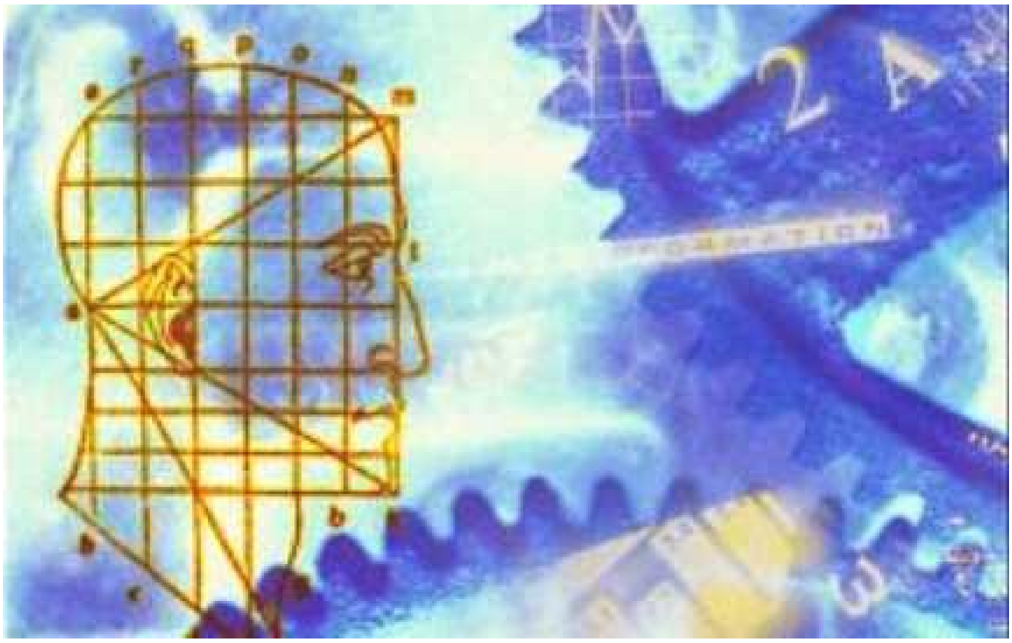
An investigation into opex productivity trends and causes in the water industry in England & Wales - 1992-93 to 2002-03

Main Report - Final

May 2004



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Introduction

This report presents the results of an investigation into trends and causes of opex productivity growth for the water industry in England and Wales. The period of investigation was 1992-93 to 2002-03.

The analysis builds upon a similar methodological approach to that employed previously to investigate economies of scale and scope in the industry.[1]

The purpose of the analysis has been to:

- Estimate trends in opex productivity growth over the period 1992-93 to 2002-03;
- Decompose those trends into the factors contributing to changes in costs over time; namely:
  - The common rate of productivity improvement due to factors such as technical change;
  - Changes in relative price of inputs;
  - Changes in capital inputs;
  - Changes in outputs;
  - Changes in the quality of outputs; and
  - Changes in other characteristics of the operating environment.

The extent to which our estimates of historical opex productivity growth should inform judgments at PR04 about the scope for future opex productivity growth is outside the scope of this work. Those judgements will be a matter for Ofwat.

Findings

The table below summarises the estimated average opex productivity growth rates for WaSCs and WoCs over the period 1992-93 to 2002-03.

Broadly, the average rate of opex productivity growth for WaSCs has been in the range 1.7-1.9% per annum over this period. For the WoCs there is clearer evidence that the average rate of opex productivity growth has been declining.

1 "Investigation into evidence for economies of scale in the water and sewerage industry in England and Wales", January 2004.

Table: Opex productivity growth rates for average WaSC and average WoC

Year	Water and Sewerage Companies		Water only Companies	
	Nr of companies	Rate of opex productivity growth for the average WaSC (% per annum)	Nr of companies	Rate of opex productivity growth for the average WoC (% per annum)
1993	10	2.02	20	1.44
1994	10	1.93	20	1.41
1995	10	1.74	20	1.37
1996	10	1.95	18	1.31
1997	10	1.92	18	1.24
1998	10	1.94	16	1.18
1999	10	1.98	16	1.16
2000	10	1.91	16	1.13
2001	10	1.91	12	1.32
2002	9	1.67	12	1.18
2003	9	1.76	12	1.09

Notes:Dwr Cymru excluded from WaSC sample in 2001-02 and 2002-03 due to non-comparability of labour cost data.

Water and Sewerage Companies (WaSCs)

- There is support for a step increase in opex productivity from 1995-96. Productivity growth was 0.20% higher between 1995-96 and 1999-00 than it would have been otherwise. As this corresponds to the period following the 1994 price review it may reflect company responses to Ofwat's judgements on the scope for efficiency improvements. There is also evidence that the impact of this step increase has weakened in the period 2000-01 to 2002-03.

- After taking account of contributions from changes in the characteristics of the WaSCs, the step change in productivity growth from 1995-96 appears to be sustained, with opex productivity growth rates staying within the range of 1.91% to 1.98% in every year between 1995-96 and 2000-2001. Thereafter there is a decline to 1.76% by 2002-03. This decline may be over-stated due to the exclusion from the sample of Welsh Water for the years 2001-02 and 2002-03.

Main factors behind the trends for WaSCs

The main factors contributing to the improvement in opex productivity growth for the WaSCs are identified as:

- *Improvements in general labour and capital productivity*. The nature of the improvement in capital productivity is different between water supply and sewerage. For water supply the gains can be attributed to capital inputs substituting for opex. By contrast, the evidence for sewerage suggests productivity gains have been gained through reducing the extent to which growth in sewerage capital inputs has increased opex rather than a process of capital substitution allowing companies to reduce total opex. These effects are significantly higher in the period after the first Ofwat regulatory price review in 1994

- *There is also evidence that sewerage quality improvements have been a source of productivity gains***.** Early in the sample period increasing the coverage of secondary treatment led directly to rising opex costs. However, by the end of the sample period this relationship has reversed. This may provide some evidence of productivity benefits from "learning by doing" as WaSCs have improved the operation of new treatment plant and processes.

Water only companies (WoCs)

The analysis reveals notably different trends in opex productivity growth for the WoCs:

- For the WoCs there is less evidence compared to the WaSCs of a step change in opex productivity growth in the period following regulatory price reviews.

- After allowing for the changes in the characteristics of the WoCs, including due to consolidation, the average rate of annual opex productivity growth is estimated to have decreased by 0.353. Most of this decrease is concentrated in the period 1996-2000 with a further and smaller decline in 2001-03. Without these changes, the average rate of opex productivity growth for the sample average WoC would have been a decrease of 0.783. Hence, the combined impact of the annual changes in the characteristics is +0.431 per annum on the rate of opex productivity growth.

Main factors contributing to the WoC trends

Analysis of the factors contributing to growth in opex productivity for WoCs shows these to be different to the WaSCs:

- A contribution from improvements in labour productivity is concentrated in the period before the 1994 price review. This contrasts the evidence on the WaSCs where the significant contributions from improvements in labour productivity are post 1995.

- A further contrast with the WaSCs is a negative contribution from changes in capital productivity. The scope to reduce opex through capital substitution has declined over the sample period resulting in a negative contribution to growth in opex productivity.

- Changes in water service outputs (volumes and connections) are associated with a positive net impact on annual productivity growth, with this concentrated in the post 1995 period. Much of this impact can be attributed to increases in firm-level output associated with consolidation. However, there is an absence of significant improvements in average annual productivity growth rates after mergers.

- A more robust interpretation is that the WoCs, as well as the WaSCs, have been able to respond positively to changes in their operating characteristics, and have therefore offset what would have otherwise been substantial declines in productivity growth.

Issues and areas for further work

The report concludes with some general observations on the findings and areas for future work.

Are WaSCs and WoCs different?

The modelling methodology dictated the use of separate WaSC and WoC models and therefore formal testing for structural differences between WaSCs and WoCs was not undertaken. The analysis nevertheless reveals some interesting differences between WaSCs and WoCs in terms of the trends for opex productivity growth. Areas for further consideration may be:

- To understand more fully the apparent differences in the impact of regulatory reviews on productivity improvements; and

- To consider whether a differentiation between WaSCs and WoCs is required when assessing the scope for efficiency improvements.

Mergers

The previous analysis of economies of scale and scope found no strong statistical evidence that mergers and consolidation in the industry had changed the underlying cost structure of the industry. An alternative hypothesis is that the impact of mergers and consolidations might be revealed through evidence on how changes in industry structure impact on the rate of change in costs. The report's findings only consider opex productivity growth and hence are not conclusive, but:

- For WaSCs, there is some evidence that the merger of Northumbrian Water and North East Water was a stimulus to average opex productivity growth in the merged company; and

- For WoCs, there is no evidence that consolidations between WoCs has resulted in an upward shift in the trend rate of opex productivity growth.

The relationship between industry structure and productivity growth has not been the primary focus of this study. This could be addressed more fully in future work to test in a more systematic fashion these relationships.

Total cost modelling

A final point to emphasise is that this study only considers productivity growth in opex. The findings with respect to the impact of capital inputs, particularly sewerage capital, suggest a need to consider total cost modelling as a way of estimating total factor productivity. The finding that capital efficiency appears to be declining for the WoCs particularly after the 1999 price review is also worthy of further investigation. It would be useful to understand if this downward shift is related to regulatory incentives on capex, including the allowance for small company premiums on the cost of capital, or whether this effect has been as a consequence of WoCs responding to perceived and/or actual "capex budget constraints". This may stem from limited incentives in the regulatory regime to invest in capital beyond the level "allowed" by Ofwat's price determinations.

1 Introduction and background

Stone & Webster recently undertook for Ofwat an investigation into economies of scale in the water industry in England & Wales.[2] That work developed econometric models of water industry costs that were used to provide evidence about economies of scale and scope. In a follow-up to work, Ofwat asked Stone & Webster to investigate what evidence these cost models also provided about the historical trends and causes of productivity growth over the period 1992-93 to 2002-03.

This report presents our assessment of the evidence provided by this modelling approach on productivity growth in the industry over the period 1992-93 to 2002-03. Our analysis only considers productivity growth in operating expenditure. We estimate industry average trends in opex productivity for this period and examine the underlying drivers for changes in productivity growth.

