The comparative impact of privatization and regulation on productivity growth in the English and Welsh water and sewerage industry, 1985–99

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Abstract

After the 10 regional water authorities of England and Wales were privatized in November 1989, the successor WASCs (water and sewerage companies) faced a new regulatory regime that was designed to promote productivity growth while simultaneously improving drinking water and environmental quality. As legally mandated quality improvements necessitated a costly capital investment programme, the industry's economic regulator – the Office of Water Services – implemented a RPI + K pricing system, designed to compensate the WASCs for their capital investment programme while also encouraging faster rates of productivity growth.

This paper considers the relative effects of privatization and regulation on productivity growth in the industry using both non-parametric and parametric methods to provide a crosscheck on the robustness of the results. While there is evidence that labour productivity improved after privatization, there is no evidence that privatization led to a growth in TFP (total factor productivity). However, there is some evidence of a small increase in the rate of TFP growth in the aftermath of a substantial tightening of the regulatory regime that took place in 1995. These results, therefore, are consistent with evidence from other research that privatization, in the absence of effective competition and/or regulation, is not necessarily associated with improved economic performance.

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Introduction

This paper studies productivity growth in the W&S–EW (water and sewerage industry in England and Wales) before and after privatization in November 1989.[1] The W&S–EW is structured as a number of regional or local monopolies. A provision was put in place in 1989, and strengthened in 1992, to allow new suppliers to operate, under licence within the area of an existing supplier (known as an 'inset appointment' [OFWAT 1995]). Water supplies have also been opened up to limited cross-border competition, and legislation currently before Parliament is expected to result in a limited expansion of competition in the industry. In practice, however, the vast bulk of consumers has had, and will continue to have, no choice of supplier. Consequently, to avoid monopoly abuse, the industry is regulated by the OFWAT (Office of Water Services) headed by a DG (Director-General). The main statutory provisions relating to the water industry can be found in the Water Industry Act, 1991; the Environment Act, 1995; and the Water Act, 2003.

The industry's revenues are primarily regulated through a price cap that takes the general form of RPI + K. RPI is the 'retail price index' and measures inflation in the economy. The K factor is composed of an efficiency factor, X, which reflects the DG's assessment of each company's scope to reduce its unit costs over a five-year period, and a Q factor to reflect the higher costs resulting from meeting stricter water quality targets. Quality is policed by the Drinking Water Inspectorate and the Environment Agency.[2] Both, along with the OFWAT, report to the Department of Environment, Transport and Regions. In recent years, the Directives of the European Commission, for example on urban waste water, have had a significant effect on costs in the industry. The industry has had to undertake much capex (capital expenditure) to meet the new water quality requirements and to make up for a large backlog of investment needs. Under state ownership, investment had been inadequate to maintain the serviceability of the system. In the 10 years following privatization, the K factor in the price cap has been positive

[1] This study is concerned only with the industry in England and Wales. Water and sewerage services in Scotland and Northern Ireland remain publicly owned. The paper builds on earlier work published in Saal and Parker (2000, 2001).
[2] The National Rivers' Authority was initially responsible for monitoring the industry's environmental impact before the establishment of the Environment Agency in 1996.

leading to price rises. The Q factor, reflecting increases in capex and associated opex (operating expenditure) has more than offset the DG's expected efficiency savings in the industry, or the X factor. However, in the last price determinations for 2000–05, the DG instituted a significant reduction in prices, with the companies required to reduce their prices by an average of 2.1% per annum over the quinquennium (OFWAT 1999).[3]

In recent years, a number of empirical studies have looked at the impact of privatization on economic performance. Some studies have confirmed performance improvements after privatization (Galal, Jones, Tandon, *et al.* 1994; Megginson, Nash, and van Randenborgh 1994; Bhaskar and Khan 1995; Newbery and Pollitt 1997; Boubakri and Cosset 1998). Others have been more sceptical, suggesting that performance improvement is by no means guaranteed and that efficiency may be related to product market competition rather than ownership *per se* (for example, Millward and Parker 1983; Vickers and Yarrow 1988). There are also theoretical studies that suggest that regulated privately-owned firms will not necessarily perform better than state-owned enterprises (for example, Sappington and Stiglitz 1987; De Fraja 1993; Laffont and Tirole 1991; Pint 1991; Willner 1996) and regulation is considered to introduce disincentives in terms of the use of factor inputs, notably capital (Averch and Johnson 1962; Bailey 1973). The 'price cap' method of regulation used in the UK was intended to overcome the efficiency disincentives of rate of return regulation, but the continued operation of price caps over time risks reducing the incentives (Littlechild 1983, 1986; Vass 1997).

Empirical studies of the effects of privatization on economic performance in the UK and elsewhere have generally supported the contention that effective competition and/or regulation are more important than ownership, *per se*, in explaining performance improvements (Bishop and Thompson 1992; Bishop and Green 1995; NERA 1996; Martin and Parker 1997; Wallsten 2001; Zhang, Parker, and Kirkpatrick 2002). To date, however, there has been very little study of the comparative performance of the W&S–EW before and after privatization. This is – at first blush – surprising, given that it was one of the largest cases of privatization in the UK and the controversy that surrounded its sell-off. But the neglect reflects the great difficulty that researchers

[3] New price determinations, for 2005–10, are due to be confirmed in December 2004.

face in creating a consistent data set for the water sector over the relevant period and in particular in measuring changes in water quality in output. The research reported in this paper involved the creation of a continuous data set and the computation of a quality-adjusted output series.[4] This is important because a substantial portion of the additional capital input has been concerned with water quality enhancement, as well as capital maintenance. Base water and sewerage output, by contrast, has been fairly static, with an average annual growth rate of base output of only 0.7% since 1990.

Turning to the few studies that have been conducted prior to the research from which the contents of this paper are drawn, Hunt and Lynk (1995) use a multi-output cost function to assess performance over the 10 RWAs (regional water authorities) in England and Wales between 1979/80 and 1987/88. They report the existence of substantial economies of scope between water supply and environmental activities (see also Lynk 1993). They argue that these economies were lost when environmental regulation and a number of other activities such as river maintenance became the responsibility of the National Rivers Authority (later the EA [Environmental Agency]) after privatization. Their study suggests that privatization may have led to a decline in performance because of the mode of restructuring. However, as these studies focus only on the pre-privatization period, they do not test this proposition directly. Nonetheless, they do highlight the importance of accounting for quality improvements when evaluating WASC performance.

By contrast, Shaoul (1997) does consider the effects of privatization on performance. Based on financial and accounting data drawn from the privatized water industry, her conclusion is that '*significant increases in efficiency had occurred prior to privatization leaving little room to improve efficiency without jeopardising levels of services and future service provision*' (p. 479).

