Office of Water Services

Scope for Efficiency Improvement in the Water and Sewerage Industries

Appendices

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APPENDIX 1: LITERATURE REVIEW

A1.1 This appendix discusses some of the literature supporting the analysis of determinants of productivity set out in Section 3, and of empirical papers cited in Sections 4 and 5. This review builds on Europe Economics (1998) and does not seek to duplicate material presented in that study.

A1.2 The review is organised in three sections:

(a) literature on the privatisation effect;

(b) literature on the microstructure and determinants of productivity growth; and

(c) literature on the impact of information and communication technology.

The Privatisation Effect

Overview of recent literature

A1.3 Several studies on the privatisation effect and on productivity trends in privatised companies were reviewed in Europe Economics (1998). These are summarised in Table A1.1 below, drawing on Europe Economics (2001).

Table A1.1
Summary of academic literature

Source	Outline of approach and results
Bishop and Thompson (1992)	Analyse productivity growth in nine privatised and state-owned enterprises, comparing the 1970s with 1980s. Significant variation between different firms' performance is seen. Higher TFP growth in latter period for British Coal, British Steel and the Post Office. Decrease in TFP growth for BA, BAA and British Gas.
Kwoka (1993)	Investigation into productivity growth in UK and US telecommunications sectors. In a decomposition of TFP growth for BT between 1984 and 1987, a 4.9 per cent increase is attributed to privatisation, while scale economies and technological progress were seen as responsible for a 16.9 per cent growth.
Haskel and Szymanski (1993)	Analyse productivity growth in panel of 12 firms that were publicly owned in 1972. Study compares 1972-80 to 1980-88. A significant increase in the average of the labour productivity growth rates of the firms is found between the two periods. Again, there is wide variation in performance across firms. Competitive pressures are seen to impact positively on productivity.

Source	Outline of approach and results
Burns and Weyman-Jones (1994)	Investigate changes in relative efficiency in the UK electricity distribution industry. Find that efficiency has increased following privatisation but consider this more a continuation of a long-run trend than a step change.
Parker (1994)	Investigation into BT's performance before and after privatisation. Labour productivity is found to have increased dramatically after 1994 but no increase in TFP growth is found.
Bishop and Green (1995)	Examine the TFP growth for BAA, British Gas, BT, British Coal, British Rail and the Post Office between 1989 and 1994. Large growth for BT and also the Post Office, which outperforms the four other privatised firms. Some of BT's good performance is attributed to relatively strong competitive pressures, in contrast to British Gas which faced little competition and performed poorly.
Newberry and Pollitt (1996)	Conduct a cost-benefit analysis of the privatisation and restructuring of the UK Central Electricity Generating Board in 1990. Estimate that the restructuring has brought a permanent cost reduction of four per cent a year, but this could possibly have been achieved under state-ownership by changing priorities (e.g. less emphasis on supporting British Coal to the detriment of efficiency).
Waddam-Price and Weyman-Jones (1996)	Examine productivity in the UK gas industry before and after privatisation. The post-privatisation increase in productivity is around 5-6 per cent a year, compared to 3 per cent before privatisation. Evidence of further scope for catch-up is however suggested.
Parker and Martin (1997)	Analyse the performance of 11 privatised firms to assess the impact of privatisation on TFP growth. The results are very mixed, with Rolls-Royce and British Ports showing a significant improvement, but an apparent worsening after privatisation for British Gas.

A1.4 The aim of this section is to update the literature review from this base. The key issues discussed, both theoretically and empirically, are:

(a) Does privatisation lead to improvements in productivity and efficiency?

(b) Where privatisation is associated with efficiency improvement is this direct result of privatisation, or is it reliant on the introduction of competition or regulation?

(c) How do the answers to these questions vary between industries and between countries?

A1.5 It has become something of a professional wisdom that privatisation translates into improved economic efficiency.

A1.6 On the theoretical side, Shleifer (1998) provides an extensive review of the case for privatisation and the areas for which it is most appropriate. Starting with the assumption

of a benevolent government, Shleifer outlines the argument for private provision in terms of the principal-agent relationship. The main result of this is that private ownership can improve a firm's performance by providing decision makers (managers) with greater incentives for efficiency.

A1.7 In addition, Shleifer draws attention to work in which the assumption of a benevolent government, maximising social welfare, is dropped in favour of models which allow politicians to be self-interested. This, he argues, can take the form of vote-seeking and attention to interest groups, though in some cases direct financial interest can be served through bribes. The influence of a self-interested politician on a state-owned enterprise can therefore be detrimental to society as a whole (e.g. preventing the closure of inefficient plants to the benefit of a particular subgroup of people). Privatisation can improve performance by limiting the scope for political intervention. The extent to which this argument for private ownership is applicable to a particular economy will depend on the political environment, but Shleifer concludes that "political considerations generally not only strengthen the case for privatization, but actually are the crucial reason for it in the first place".

A1.8 One implication of the last point is that the benefits of a firm being privately run, compared to being state-owned, may fluctuate over time, depending on political climate. We could imagine a case where a politician's decision on whether to block job cuts in a state-owned firm is dependent on the prevailing level of unemployment in the economy and the political climate. This may cast some doubts over attempts to assess the success of privatisation by comparing year on year efficiency gains.

A1.9 In a recent paper published in the Journal of Economic Literature, Megginson and Netter (2001) overview a substantial number of empirical studies published between 1990 and 2000, which investigate how privatisation affects financial and operating efficiency. Megginson and Netter show that an overwhelming majority of the empirical literature supports the positive link between private ownership and economic efficiency. They come to the conclusion that "privately-owned firms are more efficient and more profitable than otherwise-comparable state-owned firms" and that "divested firms almost always become more efficient, more profitable, increases their capital investment spending, and become financially healthier. Both single-country, single-industry and multi-national, multi-industry empirical studies document significant (often dramatic) performance improvements".

A1.10 However, it seems that there is a considerable amount of empirical work not included in Megginson and Netter (2001), which points out that privatisation by itself is not a panacea. In particular, for privatisation to lead to improved efficiency, it has to be complemented by either the introduction of competitive markets or an appropriate regulatory framework.

A1.11 The empirical literature on privatisation effects can be sub-dived into two broad methodologies. The first is to study the extent to which the performance of a given firm changes after privatisation. This method is chiefly employed in the UK. The second

method consists in comparing performance of publicly and privately-owned companies operating in the same sector. This approach is used mainly in the US, where private and public companies have long been operating side by side, for example in the electricity supply industry.

A1.12 Some earlier papers argued that as far as utilities go, the empirical evidence does not fully support the view that private utilities perform significantly better than public ones (e.g. Peters, 1993).

A1.13 Haskel and Szymanski (1997) investigate the performance of 12 UK firms, privatised in the course of the 1970s and 1980s. This study concluded that privatisation itself did not translate into increases in TFP. Instead, it is found that competition contributed to TFP growth. Nonetheless, because of relatively little changes in competition, growth in TFP stayed rather flat over the period analysed. However, the companies studied experienced rapid TFP growth prior to privatisation, but after the announcement of privatising. This finding is also borne out by Martin and Parker (1997) who examine a different set of 11 privatised firms in the UK.

