerage operating expenditure.

For capital maintenance, Northumbrian was the water service benchmark. Portsmouth had a lower residual but accounted for less than 3% of the industry. For sewerage, Wessex was the benchmark and also had the lowest residual.

2.4.3 Catch-up factors

Once it has chosen the benchmark company, Ofwat calculates the difference between each company's cost and that of the benchmark, i.e.

$$\text{Residual relative to the benchmark} = (\text{company residual} - \text{residual of benchmark}) / (1 + \text{company residual})$$

Ofwat conducts a sense check and then puts the companies into bands

- A within 5% of benchmark
- B within between 15% and 5% of benchmark
- C within between 25% and 15% of benchmark
- D within between 25% and 35% of benchmark
- E more than 35% from benchmark

Ofwat applied a 10% reduction to the water service residuals for both operating cost and capital maintenance and 20% for the sewerage service residuals before banding. The adjustments are to take account of possible errors in the residual that might be due to factors other than efficiency (this issue is explored by Cubbin⁷). Ofwat then divides the bands into half-bands and takes the mid-point of each half band as representative of all companies in that half band.

As the final step in calculating the catch up factors, Ofwat determines what proportion of the gap between the benchmark and the deemed position of each other company that should be closed within

⁷ "Assessing Ofwat's efficiency econometrics", John Cubbin, March 2004

the review period. At PR04 it decided that this should be 60% of the gap for water and sewerage base operating expenditure and 40% for water and sewerage capital maintenance expenditure. Ofwat has based these catch-up figures on what companies have tended to be able to achieve in the past.

The calculation of the catch-up factors for operating expenditure using Ofwat's PR04 assumptions and judgements is illustrated in Table 2.3.

For the individual companies, Ofwat reflects a proportion of the catch-up percentage in the company's price limit for the period, known in Ofwat parlance as the "stick", treating the rest as an incentive to encourage the companies to outperform, known as the carrot. At PR04 the stick was 60% of the total catch-up and the carrot 40%.

Table 2.3– Efficiency bandings and catch-up factors for operating expenditure

Bands	Half-bands		Assumed catch-up (five-year total) %	Mid-point x catch-up assumption	Annual percentage
A 0-5%	Frontier or better		0.0	0.0	0.0
	Lower	0-05%	60% of 2.5	1.5	0.3
B 5-15%	Upper	5-10%	60% of 7.5	4.5	0.9
	Lower	10-15%	60% of 12.5	7.5	1.5
C 15-25%	Upper	15-20%	60% of 17.5	10.5	2.1
	Lower	20-25%	60% of 22.5	13.5	2.7
D 25-35%	Upper	25-30%	60% of 27.5	16.5	3.3
	Lower	30-35%	60% of 32.5	19.5	3.9
E 35-45%	Upper	35-40%	60% of 37.5	22.5	4.5
	Lower	40-45%	60% of 42.5	25.5	5.1

For capital maintenance, the approach differs. Ofwat averaged the results from the cost base and econometric approaches to arrive at the company-specific catch-up factors and then assumed that companies could catch-up over a three-year period, with an equal reduction each year⁸. The application of the carrot and stick also differs slightly and is more complex than for opex.

⁸ At PR99, Ofwat had assumed a one year, and the Competition Commission had concluded that this was too aggressive for capital maintenance expenditure. p.36, "Mid Kent Water Plc: A report on the references under sections 12 and 14 of the Water Industry Act 1991", Competition Commission, September 2000.

3 The evolution of Ofwat's approach

3.1 Ofwat's assessment in the early 1990s

When the water industry was privatised, there was significant scope for efficiency improvement. Ofwat concluded that real competition was unlikely to prove effective but that there was scope for comparative competition among the 39 water companies.

In 1990 Ofwat commissioned KPMG to consider methods of comparative analysis. The report⁹ concluded that Ofwat should develop its data collection systems and focus on frontier cost functions. KPMG explored the use of various approaches including data envelopment analysis (DEA), maximum likelihood estimation and panel data. It recommended divisional (e.g. billing, administration) and functional (e.g. resources and treatment, distribution) comparisons.

Following the KPMG study, Ofwat established the Comparative Efficiency Studies Working Group to address, among other things, policy and methodology, data issues, the selection of explanatory factors and the allocation of assets between sub-service activities. In 1991, Ofwat issued FD33,¹⁰ updating companies on the efficiency work. Ofwat had considered DEA, SFA and econometrics and had concluded that econometric modelling was preferable. It noted that

- the additional assumptions required for stochastic frontier analysis might appear ad hoc and to lack theoretical justification
- consideration should be given to whether DEA could be integrated with the econometric approach or whether it could serve as a check on the econometric results
- the econometric results would be improved if the data were available at sub-service level, for example for divisions or plants.

Since the KPMG review the industry context has changed significantly. In this regard, the following have been significant

- Ofwat has consistently relied on OLS techniques but at the same time it has increased the number of adjustments in response to criticisms of the unadorned approach.
- The Competition Commission has been 'broadly' supportive of Ofwat but has adopted additional techniques to OLS.
- The industry questions the validity of Ofwat's approach and the level of confidence placed on the results, as highlighted by the Baker Report.
- There have been significant improvements in industry efficiency since privatisation and Ofwat's own efficiency matrices suggest there has been convergence of performance between the companies, hence reducing the value of comparative competition.
- Ofwat's division of the overall efficiency change into catch up and frontier shift appears to be at odds with the conclusions of academic commentators.¹¹

⁹ "Strategy for comparative efficiency studies" and separate technical annex, KPMG, September 1990