[4] The analysis of the impact of privatization on WASC (water and sewerage company) performance is hampered by the lack of consistent data from a single source for both the pre- and post-privatization periods. It was therefore necessary to collect and merge data on the input usage, outputs, and quality improvements of the WASCs from a variety of sources. These included the WASC and regional water authority accounts and the companies' July returns to the Office of Water Services. Various publications on the water industry published by the Water Services Association, Water UK, the Chartered Institute of Public Finance and Accountancy, and the Centre for the study of Regulated Industries were also employed.

There is no evidence of lower supply costs after privatization. This study is more comparable to the research reported in this paper, but there are serious problems with it. First, it only covers the period up to 1995, when a new and tighter price cap may have been expected to provide greater efficiency incentives. Second, productivity growth is not actually measured as performance measurement is limited to the use of accounting ratios, with all of the uncertainties associated with the accounting changes over the period discussed. Moreover, the study employs value-added as an output measure, which has been argued to be inappropriate in regulated industries where prices are not determined in markets (Bosworth, Stoneman, and Thanassoulis 1996). Third, and very important, the study does not take into account improvements in water quality. It is therefore heavily biased against finding performance improvements after privatization. The same criticism applies to a recent study by Bottasso and Conti (2004).

More limited in focus are the studies by O'Connell Davidson (1993) and Ogden (1994). These are concerned with changes in industrial relations in the water industry following privatization. These changes included sweeping away public sector methods of collective bargaining and instituting union derecognition, localized pay bargaining, and new labour contracts. A recent survey commissioned by the Transport and General Workers Union has highlighted the subcontracting of operations leading to less favourable terms for water workers after privatization (Hall and Lobina 1999). Cox, Harris, and Parker (1999) found that water companies had resorted to new procurement methods, including outsourcing, to reduce operating costs. These studies imply that privatization has been associated with gains in labour productivity and perhaps in the use of other inputs.

Also relevant to the current study is the research published by Bosworth and Stoneman (1998) and Europe Economics (1998). Both studies were undertaken as part of the price review process leading up to OFWAT's K determinations for the years 2000 through 2005 (OFWAT 2000). The Bosworth and Stoneman study was sponsored by one of the WASCs (water and sewerage companies) and the Europe Economics study by OFWAT. Bosworth and Stoneman look at data over two periods, 1979–89 and 1989–95, and employ value-added based measures of output. They report that labour productivity in water and sewerage averaged 2.2% per annum in the first period and only 0.03% per annum in the second. This suggests that labour productivity growth was *lower* under private ownership and over both periods productivity was poor compared to comparative industries. Their study only goes up to 1995, however, and does not take much account of capital inputs. By contrast, Europe Economics' study found that in the five years after 1992/93, base-service operating expenditure in the water industry fell by around 3.8% per annum. Unfortunately, their study does not allow for a comparison with performance in earlier periods. There are similar difficulties with the international comparisons of water industries found in Smith, Hitchens, and Davies (1982), O'Mahony (1998), and OFWAT (1998a).

The research reported in this paper is directly concerned with the relative impact of privatization and regulation on productivity growth during 1985–99. It contributes to the existing literature on water privatization and regulation because of the use of measures of quality-adjusted output. Moreover, in contrast to some earlier studies, the methodology employed focuses on the measure of TFP (total factor productivity), rather than simply measures of operating efficiency such as labour productivity. This is important when discussing an industry with high capital investment. The contents of the paper consolidate and extend the research findings reported earlier in Saal and Parker (2000, 2001) by providing results using both non-parametric and parametric performance measures.

The remainder of the paper is organized as follows. In the next section the structure of the W&S–EW is briefly described. The following two sections then report the results of alternative estimates of WASC productivity growth before and after privatization that are respectively based on non-parametric and parametric econometric methods. The use of two measures that should be highly correlated produces a useful crosscheck on the robustness of the results. The paper ends with a discussion of the findings and the conclusions that can be drawn from them.

The water and sewerage industry in England and Wales

The W&S–EW developed during the 19th century as a mixture of municipal and small private undertakings. A major reorganization of the industry occurred in 1974. The municipal undertakings were merged into 10 RWAs and each became responsible for the whole water cycle within their catchment area. The RWAs covered around 75% of the country with 30 'statutory water only companies' or WoCs remaining in private ownership. In the areas where water supplies were provided by the WoCs, sewerage services were the responsibility of the local RWA.

In 1989, the RWAs were privatized but most of the existing structure of the W&S–EW was retained. The 10 RWAs became publicly-quoted WASCs and the remaining 29 WoCs were re-established as normal public limited liability companies, thereby removing what had been severe constraints on their rate or return and dividends. The biggest change involved the hiving off of environmental regulation and operational activities to do with environmental services from the WASCs to a new regulatory body – the National Rivers Authority. It was felt inappropriate for the water companies to remain responsible for regulating their own water quality once privately owned. Also, the government reconstructed the balance sheets of the RWAs prior to the sale. This included writing off of the industry's debts of £4.95 billion and giving a further £1.5 billion cash injection – known as the 'green dowry' – towards the costs of future investment.

The W&S–EW serves around 22 million water consumers and 21 million sewerage consumers with households accounting for over 90% of customers and 70% of the water delivered. The WASCs and the WoCs have a combined annual revenue of almost £7 billion and invest over £3 billion a year, of which between 40%–50% is to meet environmental requirements set either by the national government or the European Union. Operating costs account for around 40% revenue and capital charges for a further 30%, the return on capital accounting for the remainder (OFWAT 1999: 21). This study is concerned with the performance of the WASCs, not the WoCs. The latter have been subject to numerous mergers and takeovers since 1989 and this creates serious data problems when tracking their performance over time. Their exclusion from the research, however, does not significantly detract from the results. This is because the WASCs dominate the W&S–EW. They provide water supply, water treatment, and water distribution for 78% of all connected properties in England and Wales (Water UK 2000), alongside all sewerage treatment, collection, and disposal. They also account for 90% of the industry's investment. Moreover, only the WASCs were privatized in 1989.

OFWAT, the industry's economic regulator, is mainly concerned with prices, profits, and the quality of services. Arguably, initially the industry's price caps were set laxly, to ensure the success of the privatization flotation and to allow price increases to finance new investment. The cap was reset and tightened from 1 April 1995 and again from 1 April 2000. With K set as a positive figure, customers saw sharp rises in their water and sewerage bills during the 1990s, the largest rises occurring before 1995 (OFWAT 1999: 24). Increases varied from company to company and across measured and unmeasured water and sewerage charges, but averaged over 40% in real terms in the 10 years after privatization (OFWAT 1999: 76). The result was a large growth in profits and some spectacular returns to investors (Parker 1997). The latest price determinations for 2000–05 are intended to allow for some of this profit to be returned to consumers through lower bills.