A1.14 Cragg and Dyck (1999) test empirically one of the principal predictions of the privatisation literature, that change of ownership can improve performance by changing the incentives of managers. Cragg and Dyck examine the relationship between a firm's financial performance and the turnover (split into 'quits' and 'fires') of its management, for a sample of state-owned, privatised and publicly limited companies in the UK from 1970 to 1994. Using a logit model, they are unable to reject the hypothesis that there is no relationship between performance and management turnover in the sub-section of firms which were state-owned. However, for established privatised firms, the probability of resignation or dismissal was found to be sensitive to financial performance.

A1.15 Interestingly, this sensitivity was not found in firms that had been privatised for less than four years, suggesting that high-powered incentive-structures do not follow immediately from a switch to private ownership. This suggests that it takes time for high-powered incentive-structures to be introduced, and thus that scope for catch-up could remain for longer than might otherwise be thought.

A1.16 Parker (1999) uses data envelopment analysis to assess the technical efficiency of BAA from 1979/80 to 1995/96. This statistical technique does not require estimation of parameters of the underlying production function, but measures the relative efficiency of "units". Firstly the units were set as individual years for BAA's performance. No evidence was found to suggest that BAA's efficiency had improved since privatisation. This was despite the fact that technical efficiency would normally be expected to increase over time. Next the study was expanded to cover a range of individual UK airports, some owned by BAA, others not, with each unit being a particular airport in a particular year. Allowing for variable returns to scale, there was a wide variation in the relative efficiency of BAA airports, with Stansted's average efficiency measure over the period almost half that for Heathrow. Hence BAAs overall performance is a composite of quite different performance levels across its individual airports. Parker acknowledges that the good

performance before privatisation could be the effect of the impending privatisation. Since the data starts in 1979, we do not have a comparison with the pre-Thatcher period. In addition, Parker points out that the government's retention of a 'golden share' in BAA could have dampened incentives by reducing the threat of take-over.

A1.17 Considering mainly the privatisation of UK public utilities from 1979 to 1996, Pollitt (1999) comes to similar conclusions. Firstly, he argues that it is not privatisation per se, but rather the whole privatisation process that matters: higher growth in productivity or profitability is not a direct consequence of privatisation, but instead, it is the corporate restructuring, including changes in management, that occurred prior to privatisation, which resulted in improved productivity performance. Furthermore, it is true to say that firms in regulated sectors, such as water, energy and gas experienced accelerated productivity growth after changes in ownership only with more stringent regulation implemented or with an increase in competition. Secondly, the post-privatisation performance of individual firms is rather mixed.

A1.18 Domah and Pollitt (2001) attempt to address the effect of privatisation in the electricity industry in England and Wales. Using data for 1985-1998, the authors show, similarly to Pollitt (1999), that the privatisation in 1990 of the 12 Regional Electricity Companies did not imply increases in productivity and decreases in costs mainly because of a lax regulatory framework. However, after the first price review, efficiency increased dramatically due to the tightened regulatory framework.

A1.19 Pollitt and Smith (2001) examine the privatisation and restructuring of British Rail. The overall approach is within the context of a cost-benefit framework, which takes account of efficiency gains, the costs of restructuring both pre- and post-privatisation, as well as distributional concerns. The authors seek to assess the restructuring and privatisation of British Rail against a hypothetical counterfactual of continued public ownership. The analysis focuses on the performance before the Hatfield disaster. Performance after this is not seen as reflective of the post-privatisation period as a whole, and in part reflects changes in risk aversion since privatisation.

A1.20 Polit and Smith consider the cost-benefit analysis under different scenarios, but reach the view that privatisation resulted in significant efficiency savings compared to realistic counterfactuals under continued public ownership. Under the authors' "central" hypothetical counterfactual scenario, the privatisation and restructuring of British Rail is considered likely to bring £1.1 billion of efficiency savings over the long-term after allowing for the substantial restructuring costs. The efficiency gains calculated reflect those in both the network infrastructure operations (Railtrack) and other derivatives of the privatisation and restructuring such as the train operating companies and rolling stock leasing companies. Polit and Smith find that, after taking account of scale effects, efficiency savings in operating costs of the order of 2 per cent per annum have been achieved since privatisation, while output quality has also improved (pre-Hatfield).

A1.21 In the US, Kwoka (2002) tests for whether private enterprises outperform public firms in the US electric power industry. Using data for 543 public and private firms, the conclusion

of the paper is that albeit privately owned electric utilities are more cost efficient in electric power generation, public utilities do better in electric power distribution. This is attributed to the idea that private ownership performs better in markets with more specifiable products or services whereas public ownership is to be preferred when products or services are less specifiable with more subtle quality (a result consistent with the theoretical predictions of Schleifer (1998) in relation to state versus private ownership in the presence of incomplete contracts). Kwoka argues that privatising production-oriented sectors has been a success story whilst the privatisation of education and prisons, which are services with subtle quality dimensions, turned out to be less successful in the longer run. Therefore, there are identifiable conditions in which public ownership is more efficient implying that privatisation should not be an automatic policy prescription.

A1.22 Nestor and Ladan (1999) carried out a study analysing the recent experience of privatisation of public utilities in OECD countries. The study attempts to analyse the effects of privatisation and the introduction of market liberalisation. Based on the example of utility sectors in New Zealand and Finland, the paper explores the idea that privatisation and competition are complementary. This challenges the view that it is the introduction of competition rather than privatisation that leads to improved efficiency. In fact, if the market is liberalised without privatisation, the state-owned enterprises will face severe problems in financing their investments and expansions. If private debt is used, although it improves corporate governance, it still might be viewed as government debt and poses undoubtedly the problem of moral hazard. At the same time, limited access of publicly owned firms to equity markets is a serious disadvantage in the presence of harsh competition by foreign firms. It is argued that privatisation will bring benefits by allowing for a more flexible financial structure.

A1.23 On the other hand, if utility companies are privatised without introducing competition, efficiency improvement can be ensured only by means of an appropriate regulatory setting.

A1.24 All in all, Nestor and Ladan (1999) concludes that "privatisation has had positive results [on efficiency] in almost all of the OECD countries that have undertaken it". Considerable positive, economy-wide spillovers have been generated by privatisation and new or improved benchmarks have been created for remaining public enterprises. Even public companies not to be privatised achieved improved efficiency, which the authors attributed to the argument that governments were left with less public firms to monitor and to police, leading to a more efficient state control.

Application to water and sewerage

A1.25 In a series of papers, Parker and Saal (2001a, 2001b) carry out econometric research to investigate the extent to which privatisation and regulation have affected the performance of the water industry in England and Wales over the last 15 years (1985-1999). The following hypotheses are put to the test:

(a) Privatisation of the water and sewerage industry did not translate into statistically significant advances in productivity growth. (This hypothesis is investigated both at the industry and individual firm levels.)

(b) Privatisation in 1989 resulted in significantly lower costs of production.

(c) In the context of the price cap regulatory scheme, profitability of the water and sewerage companies is more influenced by an increase in TFP and not by a rise in the relative price of outputs (compared to inputs).

(d) The modification (strengthening) in the stance of the regulator in 1995 resulted in a significant change in productivity performance. (As with to hypothesis (a), this is analysed taking into account both the industry as a whole and individual companies.)