More specifically, the purpose of this follow-on work is to present to Ofwat estimates for the:

- Trends in opex productivity growth over the period 1992-93 to 2002-03;
- Decomposition of those trends into the factors contributing to changes in costs over time; namely:
  - Technical change
  - Changes in relative price of inputs;
  - Changes in capital inputs;
  - Changes in outputs;
  - Changes in the quality of outputs; and
  - Changes in other characteristics of the operating environment.

The extent to which our estimates of historical opex productivity growth should inform judgments at PR04 about the scope for future opex productivity growth is outside the scope of this work. Those judgements will be a matter for Ofwat.

1.1 Structure of this report

The rest of this report is structured as follows:

- Section 2 provides details on our methodology;
- Section 3 summarises our results for WaSCs;
- Section 4 summarises our results for WoCs; and
- Section 5 offers conclusions.

[2] "Investigation into evidence for economies of scale in the water and sewerage industry in England and Wales", January 2004.

2 Methodology

The basis for the analysis is a set of translog models of operating costs developed for the work on economies of scale. A technical report accompanying this main report provides greater technical detail on our modelling approach. In summary these models provide an estimated function for operating expenditure conditioned on:

- outputs;
- input prices;
- capital stocks; and
- operating environment and quality drivers.

The estimates of total operating expenditure (opex) productivity growth in this report are derived from translog models of opex which assume that water companies have quasi-fixed capital stocks. This approach, which has been frequently employed in the analysis of network industries such as railways, is particularly relevant in the water industry. This is because the slow rate of economic depreciation of capital assets, as well as the capital investments associated with statutory quality obligations strongly suggest that the determination of capital stock levels is outside the full control of companies. More simply put, a quasi-fixed capital stock model captures the reality that while water company managers have some control over their capital expenditures, they cannot easily or instantaneously adjust the capital stock to its long run optimal level.

Given that capital is assumed to be outside of the water companies, this modelling approach does not allow for the modelling of total costs including capital costs, but instead models variable costs (opex). It is therefore important to note that the productivity estimates in this model do not reflect total factor productivity growth rates, which would account for capital costs. Instead, we are careful to describe them as opex productivity growth rates. This is because they reflect reductions in opex costs after taking into account changes in outputs, input prices, capital stocks, and any other factors such as firm characteristics or drinking water quality that may influence required opex levels.

Estimates of opex productivity growth can be obtained as the annual time-dependent shift in the translog variable cost function estimated for the economies of scale work. This is represented as:

$$-\partial \ln C_{it} \big/ \partial t = -\varphi_1 - \varphi_2 t - \sum_p \mu_p \ln W_{p,it} - \sum_k \sigma_k \ln K_{k,it} - \sum_y \xi_y \ln Y_{y,it} - \sum_z \zeta_z \ln Z_{z,it}$$

where W denotes input prices, K is the capital stock, Y are outputs and Z are operating characteristics and quality drivers. We adopt the reporting convention that positive productivity growth is expressed as a positive number (and vice versa) rather than a negative change in costs. This implies reporting the equation calibration as the negative of the derivative of operating expenditure with respect to time.

The data normalisations used in estimating the translog function (with data points expressed relative to sample averages) imply that the productivity growth for the mean firm in the sample is simpler to estimate as:

$$-\partial \ln C_{it} \big/ \partial t = -\left(\varphi_1 + \varphi_2 t\right)$$

2.1 Testing the structural stability of the productivity parameters

As the water industry has seen considerable changes in its regulation and other potential determinants of productivity growth over the 1993-2003 period, we have tested our models for structural stability by testing whether the time trend and the time interaction parameters on the explanatory variables (input prices, capital inputs, outputs and operating environment hedonic variables) were significantly different in the 1993-95, 1996-00, and 2001-03 periods. While these periods were chosen to reflect when different price reviews were in effect, these tests may indicate whether the regulatory reviews had an impact on productivity growth. However, we must note that other factors could contribute to a statistically significant shift in the productivity parameters that coincides with the timing of the regulatory reviews.

These structural stability tests as detailed below reveal an interesting difference between the WaSC and WOC models.

The WaSC models indicate that a joint test for no shift in the productivity parameters during the 1996-00 period is rejected, while we do not reject the hypothesis of no shift in the WoC productivity parameters during 1995-2000. During the 2001-2003 period however, both the WaSC and WoC productivity shift parameters are jointly significant.

This suggests, therefore, that the WaSCs exhibited structural change in their productivity parameters in the both the 1996-00 period and the 2001-03 period, while the WoCs only exhibited structural change in the later period. Moreover, as shown below, the impact of this structural change resulted in a substantial positive shift in WASC opex productivity growth rates after 1995, which was more or less sustained after a very small shift in 2001-03. In contrast, while WOC productivity growth rates shifted up moderately in 2001-03, they quickly resumed the slow downward trend that will be discussed further below.

3 Estimated trends in opex productivity growth – WaSCs

In this section we set out for the WaSCs:

- The calibration of the productivity equation derived from a revised translog econometric model that is described in more detail in the technical report accompanying this main report;

- The estimated trends in opex productivity growth for the period 1992-93 to 2002-03. These trends are evaluated for the "average" firm over the entire sample and for the average firm in each sample year.

- A decomposition of the changes in estimated annual average opex productivity growth. This provides information about the underlying drivers for productivity growth over the sample period.

3.1 Model calibration

In Table 1 below we present the calibration of the equation for productivity growth $\left(-\partial \ln C_{it} / \partial t\right)$ used for the WaSCs. These estimates can also be interpreted as showing how the relationship between opex and the explanatory factors (expressed in terms of the elasticity of operating expenditure with respect to each factor) is changing over time.[3] Also, as discussed in section 2 and the technical report, in calibrating the model we have developed a new WaSC translog model for opex costs, which allows for the testing for structural breaks in the estimated rate of change in the model's productivity growth parameters. These tests look at whether the rates of change in the underlying cost relationships differ between time periods.

3 The elasticity of cost measures the % change in opex for a given % change in an explanatory factor (i.e. input prices, capital stock, outputs, hedonic factors).

Table 1: Calibration of WaSC opex productivity growth equation

Variable	All time periods	Deviation in 1995-96 to 2002-03	Additional deviation in 2000-01 to 2002-03
Fully Interacted Translog Parameters			
μ **(Relative Cost of Labour)**	**0.0107**		
σ_1 **(Water service MEA Capital Stock)**	0.000005	**0.0120**	
σ_2 **(Sewerage service MEA Capital Stock)**	-0.0092	0.0045	**0.0050**
ξ_1 **(Water Delivered)**	**0.0081**	**-0.0120**	
ξ_2 **(Equivalent Population)**	**-0.0135**	-0.0024	**-0.0045**
φ_1	**0.0223**	**0.0020**	**-0.0011**
φ_2	**-0.0008**		
Hedonic Parameters			
l_1 **(Nr. connected sewerage properties)**	**0.0126**		
l_2 **(% of sewerage population receiving at least secondary treatment)**	**0.0081**		

Notes: Parameter estimates in bold are individually different to zero at the 95% confidence level

In testing for stability in the model parameters over time we found that structural change in the fully interactive translog parameters was evident for both the 1996-03 and 2001-03 periods, with tests of the joint significance of the structural change parameters being statistically significant at the 95% confidence level. However, as there is no evidence of further structural change in the 2001-2003 period for the σ_1 and ξ_1 parameters, we have therefore excluded these shift parameters.

Table 1 suggests:

- At the start of the sample period the common rate neutral technical change (φ_1) was around 2.2% per annum. This rate of improvement sees a small upward shift in the periods following the 1994 and 1999 price reviews. In the 1996-00 the increase is around 0.2% per annum, while in the 2001-03 period the full effect is an increase of about 0.1% per annum relative to the 1993-95 period (the sum of the two shift parameters).

  The average rate of change in neutral technical change is, however, declining by 0.08% per annum.

- Opex productivity growth is increasing in the productivity growth parameters for:

  - ***Relative labour costs*** **-** This reflects a declining elasticity of opex with respect to relative labour costs. This pattern indicates that WaSC opex productivity growth has benefited significantly by substituting away from labour[4], and also suggests that there has also been no significant shift in the potential for such substitution.;
  - ***Water service capital inputs***, with the impact concentrated in the periods after 1994-95. The elasticity of opex with respect to the water service capital inputs is negative implying evidence of capital substitution in the production of water supply services by WaSCs. The declining trend in this elasticity means not only that substantial productivity gains have been achieved through substitution of opex with capital investment in water supply, but that substantial scope for such substitution should persist into the future. We discuss this further below.
  - ***Sewerage Service Capital Inputs*** The net impact of the sewerage capital stock on opex productivity growth has been marginally positive since 2001. The impact was in fact negative during the 1993-00 period. This reflects the fact that the annual average WaSCs' positive elasticity of opex with respect to capital stock, actually increased from 0.27 to 0.36 between 1993 and 2000 before declining to 0.32 in 2003. This positive output elasticity indicates that new sewerage service capital stock investments actually lead to increased opex costs rather than the substitution of opex costs. Given this, the shift in sign in the productivity growth parameters after 2000 must be carefully interpreted, for it really indicates that the negative impact of new sewerage capital stock investment on opex costs has become less marked.
  - ***Sewerage Population Receiving at Least Secondary Treatment*** The estimated elasticity of opex with respect to population receiving secondary treatment was 0.025 for the annual average firm in 1992-93 but is declining over the sample period by 0.0081 per year and had decreased to -0.056 by 2002-03. This would imply that while increasing sewage treatment levels once led to increases in opex, by

4 For example, this could in part reflect the impact of increased out-sourcing in the industry.

2002-2003 they are reducing opex (all other things given). This parameter shift implies that the impact of improved sewage treatment quality has in fact been associated with an increase in opex productivity growth rates.

- ***Connected Sewerage Properties.*** The estimated elasticity of opex with respect to connected sewerage properties was 0.21 for the annual average firm in 1992-93 but is declining over the sample period by 0.0126 per year and had decreased to 0.08 by 2002-03. This might suggest that significant productivity growth has been achieved through new technologies and efficiency improvements related to the maintenance of sewerage connections.

- Opex productivity growth is decreasing in the productivity growth parameters for:

    - ***Water Delivered.*** The parameter estimates suggest the elasticity of opex with respect to water delivered was in fact decreasing before 1995, but has been increasing since 1995, and this increase has led to a negative impact on productivity growth rates.
    - ***Equivalent Population***. The model indicates that the elasticity of opex with respect to equivalent population has increased, which suggests that the costs associated with sewerage treatment have increased over time. Moreover, the results suggest that the rate of increase in this elasticity increased in both the 1996-2000 and the 2001-03 periods.