The industry invested around £33 billion (in May 1999 prices) in the 10 years after privatization (OFWAT 1999: 21). This has had the desired positive effect on water quality and the quality of services. OFWAT uses a range of key outputs as measures of performance, including customer service standards, leakage, water delivered, and interruptions to supply. Some of these indicators are included in OFWAT's range of nine official 'DG standards'. These standards are used by OFWAT to compare performance between companies and can have a bearing on the price caps set at the next periodic review. In OFWAT's (1998b) publication, *Prospects for Prices*, a number of significant quality improvements are mentioned. It is essential, therefore, that alterations in water quality and the quality of service are reflected in the output measure used when computing performance changes in the water industry. Output growth will be underestimated and price growth overestimated if output quality improves but is not fully measured. This is especially relevant if we consider that, while the physical output of the water and sewerage industry has not increased substantially in the past 15 years, there have been substantial increases in both drinking water and sewerage treatment quality.

Given this background, computation of the productivity estimates reported below required the construction of quality-adjusted output measures. This process began with the quality-unadjusted base output measures Y_W = water and Y_S = sewerage. Quality-adjusted output measures were then estimated as Y_W = water Q_W and Y_S = sewerage Q_S, where Q_W and Q_S are indices of the relative quality of drinking water and sewerage treatment provided by the WASCs. These estimates of quality-adjusted water and sewerage output were directly employed in the multiple output cost function discussed later. However, the non-parametric labour productivity and TFP indices reported first required the construction of an aggregated output index, which captures both the quantity and quality of water and sewerage services. This was created by using the formula $Y_t = S_{Water, t} Water_t Q_{W, t} + S_{Sewerage, t} Sewerage_t Q_{S,t}$, where $S_{Water, t}$ and $S_{Sewerage, t}$ are the respective shares of water and sewerage services in total turnover at time 't', $Water_t$ and $Sewerage_t$ are indices of the base level of water and sewerage treatment demand indexed to equal 1 in 1990, and $Q_{W, t}$ and $Quality_{S, t}$ are indices of the quality of drinking water and sewerage treatment indexed to 1 in 1990.

Non-parametric indices of labour and total factor productivity growth

In this study, productivity growth is assessed using both non-parametric and parametric methods. The two different approaches are used as a crosscheck on each set of results, given evidence from earlier studies that performance results can be sensitive to the estimation methods used (Martin and Parker 1997; Saal and Parker 2000; 2001). First, the results of an estimation of non-parametric labour and TFP growth rates are reported. Labour productivity growth was measured as changes in the volume of output relative to the volume of labour usage. Where substantial factor substitution occurs, as indicated by substantial labour shedding alongside capital investment, labour productivity gives an upwardly biased estimate of total productivity growth. Nevertheless, as labour inputs are the largest single component of non-capital-related WASC operating costs, labour productivity growth is still a useful measure of improvements in WASC operating performance.

In the W&S–EW, a substantial and increasing portion of the industry's employment costs result from internally performed capital projects. It is necessary, therefore, to adapt the standard labour productivity growth measure, if we wish to employ it as an accurate index of WASC operational efficiency. If the labour productivity growth measure were based on total employment, downwardly biased estimates of operational efficiency improvements would be generated. An index of non-capitalized labour productivity was therefore created by using data in each WASC annual report to remove employment attributable to internal capital projects. However, we also calculated a further labour productivity series based on total employment for comparison.

In contrast to labour productivity growth, TFP growth indices provide a fuller estimate of productivity performance. They take into account other factors of production, notably capital, materials, and fuel usage. Also, despite several well-known theoretical limitations, TFP growth is accepted as a standard index of technical progress because it provides a readily estimable index of Hicks neutral technical change (Diewert 1976). We therefore follow common practice and estimate TFP growth as output growth less a Tornqvist weighted index of input usage growth. The formulation can be specified in logarithmic form as follows.

$$TFP_t = \ln(Y_t / Y_{t-1}) - \sum_i 1/2(s_{j,t} + s_{j,t-1}) \ln(X_{j,t} / X_{j,t-1}) \qquad (1)$$

where $s_{j,t}$ represents factor $X_{j,t}$'s share of total economic costs at time 't', and Y_t is an output index. The factor inputs employed are labour, capital, and others including fuel and services.[5]

To evaluate the performance of the privatized WASCs, several distinct periods were identified. Privatization took place on 22 November 1989, which was almost eight months into the 1989/90 accounting year (the WASCs' accounting years end on 31 March). The years ending 1985–90 were considered, therefore, to be part of the transitional/pre-privatization period. The post-privatization period was defined as 1990/99 or accounting years ending 1991–99.

The RPI + K pricing regime was more lenient to the companies from privatization up until the first periodic review by the regulator in 1994/95, therefore the post-privatization period was divided into two sub-periods, 1990–95 and 1995–99, to identify the impact of the regulatory regime. As the K limits were announced by OFWAT a few months before their implementation, it could be argued that anticipation effects would result in changes in WASC performance in the year before the actual implementation of new K price limits. Moreover, given that actual privatization took place during the 1989/90 accounting year and managers would have begun implementing changes in anticipation

[5] The basis of the capital measure is the modern equivalent assets estimation of the replacement cost of fixed assets provided in each of the WASCs regulatory accounts. For full details of the method of estimation, see Saal and Parker (2001: 73–74).

of privatization, it could also be argued that the accounting year ending 1989 should be taken as the last under state ownership. The results were checked, therefore, to see whether they were significantly altered by defining the pre-privatization period as 1985–89, the post-privatization period as 1989/99, and the two sub-periods of the privatization period as 1989–94 and 1994–99. Differences from the main results are highlighted, where relevant, in the discussion below, and full details of these alternative estimates are available from the authors upon request.