(e) There are economies of scope between water and sewerage services.

A1.26 The estimation results indicate that hypothesis (a) cannot be rejected. Put differently, the authors found no statistically robust evidence that TFP growth underwent significant changes after privatisation, whether or not the industry as a whole or individual companies are considered. It is argued that although labour usage is dramatically decreased, leading to rapid growth in labour productivity after privatisation, TFP has not been improved. The authors explain this in part by reference to the substantial capital investments required in the 1990s due to enhanced regulation relative to water quality and environment and the under-investment under state control.

A1.27 Hypothesis (b) was rejected by the tests as the trend of the growth rates related to total costs did not significantly decrease after privatisation.

A1.28 Results related to hypothesis (c) are somewhat inconclusive. While it is true to say that economic profitability at industry-level is mainly driven by advances in productivity during the period 1990-1999, the more disaggregated, company-level analysis clearly indicates that this is chiefly achieved because of a single excellently performing company and that in seven out of 10 companies, increases in the relative price of outputs account for 50 per cent of total economic profitability.

A1.29 Thus far, we have seen that Parker and Saal's results do not support the view that significant improvements in TFP, labour productivity and total costs have occurred during the post-privatisation period. However, according to these authors, hypothesis (d) is a plausible one. This can be explained by the fact that labour productivity grew faster and total costs decreased more rapidly after 1995 than during 1990-1994. This reflects the believe that a more stringent regulatory setting aimed at preventing excess profits after 1995 and that privatisation itself did not lead to improved economic efficiency but rather a mix of privatisation and tighter regulatory environment resulted in the desired efficiency gains.

A1.30 The tests accept hypothesis (e) (i.e. the absence of economies of scope between water and sewerage services) and thus lend empirical support to the fact that water and

sewerage services should be treated separately from an economic viewpoint. However, the authors note that there are signs in favour of "quality-driven economies of scope". In other words, improved quality of one of the services is likely to reduce the production cost of the other service. Therefore, the considerable effort spent on improving quality of water supply and sewerage treatment is expected to be at least partially offset by a fall of other production costs.

A1.31 Ashton (2000) investigates operating cost efficiency in the 10 England and Wales water and sewerage companies, from privatisation in 1989 until 1997. Using the individual firms' K factor as a proxy for the underlying differences between the firms' operating environments, relative efficiency is compared across the industry. Parameters of a cost function are estimated from the panel data. From these, average operating cost efficiency is calculated as 84 per cent, which indicates that the current output could be produced with 16 per cent lower costs.

Microstructure and Determinants of Productivity Growth

A1.32 The following sections build on Europe Economics (1998) and discuss other recent contributions to the economic literature on the determinants of productivity growth. In particular, a summary is given of a recent strand of the productivity literature that considers the microstructure of productivity growth: the relationship between productivity growth at the industry level and productivity growth at the level on individual firms or plants.

A1.33 A conventional approach for analysing the level and changes of total, multi- or partial factor productivity consists in using the accounting framework where productivity is given as total output net of inputs, i.e. the residual. This approach is often applied for highly aggregated macroeconomic data. Thus, productivity measures are derived that relate to the economy as a whole, or to broadly defined sectors.

A1.34 Considerable effort has been made recently to explore the firm-level dynamics that underlie aggregate productivity developments.

A1.35 Barnes and Haskel (2000) put forward the view that, on theoretical grounds, productivity growth can occur for the following reasons:

(a) Each firm raises productivity, which can be referred to as "within-firm" productivity growth or "internal restructuring" (e.g. changes in working practices in given plants for multi-plant firms (Green and Haskel, 2002)).

(b) Firms which successfully improve productivity expand their market share whereas low-productivity firms lose ground. This phenomenon is termed in the literature as the "between-firm effect".

(c) Low-productivity firms do not resist competition and exit the market whilst simultaneously high-productivity firms enter the market and gain ground ("exit and entry effect"). This is tantamount to the creative destruction described by Schumpeter

in which new innovative firms replace the old less innovative firms (changes in the stock and composition of plants (Green and Haskel, 2002)).

(d) The expansion and contraction of incumbents and the exit and entry of new and old firms can be labelled as "external restructuring".

A1.36 Completing this analysis, Disney et al. (2000a, 2000b) suggest that internal restructuring can be achieved by: downsizing the workforce; introducing new technology and implementing organisational changes.

A1.37 In this context, authors including Haltiwanger (2002) emphasise that market institutions and market imperfections can affect the reallocation process within and between firms. Market imperfections, such as labour market distortions may render the reallocation inefficient and may easily influence the magnitude and the timing of the reallocation process. Thus even if an industry is broadly competitive, the relative ability of firms within it to increase productivity will be dampened by rigidities not found in other sectors.

Heterogeneity at firm-level

A1.38 In economic growth models and their empirical applications it is common practice to rely on the representative agent hypothesis, which explicitly assumes homogeneity across individual firms. This is akin to saying that firms behave roughly the same way or idiosyncratic behaviours eventually cancel out each other in the aggregation from micro-level to industry or economy level. However, if differences in individual firms' behaviour are not random, the representative agent's hypothesis becomes irrelevant.

A1.39 In recent years, numerous studies have examined productivity growth at the firm level, using longitudinal microdata. The empirical evidence clearly indicates that the representative agent hypothesis is a heroic assumption. The consensus emerging from the empirical literature is that, whatever the country and sector under investigation, there is a great deal of systematic heterogeneity across firms as regards size, age, and technology. Most importantly, differences in levels and developments of productivity turn out to be large and persistent even in the same narrowly defined sector, and this largely discredits models based on the representative agent assumption.

A1.40 According to Scarpetta et al. (2002), Haltiwanger (2002) and Haskel (2000), there are several reasons why differences in productivity growth across individual firms can occur.

A1.41 First, significant importance is attributed to experimentation under uncertainty and competition. The passive learning model proposed by Jovanovic (1982) suggests that a new firm enters the market without knowing ex ante its potential — uncertain but time-invariant — profitability. However, once established in the market, the firm finds out passively its true efficiency based on past profit streams and decides consequently whether to stay, to expand, to shrink or to exit the market. The model can give an explanation how new productive firms survive and expand while less productive firms shrink and leave the market. Another implication of the model is that young firms will exhibit higher and more volatile growth rates. The active learning model discussed by

Ericsson and Pakes (1995) is based on the assumption that the new entrant knows both its own potential profitability and its competitors' profitability. The firm aims at maximising the net present value of its expected future profit flow under competitive pressure. Therefore it actively explores new activities and technologies with a view to increasing its potential and actual profitability.

A1.42 Other reasons considered important are:

(a) Differences in human capital and managerial skills.

(b) Differences in capital vintage. As a matter of fact, innovative firms tend to shift towards more capital-intensive technology and more skilled labour leading to higher productivity growth.

(c) Differences in diffusion of knowledge, i.e. technology and R&D. More specifically, firms disposing of high technology capital and experiencing FDI spillover (through technical and labour spillover) are more likely to enjoy higher-than-average productivity gains.

(d) Differences in ownership (public versus private and domestic versus foreign ownership) also play a crucial role and can lead to divergence in productivity advances across individual firms.

(e) Location and disturbances.