3.1.1 Further comment on the relationship with capital inputs

As noted above, our estimates provide interesting evidence on the elasticity of total opex with respect to service capital inputs. In general, this evidence points to improvements in capital efficiency.

With respect to water supply capital inputs, there is consistent evidence of capital substitution contributing to reductions in total opex and the rate of improvement due to this factor has increased throughout the sample period, but especially in the period following the first Ofwat price review in 1994. As a result, water service capital stock investments have contributed significantly to WaSC productivity growth. Moreover, given the current magnitude and trend of the elasticity of opex with respect to water service capital stocks, it would be reasonable to expect such opex productivity enhancing effects to continue into the future given the continuation of capital investment of a similar level and type.

Table 2: Trends in the average opex elasticity with respect to water supply capital inputs for WaSCs

Year	Estimated capital elasticity	standard error	95% Lower bound	95% Upper bound
1993	-0.11	0.07	-0.24	0.03
1994	-0.12	0.07	-0.25	0.02
1995	-0.11	0.07	-0.24	0.02
1996	-0.14	0.07	-0.28	0.00
1997	-0.15	0.07	-0.30	-0.01
1998	-0.17	0.08	-0.32	-0.01
1999	-0.19	0.08	-0.34	-0.03
2000	-0.20	0.08	-0.36	-0.04
2001	-0.20	0.08	-0.37	-0.04
2002	-0.22	0.08	-0.39	-0.06
2003	-0.23	0.09	-0.40	-0.06

Table 3 presents the equivalent trends on the opex elasticity with respect to sewerage capital inputs.

Table 3: Trends in the average opex elasticity with respect to sewerage capital inputs for WaSCs

Year	Estimated capital elasticity	standard error	95% Lower bound	95% Upper bound
1993	0.27	0.13	0.02	0.52
1994	0.30	0.13	0.04	0.55
1995	0.29	0.13	0.03	0.55
1996	0.28	0.13	0.02	0.54
1997	0.30	0.13	0.03	0.56
1998	0.32	0.14	0.05	0.59
1999	0.35	0.14	0.07	0.63
2000	0.36	0.14	0.07	0.64
2001	0.32	0.14	0.03	0.61
2002	0.31	0.14	0.02	0.60
2003	0.32	0.15	0.03	0.62

Contrary to standard economic theory, our estimate for the elasticity of opex with respect to sewerage service capital inputs for the annual average WaSC is positive and statistically significant, for all years in our sample. This positive elasticity would normally be interpreted as suggesting a possible over-investment in capital inputs. However, the circumstances faced by the WaSCs after their privatisation in 1989 would suggest that this could equally reflect the poor quality of the sewerage capital stock, which had suffered substantial underinvestment under public ownership. In this context, therefore, the positive capital elasticity might reflect that, given the poor state of capital assets, increased opex was necessary to meet the increase in sewerage quality standards in the post privatisation period. Given the nature of the substantial capital investment programmes since privatisation – e.g. new treatment works and processes to meet higher standards – it is also likely that new capital investments will have generated additional opex.

Moreover, while our evidence suggests that the WaSCs have reduced the amount of opex associated with new sewerage capital investment, they only began to marginally reduce the amount of new opex associated with new sewerage capital investment after 2000. This may be associated with a regulatory tightening on opex at the 1999 price review requiring more focus on capital substitution opportunities in the sewerage businesses. As a result, new sewerage capital stock has not been a significant contributor to opex productivity growth rates, and in fact had a small negative impact over the entire 1993-2003 period. However, the recently established trend towards a reduced elasticity of opex with respect to sewerage capital stocks is noteworthy and could be expected to continue into the future given a continuation of significant levels of sewerage capital investment. However, the small magnitude of this effect would imply that significant productivity gains will still not accrue, unless the WaSCs further improve their performance in this area.

3.2 Estimates of opex productivity growth for WaSCs

We present the estimated trends in opex productivity in two ways:

- First, the estimates are presented based on the sample average values over the entire 1992-93 to 2002-03 periods for the explanatory factors entering the productivity growth equation. These estimates are reflective of underlying trends in the WaSC opex cost function, in the absence of changes in the characteristics of the WaSCs; and

- Secondly, we evaluate the model for the average WaSC in each time period. **We consider these estimates more reflective of overall trends in productivity growth because they control for changes in the characteristics (inputs, outputs, factor prices, and operating environment) of the average firm in each time period.**

3.2.1 Estimated growth in opex productivity growth for the sample average WaSC

Table 4 below reports the estimates for annual opex productivity growth evaluated at the sample averages. This equates to the estimates for $-\partial \ln C_{it} / \partial t = -(\varphi_1 + \varphi_2 t)$ as outlined in section 2.

Productivity growth is shown to be positive and statistically different to zero in all years, but declining from a mean value of 2.15% per annum in 1992-93 to 1.44% in 2002-03. However, this decline takes no account of the impact of changes in the characteristics of the average WaSC over this period.

A key finding is a step increase in opex productivity from 1995-96 due to structural change in the estimated parameters, with the structural break in the φ_1 parameter indicating that the sample average firm's productivity growth was 0.20% higher between 1995-96 and 1999-00 than it would have been in the absence of structural change. As this corresponds to the period following the 1994 price review it may reflect company responses to Ofwat's judgements on the scope for efficiency improvements. A step decrease is also evident after the 1999 price review, with further structural change in the φ_1 parameter indicating that the sample average firm's productivity growth was 0.11% lower in the 2000-03 period than it would have been in the absence of this further structural change. Given these opposing structural breaks, it is important to note that the net impact of the two structural break parameters is that the sample average firm's productivity growth rates was in fact 0.09% higher in the 2000-01 to 2002-03 period than it would have been in the absence of structural change in the productivity growth parameters.

Table 4: Estimated opex productivity for sample average WaSC

Year	Number of Firms	Estimated Prod Growth Rate	Std Error of the Estimate	T-Stat	95% conf interval lower bound	95% conf interval upper bound
1993	10	2.15	0.22	9.83	1.72	2.59
1994	10	2.07	0.21	9.90	1.65	2.49
1995	10	1.99	0.20	9.92	1.59	2.39
1996	10	2.12	0.18	11.86	1.76	2.47
1997	10	2.03	0.17	11.85	1.69	2.38
1998	10	1.95	0.17	11.72	1.62	2.29
1999	10	1.87	0.16	11.43	1.55	2.20
2000	10	1.79	0.16	10.99	1.47	2.12
2001	10	1.60	0.15	10.45	1.29	1.90
2002	9	1.52	0.16	9.75	1.21	1.83
2003	9	1.44	0.16	8.95	1.12	1.76

Notes:Dwr Cymru excluded from data in 2001-02 and 2002-03 due to non-comparability of labour cost data.

3.2.2 Estimated growth in opex productivity for the average WaSC in each year

To better understand the contribution of changes in firm characteristics (relative to the sample average) to opex productivity growth we now evaluate our model for the average WaSC characteristics in each sample period. Table 5 reports the estimates for the average WaSC for each year, with the trend illustrated also in Figure 1.

This figure serves to emphasise that for the average WaSC in each year, the step change in productivity growth from 1995-96 appears to be sustained, with opex productivity growth rates staying within the narrow band of 1.91% to 1.98% in every year between 1995-96 and 2000-2001. Moreover, it is worth noting that much of the fall in opex productivity growth which occurred in the year ending 2002, was recovered in the subsequent year when the estimated opex productivity growth rate for the annual average WaSC was 1.76%. It is worth further noting, that as Dwr Cymru's (Welsh Water) estimated firm specific opex productivity growth rate was above the sample average, its exclusion from the sample in the last two years of the sample period is likely to exaggerate the actual decline in the estimated annual average.

The comparison between Table 4 and Table 5 helps to identify the overall contribution to opex productivity growth of changes in the characteristics of the average WaSC relative to the sample average. This comparison is also shown in Figure 1. From 1995-96 these changing characteristics have allowed the annual average WaSC to maintain opex productivity growth in excess of 1.75% per annum, in all years other than 2001-02. In contrast, if the WaSCs' characteristics had not changed, they would have experienced a steady decline in productivity growth that would have only been temporarily slowed by the structural break that occurred after 1995-96. This suggests that the underlying process of technical and efficiency changes that characterises the WaSCs has allowed them to respond positively to changes in their operating environment. This is examined more fully in 3.3 below. Caution is also needed when interpreting the decline for the last two sample periods since these periods exclude Welsh Water, who we estimate to be above the mean rate of opex productivity growth for WaSCs.

Table 5: Estimated opex productivity growth for the average WaSC in each year

Year	Number of Firms	Estimated Average Prod Growth Rate	Std Error of the Estimate	T-Stat	95% conf interval lower bound	95% conf interval upper bound
1993	10	2.02	0.21	9.49	1.60	2.45
1994	10	1.93	0.21	9.37	1.52	2.34
1995	10	1.74	0.19	9.12	1.36	2.12
1996	10	1.95	0.17	11.33	1.60	2.29
1997	10	1.92	0.17	11.58	1.59	2.25
1998	10	1.94	0.16	11.84	1.61	2.26
1999	10	1.98	0.17	11.81	1.64	2.31
2000	10	1.91	0.17	11.51	1.58	2.24
2001	10	1.91	0.16	11.67	1.58	2.23
2002	9	1.67	0.16	10.60	1.36	1.99
2003	9	1.76	0.17	10.46	1.43	2.10

Notes: The T-Statistic tests the null hypothesis that the estimate productivity growth rates equals zero