¹⁰ "FD33: Comparative efficiency studies", Ofwat, 20 June 1991

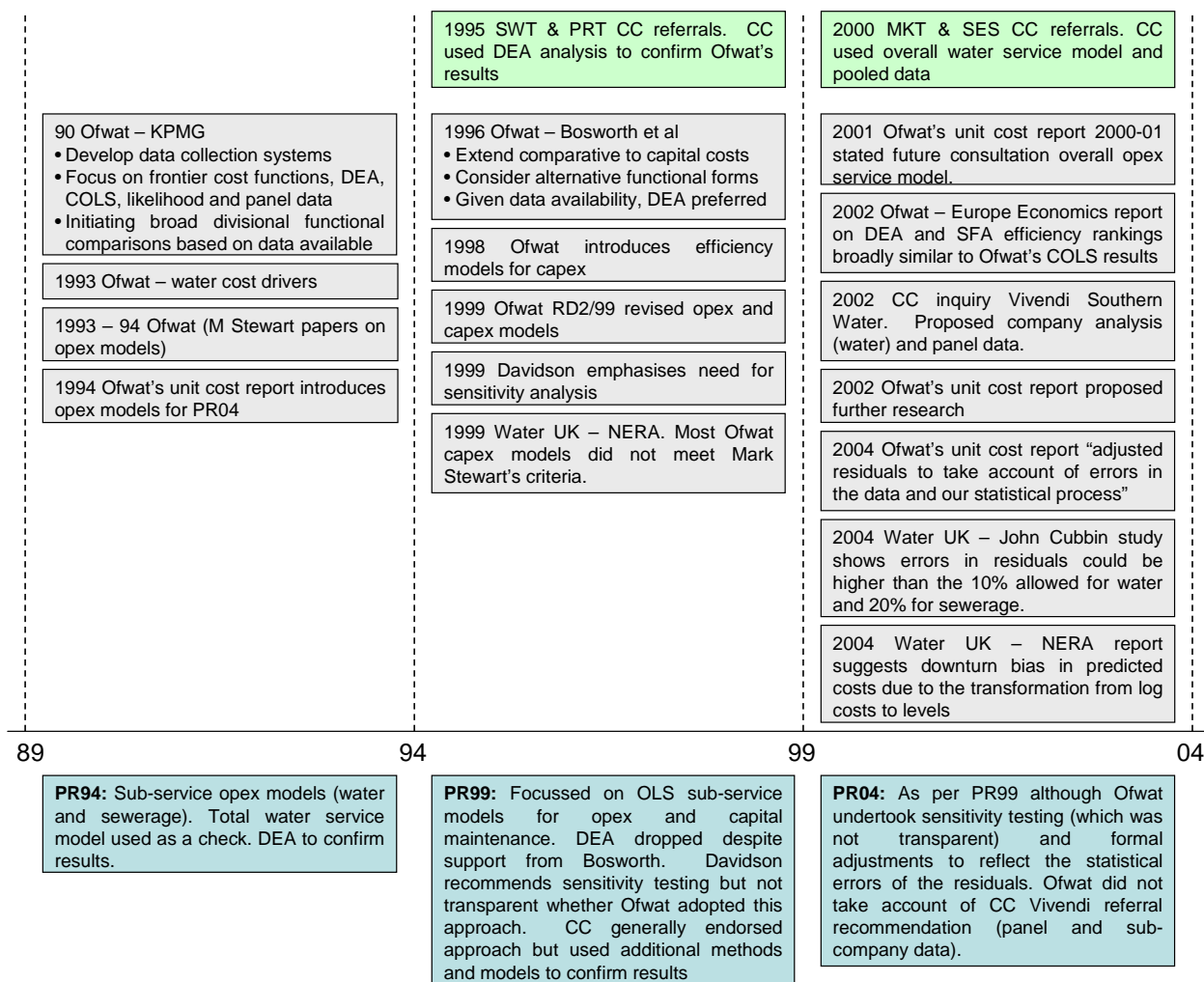
¹¹ Growth in total factor productivity incorporates efficiency change, technical change and the consequences of scale change. In the work by Saal et al technical change is identified as the dominant driver of improvements. Mark Stewart noted that Ofwat had investigated the issue of scale economies in the past, but that the lack of data presented problems. It is interesting to note (see Table 4.1) that Ofwat efficiency assumptions place greater emphasis on catch-up than frontier shift which is at odds with findings of Saal et al

- On the one hand, the number of water comparators has fallen but on the other the availability and quality of the data have improved over time.

3.2 Application at Periodic Reviews

Ofwat has completed Periodic Reviews in 1994, 1999 and 2004. Figure 4.1 summarises the studies undertaken for these Reviews that are relevant to the efficiency story. It also covers the relevant Competition Commission referrals.

Figure 3.1 – Summary of Ofwat's efficiency approach and literature



At PR94 Ofwat used COLS and DEA (for operating costs) as was consistent with the recommendations of the reports. The reports on the 1995 Competition Commission referrals¹² broadly endorsed Ofwat's approach.

At PR99 Ofwat focused on COLS. It did not use DEA despite support from Bosworth et al¹³. Davidson¹⁴ had recommended sensitivity testing but it is not clear whether this was undertaken. The

¹² "Appendix 8.3 Ofwat's analysis of efficiency", in "South West Water Services Ltd: A report on the determination of adjustment factors and infrastructure charges for South West Water Services Ltd", Competition Commission, 1995

¹³ "Water and sewerage industries: general efficiency and the potential for improvement", Professor Bosworth, Professor Stoneman and Joanne Roe for Ofwat, February 1994

¹⁴ "Ofwat efficiency assessments using econometric models: A comment", James Davidson, February 1999

Commission generally endorsed Ofwat's approach¹⁵ but used additional methodologies, models and assumed different profiles for catch-up. Ofwat introduced COLS sub-service models for capital maintenance, only combining the opex and capital maintenance results for presentational purposes.

At PR04 Ofwat used OLS only and not DEA or SFA. Ofwat did not take account of the Commission's Vivendi/Southern Water report¹⁶, which recommended the use of panel data including sub-company data. Ofwat undertook sensitivity testing (using alternative OLS sub-service models) but this was not transparent to the industry. For the first time made explicit adjustments to reflect judgements about the statistical errors in the residuals.

Table 3.1 sets out the ranges of efficiency assumptions made by Ofwat at Price Reviews.

Table 3.1 – Efficiency assumptions for water service base opex

	Service	PR94	PR99	PR04
Frontier	Water	1.0%	1.4%	0.3%*
	Sewerage	1.0%	1.4%	0.5%*
Catch-up	Water	0.0% - 2.5% (1% avge)	0.0% - 3.5% (1% avge)	0.0 - 2.7% (1.1% avge)
	Sewerage	0.0% - 2.4% (1% avge)	0.0% – 2.9% (1.7% avge)	0.0 – 1.5% (0.8% avge)
Total	Water	2.0%	2.4%	1.4%
	Sewerage	2.0%	3.1%	1.3%

The notable changes are

- the larger number for frontier shift at PR99
- the reduction in efficiency assumptions built into price limits in PR04 reflecting not only a lower contribution from frontier shift but also the application of the carrot and stick methodology which effectively halved both the frontier and catch-up figures.

3.3 Relevant points from the literature

We have reviewed a substantial number of reports commissioned variously by Ofwat, Water UK, the companies and others together with relevant academic articles.

In this section, we summarise the key points arising under the headings

- selection of estimation methodology
- model development and specification
- results
- interpretation and application.

These headings are based on those in Stewart's work for Ofwat in 1993/94¹⁷.

¹⁵ The CC tested Ofwat's opex models by developing separate models for using data for each of the two or three years as well as assessing the alternative 'panel data' model put forward by Mid Kent.