Empirical evidence from manufacturing

A1.43 The first set of papers examining the microfoundations of productivity growth has chiefly dealt with the US, mainly because of the lack of data for other countries. However, with the release of new databases for a score of other OECD countries and especially for the UK, a growing number of papers also provide empirical results concerning firm-level dynamics for those countries.

International evidence

A1.44 Haltiwanger (2002) provides a survey on the US literature. He draws the following conclusions:

(a) there is a large ongoing reallocation of inputs and outputs across firms in the US;

(b) entry and exit of new and old firms are very important in the reallocation process; and

(c) the pace of reallocation changes secularly, cyclically and across industries.

A1.45 There are large and persistent differences in the level of and changes in productivity even in the same "4-digit industry" (i.e. at the lowest level of industry dis-aggregation provided in US standard industry classifications — this need not be equivalent to the economic markets in which firms compete, as understood in competition policy). Haltiwanger

(2002) shows that the productivity level of firms situated in the 75th percentile of the productivity distribution is 2.4 times higher compared with that of firms in the 5th percentile when TFP is used. If labour productivity is considered, the same figure rises to 3.5. Furthermore, high-productivity firms tend to keep their position in the distribution and low-productivity firms also stay low in the distribution over time. New entrants usually exhibit considerably higher productivity levels than exiting firms, while low productivity firms are a good indicator of future exit.

A1.46 When it comes to decomposing total industry productivity growth into the contribution ascribed to internal and external restructuring, results show high dispersion. For example, the contribution of entry and exit to total productivity growth varies between 20 per cent and 100 per cent. However, some of this dispersion could be due to data problems: results are highly sensitive to the time period studied, the frequency at which data are used, industry coverage and the productivity measures (total or partial) employed.

A1.47 Two related studies by the OECD (Ahn (2001) and Scarpetta et al. (2002)) draw evidence from a larger set of countries. Some of the conclusions of these studies are close to those of Haltiwanger (2002):

(a) A large number of firms enter and exit each sector every year. Approximately 20-40 per cent of new firms do not survive the two first years and only 30-50 per cent of newborn firms are still present in the market 7 years later. On average, 20 per cent of firms enter and exit each year, although this accounts for only 10 per cent of total employment since newborn companies tend to be smaller than the industry average size. Entry for small firms is easier whereas entering with a large size may prove much more difficult.

(b) The probability is high that small entrants will not survive the first two years. As a consequence, they need to grow fast in order to reach the critical size for survival. Because small non-competitive firms exit, firms that survive are bigger and expand faster than average new entrants. Comparing the US with Europe, it turns out that newborn firms in the US are smaller in proportion to industry average than their European counterparts. In addition, entrants in the US exhibit lower levels of labour productivity than incumbents. Nonetheless, new entrants in the US grow considerably faster during the initial years of existence than those in Europe. Audretsch et al. (2002) notes that the size of entrants is expected to be a function of industry-specific sunk costs, capital intensity and economies of scale.

(c) The average size of existing firms appears to vary substantially across sectors and countries, and the average size is smaller in Europe than in the US. The variability of the firms' size is large within the same sector. However, it seems that the dispersion in size is positively related to the size of the domestic market.

(d) Entry and exit rates are found to be highly correlated across sectors. This implies that the total number of firms in the market does not change significantly as entrants simply replace exiting firms.

(e) Empirical evidence shows that the rate of entry, exit and survival may differ across countries. The size of the country seems to partly explain this phenomenon.

(f) A large dispersion in entry rates can be observed across sectors, and this is found not to be persistent over time. In other words, sectors with high entry rates at one time may display lower entry rates in the medium and long run (5-10 years later). This also holds true for variability in survival rates, and may hold particularly well for sectors at an early stage of product life cycle in an innovative and competitive environment. In such a sector where there is no established technology, there is more scope for new entrants who experiment with new technology. But innovation is a risky business, and a great deal of firms fail and exit.

A1.48 The need for newborn firms to grow faster than the industry average is reflected in the debate on Gibrat's law. In accordance with Gibrat's law, the growth rate of a firm should be independent of the size of the firm. In a survey paper, Geroski (1995) draws upon previous research and shows that Gibrat's law holds for manufacturing when only large businesses are considered. However, if small-size companies are also taken into consideration, the growth rate turns out to be negatively linked to size: the smaller the firm's size, the higher the growth rate.

A1.49 Cefis et al. (2002) investigate the pharmaceutical sector for seven OECD countries. Using micro data for the period spanning from 1987 to 1998, the sample composed of over 200 firms indicates that Gibrat`s law does not hold true. More specifically, it turns out that the rate of growth of firms is independent of other factors, either within or across industries. In particular, smaller firms are found to remain small in the long run. The reason why Gibrat`s law does not hold is not because of differences in size across firms, but rather due to firm-specific features not discernible from the data. The authors suggest one candidate factor responsible for heterogeneity might be age.

A1.50 Nurmi (2002) considers the case of Finland. The analysis of roughly 10,000 firms operating in manufacturing reveals that over the period covering 1981-1994 smaller firms exhibit higher growth rates compared with larger ones and that the younger the firm the higher its rate of growth. These findings appear robust irrespective of sub-samples of younger and older firms and thus provide another piece of evidence against Gibrat`s law.

A1.51 Scarpetta et al. (2002) underscore the importance of the regulatory setting (interpreted broadly as state interaction with the economy) as more market intervention is found to be negatively linked to TFP. They observe that regulation that increases the costs of hiring and firing employees prevents access to markets for a score of new firms. Small and medium size enterprises are found to be particularly affected by product and labour market regulation whereas very small and very large businesses are not affected to the same extent.

A1.52 De Backer and Sleuwaegen (2002) analyse the impact of ownership structure on labour productivity in Belgium during the period of 1990-95. Using a sample of 18,000 firms in manufacturing, they distinguish between foreign subsidiaries and domestic firms and find that foreign subsidiaries contribute disproportionately to growth in aggregate labour productivity. They show that the reallocation process is very dependent on ownership. Internal restructuring is observed only in foreign owned companies (within the group). 78 per cent of foreign owned firms enhanced labour productivity by downsizing workforce. Internal restructuring is achieved by the additional use of large-scale automatisation and through the relocation of labour intensive activities to other countries.

A1.53 It should be noted that growth in labour productivity is 2.7 times higher in foreign owned firms than in domestic ones. 75 per cent of total productivity growth in foreign firms is due to internal restructuring and 25 per cent comes from net entry (productivity gains obtained via the entry of high-productivity firms and the exit of low-productivity firms). Conversely, the contribution of internal restructuring accounts for 21 per cent in the case of domestic firms, and between-firm reallocation and net entry explain respectively 26 per cent and 53 per cent of total productivity gains.

A1.54 Foreign owned entrants exhibit labour productivity levels well above those of domestic entrants and exit the market at slightly below-average productivity levels whilst the level of productivity of domestic firms is considerable lower than average at the time of leaving/ceasing the activity. In addition, the turnover of domestic firms is much higher than that of foreign ones.

A1.55 The finding that foreign firms are more productive compared with domestic ones is generally consistent with the literature on multinational enterprises. For instance, Girma et al. (2002) shows for an unbalanced panel including approximately 1,100 firms in the UK that foreign companies are by 8-15 per cent more productive than domestic firms during 1989-1994. This is mainly because of a more productive use of capital, which translates into higher wages. Likewise, according to Te Velde (2002), enterprises with US and Canadian ownership tend to pay higher wages than their domestic (UK) counterparts.