Figure 1: Trends in opex productivity growth for the average WaSC in each year

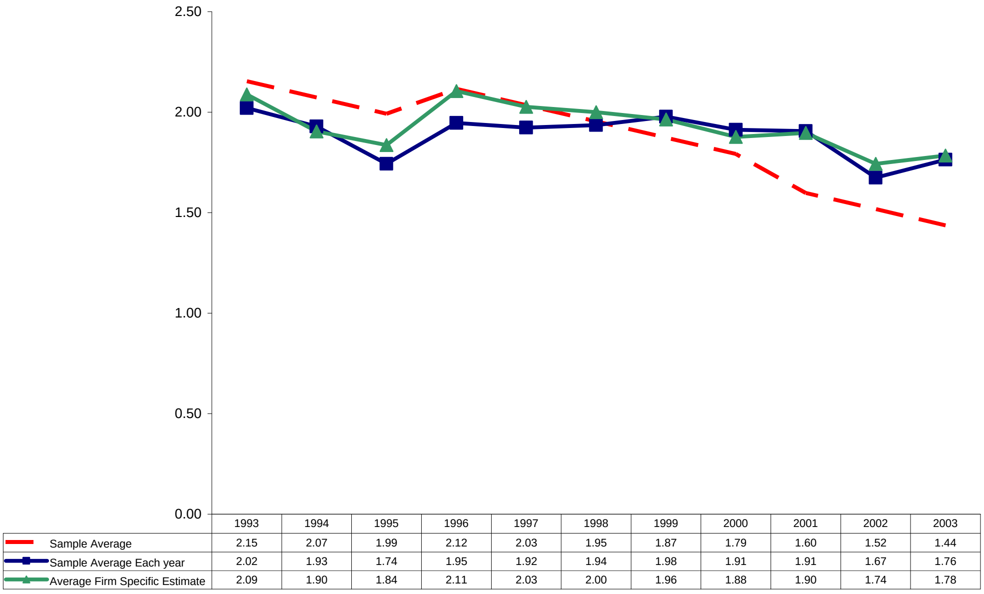

Table 6 presents evidence of the spread around the mean estimates presented above. The coefficient of variation (standard deviation relative to the mean) for the estimated firm specific opex productivity growth rate, suggests that productivity growth rates converged until 1998. While they diverged moderately after this, they subsequently converged again, suggesting that most firms have achieved rates of opex productivity growth relatively close to the average rate in a given year.

Table 6: Distribution of company specific estimates – WaSCs

Year	Number of Firms	Average	Median	Minimum	Maximum	Standard Deviation	Coef of Variation
1993	10	2.09	2.09	0.90	3.20	0.68	0.33
1994	10	1.90	1.93	0.91	2.98	0.59	0.31
1995	10	1.84	1.82	0.82	2.71	0.49	0.27
1996	10	2.11	2.09	1.44	2.65	0.41	0.20
1997	10	2.03	1.97	1.44	2.69	0.41	0.20
1998	10	2.00	2.05	1.43	2.35	0.35	0.17
1999	10	1.96	2.03	1.11	2.49	0.45	0.23
2000	10	1.88	1.95	0.97	2.46	0.46	0.24
2001	10	1.90	1.89	1.16	2.49	0.47	0.25
2002	9	1.74	1.79	1.09	2.35	0.38	0.22
2003	9	1.78	1.74	1.27	2.28	0.36	0.20

Table 7 summarises the changes in the estimated annual average WaSC's opex productivity growth demarcated by the associated price review period (i.e. 1992-93 to 1994-95, 1995-96 to 1999-00, 2000-01 to 2002-03). This shows that a statistically significant decline occurred before the first price review. This was followed by an increase in the rate of opex productivity growth in the 1996-00 period, followed by a statistically significant decline in the 2001-03 period.[5] However, it is interesting to note that over the entire 1993-2003 period, the -0.257% reduction in opex productivity growth is not statistically significant. As a result, we cannot reject the assumption of stable opex productivity growth rates for the annual average WaSC in the range of 1.76%-2.02% per annum over the entire 1993-2003 period.

Table 7: Estimated change in opex productivity growth for the Average WaSC

Period	Estimated Change in Average Prod Growth Rate	Std Error of the Estimate	T-Stat	95% conf interval lower bound	95% conf interval upper bound
1993-1995	-0.278	0.04	-7.02	-0.36	-0.20
1995-2000	0.170	0.11	1.49	-0.06	0.40
2000-2003	-0.149	0.05	-3.21	-0.24	-0.06
1993-2003	-0.257	0.17	-1.47	-0.61	0.09

Notes: The T-Statistic tests the null hypothesis that the change in the estimate productivity growth rates equals zero

3.3 Decomposition of trends in productivity growth

The ability to decompose the overall estimate for opex productivity growth follows directly from the equation (see technical report):

$$\begin{aligned}
&P_{AnnualAverage,t} = -\partial \ln(C_{i,t}) \big/ \partial t = -\varphi_1 - \varphi_2 t - \varphi_{\mathrm{Reg}2} D_{\mathrm{Reg}2,t} - \varphi_{\mathrm{Reg}3} D_{\mathrm{Reg}3,t} \\
&-\sum_p \left(\mu_p + \mu_{p,\mathrm{Reg}2} D_{\mathrm{Reg}2,t} + \mu_{p,\mathrm{Reg}3} D_{\mathrm{Reg}3,t} \right) Wavg_{p,t} \\
&-\sum_k \left(\sigma_k + \sigma_{k,\mathrm{Reg}2} D_{\mathrm{Reg}2,t} + \sigma_{k,\mathrm{Reg}3} D_{\mathrm{Reg}3,t} \right) Kavg_{k,t} \\
&-\sum_y \left(\xi_y + \xi_{y,\mathrm{Reg}2} D_{\mathrm{Reg}2,t} + \xi_{y,\mathrm{Reg}3} D_{\mathrm{Reg}3,t} \right) Yavg_{y,t} \\
&-\sum_z \left(\zeta_z + \zeta_{z,\mathrm{Reg}2} D_{\mathrm{Reg}2,t} + \zeta_{z,\mathrm{Reg}3} D_{\mathrm{Reg}3,t} \right) Zavg_{z,t} \\
&-\sum_h \left(\iota_h + \iota_{h,\mathrm{Reg}2} D_{\mathrm{Reg}2,t} + \iota_{h,\mathrm{Reg}3} D_{\mathrm{Reg}3,t} \right) Havg_{h,t}
\end{aligned}$$

and the calibration of this equation as reported in Table 1. For ease of reference this calibration identifies the following factors as contributing to opex productivity growth:

5 As above, we caution the reader to note that this statistically significant decline may be influenced by the exclusion of Dwr Cymru from the last two years of the sample.

- relative labour costs;
- water and sewerage service capital inputs;
- Outputs (in the form of water delivered and equivalent population served);
- Neutral technical change (as captured by a time trend); and
- Hedonic factors (in the WaSC model represented by connected sewerage properties, and the sewerage population receiving at least secondary treatment)

In the tables below, we report the decomposition in terms of the changes in estimated productivity growth. That is we identify the contribution of changes in each factor to changes in opex productivity growth.

Table 8 reports the absolute contribution of each factor to the overall change in opex productivity growth. Table 9 re-expresses the same data in terms of the relative % contribution of each factor to the change in opex productivity growth.

Table 8: Decomposition of changes in opex productivity growth – WaSCs

Year ending 31st March	Relative Cost of Labour	MEA Water Service Capital Stock	MEA Sewerage Service Capital Stock	Water Delivered	Equivalent Population	Sample Average Firm's Rate of Productivity Growth	Connected Sewerage Properties	Sewerage Population Receiving Secondary Treatment	Total Change in OPEX Productivity Growth Rate
1994	0.048	0.000	-0.007	-0.009	-0.050	-0.081	0.003	0.003	-0.092
1995	-0.156	0.000	-0.005	0.009	0.021	-0.081	0.011	0.014	-0.186
1996	0.039	-0.028	-0.015	0.002	0.049	0.124	0.022	0.010	0.203
1997	0.017	0.015	-0.002	0.007	0.015	-0.081	0.007	0.000	-0.023
1998	0.050	0.017	-0.003	0.011	0.006	-0.081	-0.006	0.019	0.013
1999	0.137	0.016	-0.004	0.010	-0.060	-0.081	0.008	0.018	0.042
2000	-0.015	0.013	-0.004	-0.005	-0.010	-0.081	0.008	0.029	-0.065
2001	0.115	0.051	0.005	-0.019	-0.050	-0.194	0.015	0.070	-0.007
2002	-0.153	0.013	0.001	-0.014	-0.139	-0.081	0.065	0.077	-0.231
2003	0.129	0.009	0.000	0.001	0.021	-0.081	0.009	0.000	0.089
1993-1995	-0.107	0.000	-0.012	0.000	-0.029	-0.162	0.014	0.018	-0.278
1996-2000	0.228	0.033	-0.030	0.025	-0.001	-0.200	0.039	0.076	0.170
2001-2003	0.091	0.074	0.006	-0.032	-0.168	-0.356	0.089	0.147	-0.149
1993-2003	0.211	0.106	-0.036	-0.007	-0.199	-0.718	0.143	0.241	-0.257

Values indicate the net impact on annual average productivity growth of technical change associated with this factor as well as growth in its average level

Positive values indicate increases in annual average productivity growth attributable to this factor

Negative values indicate decreases in annual average productivity growth attributable to this factor

Table 9: Relative % contributions to overall opex productivity growth

Year ending 31st March	Relative Cost of Labour	MEA Water Service Capital Stock	MEA Sewerage Service Capital Stock	Water Delivered	Equivalent Population	Sample Average Firm's Rate of Productivity Growth	Connected Sewerage Properties	Sewerage Population Receiving Secondary Treatment
1994	52.4	0.0	-7.3	-10.1	-54.5	-87.8	3.6	3.6
1995	-83.6	0.0	-2.8	5.0	11.4	-43.5	5.9	7.7
1996	19.0	-13.7	-7.3	1.0	24.0	61.0	10.9	5.0
1997	76.5	64.1	-10.8	29.5	64.4	-357.8	32.5	1.5
1998	392.0	136.1	-27.1	88.0	44.6	-638.1	-46.7	151.2
1999	325.9	36.9	-10.5	23.1	-143.5	-192.6	18.8	42.0
2000	-23.0	19.9	-6.9	-7.0	-15.3	-123.8	11.9	44.1
2001	1727.9	772.9	71.6	-286.4	-755.9	-2913.3	227.5	1055.7
2002	-66.3	5.5	0.5	-6.0	-60.2	-35.0	28.3	33.2
2003	144.7	10.5	0.1	1.6	24.0	-90.7	9.7	0.1
1993-1995	-38.5	0.0	-4.3	0.0	-10.5	-58.2	5.2	6.3
1996-2000	133.9	19.1	-17.4	14.8	-0.8	-117.5	23.1	44.8
2001-2003	61.2	49.5	4.0	-21.3	-113.1	-239.4	60.1	99.0
1993-2003	82.2	41.3	-13.9	-2.5	-77.3	-279.2	55.6	93.8

Values indicate the net impact on annual average productivity growth of technical change associated with this factor as well as growth in its average level

Positive values indicate increases in annual average productivity growth attributable to this factor

Negative values indicate decreases in annual average productivity growth attributable to this factor

Over the entire sample period, after allowing for the changes in the characteristics of the average WaSC, the average rate of annual opex productivity growth is estimated to have decreased by 0.257. Without these changes, the average rate of opex productivity growth for WaSCs would have decreased by 0.718, with this negative impact occurring in each of the sample periods. Hence, the combined impact of the annual changes in the characteristics equates to about +0.461 per annum on the rate of opex productivity growth. This includes the impact of the step change identified in the modelling from 1995-1996.