Table 1 provides a summary of the growth rates and levels of the various input, output, and productivity indices. Focusing first on input usage and taking the entire period to 1999, while the growth rate of the employment and other costs indices are

Table 1 Performance Indices in the water and sewerage industry in England and Wales, 1985–99

	Average annual percentage[a] change				*Index 1990 = 100*		
	85–90	*90–95[b]*	*95–99[c]*	*90–99[b]*	*1985*	*1995*	*1999*
Input indices							
Employment	–1.9	–1.5	***–4.5***	–2.8	109.7	92.7	77.5
Non-capitalized employment	–1.8	–2.5	***–6.4***	***–4.2***	109.2	88.2	68.4
Capital stock	0.2	***1.2***	1.1	1.1	99.0	106.2	110.9
Other costs index	4.3	2.6	**–1.3**	0.9	80.8	113.9	108.1
Aggregate input index	0.4	**1.2**	**0.8**	**1.0**	98.2	106.1	109.4
Output and implicit quality indices							
Base output[d]	0.2	***0.6***	0.7	***0.7***	98.9	103.1	106.2
Quality adjusted output[e]	2.7	3.2	**1.8**	2.6	87.6	117.6	126.5
Implicit quality index[f]	2.4	2.6	***1.1***	1.9	88.6	114.1	119.1
Productivity indices							
Labour productivity	4.5	4.8	6.3	5.4	79.8	126.9	163.2
Non-capitalized labour productivity	4.4	5.8	**8.2**	***6.8***	80.2	133.4	185.0
Total	2.3	2.1	1.0	1.6	89.2	110.8	115.6

[a] Growth figures are estimated as log differences.
[b] Average growth figures in **bold** are significantly different from those in 1985–90 at 10%, ***bold italic*** figures at 5%.
[c] Average growth figures in **bold** are significantly different from those in 1990–95 at 10%, ***bold italic*** figures at 5%.
[d] Base output is measured as $Y_{base,t} = S_{water,t}Water_t + S_{sewerage,t}Sewerage_t$
[e] Quality-adjusted output is measured as $Y_t = S_{water,t}Water_tQ_{W,t} + S_{sewerage,t}Sewerage_tQ_{S,t}$
[f] The implicit composite quality index is calculated as $Y_t/Y_{base,t}$

not significantly different in the pre- and post-privatization periods, non-capitalized employment growth was significantly lower and capital growth was significantly higher after privatization. Given the capital intensity of the WASCs and the rapid capital stock growth, it is not surprising that aggregate input usage growth was also significantly higher after privatization. Based on these trends, it would appear that privatization has resulted in an overall increase in the volume of resources dedicated to water and sewerage services. At the same time, a comparison of the 1990–95 and 1995–99 periods reveals that, despite the continued growth of the capital stock at a rate that is not significantly different from that during 1990–95, the 1995–99 growth rate of the aggregate input index is significantly lower than it was in 1990–95. This is because of a statistically significant increase in the rate of labour shedding and a statistically significant reduction in the WASCs' other costs index (mainly hired and contract services, materials, and power), that had earlier been increasing. This result suggests that while the initial regulatory regime had been relatively lax, the 1994/95 price review appears to have been successful in encouraging the WASCs to improve their operational efficiency, while simultaneously maintaining incentives to invest in the capital stock. This price review significantly increased the pressure on the management in the water industry to introduce efficiencies by tightening the price cap. Prior to 1995, the average cap was RPI + 5%, and afterwards RPI + 1.4%. This meant that customer prices could not be increased as much to fund improvements in the capital stock.

The base output, implicit quality indices (output adjusted for quality of water and sewerage achieved), and quality-adjusted output data summarized in Table 1 provide a less favourable impression of the post-privatization period. Despite a statistically significant increase in the average rate of base output growth, from 0.2% per annum before privatization to 0.7% afterwards, the average growth rates of both the implicit quality index and quality-adjusted output are lower across the entire post-privatization period, although this is not statistically significant.[6] Moreover, the annual growth rate of both the implicit

[6] The increase in estimated base output may occur because the base sewerage output measure – population connected to sewerage treatment plants – captures some improvements in quality. This results because the percentage of connected population served by any sewerage treatment plant has increased somewhat since privatization. Nevertheless, despite this potential bias toward higher measured quality-adjusted

quality index and quality-adjusted output for 1995–99 is significantly lower than for 1990–95. This suggests that the marginal returns, measured in increased quality-adjusted output, of the WASCs' capital investment programme were declining during the 1990s. This, in turn, suggests possible diminishing marginal returns to environmental investment.[7] This result is particularly striking, because, as discussed in Saal and Parker (2001), the quality and output indices that have been built into these estimates are, if anything, biased towards finding *higher* quality growth during the post-privatization period.[8]

Table 1 also provides a summary of the aggregated WASC productivity trends. While estimates of total labour productivity are provided for comparative purposes, non-capitalized labour productivity is a more accurate estimate of actual WASC labour productivity trends, for reasons already discussed. Given the large capex of the WASCs, it is not surprising that while both labour productivity and non-capitalized labour productivity exhibit higher average growth rates in the post-privatization period, only non-capitalized labour productivity exhibits a statistically significant higher growth rate. Similarly, while both labour productivity indices exhibit higher growth rates over 1995–99, relative to those achieved for 1990–95, only non-capitalized labour productivity exhibits a statistically significant increase.

As non-capitalized labour productivity is an effective index of improvements in the WASCs' day-to-day operational efficiency,

output growth in the post-privatization period, the estimates do not generate a statistically significant increase in quality-adjusted output growth.

[7] A similar decline in the growth rates of the implicit quality index and quality-adjusted output is also evident in the alternative time periods, as mentioned earlier. However, in contrast to the results reported in the main text, the difference in growth rates between the 1989–94 and 1994–99 is not statistically significant.

[8] As detailed in Table 1, the implicit quality index for the composite production of both drinking water and sewerage treatment increased by 19.1% between 1990 and 1999. As the aggregate drinking water quality index only improved by 6.8%, most of the change in the aggregate implicit quality index is attributable to a 28.4% increase in the sewerage quality index over this period. Similarly, given our assumption that drinking water quality did not improve before 1990, the reported increase in the implicit quality index before 1990 is attributable to increases in the sewerage quality index before 1990. Thus sewerage quality improvements are largely responsible for the measured quality improvement of the WASCs. Nevertheless, alternative estimates based on more conservative indices of sewerage quality improvements would not change our main conclusions substantially. These alternative estimates are available from the authors upon request.

the statistically significant increase in the average growth rate during the post-privatization period suggests that some improvement in the operation of the existing water and sewerage network can be attributed to the post-privatization regime.[9] However, no statistically significant increase in average non-capitalized labour productivity growth occurred between 1985–90 and 1990–95, while a statistically significant increase did occur between 1990–95 and 1995–99. This strongly suggests that the more rigorous economic regulation embodied in the 1994/95 price review was the primary stimulus for operational efficiency gains and not the change of ownership *per se*.