Evidence from the UK

A1.56 A number of studies examine the microstructure of productivity growth in the UK.

A1.57 Disney and Haskel (1999) use the Annual Respondents Database (ARD) database for the period 1986-1991. They include all businesses with over 100 employees in manufacturing and an additional sample of small and medium-size enterprises. Their findings seem consistent with studies conducted on the US and other OECD countries:

(a) entry and exit rates in the UK strongly correlate across time and within industry;

(b) each year, roughly 3 firms out of 10 have just entered the market or will exit;

(c) incumbent firms are nearly 4 times larger than new entrants and firms leaving the market; and

(d) 65 per cent of newborn firms disappear within 5 years.

A1.58 Disney et al. (2000b) use the same, but extended version of the ARD dataset, which covers the period from 1980 to 1992 and contains data for 140,000 manufacturing establishments a year. They use the term "establishment" to refer to the individual plants of firms. Thus, they distinguish between multi-establishment/plant and single-establishment/plant firms. The originality of their work consists in investigating differences in multi-establishment and single-establishment firms. They reach the following conclusions.

(a) External restructuring explains approximately 50 per cent of changes in labour productivity, and 90 per cent of TFP.

(b) The level of labour productivity of new-born firms is on average higher than that of established firms.

(c) The level of productivity of exiting firms is below that of incumbents.

(d) Three quarters of employment is in multi-establishment firms.

(e) Exit and entry operate both through the birth and disappearance of single-establishment firms and the opening and closing down of new and old plants within multi-establishment firms.

(f) Productivity gains of incumbent single-plant firms are close to zero and all productivity growth is brought about by the entry and exit dynamics of new and old firms.

(g) In contrast, half of the productivity growth multi-establishment firms experience is due to a special form of internal restructuring, namely closing down and opening of plants (entry and exit within firms). The authors conclude that the reason for this is that new technology is easier to be introduced in new plants and with new workers rather than by reorganising old plants.

A1.59 Disney et al. (2000b) and Carlin et al. (2001) make considerable efforts to investigate the role business cycles play in productivity growth. Disney et al. (2000) conclude that during booms, the fraction of total productivity growth due to net entry falls and the fraction coming from internal restructuring increases. Conversely, during recessions, productivity growth is mainly achieved through external restructuring whereas productivity within firms tends to be unchanged. Using the same dataset, Carlin et al. (2001) tests the hypothesis whether business cycles promote productivity growth. These authors find that booms are less selective for entry while recessions do not filter survivors better than normal times and do not foster innovation. Thus, large cyclical movements are likely to penalise productivity growth.

A1.60 Haskel (2000) conducts research based on 157,660 firms in the UK for the period of 1982-1992. Investigating labour productivity of the overall firm population, plants at the 90th percentile of the distribution turn out to have almost five times higher productivity

levels than those in the 10th percentile over the whole period. Even though the average productivity level is found to have risen from 1980 to 1992, the gap between high- and low-productivity firms is found to be quite stable (the corresponding ratios are 4.4 and 4.5 in 1980 and 1992 respectively).

A1.61 Barnes and Haskel (2000) confirm this finding for the period 1994-1997: plants at the top 90th percentile of the distribution produce 5.5 times more in value per worker than plants at the bottom 10th percentile. They also report that a great deal of plants remain in the productivity distribution at the end of the period under study where they were at the beginning. 50 per cent in the top quintile is still there in 1997. Only 1 per cent of the bottom quintile in 1994 enter the top quintile by 1997. Entry and exit is chiefly concentrated in the bottom of the distribution with 68 per cent of existing firms in 1994 have exited by 1997.

A1.62 Carlin et al. (2001) seek to examine the heterogeneity in productivity growth across firms in the UK. They find that differences in the type of activity, the location of the firm and the inputs used are able to explain only a fraction of heterogeneity across firms.

A1.63 Similarly, Haskel (2000) provides strong evidence that such heterogeneity comes only partly from differences in industries, location and inputs. First, the difference in productivity between high- and low-productivity firms in a sample of the clothing industry (composed of 2042 firms) is still fairly high (a factor of 3.2). When the industry is further narrowed down to men's outwear, firms in the 90th percentile exhibit productivity levels 2.7 greater than those in the 10th percentile. However, one might argue that this gap is due to different local firm clusters, wage levels and workforce type. The analysis of 148 men's outwear plants located in the Northwest shows that the difference is still there with the ratio being as high as 2.7. Classifying men's outwear plants in the Northwest and according for capital-labour intensity and the blue collar-white collar mix (as a proxy for different skills) yields differences in labour productivity as high as 3.6 times and 5.5 times respectively. In sum, plants in similar industry, located in the same region and using a similar mixture of inputs tend to have different labour productivity levels. Nonetheless, Haskel (2000) also notes that differences found when considering TFP are somewhat lower, with the ratio being around 2.1.

International evidence from the service sector

A1.64 There are relatively few studies on the microstructure of productivity growth for services. This is likely to be due to the lack of data and the relative difficulties of measuring productivity in services, especially in regulated and public services where prices are not determined in the markets (in such cases, the value of production is usually proxied by wages).

A1.65 Haltiwanger et al. (2000) reports results regarding the US retail sector. Empirical evidence suggests that differences in productivity levels in 4-digit retail industries are nearly as large and persistent as in manufacturing. Furthermore, new entrants are approximately as productive as established firms, but the exitors' labour productivity is

lower that that of newborn and incumbent firms. Net entry is responsible for almost 100 per cent of total labour productivity growth in these results, which is in sharp contrast to US manufacturing where net entry account only for one third of productivity growth.

A1.66 Audretsch et al. (2002) analyses the tourism sector in the Netherlands. They analyse 1170 firms, of which 95 per cent single-establishment firm, operating as restaurants, cafeterias, cafes, hotels and camping sites over the period 1987-1991. Their results indicate that small firms in services do not tend to have higher growth rates compared with larger ones, thus supporting the validity of Gibrat's law.

Competition and productivity growth

A1.67 It is a widely accepted professional belief that the effectiveness of competition materially enhances economic efficiency and thus translates into higher productivity growth rates within an industry. Despite this theoretical background, empirical evidence has been relatively scarce in this area until recently. (But note that some of the privatisation literature discussed above is relevant to the issue of competition and efficiency.)

A1.68 One paper that seeks to investigate the relationship between competition and efficiency empirically over a large sample is Nickell (1996). In a panel context, strong empirical evidence is provided in favour of the connection between competition and TFP growth. Employing panel econometric techniques to a set of nearly 700 UK manufacturing firms reveals that first, market power, measured by reference to indices of market concentration, leads to lower productivity growth, and second, competition, proxied by the number of incumbents and the level of rents, is clearly linked to faster productivity growth over the period 1972-86.

A1.69 More recently, a string of papers has sought to uncover the relationship between competition and productivity growth. Januszewski et al. (2002) investigate the case of Germany. Based on the analysis of 500 firms between 1986-1994, they reach a clear conclusion that product market competition fosters productivity growth in German manufacturing. In addition, they also establish that in addition to competition, corporate governance matters. Hence, tighter control enforces productivity growth except when a financial institution is the ultimate owner.