¹⁶ "Vivendi Water UK PLC and First Aqua (JVCo) Limited", Competition Commission, November 2002

¹⁷ Ofwat Research Papers Numbers 2 to 4, Mark Stewart

A more detailed description of the literature is in Appendix B. The findings represent Indepen's assessment of the literature together with interviews with academics involved in the field and our understanding of Ofwat's approach.

3.3.1 Estimation Methodology

The literature suggests the following.

- OLS, SFA and DEA are all valid methodologies for assessing efficiency.
- OLS is arguably better at dealing with smaller data samples than either DEA or SFA and it requires relatively few initial assumptions.

The literature also suggests that certain developments to Ofwat's approach should be considered.

- Estimating the overall scope for efficiency is a difficult exercise and an area of significant debate between regulators and companies. Both parametric and non-parametric techniques can provide useful information for regulators. Ofwat has not made full use of parametric techniques.
- In assessing relative efficiency at price reviews Ofwat currently only applies one parametric technique, OLS. This may be overly restrictive and that more systematic use of other parametric approaches in parallel with OLS would permit crosschecks and a richer interpretation of the data.
- A reasonably consistent time series of data now exists. Several studies conclude that the application of panel data techniques to this data set is feasible and desirable.

3.3.2 Model development and specification

We summarise points from the literature under the following headings

- transparency
- company specific factors

Transparency

- Ofwat consultation with the industry about cost drivers and model specification is somewhat ad hoc.
- Ofwat is not transparent about how it balances economic and engineering input on the one hand with the statistical results on the other.
- Ofwat develops alternative models to test modelling results and provide it with more certainty over its assessments. These models are not made public, although they are shared with companies on request.
- The transparency of model testing is weak.
- The models are not all transparent in that Ofwat does not clearly explain the reasoning behind the cost drivers. We note that Ofwat, in its latest unit cost and relative efficiency report, has provided a better explanation of the reasoning that supports the cost drivers¹⁸.

Company specific factors

- While Ofwat provides companies with a list of company specific factors (CSFs) and the value of the adjustments it has made, the details of CSFs claimed are not made known to other companies.

¹⁸ Water and sewerage service unit costs and relative efficiency, 2004-05 report, December 2005, Ofwat

- Ofwat does not appear to investigate positive company specific factors (i.e. conditions that might lower a company's costs compared with its peers) or test whether company specific factors are industry wide cost drivers.
- Ofwat adjusts for company specific factors post model estimation. This may lead to model mis-specification. Ofwat has tested whether making this adjustment for CSFs post model estimation affects the ranking of companies but has not published its conclusions.

Sub service and sub-company models

- The models for similar sub-services do not have consistent functional form and scale variables.
- There is inconsistency from year to year in cost drivers although this appears to have declined over recent years.
- There are only 10 sewerage companies and so Ofwat has requested information at the sub-company level (e.g. zones or individual works). The advantage of more 'local' observations is that a greater range of characteristics may be observed (i.e. averaging effects are removed). Whilst this provides more modelling observations and potentially a greater range there is a question over the confidence Ofwat can place on the data as cost allocation issues will tend to increase.

3.3.3 Results

The main points are as follows.

- Ofwat is transparent in interpreting the results of its preferred models. The data and models are available for companies to replicate.
- Ofwat does not publish its alternative models although they are available to companies on request, nor does it publish the annual letter of verification by Mark Stewart.
- The coefficient of determination (or explanatory power) of the unit cost econometric models are relatively low. In some cases Ofwat considers the models are preferable to simple unit cost comparisons.
- The confidence level for inclusion of any cost driver is usually 90% although Ofwat explained that this is sometimes relaxed to permit the inclusion of cost drivers on an economic or engineering basis.
- Ofwat presents the findings of its separate analyses of operating costs and capital costs in its annual unit costs and relative efficiency report. It does not seek to model interactions between them.
- There is a degree of regulatory judgement at nearly every stage of the estimation of catch-up factors. This may be inevitable but it should be accompanied by full explanations of the scope and basis of the judgements.
- Ofwat should recognise explicitly that in some areas, for example selection of the benchmark company, there is a degree of uncertainty attached to these adjustments.
- Ofwat makes assumptions over the degree to which companies can catch up to the benchmark. These assumptions appear arbitrary although Ofwat notes that they are consistent with what companies have been able to achieve in the past.
- Panel data techniques might mitigate some of the problems which characterise the basic OLS model. Panel data can account for company specific factors that are time invariant, and facilitate the separation of efficiency from other factors.

4 Conclusions and future developments

4.1 Overall conclusions

All regulators' suffer from an information disadvantage compared with the companies¹⁹. In order to engage in the regulatory debate with confidence, regulators have sought to make comparisons between companies. Compared with some regulators, Ofwat has the advantage of being able to make comparisons between several companies with similar structures from the same country.

To be effective, incentives have to be reasonably predictable in their effect so that companies can respond appropriately. Under RPI – X this entails an approach that needs to be

- not subject to frequent changes
- technically sound and not the subject of dispute
- soundly based on relevant data
- widely understood and supported within the sector and by stakeholders generally
- ideally, supported by academic experts in the field.

An important example of this concerns efficiency. Rather than set a single efficiency target Ofwat sets company-specific targets, thereby introducing a substantial degree of complexity and information burden.

In evaluating the evolution of Ofwat's approach we provide a number of positive conclusions.

- Ofwat's approach to company specific efficiency targets has been consistent over time. In essence it has applied OLS techniques consistently to try to take account of different companies' circumstances.
- While there are those who dispute Ofwat's technical work, in practice the literature we reviewed is broadly supportive of the use of OLS as an estimation method.
- The approach has required the creation of an extensive database, which, while burdensome, forms a better basis than those available to most other UK regulators.

This does not mean that there is no scope for improvement and our suggestions in this regard are listed in the following section.

In terms of understanding and support, the picture is ambiguous. Ofwat has made its data and main models available with a view to aiding understanding and stimulating debate. However, the complexity of the process and in particular the large number of technical issues/adjustments involved together with a lack of transparency over checks and testing of the data and approach, result in few people being able to understand what is going and effectively take part in the debate. We also note that the ability of companies to meet efficiencies assumed in prices should not be taken as evidence that the regulator's assessments of relative efficiency were accurate rather that companies have responded to the incentive of the price cap.

In our view, this is behind the recommendation of the Baker report which referred to "... *the widespread industry dissatisfaction with Ofwat's efficiency methodology*".

This too leads us to a number of suggestions that we list in the following section.

¹⁹ Although companies do not have perfect information, they themselves will not know their own efficient level of costs.

4.2 Future developments

The stability of Ofwat's approach has been beneficial but circumstances now differ significantly from those that were present when the approach was first developed and we agree with the Baker report that there is a need for review.