From Table 8 we identify the following factors contributing to this net impact of +0.461:

- Improved labour productivity contributes to an increase of 0.211 in annual average opex productivity growth over the sample period with positive changes after 1995 offsetting an earlier +negative impact. This suggests that labour productivity improvement after manpower reductions which followed both the 1994 and 1999 price review explain a considerable proportion of opex productivity growth. This may reflect the increased trend towards out-sourcing by the WaSCs.

- The improvement in the elasticity of opex with respect to water service capital stocks discussed above, results in a substantial positive net impact of changes in the water service capital stock for the entire 1993-2003 period. Thus increased water capital stocks result in an increase in average annual opex productivity growth rates of 0.106, that can be attributed to the opex substituting effects of water capital investments

- In contrast, given that increased sewerage capital stocks are associated with increasing opex requirements for much of the sample period, increases in sewerage capital stocks have in fact contributed to a 0.036 decline in annual average productivity growth rates over the sample period. Moreover, it should be noted that the improvement in productivity growth rates of 0.006 that can be attributed to improved capital productivity in the 2000-2003 period has resulted because of a reduction of the extent to which growth in sewerage capital inputs increases opex rather than a process of capital substitution allowing companies to reduce total opex.

- Over the entire sample period increases in water service outputs as measured by water delivered contribute a small decrease in opex productivity growth of 0.007. This, however, masks a positive impact before 2000 and a negative impact after this time. As discussed above, these trends may be attributable to increased drinking water quality standards. This is the case, because while water connections and the estimated number of customers living in fully compliant DWI zones are included in the model, a specification including time interactions on these hedonic variables was rejected. Nevertheless, the models suggest that even if a small negative impact on productivity growth can be attributed to water volumes and quality, this has been more than offset by the continuing positive impact of water capital stock investments on WaSC opex productivity growth.

- Changes in the quantum of sewerage service outputs (volume & connections) over the entire sample period make a net negative contribution to opex productivity growth of 0.056, which is consistent with rising unit opex for the sewerage service over the sample period. However, increases in the sewerage population receiving secondary treatment over the sample period are associated with a 0.241 increase in annual average WaSC opex productivity growth, which more than offsets the decreases associates with the other sewerage outputs.

In order to more concisely summarise the sources of changes in WaSC productivity growth, Table 10 aggregates all water and sewerage service specific factors. This reveals a number of interesting factors related to the composition of the 0.461 increase in annual average opex productivity growth rates that can be attributed to changes in the characteristics of the average WaSC in each year over the 1993-2003 period.

First, 0.211 or 46% can be attributed to improved labour productivity, suggesting that the process of labour shedding and labour substituting capital investment that has characterised the WaSCs since privatisation is a significant source of productivity growth. Secondly, 0.100 (22%) and 0.150 (32%) can be respectively attributed to changes in water and sewerage specific characteristics, thereby suggesting a relatively balanced service impact on opex productivity growth rates.

Table 10 is revealing also, as it details changes in productivity growth rates that can be purely attributed to parameter change, and changes that would have occurred in the absence of parameter change (see the technical report for a description of the methodology employed). This decomposition is useful, as it reflects the net impact of structural change in the productivity growth parameters on productivity growth rates. Thus, if the total change in opex productivity growth rates that can be attributed to parameter change is positive, this indicates that structural changes have had a positive impact on productivity growth rates. In contrast, if the total change in productivity growth rates that can be attributed to parameter change is negative, it suggests that structural changes reflect reductions in potential opex productivity growth rates.

Focusing on the 1995-2003 period, when the structural breaks occurred reveals that in the absence of parameter change, annual average productivity growth rates would have fallen by 0.127 However, because the net impact of parameter change was a +0.148 boost to annual average productivity growth rates, annual average productivity actually increased by 0.021. Thus, these results suggest that structural changes have had a significant positive impact on opex productivity growth rates. While it cannot be definitely attributed to any one factor, these positive structural changes may reflect the stronger efficiency incentives WaSCs have faced since the first regulatory tightening in the 1994 price review.

Table 10: Impact of structural change in estimated parameters on productivity growth

Time Period	Total Change in OPEX Productivity Growth Rate	Sample Average Firm's Productivity Growth	Total From Changes in the Avg. Firm.	Relative Cost of Labour	Total Water Service Specific Factors	Total Sewerage Service Specific Factors
1993-1995						
In Absence of Parameter Change	-0.278	-0.162	-0.116	-0.107	-0.000001	-0.009
Attributable to Parameter Change	-	-	-	-	-	-
Total Change in Productivity	-0.278	-0.162	-0.116	-0.107	-0.000001	-0.009
1995-2000						
In Absence of Parameter Change	-0.112	-0.405	0.293	0.228	-0.013	0.079
Attributable to Parameter Change	0.282	0.205	0.077	-	0.071	0.006
Total Change in Productivity	0.170	-0.200	0.370	0.228	0.058	0.084
2000-2003						
In Absence of Parameter Change	-0.015	-0.243	0.228	0.091	0.067	0.070
Attributable to Parameter Change	-0.133	-0.113	-0.020	-	-0.025	0.005
Total Change in Productivity	-0.149	-0.356	0.207	0.091	0.042	0.074
1995-2003						
In Absence of Parameter Change	-0.127	-0.648	0.521	0.319	0.053	0.149
Attributable to Parameter Change	0.148	0.092	0.056	-	0.046	0.010
Total Change in Productivity	0.021	-0.556	0.577	0.319	0.100	0.159
1993-2003						
In Absence of Parameter Change	-0.405	-0.810	0.404	0.211	0.053	0.140
Attributable to Parameter Change	0.148	0.092	0.056	-	0.046	0.010
Total Change in Productivity	-0.257	-0.718	0.461	0.211	0.100	0.150

4 Estimated trends in productivity growth – WoCs

Our previous modelling for the economies of scale work rejected the idea of a common cost function for WaSCs and WoCs. This means that our estimates for WoCs are based on a WoC only translog model for opex.

In this section we set out for the WoCs:

- The calibration of the productivity equation derived from the translog econometric model that is used to generate the estimates;
- The estimated trends in opex productivity growth for the period 1992-93 to 2002-03. These trends are evaluated for the "average" firm over the entire sample and for the average firm in each sample year. We also report on the distribution of firm specific estimates.
- A decomposition of the changes in estimated productivity growth. This provides information about the underlying drivers for productivity growth over the sample period.

4.1 Model calibration

Table 11 presents the calibration of the equation for productivity growth $\left(-\partial \ln C_{it} / \partial t\right)$ used for the WoCs. As for the WaSCs we investigated the possibility of changes in the estimated parameters over time. We only found evidence of structural change in the 2001-03 period. While all 8 potential WoC productivity shift parameters were jointly significant, it was possible to test these down to the four parameters reported below, with the remaining four parameters being both jointly and individually insignificant.

When interpreting these parameters, it is important to remember that they represent the impact of changes in the underlying model parameters on the productivity growth of the sample average WoC, all other things being equal. In other words, they measure the sign and magnitude of the impact of underlying changes in the estimated opex cost function on productivity growth.

Table 11: Calibration of WoC opex productivity growth equation

Variable	All periods	Deviation in 2000-01 to 2002-03 period
Fully Interacted Translog Parameters		
μ (Relative Cost of Labour)	**0.0082**	**0.0015**
σ (MEA Capital Stock)	-0.0056	**-0.0022**
ξ_1 (Water Delivered)	**-0.0130**	
ξ_2 (Connected Properties)	**0.0190**	
φ_1	**0.0168**	**0.0022**
φ_2	**-0.0010**	
Hedonic Parameters		
ζ_1 (Distribution Losses)	-0.0029	
ζ_2 Nr of metered properties	0.0005	
ζ_3 Population in Fully Compliant DWI Zones	0.0017	**0.0019**

Notes: Parameter estimates in bold are individually different to zero at the 95% confidence level

Table 11 suggests:

- The common rate of neutral technical change (φ_1) at the start of the sample period was around 1.7% per annum. This rate of improvement sees a small upward shift in the period following 1999 price review. In the 2001-2003 the increase is around 0.2% per annum. This annual rate of change in opex productivity is, however, declining by 0.1% per annum, which is a marginally higher rate of decline than estimated for the WaSCs.