A1.70 Griffith (2001) sets out to analyse the British case. Using the ARD database for 1980-1996, she examines whether the EU single market brought about increased competition. The answer to this question is a resounding yes in some sectors whereas it is no in other sectors. Subsequently, she argues that if the conjecture that increased competition results in improved productivity holds true, the introduction of the European Union Single Market Programme should have positively affected productivity growth in these sectors. The evidence is that in sectors where competition increased as a result of the single market, productivity growth also accelerated. Furthermore, productivity increased only in firms with a principal-agent ownership structure. Griffith (2001) points out that this is a considerable piece of evidence in favour of the view that product market competition increases productivity chiefly through dwindling agency costs.

A1.71 The emphasis of Aghion et al. (2002) is somewhat different compared with the previous papers as they seek to disentangle how product market competition and innovation are linked to one another. They develop an endogenous growth model and derive the main prediction: the link between product market competition and innovation can be described by an inverted U-shape. Additional predictions of the model are as follows. First, higher product market competition will translate into a lower degree of neck-and-neck competition among firms. Second, a high degree of "neck-and-neckness" implies a steeper U-curve between competition and innovation. Lastly, high indebtedness may replace competition and push firms to innovate. The empirical section of the paper broadly confirms the prediction of the inverted U-shape relationship between product market competition and innovation (for the UK). Furthermore, it is shown for a panel composed of nearly 500 UK firms over 1968-1997 that the three other predictions are also validated by data.

A1.72 One caveat is needed with regard to these studies of the relationship between competition and innovation. How competitive an industry is remains an elusive concept. It is somewhat naïve to rank industries in terms of how competitive they are by looking at simple variables like whether price is close to marginal cost, at accounting measures of profit or at a concentration measure at the level of a given industry category. For example, the threat of entry is often a key determinant of how competitive a market is, but is not captured in such measures. Thus we should be wary as to what such studies are capturing when they measure competition. On the other hand, because of the time and data requirements, it would not be possible to use the disciplines of assessing competition found in competition policy investigations in a study encompassing hundreds of firms. And results should be indicative of what might be found from a more robust assessment of competition because the proxies used do have some merit for purpose.

Impact of Information and Communication Technology

A1.73 There have been several studies recently aimed at assessing the potential effect of the New Economy or the ICT (information and communications technology) sector on productivity trends. This section highlights key results for the US and UK, and provides an update to Europe Economics (2001).

A1.74 There are three main channels through which the ICT sector could lead to increases in the whole-economy productivity growth rate:

(a) through ICT capital deepening (which will affect labour productivity by increasing the average ICT capital available per worker);

(b) through TFP growth in the ICT production sector (e.g. improvements in technology allowing greater efficiency of production of ICT equipment, which will affect whole-economy productivity to according to the importance of the ICT production sector to the composition of the economy as a whole); and

(c) through TFP spillovers from ICT to other sectors of the economy.

A1.75 As far as whole-economy TFP growth is concerned, the big question concerns the third channel: how large are the spillovers associated with the ICT sector?

A1.76 Gordon (2000) sets out to investigate whether the New Economy is likely to herald a change in the trend growth rate of US productivity. Examining TFP growth over time, it is clear that following the US productivity slowdown, which is evident from 1972, there has been a revival between 1995 and 1999. The question is whether this marks a lasting shift in productivity growth rates or a temporary effect. Gordon stresses that the important point is to distinguish between a productivity improvement in the sectors which produce the new technology, and a productivity improvement in the sectors which might make use of this technology. The latter would bring a more significant long-term change to the economy's productivity growth rate.

A1.77 In terms of labour productivity, which accelerated rapidly between 1995 and 1999, the issue is between direct effects of the New Economy and potential spillovers. In particular, an economy-wide increase in capital investment would increase labour productivity (the direct effect) but would not raise TFP unless there was some spillover such that the improvement in total productivity was greater than could be attributed to an increase or improvement in inputs. Gordon takes the view that to carry out an analysis of productivity changes, especially over the short period from 1995 to 1999, it is necessary to adjust for cyclical effects. He therefore decomposes the acceleration of the growth rate of output per hour into a cyclical and a trend component, before making conversions to estimate the acceleration in total factor productivity from 1995 to 1999 (compared to 1972–1995). Despite acceleration in labour productivity, evidence of spillovers is absent. In non-farm private business, of a realised growth rate of 2.82 per cent, 0.54 per cent is attributed to the cyclical effect. After removing the contribution of TFP growth in computer and semiconductor manufacturing sectors, this produces acceleration in TFP growth of 0.00. The 'New Economy' does not appear to exist beyond the sectors actually producing the technology. In other words, whilst the productivity upsurge in the ICT sector has had a large impact on overall productivity growth, there has been no spill-over towards the traditional sectors.

A1.78 Although at first this result seems surprising, Gordon compares the computer and IT 'revolution' to the waves of inventions that contributed to the 'golden age' of growth prior to 1973. The following quote from Gordon (2000) helps put the introduction of the Internet into perspective:

> "Internet surfing may be fun, but it represents a far smaller increment in the standard of living than achieved by the extension of day into night achieved by electric light, the revolution in factory efficiency achieved by the electric motor, the flexibility and freedom achieved by the automobile, the saving of time and shrinking of the globe achieved by the airplane, the new materials achieved by the chemistry industry, the first sense of live two-way communication achieved by the telephone, the arrival of live news and entertainment into the family parlor achieved by radio and then television, and the enormous improvements in life expectancy, health, and comfort achieved by urban sanitation and indoor plumbing."

A1.79 Oliner and Sichel (2000) tackle the same question as Gordon but reach a different conclusion. They examine whether the recent acceleration in US productivity can be attributed to computers and related inputs. The principal difference between this paper and Gordon's is that the authors do not attempt to decompose the change in the rate of productivity growth into a trend and a cyclical component. They argue that "[s]eparating trend from cycle is always difficult in the midst of an expansion — and is particularly hazardous now because the current expansion has not conformed to cyclical norms. In the face of this uncertainty, Gordon imposes a strong assumption that effectively pre-ordains his result."

A1.80 Oliner and Sichel's main result is that the use of information technology contributed very little to productivity growth in the early 1990s but its contribution surged in the second half of the decade. Out of the 1.04 per cent per annum acceleration in labour productivity from 1991 – 1995 to 1996 – 1999, 0.37 is associated with TFP growth in computer and related production and 0.30 is associated with growth in TFP outside the computer and semiconductor production industries. In addition to that, another 0.45 percentage point is added by ICT-related capital deepening. Hence productivity growth in sectors manufacturing computers and computer-related semiconductors was found to be an important part of the overall TFP acceleration, but a positive contribution from the rest of the economy is also recorded. In contrast to Gordon's work, evidence is found that the use of information technology has had a significant impact on US productivity in the second half of the decade.