In the interest of transparency and understanding, Ofwat and the industry should consider re-establishing a cross industry group such as the one that was effective in the early 1990s. This will aid constructive engagement. The UKWIR project may be a step in the right direction but may not go far enough. Such a group should critically evaluate existing approaches with a view to improving understanding. This might entail a programme of work to

- examine the convergence of companies' performance and what this means for assessing relative efficiency and price setting
- examine evidence that the privatisation effect maybe diminishing in scale
- publish the results of using not only OLS but also a range of other techniques, particularly panel data analysis: although Ofwat has considered alternative models, primarily as robustness checks and not in price setting, there would be an increase in transparency if these results were published.
- consider the balance between economic and engineering judgements and the statistical significance tests
- test models in which CSF adjustments precede model estimation
- consider the stability of the models over time
- consider the inability of the partial approach adopted to properly deal with the capex / opex trade-off: this could be particularly important in a post privatisation environment when we would expect there to be significant allocative inefficiency
- consider the appropriateness of Ofwat's approach to aggregating the results from its sub-service models to form an overall view of company performance
- consider the usefulness and reliability of sub-company data.

As far as we are aware, Ofwat did not consider any alternative to its comparative approach nor did it at that time or subsequently publish any appraisal of the benefits that comparative analysis would provide. Nonetheless, a comparative approach was implemented and the significant undertaking of data collection and analysis started. The programme of work outlined above will stimulate the debate over whether the regulator should have confidence to set company specific efficiency assumptions and if he does whether the current approach is suitable and sustainable.

The process will be healthier if it is more transparent, involving people at a senior level in companies and Ofwat and not primarily the econometrics fraternity. This might be instrumental in creating a simpler approach.

Appendix A: List of titles reviewed

- Strategy for comparative efficiency studies and separate technical annex by KPMG for Ofwat, September 1990
- FD33 “Comparative efficiency studies”, Ofwat, 20 June 1991
- Cost comparisons and the Periodic Review – Framework and Progress, Ofwat, March 1992
 - Annex 4, Explanatory factors – responses to consultation
 - Annex 5, Cost comparisons in the sewerage service – report of the pilot study
- Ofwat research paper number 1 – Comparing the cost of water delivered, March 1993
- Series of papers from the Efficiency Seminars held in March 1993
 - Paper 1 – Overview and issues
 - Paper 2 – Comparative costs
 - Paper 3 – Cross industry trends
 - Paper 4 – Water and sewerage industry cost trends
 - Paper 5 – General assessments
- Ofwat research paper number 2 – Modelling water costs 1992-93 + separate technical annex, December 1993
- Ofwat research paper number 3 – Modelling sewerage costs 1992-93 + separate report of tables and figures, January 1994
- Ofwat research paper number 4 – Modelling sewerage treatment costs 1992-93 + separate report of tables and figures, January 1994
- Comparing sewerage service operating expenditure, Ofwat, February 1994
- Water and sewerage industries: general efficiency and the potential for improvement by Professor Bosworth, Professor Stoneman and Joanne Roe for Ofwat, February 1994
- Measurement of comparative total efficiency in the sewerage and water industry: an exploratory study. Final report by Professor Derek Bosworth, Professor Paul Stoneman and Dr Emmanuel Thanassoulis for Ofwat, October 1996
- Water and sewerage industries general efficiency and potential for improvement by Europe Economics and Professor Crafts for Ofwat, October 1998
- Ofwat efficiency assessments using econometric models: A comment by James Davidson, February 1999
- Water and sewerage industries general efficiency and potential for improvement – An update by Europe Economics and Professor Crafts for Ofwat, May 1999
- Investigation into the robustness of Ofwat's comparative efficiency analysis of capital maintenance expenditure by NERA for Water UK, June 1999
- The general efficiency assumption: Setting X in RPI-X by NERA for Water UK, October 2002
- An assessment of comparative efficiency measurement techniques by Europe Economics for Ofwat, October 2002

- Scope for efficiency improvement in the water and sewerage industries by Europe Economics for Ofwat, March 2003
- Scope for efficiency improvement in the water and sewerage industries – Uncertainties and measurement issue paper by Europe Economics for Ofwat, November 2003
- Review of Europe Economics 'Scope for efficiency improvement in the water and sewerage industry by NERA for Water UK, May 2003
- PR04 Scope for efficiency studies by London Economics, Binnie Black and Veatch and Professor Maurice Shutler for Ofwat, November 2003
- An investigation into evidence for economies of scale in the water and sewerage industry in England and Wales by Stone and Webster for Ofwat, January 2004
- An investigation into opex productivity trends and causes in the water industry in England and Wales – 1992-93 to 2002-03 by David Saal and Scott Reid for Ofwat, May 2004
- Assessing Ofwat's efficiency econometrics by Professor John Cubbin for Water UK, March 2004
- Estimating opex and capex efficiency by NERA for Water UK, July 2004
- A bias in Ofwat's efficiency estimates by NERA for Water UK, October 2004

Other references include

- A report on the determination of adjustment factors and infrastructure charges for Portsmouth water plc, Competition Commission, June 1995
- A report on determination of adjustment factors and infrastructure charges for South West Water Services Ltd, Competition Commission, July 1995
- Regression versus data envelopment analysis for efficiency measurement by John Cubbin and George Tzanidakis, *Utilities Policy* (1998) 7 pp. 75-85
- Mid Kent Water plc: A report on the references under sections 12 and 14 of the Water Industry Act 1991, Competition Commission, September 2000
- Sutton and East Surrey Water plc: A report on the references under sections 12 and 14 of the Water Industry Act 1991, Competition Commission, September 2000
- The Use of Data Envelopment Analysis in the Regulation of UK Water Utilities: Water Distribution by Emmanuel Thanassoulis, *European Journal of Operational Research* (2000), 126, 2, pp. 436-453
- DEA and its use in the regulation of water companies by Emmanuel Thanassoulis, *European Journal of Operational Research* (2000), 127, 1, pp. 1-13
- The impact of privatisation and regulation on the water and sewerage industry in England and Wales: A translog cost function approach" by David Saal and David Parker, *Managerial and Decision Economics* (2001) 21:6 pp. 253-268
- Productivity and price performance in the privatised water and sewerage companies of England and Wales by David Saal and David Parker, *Journal of Regulatory Economics* (2001) 20:1 pp. 61-90