Finally, the estimates show that there was no statistically significant change in quality-adjusted TFP growth relative to the pre-privatization period, while the raw figures suggest that the overall trend has been downward.[10] While average quality-adjusted TFP growth during 1985–90 was 2.3% per annum, it was only 1.6% during the post-privatization era. Also, average quality-adjusted TFP growth was 2.1% during the first period of privatization but only 1% per annum during 1995–99 (Table 1). In other words, the results suggest that, while labour productivity has increased, the WASCs' rate of total productivity improvement has declined or, at best, remained little changed. The results suggest, therefore, that high capital investment was undertaken relative to the actual increase in quality-adjusted output in the post-privatization period. This suggestion is reinforced when it is recalled that if the output and quality indices

[9] This conclusion was tempered by the alternative estimates of average non-capitalized labour productivity growth. The alternative time period estimates referred to earlier exhibit an identical trend in average non-capitalized labour productivity growth rates for the pre- and post-privatization periods, as well as for the two sub-periods of the post-privatization era. In contrast to the results reported in the main text, however, the difference in growth rates between the periods 1989–94 and 1994–99 is almost always statistically significant, while the difference between the 1985–89 and the 1989–99 periods is usually not. Thus, while it can be concluded that non-capitalized labour productivity improved in the second period of privatization, it cannot be unequivocally concluded that the non-capitalized labour productivity growth rate has been higher during the entire post-privatization period.

[10] None of the various alternative estimates of quality-adjusted TFP growth calculated by the authors suggested that TFP growth trends have increased since privatization. In fact, several suggest that average TFP growth during the post-privatization period has been statistically significantly lower. Even estimates with a reduced opportunity cost of capital, which tend to downplay the role of increases in the capital stock on TFP growth, do not generate any statistically significant changes in the rate of aggregate TFP growth after privatization.

built into the results are biased, they are most likely to suffer from an upward bias over time.

Cost function estimates of productivity growth

The above productivity estimates suffer for the normal limitations of non-parametric productivity measurement, notably the assumption of constant returns to scale and full technical efficiency (Millward and Parker 1983). As a crosscheck on the reliability of these results, therefore, a parametric cost function analysis of performance was undertaken using the same data set. In principle, this measure might be preferred because of the restrictive assumptions underpinning the non-parametric measure of productivity above. However, the use of a cost function requires the prior specification of the functional form, something avoided by the non-parametric method. Misspecification of the functional form will bias the results. Thus, we report both non-parametric and parametric results.

A WASC total cost function can be estimated by employing a translog specification, as first derived by Christensen, Jorgensen, and Lau (1973).[11] As demonstrated by them, the translog cost function is a second-order Taylor series approximation to any twice-differentiable cost function. This framework has been extended to multiple-output settings by a host of authors including Berry and Mixon (1999), Evans and Heckman (1983), Fuss and Waverman (1981), Kim (1987; 1995), and Sing (1987) while Chambers (1988), Jorgenson (1986), Panzar (1989), and Panzar and Willig (1977) provide greater details on the theoretical characteristics of multiple-output production.

The great advantage of the translog cost function is its significant flexibility relative to alternative specifications, namely the Cobb Douglas and Constant Elasticity of Substitution functions and the non-parametric index number approach employed above (Heathfield and Wibe 1987). This well-known flexibility facilitates the measurement of changes in the water and sewerage industry's structure of production—changes evident in the

[11] The translog total cost function has been previously applied to the case of water utilities in the US by Kim (1987; 1995) . An alternative possibility would be to model variable costs with capital as a quasi-fixed input as in Mocan (1997) and Caves, Christensen, and Swanson (1981). However, because Saal and Parker (2001) demonstrate that capital growth has increased and the use of other inputs (particularly labour) has declined since privatization, it is likely that substantial factor substitution is occurring. We have therefore chosen not to model capital as a quasi-fixed input.

post-privatization substantial labour shedding and capital investment.

The multiple-output translog function is also well suited to determine the presence of economies of scope and scale. The presence of such economies between the WASCs' water supply and sewerage activities is of interest because the OFWAT's practice has been to consider the efficiency of these activities separately, a methodology that makes the implicit assumptions of separability and non-jointness in production. Similarly, the presence of scale economies in the WASCs is of interest because scale economies provide an economic rationale for mergers between WASCs, consolidation which has been opposed by OFWAT on the grounds that any resulting gains in efficiency would be offset by the loss of comparators in the regulatory process (see, for instance, OFWAT's evidence to the Competition Commission 2002).

WASCs produce water and sewerage services using capital, labour, materials and fuel, and contracted services as inputs. It is therefore assumed that their total costs can be represented by the function: $C = f(Y_W, Y_S, W_L, W_K, W_O, T)$, where Y_W is a vector of water supply outputs, Y_S is a vector of sewerage outputs, and W_L, W_K, and W_O are respectively the wage rate, the capital rental rate, and a composite price index for materials, fuel, and other services. It is assumed that this function can be approximated and empirically estimated with the following translog form, which closely follows Evans and Heckman (1983). The inclusion of a full set of interaction terms between 't' and the input price and output indices, allows the estimation of both the rate and the characteristics of technological change in the water and sewerage industry.

The cost function was modified to estimate the impact of privatization on WASC productivity growth by introducing the terms $\varphi_{private,\,t} D_{private} t$, where $D_{private}$ is a dummy variable equal to one for each year after privatization.[12] The parameter $\varphi_{private,\,t}$ can then be employed to test whether a statistically significant change in productivity growth occurred after privatization. As it is commonly argued that OFWAT's 1994/95 price determination

[12] Models including *t2* were also tested. However, the *t2* parameter was found to be statistically insignificant after the inclusion of the and the parameters, while the results for privatization and regulation were broadly the same.

caused a tightening of the economic regulatory regime over that which existed immediately following privatization (Parker 1999: 125), an additional term is also included to test whether this had an impact on WASC performance.[13] Therefore, if the dummy variable D_{Ofwat} is defined as equal to one for each year after the 1994/95 price review, the inclusion of the term $\varphi_{Ofwat,t}D_{Ofwat}t$ allows a test of whether, after this price review, the productivity growth rate of the WASCs was significantly higher.

To reduce the number of necessary parameters to be estimated and simultaneously impose the necessary homogeneity condition on the function, costs, and input prices were normalized using the price of one of the inputs (Jorgenson 1986). Also, input share equations were derived[14] (details of all of the adjustments made can be obtained from the authors). By defining $P_L = W_L/W_O$ and $P_K = W_K/W_O$ the cost function could be written as follows.

$$\begin{aligned} \text{In}(C/W_O) &= \delta + \sum_P \alpha_P \ln P_P + \sum_Y x_y \ln Y_y + \varphi_t t \\ &+ \frac{1}{2}\sum_P \sum_v \gamma_{P,v} \ln P_P \ln P_v + \sum_P \sum_y \kappa_{P,y} \ln P_P \ln Y_y + \sum_P \mu_{P,t} \ln P_P t \qquad (2) \\ &+ \frac{1}{2}\sum_y \sum_z \varsigma_{y,z} \ln Y_y \ln Y_Z + \sum_y \xi_{y,t} \ln Y_y t \\ &+ \varphi_{private,t} D_{private} t + \varphi_{Ofwat,t} D_{Ofwat} t \end{aligned}$$

The impact of privatization and increasingly stringent economic regulation on WASC productivity growth could then be measured as an annual time-dependent shift in the total cost function, which can be represented as follows.