A1.81 Oliner and Sichel (2002) update the time series used in Oliner and Sichel (2000). Taking account of two additional years, namely 2000 and 2001 provides further evidence that the use of information technology has exerted a very important influence on labour productivity growth during the late 1990s and the early years of the new millennium. The acceleration in labour productivity growth between 1991-1995 and the post-1995 period with 2000 and 2001 being the last year amounts respectively to 1.00 and 0.89 per cent against 1.04 per cent reported in Oliner and Sichel (2000). Out of this, 0.90 and 0.91 per cent can be associated with ICT-related capital deepening and TFP growth. Contrasted with the 0.82 per cent obtained for 1996-2000 illustrates an even higher role of ICT.

A1.82 Oliner and Sichel (2002) not only assess the robustness of their previous results but also attempt to analyse to what extent the acceleration in productivity growth due to a more extensive use of information technology can be viewed as sustainable. For this purpose, they analyse the steady-state properties of a multi-sector growth model using calibrated parameters. What they obtain indicates rates of growth of labour productivity growth ranging between 2 and 2.75 per cent in the long-run. Comparing this result with the actual 2.43 per cent growth rate over 1996-2001 supports the sustainability of the pickup in US productivity growth.

A1.83 Jorgenson and Stiroh (2000) also set out to quantify the sources of the acceleration in US economic growth in the late 1990s. Again, stress is placed on the need to separate productivity growth in the sectors producing computers from productivity growth in the sectors using them. Importantly Jorgenson and Stiroh address the problem caused by

the possibility of significant changes in the quality of information technology capital by providing different decompositions of TFP growth under three different assumptions of how fast prices should be deflated to take account of increases in quality. The effect of allowing a more rapid decline is that calculations of real output growth will rise. However, although the decomposition of TFP growth into different capital areas is affected by using a more rapid deflation for information technology prices, the estimated TFP acceleration from the early to late 1990s is barely affected, suggesting it is not an artefact of the way IT prices have been deflated.

A1.84 Under the three different assumptions of the appropriate IT price deflator, the authors further decompose TFP growth so that the contribution of IT related fields can be examined. Evidence is found to support the idea that there has been an acceleration (but not an 'eruption') in productivity growth outside the IT-producing industries, though the exact contribution does depend on the IT price deflator used. Jorgenson and Stiroh suggest that this evidence is consistent with ideas of New Economy spillovers, but point out that the productivity acceleration in sectors outside computer manufacturing could be the result of technological progress independent of the IT revolution. Differentiating between these alternatives is, they say, impossible at the aggregate level.

A1.85 Nordhaus (2002) also aims to disentangle the New Economy conundrum and to clarify the extent to which information technology contributes to productivity growth. In so doing, he computes several alternative productivity measures. Besides the conventional production-side productivity measure, he also constructs income-side based variables. In addition to that, so-called "well-measured" productivity is also determined by excluding sectors for which measuring either value added or price deflators are usually viewed as problematic (such as education and public services). Using these three types of measures applied to the whole economy, the non-farm business sector and the new economy composed of machinery, electric equipment, telephone and telegraph and software, Nordhaus finds that irrespective of the measures employed, labour productivity growth has jumped between 1996-2000 compared with the period 1977-1995.

A1.86 Nordhaus also considers Gordon`s conjecture that the pickup in labour productivity growth has been exclusively due to that of the ICT sectors, whereas productivity developments in the other "traditional" sectors have not been significantly affected. He finds that even though the contribution of the ICT sectors, especially that of computers and semiconductors, has been very substantial, productivity has also experienced considerable growth in the other sectors. This implies that not only the production but also the use of information and communication technology in other sectors has resulted in higher productivity growth.

A1.87 Schreyer (2000) examines the role of information and communications technology (ICT) on productivity in a cross-country context. The advantage of this approach is that if there are significant spillovers associated with ICT capital then we would expect these to be present across different economies that employ it. Since TFP growth rates can change for any number of reasons, evidence of recent acceleration in multiple countries is more compelling evidence of New Economy effects than evidence from a single country would

be. Of course, an international comparison generates further problems. In particular Schreyer has to adopt a method to harmonise the price deflators applied to ICT equipment in different countries. Though his treatment is reasonably consistent with the US studies above, the harmonisation itself could bring further errors to the assessment of levels of capital stock.

A1.88 Using a growth accounting decomposition, ICT capital is found to have contributed to output growth, but Schreyer finds no convincing evidence of a general acceleration in TFP growth across the G7. Unfortunately the data only runs to 1996, so this result is not especially inconsistent with the US studies referred to above because in these the TFP acceleration was only found in the late 1990s.

A1.89 Crafts (2002) addresses three key questions, the contribution of ICT towards 1990s American growth, US growth prospects for the early 21st century, and whether ICT will change growth prospects in the rest of the world. He finds that most of the acceleration in US labour productivity growth after 1995 was due to the production and use of ICT. Crafts predicts that continuing falls in ICT equipment prices and increased importance of ICT capital in the economy will make it likely that the faster growth will be sustained in the first decade of the 21st century in the US. Crafts also believes the opportunities associated with ICT will raise European growth but stresses doubts over Europe's ability to fully realise the potential. This is because the American experience shows that reorganisation is fundamental to fully extract the productivity gains from ICT. The doubt then rises whether in Europe where there may be less competitive pressures in product markets and greater worker resistance to more flexible working arrangements can take the full benefits of the opportunity. The author also points out there is no reason to assume ICT will of itself change the growth prospects of the developing world.

A1.90 There are two major papers aiming to assess the empirical contribution of ICT on productivity growth for the case of the UK. The first, Kodres (2001), adopts the methodology employed in Oliner and Sichel (2000). Defining the ICT sector in terms of computers, software and telecommunication equipment, the analysis sheds lights on the fact that the impact of ICT on output growth was very low during 1987-1990 but turns out to be on an accelerating path since then, with an average annual contribution of 0.21 and of 0.59 percentage point respectively between 1991-1996 and 1997-1999.

A1.91 When looking more closely at the connection between ICT and the growth rate of labour productivity, Kodres points out that labour productivity can be broken down into capital deepening and TFP. Accordingly, 0.1, 0.87 and 1.19 percentage points of labour productivity growth can be ascribed to capital deepening related to ICT during 1987-1990, 1991-1996 and 1997-1999 respectively.

A1.92 Finally, Kodres proceeds to decompose TFP growth into two components, namely TFP growth in ICT and TFP growth in the rest of the economy. The extent to which the ICT sector contributed to TFP growth is found to have jumped to 0.66 per cent from 1997-1999 against 0.35 per cent per annum during 1993-1996.

A1.93 Oulton (2002) differs from Kordes (2001) in two respects. First, the time period under investigation is considerably longer and spans from 1979 to 1998. Second, a larger definition for the ICT sector is considered, which includes semiconductors (the heart of microprocessor chips) besides telecommunication equipment, software and computers.

A1.94 Using the growth accounting framework as in Kodres (2001), the contribution of ICT to total output growth is estimated as 0.33 per cent during 1979-1989, whilst it is found to have increased to 0.36 between 1989-94 and nearly doubled to 0.57 per cent in the last part of the period investigated (1994-1998).

A1.95 Similarly to Kodres (2001), Oulton (2002) underscores the importance of the ICT-related capital deepening. He argues that this was as high as 0.7 per cent in 1994-98 against 0.4 per cent during the 1980s. The results suggest that 50 per cent of labour productivity can be attributed to capital deepening in ICT in the late 1990s, against as low as 15 per cent in the 1980s. Both authors stress that other (non-ICT) capital deepening was low during the mid to late 1980s.