- Comparative performance measurement in regulation: the case of English and Welsh sewerage services by Emmanuel Thanassoulis, *Journal of the Operational Research Society* (2002), 53, pp. 292-302
- Vivendi Water UK PLC and First Aqua (JVCo) Limited, Competition Commission, November 2002
- Comparative efficiency analysis in the water industry by Tom Weyman-Jones, December 2002
- Productivity improvements in distribution network operators by Cambridge Economic Policy Associates Ltd for Ofgem, November 2003
- A critique of CEPA's report on "Productivity improvements in distribution network operators. A report for EDF Energy by NERA, December 2003
- Determining the contribution of technical, efficiency, and scale change to productivity growth in the privatized English and Welsh water and sewerage industry: 1985-2000 by David Saal, David Parker and Tom Weyman-Jones, Aston Business School Working Paper RP0433, December 2004
- Estimating opex productivity growth in English and Welsh water and sewerage companies: 1993-2003 by David Saal and Scott Reid, Aston Business School Working Paper RP0434, December 2004
- Assessing the performance of water operations in the English and Welsh water industry: A panel input distance function approach" by David Saal and David Parker, in Coelli, Tim and Lawrence, Denis eds., *Performance Measurement and Regulation of Network Industries*, forthcoming 2006

Appendix B: Summary of the relevant literature

B.1 Papers reviewed

The documents we have reviewed include reports prepared for Ofwat, the companies and Water UK. The majority are published papers and we have also reviewed internal Ofwat documents. Our review has not covered company submissions, such as Business Plans.

The full list of papers we have considered is in Appendix A. Table B.1 summarises those that we found to be the most relevant. The table groups them according to topic

- the overall scope for efficiency
- catch-up
- opex or capital maintenance or both

and purpose

- evaluations of methods
- estimates of efficiency parameters
- critiques of Ofwat's approach.

Table B.1 – Summary of reports reviewed

	Evaluation of methods	Estimation	Critique
Overall scope	Ofwat – Bosworth et al (1994) Ofwat – Europe Economics (EE) & Crafts (1998) Ofwat – EE & Crafts (1999) Ofwat – EE (2003) Ofwat – London Economics (2003) Ofwat – Stone & Webster (2004) WUK – NERA (2004)		WUK – NERA (2003)
Catch-up Opex	Ofwat – KPMG (1990) Ofwat – Bosworth et al (1996) Ofwat – EE (2002)	Ofwat – Price (1993) Ofwat – Stewart (1993,94)	Opex models: None Capital maintenance models: WUK – NERA (1999) General: Davidson (1999)
Catch-up Capex	None	None	WUK – Cubbin (2004) WUK – NERA (2004)

The papers that are not included in the table were

- Those addressing general methodological issues, e.g. NERA (2002)
- Competition Commission reviews – 1995 (South West Water and Portsmouth), 2000 (Mid Kent and Sutton and East Surrey Water), and 2001 (Vivendi Water)
- academic papers on efficiency and productivity in the utility sector.

B.2 Estimation methodology

Ofwat has generally considered the overall scope for efficiency improvement separately from the relative efficiencies of companies. The papers are summarised in Table B.2, and we have shown (in red) the approaches that Ofwat has actually used to set price limits.

In addition, for the assessment of overall scope, both Ofwat and Water UK commissioned papers focused on growth accounting methods.

Table B.2 –Ofwat's techniques and related reports

Methods		Overall Scope	Catch-up
Parametric	OLS	Stone & Webster (2004)	Used in PR94, PR99, PR04
	SFA	None	Used by Europe Economics (2002) to compare against COLS
Non-parametric	Simple ratios	N/A	Used in PR94, PR99, PR04
	Index or growth accounting	Bosworth et al (1994) Europe Economics (1998, 1999, 2003) London Economics (2003) NERA (2003)	N/A
	DEA	None	Used in PR94 to confirm OLS results Used by Europe Economics (2002) to compare against COLS
Panel data methods		None	Used in Competition Commission referral (2000)

B.2.1 Reports on overall scope

Table B.3 summarises these reports.

The majority used a growth accounting approach to estimate productivity. Top-down approaches used data from supposedly comparable industries and companies e.g. British Gas, British Rail, BT, electricity to estimate productivity increases. Bottom-up approaches using comparable functions e.g. mining and extraction, transport and communications, financial & business services (to match customer services) and manufacturing (to match sludge treatment and disposal costs).

The Stone & Webster study²⁰ was a development of an earlier paper on economies of scale in water²¹ and estimated the productivity growth in operating expenditure using standard OLS techniques. Ofwat did not use the results of this study in the 2004 Periodic Review.

²⁰ "An investigation into opex productivity trends and causes in the water industry in England and Wales – 1992-93 to 2002-03", Stone & Webster (David Saal and Scott Reid), May 2004

²¹ "An investigation into evidence for economies of scale in the water and sewerage industry in England and Wales", Stone and Webster, January 2004

Table B.3 – Summary of reports into the overall scope for efficiency

Study	TFP	Opex		Capital Maintenance		Assumptions
		Water	Sewerage	Water	Sewerage	
Europe Economics (2003)	Estimated a sector TFP growth of 0.8% to 1.4% over and above that for the economy generally (higher for sewerage than for water)					Used NIESR ²² sector TFP measures, with top-down and bottom-up approaches
London Economics (2003)	Water: 1.2%	Top-down approach: 0.1% to 1.3%				Used data from 1990-2000, considered comparator industries for benchmarking purposes
	Sewerage: 4.7%	Bottom up approach:				
		2.9% to 3.0%	-0.1% to 1.9%	1.1%	1.4%	
CEPA (2003)	2.6%	5.0%				Quality adjusted TFP using capex weighting, based on 95/96 – 01/02 WaSC data
NERA (2004)	90/00: 0.5% 00/05: 0.4%	1.0%, derived assuming capital share of 60%		0.0%, based on CEPA assumption that capital productivity is c. 0.4% below TFP		Used data from 1990-2000 for estimating capital share
Stone & Webster (2004)	N/A	WaSCs: 2.02% in 1993, 1.76% in 2003 WoCs: 1.44% in 1993, 1.09% in 2003		N/A		Used data from 1992/93 to 2002/03. The only study to adopt a parametric analysis.

The papers adopted a limited range of estimation methodologies with growth accounting the most widely used. There may be merit in considering alternative methods given the wide range in the estimates. For example, Thanassoulis suggested that Malmquist indices could be computed using DEA to obtain productivity growth rates. This has been applied in other contexts to determine productivity growth rates²³. Saal, Parker and Weyman-Jones adopted SFA to estimate productivity growth rates in the water and sewerage industry²⁴ and decomposed it into the three components: technical change, efficiency change and scale change.

B.2.2 Catch-up

Ofwat commissioned KPMG in 1990 and Bosworth et al in 1996 to evaluate the different estimation methods for comparative efficiency assessment. KPMG evaluated the methods within the context of the water industry and highlighted data (definition, collection and measurement) as the major issue in determining the appropriate approach. The study did not suggest a preferred method. We understand that following the KPMG study Ofwat asked Mark Stewart to consider the appropriateness of DEA as a technique and that he concluded that OLS was preferable. This study was not published and was not available for our review.