- Opex productivity growth is increasing in the productivity growth parameters which have positively influenced the cost impact of:

  - ***Relative labour costs***, with this slightly higher in the period 2001-2003. This reflects a declining elasticity of opex with respect to relative labour costs and this decline has increased after 2000 This pattern reflects that WoC opex productivity growth has benefited significantly by substituting away from labour (and perhaps towards out-sourcing);
  - ***Connected Properties*** The productivity growth parameters indicate that substantial improvements in the underlying cost impact of servicing connected properties has been a strong source of productivity growth over the sample period.
  - ***Numbers of metered properties***. The WoC estimate of the elasticity of opex with respect to metered properties is positive which implies, that

all other things being equal, that more widespread metered billing is associated with higher opex. However, despite being small and statistically insignificant, ζ_2 suggests that there have been productivity improvements in metering technology and billing, and/or that metering has led to reduced water output costs that have partially offset the cost of increased metering.[6]

- ***DWI compliance.*** The estimated elasticity of opex with respect to compliance with quality standards for drinking water is negative, which implies that unit opex <u>declines</u> as the quality of water supply improves. Moreover, the relevant productivity growth parameters in Table 11 indicate that this effect is becoming larger in absolute value, and this change even accelerated after 2000. This indicates not only that improved drinking water standards reduce opex costs, but that this effect is becoming stronger over time, and therefore contributes positively to productivity growth. This is a very interesting finding of this study, which merits further research.[7]

- Opex productivity growth is decreasing due to both the sign of and / or structural changes in the productivity parameters which have negatively influenced the cost impact of:

  - ***Water Delivered*** The productivity growth parameters indicate that deterioration in the underlying cost impact of providing water volumes has been a source of productivity decline over the sample period. This effect is relatively small however, as evidenced by the fact that it caused the estimated elasticity of opex with respect to water delivered for the sample average firm to only increase from 0.57 in 1992-93 to 0.59 in 2002-3;

  - ***Capital inputs.*** The estimated elasticity of opex with respect to the capital stock for the sample average WoC in 1992-93 was -0.077, which implies that unit opex <u>declines</u> as the capital stock increases. However, given a standard error of 0.066 this cost elasticity was not statistically different from zero. Moreover, the productivity growth parameters indicate that the elasticity of opex with respect to the capital stock is increasing for the sample average WoC and the rate of increase is higher from 2000. As a result, for the sample average firm the estimated elasticity of opex with respect to the capital stock was virtually zero in 2002-3 with a value of 0.002

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[6] It should be further noted that while the sample average WoCs estimated cost elasticity has only declined from 0.0261 to 0.0211 over the sample period, the estimated elasticity of WOC opex with respect to metering for the annual average WOC has declined from a highly statistically significant value of 0.038 in 1992/93, to a statistically insignificantly different from zero value of 0.010 in 2002/3, suggesting, that when changes in WoC characteristics are fully taken into account, a more dramatic impact on the cost effects of metering has in fact occurred.

[7] Again comparison of the estimated elasticity of opex costs with respect to DWI Compliance for the sample average WoC and the annual average WOC is illuminating. Thus while the estimated elasticity for the sample average firm has only increased from -.010 to -.028, the estimated elasticity for the annual average WoC has increased from -.014 to -.042 over the sample period and become highly statistically significant. We therefore again see, that when changes in the average annual WoCs characteristics are accounted for, a more significant impact in the opex cost effects of quality compliance is revealed.

Taken together, these statistics indicates not only the absence of statistically significant evidence that capital substitution reduces opex costs. They also imply that all other things being equal, structural change in the productivity parameters has in fact resulted in an even further deterioration in the scope for capital substitution, and this deterioration has contributed negatively to productivity growth.[8]

- ***Distribution losses***. The elasticity of opex with respect to distribution losses is estimated to be negative for the WoCs. All other things given, this implies reducing distribution losses will lead to rising opex. However, the magnitude of this effect has been declining over time. The estimated elasticity for the sample average WoC declines in magnitude at the annual rate of 0.0029, meaning that estimated elasticity for the sample average WoC has fallen in magnitude from -0.0426 to -0.0397. Hence, it is implied that the same % reduction in distribution losses is associated with a lower % increase in opex in 2002-03 than 1992-93. This could reflect improved productivity in leakage control activities. Alternatively, it may reflect increasing water treatment costs which would make it less productive to trade off higher water treatment costs for reduced leakage control activities, and the negative sign on ξ_1 supports this later hypothesis. However, it should be noted that neither this cost elasticity nor the productivity growth parameter associated with it are statistically significant.

4.2 Estimates of opex productivity growth for WoCs

We report here for the WoCs, the trends for estimated opex productivity growth in the same format as the WaSC estimates reported in section 3.

4.2.1 Estimated growth in opex productivity growth for the sample average WoC

Table 12 below reports the estimates for annual opex productivity growth evaluated at the sample averages. This estimate is derived from the estimated parameters based on the estimated parameters φ_1 and φ_2 and shifts in the φ_1 parameter, and this estimate reflects the underlying rate of productivity growth the sample average firm would have achieved in the absence of changes in its characteristics.

Opex productivity growth is shown to be positive and statistically different to zero in all years, but declining from a mean value of 1.68% per annum in 1992-93 to 0.90% in 2002-03. This suggests, that the WoCs faced an operating environment in which the underlying rate of technological and efficiency change was declining. However, this decline takes no account of the impact of the significant changes in the characteristics of the average WoC due to mergers and consolidations, as well as general trends in outputs, quality and other characteristics, over this period.

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8 The estimated cost elasticity for the annual average WOC experiences a similar decline. Its value, which is insignificantly different from zero in all years, was -.062 in 1992-3 and had declined to -.004 by 2002-2003. Thus, if we take into account changes in the annual average characteristics of the WoCs, the average WoC in 2002-2003 is still estimated to have a negative, albeit insignificant capital cost elasticity.

For the WoCs there is less evidence compared to the WaSCs of a structural shift in opex productivity growth for the sample average firm following regulatory price reviews. Unlike the WaSCs, there was no shift in productivity growth following the 1994 price review. There is evidence of an increase in +0.1 in 2000-01 – the year following the 1999 price review - but this is not sustained. These findings emphasise potentially important differences between WaSCs and WoCs in terms of opex productivity growth.

Table 12: Estimated opex productivity for sample average WoC

Year	Number of Firms	Estimated Prod Growth Rate	Std Error of the Estimate	T-Stat	95% conf interval lower bound	95% conf interval upper bound
1993	20	1.68	0.31	5.44	1.07	2.29
1994	20	1.58	0.29	5.43	1.01	2.16
1995	20	1.48	0.28	5.39	0.94	2.03
1996	18	1.38	0.26	5.30	0.87	1.90
1997	18	1.28	0.25	5.16	0.79	1.77
1998	16	1.18	0.24	4.96	0.71	1.65
1999	16	1.08	0.23	4.67	0.62	1.54
2000	16	0.98	0.23	4.32	0.53	1.43
2001	12	1.10	0.20	5.57	0.71	1.49
2002	12	1.00	0.20	4.99	0.60	1.39
2003	12	0.90	0.21	4.36	0.49	1.31

4.2.2 Estimated growth in opex productivity for the average WoC in each year

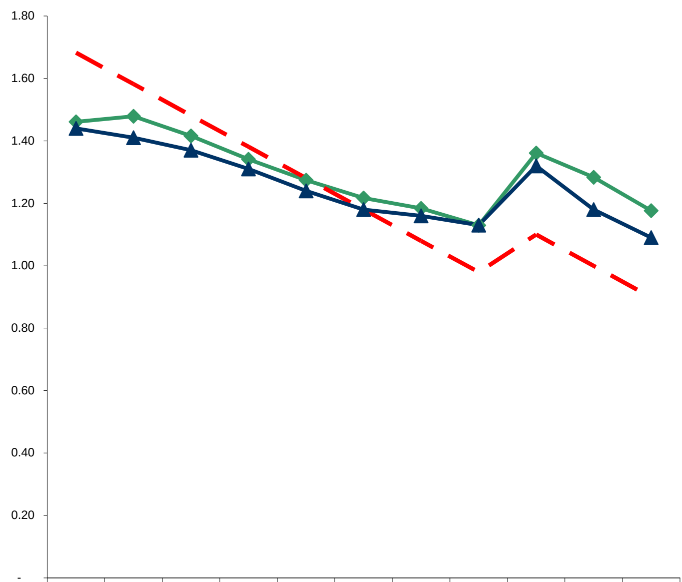
To better understand the contribution of changes in firm characteristics to opex productivity growth we now evaluate our model for the average WoC characteristics in each sample period. Table 13 reports the estimates for the average WoC for each year with the trends also illustrated by Figure 2.

Table 13: Estimated opex productivity growth for the average WoC in each year

Year	Number of Firms	Estimated Average Prod Growth Rate	Std Error of the Estimate	T-Stat	95% conf interval lower bound	95% conf interval upper bound
1993	20	1.44	0.25	5.76	0.95	1.94
1994	20	1.41	0.25	5.66	0.92	1.90
1995	20	1.37	0.25	5.50	0.88	1.86
1996	18	1.31	0.25	5.28	0.82	1.80
1997	18	1.24	0.24	5.28	0.78	1.71
1998	16	1.18	0.23	5.09	0.72	1.63
1999	16	1.16	0.24	4.87	0.69	1.63
2000	16	1.13	0.25	4.52	0.64	1.63
2001	12	1.32	0.22	6.05	0.89	1.75
2002	12	1.18	0.21	5.50	0.75	1.60
2003	12	1.09	0.21	5.06	0.66	1.51

Notes: The T-Statistic tests the null hypothesis that the estimate productivity growth rates equals zero

Figure 2: Trends in opex productivity growth for the average WoC in each year



	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Average of Firm specific estimates	1.46	1.48	1.42	1.34	1.27	1.22	1.18	1.13	1.36	1.28	1.18
Sample average	1.68	1.58	1.48	1.38	1.28	1.18	1.08	0.98	1.10	1.00	0.90
Average WoC in each year	1.44	1.41	1.37	1.31	1.24	1.18	1.16	1.13	1.32	1.18	1.09

Figure 2 helps to emphasise the general decline in opex productivity growth, even after allowing for changes in WoC characteristics. It is also apparent that the increase in 2000-01 appears not to have been sustained.

Figure 2 also provides a comparison between opex productivity growth with and without changes in the characteristics of the average WoC. The main observation is that these differences in characteristics (in terms of input prices, capital stocks, outputs and the operating environment) would imply a lower rate of productivity growth early in the period that has declined at a slower rate such that higher rates of productivity growth are now being sustained.

The interesting observation here is that an important driver of these changing characteristics has been a trend of consolidation of the WoCs and the merger of smaller WoCs with larger WaSCs. While these mergers may have caused some significant shifts in the source of productivity growth changes, they do not appear to have significantly altered the trend in overall average annual productivity growth. Instead, a more robust interpretation is that the WoCs, as well as the WaSCs, have been able to respond positively to changes in their operating characteristics, and have therefore offset what would have otherwise been larger declines in productivity growth

Table 14 presents evidence of the distribution of firm specific productivity estimates in each year. The interesting observation here is that, unlike the WaSCs, the WoCs appeared to have diverged in terms of productivity growth. The coefficient of variation (standard deviation relative to the mean) is 0.21 in 1992-93 rising to 0.30 by the end of the sample period.