[13] As Sawkins (1996) reminds us, in 1992, OFWAT placed pressure on the companies not to introduce the full permitted price rises under the price cap, in recognition of the high profits being earned. Nevertheless, it was only at the first price review in 1994/95 that the regulator could take formal action to alter the price formula set by the government at privatization.

[14] We have also followed the standard practice of normalizing all variables except the time trend by sample means.

$$\partial \ln C / \partial t = \varphi_t + \sum_P \mu_{P,t} \ln P_P + \sum_y \xi_{y,t} \ln Y_y$$

$$+ \varphi_{private,t} D_{private} + \varphi_{Ofwat,t} D_{Ofwat} \quad (3)$$

If $\varphi_{private,\,t}$ is negative, it indicates that WASC productivity growth was higher after privatization than under public ownership. Furthermore, if $\varphi_{Ofwat,\,t}$ is also negative, this implies that a further increase in productivity growth occurred after the 1994/95 price review. The model could also be employed to test whether the WASCs were characterized by factor and/or output augmenting technological change during the 1985–99 period. This is accomplished simply following Evans and Heckman (1983). Acceptance of the parameter restrictions, $\xi_{W,\,t} = 0$ and $\xi_{S,\,t} = 0$, implies non-output augmenting technological change, while acceptance of the parameter restrictions, $\mu_{L,\,t} = 0$ and $\mu_{K,\,t} = 0$, implies non-factor augmenting changes in technology. Acceptance of both sets of restrictions implies neutral technological change.[15]

It is also straightforward to test for separability in production, as well as the economies of scope between water and sewerage services, and the existence of economies of scale within the WASCs, thereby allowing a fuller characterization of WASC costs. Following Evans and Heckman (1983), who in turn cite Denny and Pinto (1978), we could test for the separability of inputs and outputs by imposing the parameter restrictions $\chi_W \kappa_{L,\,S} = \chi_S \kappa_{L,\,W}$ and $\chi_W \kappa_{K,\,S} = \chi_S \kappa_{K,\,W}$. As the acceptance of these restrictions at the point of expansion for the translog approximation of the cost function implies that it is appropriate to employ an aggregate output measure and estimate a single output cost function, rejection implies that it is inappropriate to evaluate WASC costs without using a multiple output cost function. A test of non-jointness can subsequently be implemented by imposing the parameter restriction $\zeta_{W,\,S} = -\chi_W \chi_S$. Acceptance of this restriction, at the point of expansion of the translog cost function, implies that the costs of producing several outputs is the same regardless of whether they are produced jointly or separately.

[15] The model was further extended to test whether privatization and/or the 1994/95 price review was associated with a change in the rate of factor-augmenting and output-augmenting technological change. However, while this extension suggested that the rate of labour-shedding, capital-augmenting technological change hastened after 1994/95, these results were not robust to the alternative assumptions with regard to capital costs discussed below. They have therefore not been reported.

It would therefore imply that neither economies nor diseconomies of scope between water and sewerage services exist. Similarly, following Panzer and Willig (1977), economies of scale can be measured by estimating the scale elasticity:

$$\varepsilon_{scale} = \left(\frac{d \log C}{d\lambda} \right)^{-1} = \left(\sum_{y} \frac{\partial \log C}{\partial \log Y_y} \right)^{-1}$$, where λ is a proportionate increase in outputs. Values of less than one imply the presence of diseconomies of scale, while values greater than one imply economies of scale.

A final issue, influencing both the theoretical model as well as its empirical implementation, is how to control for the substantial increases in both drinking water and sewerage treatment quality that have occurred in recent years. As these quality improvements have resulted in significant costs, trends in the base output of water and sewerage services will not adequately measure the costs of output growth. It is therefore necessary to consider alternative specifications that allow for the considerable costs imposed by these quality improvements. An ideal alternative specification would allow the separate identification of the impact of quality improvements on costs, as demonstrated in Mocan's (1995; 1997) pioneering models of costs in US day care centres. Unfortunately, attempts at adapting this methodology to the analysis of WASC total costs required another 15 parameter estimates, and therefore floundered because of the limited number of observations available. The methodology employed, therefore, follows Hunt and Lynk (1995) and replaces the base output measures with quality-adjusted measures of water and sewerage services. While this methodology has the advantage of requiring no increase in the required number of estimated parameters, it does not allow the separate identification of the impact of quality improvements on costs. Nevertheless, alternative estimates drawn from a quality-unadjusted model will also be presented, so that some insights into the impact of quality improvements on WASC total costs can be made.

We first considered several tests of alternative hypotheses concerning the structure of production, which yielded largely similar results for both the quality-adjusted and unadjusted estimates, as well as the quality-adjusted specification, which assumes a reduced cost of capital (Table 2). Separability of inputs and outputs was rejected, thereby demonstrating that it is

Table 2 Testing alternative hypotheses concerning the structure of production and technological change

Hypotheses[a]	Parameter restrictions[b]	Number of restrictions	*Quality-unadjusted specification* Likelihood ratio statistic	*Quality-unadjusted specification* Significance from Chi^2	*Quality-adjusted specification* Likelihood ratio statistic	*Quality-adjusted specification* Significance from Chi^2
Separability of inputs and outputs[c, d]	$\chi_W\kappa_{L,S} = \chi_S\kappa_{L,W}$, $\chi_W\kappa_{K,S} = \chi_S\kappa_{K,W}$	2	43.97	0	19.61	0
Non-jointness[d]	$\zeta_{W,S} = -\chi_W\chi_S$	1	0.07	0.80	2.24	0.13
Neutral technological change	$\xi_{W,t} = 0, \xi_{S,t} = 0, \mu_{L,t} = 0, \mu_{K,t} = 0$	4	208.38	0	140.41	0
Non-output augmenting technological change	$\xi_{W,t} = 0, \xi_{S,t} = 0$	2	12.22	0	3.54	0.17
Non-factor augmenting technological change	$\mu_{L,t} = 0, \mu_{K,t} = 0$	2	193.63	0	132.11	0
No impact of privatization or regulatory tightening	$\varphi_{Private,t} = 0$, $\varphi_{Ofwat,t} = 0$,	2	13.44	0	14.65	0