²² National Institute of Economic and Social Research

²³ For example, see "Sources of efficiency gains in port reform: a DEA decomposition of a Malmquist TFP index for Mexico", Antonio Estache, Beatriz Tovar de la Fé and Lourdes Trujillo, Utilities Policy, 12:4, December 2004

²⁴ "Determining the contribution of technical, efficiency, and scale change to productivity growth in the privatized English and Welsh water and sewerage industry: 1985-2000", David Saal, David Parker and Tom Weyman-Jones, Aston Business School Working Paper RP0433, December 2004

Bosworth et al suggested that parametric methods and DEA were feasible but given the data situation at the time, the latter was preferred. However, in order for it to be fully operational, more work would be required.

For opex, OLS has dominated the 1994, 1999 and 2004 Periodic Reviews. Other methods have been used at various points to illuminate the OLS results. Ofwat used OLS for evaluating capital maintenance expenditure at the last two reviews.

At Ofwat's request, Stewart has looked at panel data models (for example, in connection with the 2000 Competition Commission referrals). He found no evidence at the time to support the assumption that the coefficients would be constant over time and concluded that panel data techniques would not be appropriate. Stewart indicated in conversation that some of the models appear to have become more stable and that panel data could now be considered again.

In 2002, Ofwat commissioned Europe Economics to emulate the OLS results using SFA and DEA. Stewart noted that the estimates from OLS and SFA differ only with respect to the intercept and that one would expect them to identify the same set of cost drivers. The difference arises from the allocation of the residuals to inefficiency and statistical noise.

Ofwat has been consistent in supporting OLS as the preferred technique. It has intermittently used both DEA and SFA techniques but not since 1994 in the price setting process²⁵.

The 2002 Europe Economics paper²⁶ concluded that all three methods are "*workable techniques*". Parker referred to the "triangulation of evidence" by using different methods to arrive at a judgement, so that if the different methods gave broadly similar conclusions or different conclusions that could be rationalised according to the particular methods, then one would be more confident in the results. Stewart noted that this would be useful as a crosscheck but averaging results from different methods could be misleading as they could be measuring different aspects of performance.

In single-year cross-section models the ability to explain differences between companies relies on additional assumptions. In principal, the OLS residual consists of

- statistical errors
- measurement errors
- omitted factors that reflect differences between firms (i.e. firm-specific factors)
- efficiency differences.

Without additional assumptions, it is not possible to decompose the residual. Ofwat makes judgements about the validity and extent of the impact of the special factors submitted by companies, and how much of the remaining residual is assumed to be inefficiency.

Compared with OLS, SFA makes an additional assumption and can separate statistical noise from the other components including inefficiency. However, there is no theoretical guidance regarding the nature of this assumption and the method requires a larger sample size in order to obtain precise estimates. Since the results can be heavily influenced by the assumption, care is required in its application for regulatory purposes.

One possible solution would be to undertake a panel OLS analysis, where companies are observed over time. Assuming that firm-specific characteristics are time invariant, this approach allows the separation of company specific factors from efficiency without imposing explicit assumptions on the

²⁵ A description of the DEA approach adopted in the 1994 review can be found in Thanassoulis (2000a, 2000b).

²⁶ "An assessment of comparative efficiency measurement techniques", Europe Economics, October 2002

distribution of the error term. This is known as the standard fixed effects panel data model, which captures effects that vary across firms but are not captured in the cost drivers included in the model. This might include, for example, topography and regional cost differences providing they affect companies in a similar way year after year. Post-estimation adjustments may still be needed for one-off factors but this approach would be an internally consistent treatment of firm-specific factors. The panel data approach can be applied with SFA and then, as with cross-sectional analysis, additional assumptions would be needed.

B.3 Model specification

B.3.1 Overall scope

Based on their study on economies of scale and scope in the water and sewerage industry, Stone & Webster extended their study to consider productivity trends in operating expenditure from 1992 to 2003. They modelled the log of total costs as a function of input prices, variable costs, quasi-fixed capital types, outputs and operating conditions.

It is not clear how the cost drivers were selected and the report does not provide much information on the statistical properties of the estimated function. It emphasises that the results are based treating the capital stock as a quasi-fixed input and that this only provides estimates of opex productivity trends. Nevertheless, it demonstrates the feasibility of the methodology in identifying annual productivity growth rates for the sector and decomposing it according to contributory actors.

B.3.2 Catch-up

Few papers have assessed Ofwat's approach to comparative efficiency.

Davidson²⁷ highlights two main issues with Ofwat's approach. First, the residual is, by construction, everything the model excludes and it is a strong assumption that 100 per cent of the residual is inefficiency. Secondly, he believes that the preferred model should not be selected on statistical criteria alone, but should consider economic and engineering theory. As a result, he suggests that sensitivity analysis is essential.

Cubbin²⁸ estimates that percentage of the residual from Ofwat's comparative efficiency models "*which can be attributed to inefficiency as opposed to random noise, uncertainties and omitted explanatory factors*". Cubbin covers the operating cost models and not the capital maintenance models. He finds that a high proportion of the residual can be attributed to underlying variations in efficiency but notes that the estimates are "*the result of a large number of judgements each of which is subject to error and ... these numbers are not the final word on model accuracy*". Prior to this study, Ofwat had stated that it would apply a 10% and 20% adjustment to the residuals from its econometric analysis to allow for such errors.

Water UK commissioned NERA to examine the capital maintenance comparative efficiency models released by Ofwat in RD2/99. NERA replicates each of the models and evaluates them according to statistical tests and underlying economic and engineering knowledge. It concludes there are shortcomings associated with Ofwat's models in terms of inconsistency with industry technical knowledge and the lack of robustness of the models. It provides alternative cost drivers where relevant.

²⁷ "Ofwat efficiency assessments using econometric models: A comment", James Davidson, February 1999

²⁸ "Assessing Ofwat's efficiency econometrics", John Cubbin, March 2004

In 2002 Ofwat commissioned Europe Economics to compare the COLS efficiency results with those obtained using SFA and DEA techniques²⁹. The remit was to emulate Ofwat's OLS equations. Stewart noted that estimates from SFA and OLS differ only insofar as the intercept is concerned and that, subject to sample size, the two techniques would arrive at the same set of cost drivers.

Europe Economics found "*... in most cases a high degree of correlation between the results of different techniques*". This contrasts with the results obtained by Cubbin and Tzanidakis³⁰ who found substantial differences in the rankings of individual companies based on OLS and DEA efficiency scores and concluded that "*... care needs exercising in the use of raw DEA scores when the number of observations is not large, as the danger of spuriously high scores appears substantial*".