Table 14: Distribution of company specific estimates – WoCs

Year	Number of Firms	Average	Median	Minimum	Maximum	Standard Deviation	Coef of Variation
1993	20	1.46	1.48	0.66	1.91	0.31	0.21
1994	20	1.48	1.47	0.86	2.01	0.33	0.22
1995	20	1.42	1.35	0.88	2.03	0.34	0.24
1996	18	1.34	1.35	0.76	1.85	0.31	0.23
1997	18	1.27	1.18	0.72	1.87	0.36	0.28
1998	16	1.22	1.27	0.41	1.79	0.40	0.33
1999	16	1.18	1.24	0.52	1.96	0.39	0.33
2000	16	1.13	1.22	0.58	1.65	0.33	0.30
2001	12	1.36	1.36	0.69	1.86	0.35	0.26
2002	12	1.28	1.28	0.64	1.73	0.33	0.26
2003	12	1.18	1.10	0.55	1.63	0.36	0.30

Table 15 summarises the changes in average annual opex productivity growth demarcated by the associated price review period (i.e. 1992-93 to 1994-95, 1995-96 to 1999-00, 2000-01 to 2002-03). This shows that in both the 1993-95 and the 1996-00 period the average WoC experienced a statistically significant decline in the annual rate of growth in opex productivity, with the change in 1993-95 being significant at only the 90% level. In contrast, the small decline from 2000-01 is not found to be statistically significant and the hypothesis of no decline cannot be rejected. Thus while our structural stability test found statistical evidence of a shift in the productivity parameters for this period, this shift, coupled with changes in the characteristics of the average WoC over this period was not sufficiently strong to result in a statistically significant change in WoC productivity growth rates. Nonetheless, a more positive interpretation suggests that the structural breaks that occurred after the 1999 price review arrested what had been a statistically significant decline in opex productivity growth rates. However, given that the -0.353 decline over the entire 1993-2003 period is statistically significant at just under the 95% level, the inference is that average WaSC, the average WoC has experienced a statistically significant decline in opex productivity growth over the entire sample period.

Table 15: Estimated change in opex productivity growth for the Average WoC

Period	Estimated Change in Average Prod Growth Rate	Std Error of the Estimate	T-Stat	95% conf interval lower bound	95% conf interval upper bound
1993-1995	-0.072	0.040	-1.78	-0.15	0.01
1996-2000	-0.237	0.094	-2.51	-0.42	-0.05
2000-2003	-0.044	0.113	-0.39	-0.27	0.18
1993-2003	-0.353	0.179	-1.97	-0.71	0.00

Notes: The T-Statistic tests the null hypothesis that the change in the estimate productivity growth rates equals zero

4.3 Decomposition of the trends in productivity growth for WoCs

Table 16 reports the absolute contribution of each factor to the overall change in opex productivity growth. Table 17 re-expresses the same data in terms of the relative % contribution of each factor to the change in opex productivity growth.

Over the entire sample period, after allowing for the changes in the characteristics of the average WoC, the average rate of annual opex productivity growth is estimated to have decreased by 0.353. Most of this decrease is concentrated in the period 1996-2000 with a further but smaller decline in 1993-1995 and an even smaller decline in 2001-2003. Without these changes, the average rate of opex productivity growth for the sample average WoC would have been a decrease of 0.783. Hence, the combined impact of the annual changes in the characteristics equates to about +0.431 per annum on the rate of opex productivity growth.

From Table 16 we identify the following factors contributing to this net impact of +0.431:

- Improved labour productivity contributes about +0.169 over the entire period, though of interest this is concentrated in the period before the 1994 price review (+0.112). This offers an interesting contrast with the WaSCs where we identified a significant contribution from improvements in labour productivity in all of the identified periods. One explanation for this difference would be WoCs undertaking manpower reductions much earlier than the WaSCs and in advance of the Ofwat regulatory price reviews. Moreover, the timing of the improvements in labour productivity for WoCs may help explain why the relative performance of the WaSCs and WoCs after 1995 is markedly different.

- A further contrast with the WaSCs is a negative contribution from changes in water capital stock productivity (about -0.194). As discussed above, there is evidence that WoCs have substituted capital inputs for opex (revealed by a negative elasticity of opex with respect to capital inputs). However, unlike with the WaSCs, the scope for capital substitution has clearly declined over the sample period resulting in a negative contribution to growth in opex productivity.

- Changes in water service outputs (volumes and connections) are associated with a positive net impact on annual productivity growth of +0.206, with this concentrated in the post 1995 period. The benefits arise from growth in numbers of connected properties offsetting the negative effect of increases in the volumes supplied by the average WoC. This impact of connected properties might indicate that one source of opex productivity gain has been through efficiencies in the management of distribution networks.

- The positive contribution of changes in metered properties over the 1993-03 period is 0.075. Our estimates suggest opex is increasing in metered properties for WoCs (estimated elasticity of +0.026), with the magnitude of this increase declining over time implying increasing productivity. We should however note that for the WoCs, productivity gains attributable to increased metering are not statistically significant.

- Improved drinking water compliance is associated with a positive contribution to opex productivity growth (+0.165). This may suggest that WoCs have increasingly adopted less opex intensive solutions to achieve rising compliance with drinking water standards (for example renovation of distribution mains). As the quality of WoC outputs has risen (measured here by compliance with drinking water standards), this finding would be suggestive of this being delivered by greater capital intensity in the production and delivery of water supplies.

- The impact of changes in distribution losses on average annual opex productivity growth is only 0.009 over the entire sample period. Moreover, the trend in the annual average impact of this variable on opex productivity growth illustrated in Table 15 shows no clear pattern. Given this, and the actual statistical insignificance of the productivity growth parameter for distribution losses, it is clear that changes in distribution losses have not directly influenced productivity growth rates.[9]

In order to more concisely summarise the sources of changes in WoC productivity growth, Table 18 aggregates the impact water outputs and connections into a separate category. Similarly, the impact of the three hedonic variables is aggregated into a net "hedonic" category.

This reveals some further insights with regard to the composition of the 0.431 increase in annual average opex productivity growth rates that can be attributed to changes in the average WoC's characteristics over the 1993-03 period. Firstly, only

[9] This should not be interpreted this as indicating that it is inappropriate to include distribution losses in the model: This is because in the translog specification, the interaction parameters between distribution losses and both water delivered and connected properties are highly statistically significant. Thus, if distribution losses increase the elasticity of opex with respect to water delivered is substantially increased, while the elasticity of opex with respect to connected water properties is substantially decreased

0.169 or 39% can be attributed to improved labour productivity, suggesting that, because WoCs were never in the public sector, the potential gains from labour shedding and labour substituting capital investment by the WoCs were less than those of the WaSCs. However, this positive impact was offset by a -0.194 (-45%) decline in opex productivity growth that can be attributed to the deterioration in the elasticity of opex with respect to water capital stocks. Nevertheless, between 1993 and 2003, opex productivity gains of 0.206 (48%) and 0.250 (58%) can be respectively attributed to changes in water outputs and hedonic variables. This suggests that WoCs have benefited from cost reducing technical change that not only reduced the cost of outputs, but also suggests that the net impact of efforts to improve drinking water quality, metering, and reduce distribution losses, has been an increase in opex productivity growth rates.

Table 18 also details changes in productivity growth rates that can be purely attributed to parameter change, and changes that would have occurred in the absence of parameter change. Thus, if the total change in opex productivity growth rates that can be attributed to parameter change is positive, this indicates that structural changes have had a positive impact on productivity growth rates. In contrast, if the total change in productivity growth rates that can be attributed to parameter change is negative, it suggests that structural changes reflect reductions in potential opex productivity growth rates.

Focusing on the 2000-2003 period, when the structural change occurred, reveals that in the absence of parameter change, annual average WoC opex productivity growth rates would have fallen by 0.292. However, because the net impact of parameter change was a 0.248 boost to annual average productivity growth rates, annual average productivity only fell by 0.044. Thus, these results suggest that structural changes have had a significant positive impact on opex productivity growth rates. While it cannot be definitely attributed to any one factor these positive structural changes suggest that the stronger efficiency incentives WoCs faced after the 1999 price review may be responsible for this marked improvement in their productivity growth parameters.

Table 16: Decomposition of changes in Average WoC opex productivity growth

Year	Relative Cost of Labour	Water Delivered	MEA Capital Stock	Connected Properties	Distribution Losses	% of metered properties	Estimated Population in Fully Compliant DWI Zones	Sample average rate of growth	Total Change in opex Productivity Growth Rate
1994	0.047	-0.007	-0.005	0.009	0.010	0.007	0.013	-0.100	-0.028
1995	0.065	-0.030	-0.004	0.015	-0.004	0.006	0.009	-0.100	-0.043
1996	0.071	-0.076	0.017	0.022	0.004	0.007	-0.001	-0.100	-0.055
1997	-0.063	0.031	-0.004	0.029	0.010	0.006	0.020	-0.100	-0.071
1998	-0.040	-0.123	-0.069	0.234	-0.021	0.015	0.039	-0.100	-0.065
1999	0.020	0.027	-0.005	0.012	0.025	0.009	-0.003	-0.100	-0.016
2000	0.060	-0.020	-0.004	0.012	0.018	0.009	-0.002	-0.100	-0.029
2001	0.030	-0.119	-0.109	0.196	-0.030	0.008	0.092	0.121	0.188
2002	-0.018	-0.034	-0.004	0.012	-0.006	0.004	0.002	-0.100	-0.145
2003	-0.003	0.008	-0.006	0.009	0.004	0.004	-0.003	-0.100	-0.088
1993-1995	0.112	-0.037	-0.010	0.024	0.006	0.013	0.022	-0.201	-0.072
1995-2000	0.048	-0.161	-0.065	0.308	0.035	0.046	0.053	-0.502	-0.237
2000-2003	0.009	-0.145	-0.119	0.218	-0.032	0.016	0.090	-0.080	-0.044
1993-2003	0.169	-0.343	-0.194	0.550	0.009	0.075	0.165	-0.783	-0.353

Values indicate the net impact on annual average productivity growth of technical change associated with this factor as well as growth in its average level

Positive values indicate increases in annual average productivity growth attributable to this factor

Negative values indicate decreases in annual average productivity growth attributable to this factor

Table 17: Relative % contributions to changes in Average WoC opex productivity growth