[a] The maintained hypothesis is that the homogeneity and symmetry restrictions implied by producer theory hold.
[b] See the main text and Table 3 for a definition of the parameters.
[c] A sufficient condition for separability of inputs and outputs is the homotheticity of the cost function.
[d] Restriction holds at the point of expansion of the translog approximation of the cost function.

inappropriate to evaluate WASC costs without using a multiple-output cost function. Nonetheless, we could not reject the hypothesis of non-jointness, although it is worthwhile to note that the statistical significance of this result was substantially greater in the quality unadjusted specification than in the quality-adjusted specifications.[16] These results demonstrate that while the costs of water and sewerage services are intricately linked,

[16] The rejection of further restrictions testing for homotheticity of outputs, homogeneity in outputs, and a unitary elasticity of substitution further demonstrated the advantage of the multiple output translog specification over simpler specifications embodying these assumptions.

suggesting that OFWAT's preference to model WASC water and sewerage costs separately may be inappropriate, we cannot conclude that economies of scope between water and sewerage services lead to cost savings, as suggested by Hunt and Lynk (1995). Given this interesting finding, as well as marked differences in parameter estimates related to the measurement of scope economies in the quality-adjusted and unadjusted specifications, the issue of economies of scope is discussed further.

Parameter restrictions imposing the joint assumption of *both* non-output augmenting and non-factor augmenting technological change were rejected in both specifications. This demonstrates that it is inappropriate to assume neutral technological change. However, the assumption of non-output augmenting technological change alone could not be rejected in the quality-adjusted specification, suggesting that once quality has been accounted for, output-augmenting technological change has not been particularly strong. In contrast, the consistent estimation of the parameters $\mu_{L,t}$ as negative and $\mu_{K,t}$ as positive, as demonstrated in Table 3, strongly suggests that technological change has been capital-augmenting and labour-saving over the 1985–99 period. This result is not surprising, given that one of the goals of privatization was to expand capital investment in the industry.

A further distinction between the quality-unadjusted and adjusted parameter estimates highlights the importance of allowing for the significant costs imposed by water and sewerage treatment quality improvements when modelling WASC costs. Thus, while the self and cross-output interaction terms, and are each individually insignificant in the quality-unadjusted model, they are each individually significant in the quality-adjusted model. This is a particularly striking change because it suggests that once both water and sewerage treatment quality are properly taken into account, the cost effects of interactions between outputs in this multiple output setting are a more important determinants of costs than output augmenting technological change. In particular, the substantial increase in the magnitude of the parameter suggests that an improvement in the quality of one output may reduce the cost of producing the other output, as, for example, might occur if improved sewerage treatment quality reduced the costs of treating drinking water.

The implications of this can perhaps be best seen by calculating a jointness parameter, as described in Fuss and Waverman

(1981), which can be calculated for the mean WASC as $(\chi_W + \xi_{W,t}\bar{t})(\chi_S + \xi_{S,t}\bar{t}) + \varsigma_{W,S}$ in our application.[17] As this parameter will be negative if economies of scope are present and positive with diseconomies, an alternative test for non-jointness can be conducted by testing if the jointness parameter is statistically different. Given the above findings with respect to non-jointness, it is not surprising that the estimates of the jointness parameter (Table 3) are not statistically different from zero. However, the parameter's shift in sign, from being positive in the unadjusted model to negative in the quality-adjusted model, is noteworthy because it provides weak evidence that the high costs of environmental and drinking water quality improvements are partially offset by quality-driven scope economies.

In contrast to the jointness parameter, the estimated scale elasticity (ε_{Scale}), which is also evaluated for the mean WASC, displays little variation. It is estimated to be 0.85 in the quality-unadjusted model and 0.83 in the quality-adjusted model. This demonstrates that WASC production is characterized by diseconomies of scale.[18] These results suggest that OFWAT's policy of opposing mergers between the WASCs may have been appropriate, at least judged from the perspective of economies of scale.

Given these findings, we then considered the impact of privatization and regulatory tightening on WASC productivity growth. As demonstrated in Table 2, we can unequivocally reject the joint hypothesis that the trend growth in WASC costs was not different after privatization and/or the 1994/95 price review. However, the individual parameter estimates for the various models, as recorded in Table 3, systematically demonstrate that this change should be attributed to the post-1994/95 price review period rather than to the entire post-privatization period. Thus, the $\varphi_{Ofwat,\,t}$ parameter, which is estimated to be –.004 to

[17] Fuss and Waverman (1981) employed this jointness parameter to analyse further the issue of economies of scope after their model indicated an acceptance of non-jointness in production, as in our case. They note that economies of scope exist if $\partial^2 C/\partial Y_i \partial Y_j < 0$ and that $\partial^2 C / \partial Y_i \partial Y_j = \frac{C}{Y_i Y_j}\left(\frac{\partial \log C}{\partial \log Y_i}\frac{\partial \log C}{\partial \log Y_j} + \frac{\partial^2 \log C}{\partial \log Y_i \partial \log Y_j}\right)$. The non-jointness parameter is the bracketed term in this expression.

[18] In our application, the scale elasticity is estimated as $\varepsilon_{Scale} = \left(\chi_W + \chi_S + \left(\xi_{W,t} + \xi_{S,t}\right)\bar{t}\right)^{-1}$