Ofwat has developed alternative, unpublished, models, particularly for operating costs. These have been based on its own thinking and submissions from the companies. Ofwat's annual assessment is conducted internally, with advice from Mark Stewart and its scope is not known. Since Stewart's 1993 and 1994 papers, details of the development of the models, whether preferred or alternative, have not been published. As a result there has been little public evaluation or comment.

Published work on catch-up has tended to re-estimate Ofwat's models and evaluate their statistical properties with some providing suggestions for alternative cost drivers. None of them re-estimate the models from first principles.

A summary of points from the literature is in Table B.4.

²⁹ Europe Economics, 2002. Op cit

³⁰ "Regression versus data envelopment analysis for efficiency measurement", John Cubbin and George Tzanidakis, *Utilities Policy* (1998) 7 pp. 75-85

Table B.4 – Ofwat's approach to model development and specification

Issue	Ofwat approach and literature comment
Purpose of analysis	There is a general consensus an approach that seeks to estimate a cost function rather than a production function is preferable, given the nature of the water industry (exogenous outputs and input prices, different operating conditions)
Deterministic versus stochastic frontier function	<p>In 1994, Ofwat used the comparative analysis to determine relative efficiencies. In 1999 it decided to adopt COLS to determine catch-up factors based on the distance to the benchmark company. This approach was also adopted for the 2004 review.</p> <p>Europe Economics' study concluded "<i>given the relatively small sample size, there is unlikely to be much statistical significance in the parameters defining the frontier, let alone in any efficiency rankings of companies</i>".</p> <p>There is an issue regarding the inconsistencies in the results from the different deterministic frontier approaches.</p>
Choice of functional form	<p>Ofwat's choice was based on different statistical tests as reported in the Ofwat Research Papers in 1993 and 1994. Stewart stated that the cost drivers were selected on the basis of economic and engineering theories, backed by statistical results. In the past Ofwat has held workshops to discuss these models with the industry.</p> <p>Cubbin's paper questions the form of Ofwat's models but makes no alternative suggestions. His paper with Tzanikadis estimated an overall water service model from first principles and reached a model that is similar to Ofwat's 1995 model. Although Ofwat no longer publishes the results based on the overall model, it is still used internally.</p>
Variable selection and definition	<p>Ofwat carries out frequent reviews of the econometric models, taking into account company suggestions such as alternative cost drivers and functional forms, and tests them with advice from Mark Stewart.</p> <p>There was some concern among the academics we interviewed about the changes in the cost drivers over time. Given the nature of technology in the water sector, it would be surprising if the relevant cost drivers would change dramatically from one year to the next.</p> <p>Going forward, Ofwat notes that there is a trade-off between the advantages of better-specified models (for example by developing sub-company models) and the disadvantage of increasing data burdens on companies.</p> <p>NERA's paper provided recommendations on cost drivers based on economic and engineering knowledge. However, it is not clear how these proposals matched the results of Ofwat's workshops on efficiency in 2002/03.</p>
Treatment of data	<p>If an outlier is identified, Ofwat carries out checks on the results using the preferred and alternative models, June Return data and submissions on company-specific factors. It carries out additional checks for companies that are at the boundary of the bandings.</p> <p>The company-specific factors typically apply at service level, and rather than make judgements on the allocation of these effects for each sub-service equation, Ofwat applies these factors after the service-level residuals have been calculated. Given the timing of the submissions, factors that apply exclusively to a sub-service are nonetheless applied after the estimation process.</p> <p>Given that these CSF are based on individual company submissions, academic papers have little to say about them.</p>
Estimation process	The coefficients are re-estimated annually, and Ofwat carries out checks, with advice from Mark Stewart, to determine the extent to which the results have changed from one year to the next. There is a broad consensus around the estimation approach but not functional specification and choice of variables.

B.4 Results

B.4.1 Overall scope

For PR04, Ofwat set out to use index / growth accounting to determine the overall scope for efficiency but the studies did not provide a sufficiently consistent view. Ofwat, therefore, adopted a bottom-up approach based on catch-up and frontier elements and undertook a subsequent crosscheck of the results with the range from the index / growth accounting approach.

The results obtained by the various reports and the assumptions behind the productivity estimates are summarised in Table B.5.

Ofwat stated that the range of estimates provided by the studies was large. The range of estimates of productivity depend on

- the sectors considered to be potential comparators
- the time periods used
- the weights on each sector applied
- treatment of quality, privatisation, capital substitution issues
- for estimates of efficiency improvements in the water sector, different adjustments for input prices.

NERA's³¹ main criticism of the results obtained by Europe Economics was that it was sensitive to the assumptions made for each of the categories listed above. We note that the TFP figures estimated for the water and sewerage sector provided by the Europe Economics study are reported in terms of over-performance above the economy, whereas other papers do not make this adjustment.

The results from CEPA's 2003 study are taken from the Executive Summary table. However, these do not reconcile with the numbers given in the analysis section in the report. For example, the quality-adjusted figure for TFP is either 6.1% using 1994/95 to 2001/02 data or 4.2% using 1995/96 to 2001/02 data³². Furthermore, NERA³³ noted that "CEPA's estimates of TFP growth are so sensitive to subjective assessments of quality improvements as to be practically useless in the current debate".

The growth accounting approach to determining productivity growth has been widely used, and there is a reasonable consensus about the economy-wide TFP growth rates reported in the above-mentioned studies. The variation in the estimated TFP growth rates for the water sector is due to the assumptions made as well as the inconsistency in the definition of the reported figures, i.e. whether they are actual TFP growth rates for the sector or performance of the water sector above the overall economy. Therefore care is required in deciding what the results mean.

Catch-up

The initial Ofwat Research Papers provided details on the statistical tests that were carried out on the estimated models. Since then Ofwat has re-estimated the equations annually and considers a series of validation tests. It publishes high level model statistics in its unit costs and relative efficiency report. Significant movements of the company results trigger closer examination and analysis by Ofwat, such as evaluation of alternative models, i.e. different cost drivers and/or scale variables or review of data submissions. Ofwat welcomes suggestions of alternative specifications, and aims to review the models submitted by companies.

³¹ "Review of Europe Economics 'Scope for efficiency improvement in the water and sewerage industry", NERA, May 2003

³² "Productivity improvements in distribution network operators", Cambridge Economic Policy Associates, November 2003

³³ "A critique of CEPA's report on "Productivity improvements in distribution network operators. A report for EDF Energy", NERA, December 2003

Criticisms in the literature of Ofwat's approach are summarised in Table B.5.