Year	Relative Cost of Labour	Water Delivered	MEA Capital Stock	Connected Properties	Distribution Losses	% of metered properties	Estimated Population in Fully Compliant DWI Zones	Sample average rate of growth
1994	164.2	-25.5	-19.0	31.8	35.2	23.4	44.4	-354.4
1995	150.0	-68.9	-10.1	33.8	-8.9	14.9	20.8	-231.5
1996	127.6	-136.8	31.2	39.9	8.1	13.1	-1.4	-181.7
1997	-87.7	43.8	-6.1	40.4	13.5	9.1	27.9	-140.8
1998	-60.5	-188.4	-105.9	358.2	-32.4	23.1	59.8	-153.8
1999	124.3	166.8	-29.9	72.7	151.5	55.4	-19.7	-621.0
2000	208.9	-71.6	-13.8	41.6	61.6	30.1	-6.0	-350.9
2001	16.1	-63.2	-57.8	104.3	-16.0	4.0	48.6	64.1
2002	-12.3	-23.6	-3.1	8.5	-4.2	2.9	1.2	-69.4
2003	-3.9	8.9	-7.0	10.4	4.6	4.6	-3.3	-114.3
1993-1995	155.6	-51.7	-13.6	33.0	8.5	18.3	30.1	-280.1
1995-2000	20.4	-68.0	-27.5	130.3	14.8	19.6	22.5	-212.2
2000-2003	20.3	-327.7	-269.0	490.5	-72.5	35.6	203.7	-180.9
1993-2003	47.9	-97.4	-55.1	155.8	2.5	21.3	46.8	-222.0

Values indicate the % of change in annual average productivity growth attributable to this factor

Positive values indicate increases in annual average productivity growth attributable to this factor

Negative values indicate decreases in annual average productivity growth attributable to this factor

Table 18: Impact of structural change in estimated parameters on estimated opex productivity growth for WoCs

Year	Total Change in OPEX Productivity Growth Rate	Sample Average Firm's Productivity Growth	Total From Changes in the Avg. Firm.	Relative Cost of Labour	MEA Capital Stock	Water Outputs & Connected Properties	Water "Quality" Variables
1993-1995							
In Absence of Parameter Change	-0.072	-0.201	0.129	0.112	-0.010	-0.013	0.041
Attributable to Parameter Change	-	-	-	-	-	-	-
Total Change in Productivity	-0.072	-0.201	0.129	0.112	-0.010	-0.013	0.041
1995-2000							
In Absence of Parameter Change	-0.237	-0.502	0.266	0.048	-0.065	0.148	0.135
Attributable to Parameter Change	-	-	-	-	-	-	-
Total Change in Productivity	-0.237	-0.502	0.266	0.048	-0.065	0.148	0.135
2000-2003							
In Absence of Parameter Change	-0.292	-0.301	0.009	0.000	-0.079	0.072	0.016
Attributable to Parameter Change	0.248	0.221	0.027	0.009	-0.040	-	0.058
Total Change in Productivity	-0.044	-0.080	0.036	0.009	-0.119	0.072	0.074
1993-2003							
In Absence of Parameter Change	-0.601	-1.005	0.404	0.160	-0.154	0.206	0.191
Attributable to Parameter Change	0.248	0.221	0.027	0.009	-0.040	-	0.058
Total Change in Productivity	-0.353	-0.783	0.431	0.169	-0.194	0.206	0.250

5 Conclusions

This report has presented the results of an investigation into trends and causes of opex productivity growth for the water industry in England and Wales. The period of investigation was 1992-93 to 2002-03.

The analysis has been based on a similar methodological approach to that employed previously to investigate economies of scale and scope in the industry. More specifically, the results we have reported are derived from separate translog econometric models of total operating expenditures for the WaSCs and WoCs.

The purpose of the analysis has been to:

- Estimate trends in opex productivity growth over the period 1992-93 to 2002-03;

- Decompose those trends into the factors contributing to changes in costs over time; namely:

    - The common rate of productivity improvement due to factors such as technical change;
    - Changes in relative price of inputs;
    - Changes in capital inputs;
    - Changes in outputs;
    - Changes in the quality of outputs; and
    - Changes in other characteristics of the operating environment.

5.1 Opex productivity growth for WaSCs

Trends

Our analysis for the WaSCs shows:

- The opex productivity growth rate for the sample average WaSC over 1993-2003 is shown to be positive and statistically different to zero in all years, but declining from a mean value of 2.15% per annum in 1992-93 to 1.44% in 2002-03. However, this decline takes no account of the impact of changes in the characteristics of the average WaSC over this period.

- There is support for a step increase in opex productivity from 1995-96 due to structural change in the estimated cost relationships. Productivity growth was 0.20% higher between 1995-96 and 1999-00 than it would have been in the absence of structural change. As this corresponds to the period following the 1994 price review it may reflect company responses to Ofwat's judgements on the scope for efficiency improvements. A statistically significant step decrease is also evident after the 1999 price review, with productivity growth 0.11 lower in the 2001-03 period compared to the 1996-00 period. Given these opposing structural breaks, it is important to note that the net impact of the two structural break parameters is that the sample average WaSC's productivity growth rate was in fact 0.09% higher in the 2001-03 period than it would have been in the absence of structural change in the productivity growth parameters

- After taking account of contributions from changes in the characteristics of the average WaSC in each year of the sample, the step change in productivity growth from 1995-96 appears to be sustained, with opex productivity growth rates staying within the narrow band of 1.91% to 1.98% in every year between 1995-96 and 2000-2001. Thereafter there is a decline to 1.76% by 2002-03, but it is worth noting, that as Dwr Cymru (Welsh Water) was above the sample average, its exclusion from the sample in the last two years of the sample period due to missing data is likely to exaggerate the actual decline in the estimated annual average.

Main factors behind the trends

The main factors contributing to the improvement in opex productivity growth for the WaSCs have been identified as:

- *Improvements in general labour and capital productivity*. The nature of the improvement in capital productivity is different between water supply and sewerage. For water supply the gains can be attributed to capital substitution. By contrast, the evidence for sewerage suggests productivity gains have been gained through reducing the extent to which growth in sewerage capital inputs has increased opex rather than a process of capital substitution allowing companies to reduce total opex. These effects are significantly higher in the period after the first Ofwat regulatory price review in 1994

- *There is also evidence that sewerage quality improvements have been a source of productivity gains***.** Early in the sample period increasing the coverage of secondary treatment led directly to rising opex costs. However, by the end of the sample period this relationship has reversed. This may provide some evidence of productivity benefits from "learning by doing" as WaSCs have improved the operation of new treatment plant and processes.

5.2 Opex productivity growth for WoCs

Trends

Our analysis reveals notably different trends in opex productivity growth for the WoCs:

- The opex productivity growth rate for the 1993-2003 sample average WoC is shown to be positive and statistically different to zero in all years, but declining from a mean value of 1.68% per annum in 1992-93 to 0.90% in 2002-03

- For the WoCs there is less evidence compared to the WaSCs of a structural shift in opex productivity growth following regulatory price reviews. This suggests a potential difference between WaSCs and WoCs in terms of how the regulatory regime may have influenced trends in opex productivity growth.

- After allowing for the changes in the characteristics of the average WoC, the average rate of annual opex productivity growth is estimated to have decreased by 0.353. Most of this decrease is concentrated in the period 1996-2000 with a further and smaller decline in 2001-2003. Without these changes, the average rate of opex productivity growth for the sample average WoC would have been a decrease of 0.783. Hence, the combined impact of the annual changes in the characteristics equates to about +0.431 per annum on the rate of opex productivity growth.

Main factors contributing to the trends

Analysis of the factors contributing to growth in opex productivity for WoCs is also notable different to the WaSCs:

- A contribution from improvements in labour productivity is concentrated in the period before the 1994 price review. This contrasts the evidence on the WaSCs where we identified a significant contribution from improvements in labour productivity post 1995.

- A further contrast with the WaSCs is a negative contribution from changes in capital productivity. The scope to reduce opex through capital substitution has declined over the sample period resulting in a negative contribution to growth in opex productivity.

- Changes in water service outputs (volumes and connections) are associated with a positive net impact on annual productivity growth of +0.32, with this concentrated in the post 1995 period. Much of this impact can be attributed to increases in firm-level output associated with consolidation. However, there is an absence of significant improvements in average annual productivity growth rates after mergers.

- A more robust interpretation is that the WOCs, as well as the WaSCs, have been able to respond positively to changes in their operating characteristics, and have therefore offset what would have otherwise been substantial declines in productivity growth.

5.3 Issues and areas for further work

We conclude the report with some general observations on our findings and our thoughts on areas for future work.

Are WaSCs and WoCs different?

The modelling methodology dictated the use of separate WaSC and WoC models and therefore formal testing for structural differences between WaSCs and WoCs was not undertaken. The analysis nevertheless reveals some interesting differences between WaSCs and WoCs in terms of the trends for opex productivity growth. This is demonstrated most strongly by stronger evidence of structural shifts in the rates of growth post regulatory reviews for the WaSCs and important differences in the timing and trends in improvements in labour and capital productivity. Areas for further consideration may be:

- To understand more fully the apparent differences in the impact of regulatory reviews on productivity improvements; and

- To consider whether a differentiation between WaSCs and WoCs is required when assessing the scope for efficiency improvements and relative efficiency.

Mergers

Our previous analysis of economies of scale and scope found no strong statistical evidence that mergers and consolidation in the industry had changed the underlying cost structure of the industry. An alternative hypothesis is that the impact of mergers and consolidations might be revealed through evidence on how changes in industry structure impact on the rate of change in costs. Our findings only consider opex productivity growth and hence are not conclusive, but:

- For WaSCs, there is some evidence that the merger of Northumbrian Water and North East Water was a stimulus to average opex productivity growth in the merged company; and

- For WoCs, there is no evidence that consolidations between WoCs has resulted in an upward shift in the trend rate of opex productivity growth.

The relationship between industry structure and productivity growth has not been the primary focus of this study. This could be addressed more fully in future work to test in a more systematic fashion these relationships.

Total cost modelling

A final point to emphasise is that this study only considers productivity growth in opex. Our findings with respect to the impact of capital inputs, particularly sewerage capital, suggests a need to consider total cost modelling as a way of estimating total factor productivity.

The finding that capital efficiency appears to be declining for the WoCs particularly after the 1999 price review is also worthy of further investigation. It would be useful to understand if this downward shift is related to the regulatory incentives on capex, including the allowance for small company premiums on the cost of capital, or whether this effect has been as a consequence of WoCs responding to perceived and/or actual "capex budget constraints". This may stem from limited incentives in the regulatory regime to invest in capital beyond the level "allowed" by Ofwat's price determinations.