Table 3 The cost function parameter estimates

Explanatory variable		*Quality-unadjusted specification*		*Quality-adjusted specification*	
Labour price	α_L	***0.057***	(0.002)	***0.054***	(0.002)
Capital price	α_K	***0.843***	(0.009)	***0.849***	(0.008)
Water output	χ_W	***0.727***	(0.062)	***0.676***	(0.074)
Sewerage output	χ_S	***0.403***	(0.068)	***0.487***	(0.088)
Labour price^2	$\gamma_{L,L}$	***0.031***	(0.005)	***0.031***	(0.005)
Labour price * capital price	$\gamma_{L,K}$	***–0.029***	(0.002)	***–0.027***	(0.002)
Capital price^2	$\gamma_{K,K}$	***0.112***	(0.011)	***0.104***	(0.011)
Labour price * water output	$\kappa_{L,W}$	***0.010***	(0.002)	**0.006**	(0.003)
Capital price * water output	$\kappa_{K,W}$	**–0.021**	(0.009)	–0.007	(0.011)
Labour price * sewerage output	$\kappa_{L,S}$	***–0.021***	(0.003)	***–0.017***	(0.003)
Capital price * sewerage output	$\kappa_{K,S}$	***0.047***	(0.010)	**0.032**	(0.012)
Water output^2	$\varsigma_{W,W}$	0.498	(0.335)	***0.778***	(0.145)
Water * sewerage output	$\varsigma_{W,S}$	–0.204	(0.347)	***–0.569***	(0.175)
Sewerage output^2	$\varsigma_{S,S}$	0.099	(0.174)	***0.325***	(0.102)
Constant	δ	***–0.405***	(0.096)	***–0.316***	(0.073)
Time	φ_t	***0.049***	(0.003)	***0.030***	(0.004)
Labour price * time	$\mu_{L,t}$	***–0.003***	(0)	***–0.002***	(0)
Capital price * time	$\mu_{K,t}$	***0.006***	(0.001)	***0.005***	(0.001)
Water output * time	$\xi_{W,t}$	**–0.012**	(0.005)	0.005	(0.006)
Sewerage output * time	$\xi_{S,t}$	***0.018***	(0.005)	0	(0.007)
$D_{Private}$ * time	$\varphi_{Private,t}$	0.001	(0.002)	0.003	(0.002)
D_{Ofwat} * time	$\varphi_{Ofwat,t}$	***–0.004***	(0.001)	***–0.005***	(0.001)
	ρ_C	***0.96***	(0.02)	***0.94***	(0.02)
	ρ_{Share}	***0.83***	(0.04)	***0.83***	(0.04)
Estimated jointness parameter		0.14	(0.34)	–0.22	(0.17)
Estimated scale elasticity		***0.85***	(0.01)	***0.83***	(0.01)
Log-likelihood		1347.10		1325.20	

Note Estimates in **bold** are significant at the 95% confidence level, while those in ***bold italics*** are significant at the 99% confidence level. Figures in parentheses are the standard errors of the parameter estimates.

–.005, is found to be significant in both specifications. However, the $\varphi_{Private,t}$ parameter is found to be positive but insignificant at the 90% level. This suggests that privatization had no beneficial impact on WASC productivity growth; while the post-1994/95 price review period saw a statistically significant increase in productivity growth relative to the entire post-privatization period. The parameter values suggest that after the regulatory review costs rose more slowly, by around 0.5% per annum. Applied to the quality-adjusted models, this means that the trend growth rate of costs was now between 15% and 25% lower (compare the coefficient on the time variable, φ_t, with the coefficient on $\varphi_{Private,t}$).

Conclusions

This paper has reported the results for productivity growth in the English and Welsh water industry since privatization using non-parametric index numbers and a parametric method based on a translog cost function model. As we have seen, the findings with regard to TFP growth trends are different. The parametric translog cost function model found statistically significant evidence of a faster TFP growth rate after the tightening of price cap regulation that took place in 1994/95, and no statistical evidence of an improvement in TFP growth in the immediate aftermath of privatization in 1989. In contrast, despite employing the same underlying data set, the non-parametric index number approach to TFP measurement demonstrated no statistical evidence for any improvement in TFP growth after privatization, including after 1994.

Despite some contradiction in the results, neither measure finds any evidence of an increase in TFP growth that can be directly attributed to privatization independent of regulatory changes. At the same time, the non-parametric index number estimates do suggest that an improvement in labour productivity did occur after privatization, but this was largely focused in the post-1995 period, suggesting again the importance of effective regulation in driving performance improvements in a monopoly industry. Labour costs are a substantial component of operational expenditure and the finding of a statistically significant increase in labour productivity growth, especially after the 1994/95 price review, is suggestive of an improvement in the operational efficiency of the WASCs during the 1990s. This is consistent with the findings on unit costs of OFWAT (1999; 2000) and Europe Economics (1998) and with the study by Shaoul (1997), who found no evidence of lower post-privatization supply costs but was dealing with performance only up to 1995. Moreover, these results are supportive of OFWAT's positive contribution to productivity growth in the industry. The regulator has more direct influence over the opex efficiency of the industry. Capex is also affected by the environmental regulator, the Environment Agency, and European Union directives.

Overall, the results suggest that the productivity gains which occurred after the privatization of the W&S–EW are not so much directly attributable to privatization, but rather to the system of economic regulation that was implemented at privatization and made more stringent after 1994. The successful privatization of the industry was achieved at the expense of not building in sufficient regulatory pressures for management to pursue efficiency gains at the outset. The first price review, in 1994/95, was the first real opportunity for OFWAT to change regulation in such a way as to produce better cost-saving incentives. These results therefore confirm that privatization of monopoly enterprises in the absence of effective regulation will tend not to be associated with improved performance. However, it could be reasonably argued that, in the absence of privatization, the OFWAT regulatory structure would not have been created and the later improved performance in the water industry would not have materialized. As always in such research, the counterfactual is uncertain.

Also, our results raise some questions with regard to the design of the regulatory system imposed at privatization. This is because, while capital for labour substitution did occur during the 1990s, the simultaneous existence of significantly faster labour productivity growth rates and disappointing TFP growth rates suggests that it is far from certain that such substitution improved the overall productive efficiency of the WASCs. New and more stringent drinking water and environmental regulations requiring extra investment, from which there may have been diminishing returns, coupled with the economic regulator's focus on operating efficiency given mandated environmental capital investments, seem to have created a regulatory bias in favour of operating efficiency gains at the expense of TFP growth. Thus, while a price cap system is generally deemed to be superior to rate of return regulation, because of the latter's well known incentives in favour of over investment (Averch and Johnson 1962), in the W&S–EW the combination of environmental and economic regulation seems to have led to technical inefficiency. In sum, the productivity trends reported above suggest that insufficient regulatory attention has been placed on capital efficiency in the WASCs, which are after all highly capital-intensive firms.

Two further interesting conclusions arise from our cost modelling. First, it was revealed that the WASC cost function is characterized by non-separability, which implies that a multiple output function should be employed to measure changes in costs properly. This is a significant finding because it implies that OFWAT's policy of separately evaluating the relative efficiency of water and sewerage services, as part of its price setting process (OFWAT 1998a), may be inappropriate. Instead, the findings of our model suggest that WASC efficiency is more appropriately evaluated by considering all water and sewerage outputs and costs for a given WASC in a single unified model of operating efficiency.

Second, we rejected the hypothesis that economies of scope between water and sewerage services exist. Nonetheless, the shift of the estimated jointness parameter from positive in the quality-unadjusted model to negative in the quality-adjusted model is telling. We interpret this as suggesting the possible existence of scope economies in which an improvement in the quality of one output may reduce the cost of producing another. The presence of such economies would imply that some of the substantial costs that have been borne since privatization in order to improve drinking water and sewerage treatment quality have been offset by a reduction in other water company costs. We therefore suggest that future research should attempt to identify separately the impact of quality improvements on costs. The presence of quality-driven scope economies could well alter a WASC's potential for overall cost savings with implications for future price regulation.

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