Table B.5 – Critiques in the literature of Ofwat's modelling results

Criteria	Critique
Model effectiveness	<p>The R^2 for the unit cost equations are, as expected, lower than those for total cost equations. For example, the 2004-05 opex unit cost models have R^2 of between 0.25 and 0.45 with 'total' cost models recording 0.7 to 0.98.</p> <p>The increase in the number of company-specific factors that are required raises questions as to the effectiveness of these models.</p> <p>The F-test of the overall significance of the cost drivers in the water resources and treatment model used in the 2004 review shows that there is a 4.8% probability that the model is just as well specified by a constant (unit cost comparison would be appropriate) compared to a 0% probability for the other models.</p>
Compliance with theoretical properties	<p>It is not clear that the theoretical properties of the cost function are considered; particularly as operating costs are modelled separately from capital costs.</p> <p>NERA (1999) does not assess the theoretical properties of Ofwat's models. Cubbin (2004) assesses their mathematical properties, and suggests potential problems with interpretation. For example, he concludes that the use of population as the scale factor in the water distribution opex model is "<i>curious</i>", since if population fell by 10% but per capita consumption rose by the same magnitude (i.e. no change expected in distribution input), modelled water distribution expenditure would fall by 10%.</p>
Plausibility of results	<p>Ofwat has held workshops to discuss each model with the industry in terms of the cost drivers included and how they affect costs.</p> <p>NERA's 1999 critique of Ofwat's capital maintenance models concludes that there are severe shortcomings associated with Ofwat's models in terms of inconsistency with industry technical knowledge and that the models are not robust. Cubbin (2004) assesses their plausibility based on a combined assessment of the interpretation of the mathematical properties, descriptive statistics, likely sources of error, and comments from industry knowledge.</p>
Parameter stability	<p>Given the conditions following privatisation, Stewart's panel data analysis concluded that there were changes from one year to the next (i.e. panel data analysis might be inappropriate). More recently, he has suggested that some of the sub-service models are becoming more stable.</p> <p>Most critiques have not considered this aspect of Ofwat's models.</p>
Use of priors	<p>In any analysis of this kind, there should be a balance between the economic or engineering theory and the statistical results. There is concern among academics and in the industry that Ofwat has not explained the econometric models sufficiently. Ofwat notes that workshops have been held in the past and that they have gone through the process of information dissemination to the industry. However, the lack of information in the public domain seems to lead people to the view that the models are selected on statistical grounds rather than relevant theory. We discussed this issue with Ofwat as part of this project and observe that it has in its latest unit costs and relative efficiency report³⁴ explained the reasoning behind the cost drivers.</p>
Robustness	<p>Given the context within which Ofwat will set prices and the changes in the sector since privatisation, there may be a need to re-evaluate the approach to comparative efficiency assessment. The issue of robustness has been considered by academics, for example Cubbin's 2004 paper provides a simulation which shows that it is possible to adopt a better approach to allowances for errors in the inefficiency estimates.</p>

³⁴ Water and sewerage service unit costs and relative efficiency, 2004-05, Appendix 1 (online version see www.ofwat.gov.uk).

B.5 Interpretation and application

Ofwat uses its econometric models to determine predicted costs for each of the sub-services before aggregating to give predictions for the water and sewerage services that it compares with the actual costs. Company-specific factors are then applied, subject to Ofwat's evaluation of their validity and magnitude. A benchmark is selected before the initial efficiency bandings are determined. At this stage there are further checks.

Table B.6 – An analysis of Ofwat's interpretation and application

Criteria	Findings
Consistency of company specific factors	The treatment of company-specific factors is based on Ofwat's judgement.
Confidence of parameter and inefficiency estimates	Ofwat does not calculate confidence intervals for the inefficiency estimates. Instead it makes an adjustment for the assumed error in the residual (i.e. non-efficiency element) and then it assumes that a proportion of the remaining difference between companies (the 'stick') is included in prices as an efficiency challenge. This method compares with the 1994 approach where Ofwat stated companies would catch-up around 50% to 60% of the distance to the benchmark company, reflecting " <i>uncertainties involved in identifying the efficiency frontier</i> ".
Revision and updating	Ofwat re-estimates the equations annually, and uses the most recent data to set the price limits.

Ofwat's current sub-company models assume that each observation is independent rather than linking same company observations. Different approaches have been considered but there are two issues:

- Estimation of company-specific factors. Ofwat makes post-modeling adjustments to the residuals to take account of company specific factors (which companies have submitted information on). A better approach, in theory, would be to adjust the data for these factors and then estimate the models. Stewart found that the company residuals were not unduly affected by the timing of these adjustments. Ofwat has not published this work.
- Correlation between the errors. Mark Stewart has reviewed one of the sub-company models and found that allowing for the correlation between the residuals of different areas within the same company did not unduly alter the estimated model or the company-level differentials from it. In other words that the use of OLS, which does not account for the link between same company observations, produces results which are essentially unchanged when this link is taken into account. In essence the OLS methodology is robust to whatever degree of correlation that might exist.

There is consensus among the academics that the sub-company level modelling undertaken for the sewerage service works better than company level modelling (as carried out for the water service), due to the increased number of observations and greater range in observations (i.e. removing the effects of averaging). However in disaggregating further there is a question about the reliability of the information and the cost to companies (see above). It could be argued that concerns around data reliability could be addressed by further validation work on the data submissions.

The opex / capex trade-off is a significant issue. Mark Stewart is not sure that current econometrics methods can contribute significantly to a solution. His view is that more use could be made of the informal treatments such as the matrix in the unit cost reports (e.g. scaling back of the efficiency catch-up factors depending on the position on the matrix). It is already being used in the selection of

the benchmarks (i.e. a company cannot be a benchmark if it performs badly in the other category) and the re-allocation of leakage expenditure.

Ofwat recognises that judgements are required in setting price limits. However, this does not preclude it from carrying out good analysis for which good data is required. There are no reports that consider solely Ofwat's application and interpretation. Mark Stewart's view of the apparent lack of academic and consultant papers on Ofwat's application and judgement in this area maybe due to the lack of accessibility over Ofwat's judgements.

To date, Ofwat has considered the scope for continuing improvement and catch-up separately. Given the methodologies available, it is possible to bring the two together, as many academics have done (e.g. Saal and Parker) would result in a consistent view of the scope for the industry to improve in the future, whether it is due to companies moving closer to the frontier or technical improvements. Ofwat has recently employed a PhD student to examine the modelling dataset using panel data techniques.

The use of panel data could remove the need for adjusting for company specific factors outside of the modelling. The models can be used to track individual company's productivity improvements over time. However, if Ofwat were to use panel data techniques in the same manner it uses OLS (i.e. catch-up to the benchmark company) then there would remain a need for company specific adjustments.