A1.96 The results in Oulton (2002) are consistent with those in Kodres (2001). All in all, these results lend strong empirical evidence in favour of the fact that ICT has increasingly contributed to and now plays an essential role in output and labour productivity growth in the UK.

APPENDIX 2: PRODUCTIVITY MEASUREMENT METHODS

A2.1 Industry- and economy-level estimates of productivity improvement need to rely on aggregated data on inputs and outputs. However, productivity is defined by reference to *volumes* of inputs and outputs, but the volumes of different inputs or outputs cannot be simply aggregated: for example, whilst it seems sensible to consider the supply of vegetables as a single industry, it is not appropriate to define a volume measure covering all types of vegetables through a simple aggregation. Furthermore there are often no direct data sources, and proxies must therefore be used. The first section of this appendix reviews methods that can be used to obtain estimates of productivity improvement in these circumstances, considering in turn output, labour, and capital.

A2.2 Once relevant data have been obtained, there remain a number of issues to be addressed to obtain robust and comparable measures of productivity improvement. The remainder of this appendix discusses the treatment of economies of scale, factor substitution (especially capital substitution), input prices, and the way in which trends of productivity improvement may be estimated in the presence of data noise.

Measurement Methods

Measuring outputs

A2.3 Four basic measurement approaches can be considered to estimate outputs and output growth in a way that is consistent between industries and countries: physical units; gross and net value added; and gross output.

A2.4 Physical output is an attractive measure in that it does not pose the problem of converting values expressed in different currencies. In general, one can use quantity indicators and then adjust for differences in the mix of services produced. This can be done, for example by using regression methods to estimate the elasticity of productivity with respect to a set of explanatory factors. The applicability of this methodology, clearly, depends on the availability of sufficient data to identify the relationship of interest.

A2.5 Despite this potential attractiveness and the apparent simplicity of physical measures, when an international comparison is undertaken it is necessary to be aware of, and in a position to make some allowance for the possible quality differences of the goods and services provided in different countries.

Measuring inputs: labour

A2.6 The simplest way to measure labour input is a head count of jobs or employees. This measure can be extended to all wage and salary earners and the self-employed. This measure, total employment, is a stock measure, and its use implicitly assumes that the flow of labour services (i.e. the hours worked) is proportional to the stock. Nonetheless, hours worked are, in all likelihood, differently related to the "labour stock" in different countries, which consequently leads to inconsistencies in estimates of productivity measured in levels.

A2.7 When rate of changes are computed, and if there is a shift in average working hours over time, the use of total employment will lead to differing results when compared with hours actually worked even in the same country. This is the reason why total hours actually worked should be preferred to total employment. Nevertheless, total hours worked ignores the skill composition of the labour force, which can change considerably over time. It is therefore desirable to adjust for changes in skill. For example, an increase in skilled workforce would lead to a labour input increasing faster than the unadjusted labour input. A practical problem with total hours worked, and adjustments for skills, is that the accuracy and reliability of the data might be different across sectors and countries.

A2.8 There are two different sources of labour input: household-based labour force survey and establishment or firm-based surveys. The former covers the whole economy and analyses the composition of the labour force (i.e. educational background, age, multiple job holding etc.) whereas the latter investigates only a sample of firms in an industry above a certain size (e.g. with more than 20 employees), and surveys jobs rather than persons employed. In some countries, the two sources are merged into a unique dataset whilst other countries use them separately. Some contest the overall accuracy of the data gathered this way and argue that the reported hours worked is actually below under hours actually worked. This naturally invites comment that those statistics should be treated with caution when compared one with another.

Measuring inputs: capital

A2.9 Measuring capital input is generally considered even more complicated, and the outcomes even more uncertain. Analogously to labour stock, capital goods (i.e. the capital stock involved in the production process) provide a flow of capital services, which constitutes capital input. Thus, from a theoretical point of view, the flow of capital services should be quantified and priced in order to derive the value of capital input.

A2.10 However, neither quantity nor the price of capital services can be observed because of the absence, in most cases of, informative market transactions. Therefore, it is usually assumed that the quantity of capital services is proportionally related to the stock of capital goods. In practice, the price of capital services is determined by estimation of their rental price. This is referred to as the user's costs of capital, which is basically determined as the opportunity cost and the depreciation of the capital goods.

A2.11 Assuming proportionality between capital stock and the services that flow from it allows us to attempt to quantify the capital stock. This can be done, at least theoretically, in a number of ways including using balance sheet data, insurance valuations, or specific direct enquiries.

A2.12 However, book values are likely to be affected by somewhat arbitrary choices of accounting standards, and perhaps by capital allowances for tax purposes. Company policies are different as to which items are booked as investments or operational costs and to which life time and depreciation to assign, leading to different capital stock

estimates for the same pool of assets. Thus such measures may deviate substantially from the true prevailing economic value of the capital good.

A2.13 Direct enquiries require a lot of time to be implemented and are fairly costly.

A2.14 Thus, the most effective approach is often a accumulation method such as the perpetual inventory method (PIM), whereby the volume of services of capital is deemed to be proportional to the capital stock, and the capital stock is estimated by accumulating the value of past investments (capital expenditure data e.g. from national accounts) and applying assumptions as to the rate at which different classes of capital are consumed (depreciated) or disposed of. There remain however significant divergence in practices regarding the maximum service life, the survival function, the depreciation function of different asset types and the treatment of the initial capital costs, which can materially affect the comparability of productivity improvement estimates.

Adjustments for Economies of Scale

A2.15 The traditional definition of the growth in total factor productivity is the residual of the increase in outputs over what can be explained by increases in input volumes:

$$g_{TFP} = \sum \beta_j g(y_j) - \sum \alpha_i g(x_i)$$

where

g_{TFP} is the increase in total factor productivity

$g(x_i)$ is the rate of growth (derivative of the logarithm) of the volume of input x_i

$g(y_j)$ is the rate of growth of the volume of output y_j

α_i is the marginal rate of substitution between using more of input x_i and using more of all inputs (in both cases expressed as a percentage increase)

β_j is the marginal rate of substitution between producing more of input y_j and producing more of all inputs (in both cases expressed as a percentage increase)

A2.16 Given these definitions, both the sum of all α_i and the sum of all β_j is unity, as it is the marginal rate of substitution between two identical baskets of inputs (respectively outputs).

A2.17 However, the above definition of total factor productivity growth is affected by economies of scale. If the technology is such that an increase of 1 per cent of all outputs requires only an increase of γ per cent of all inputs, where $\gamma < 1$ in the case of economies of scale, then a definition of total factor productivity growth that is independent of scale and

thus reflects the underlying efficiency of the way in which activities are conducted would be as follows:

$$g_{TFP}^{adjusted} = \gamma \sum \beta_j g(y_j) - \sum \alpha_i g(x_i))$$

A2.18 The above definition could be described as "input-based", in that a 1 per cent growth in productivity would correspond to a 1 per cent reduction in cost, everything else being the same. Whilst this is the appropriate definition for the purposes of the present study, it would also be possible to define a measure of productivity adjusted for economies of scale whereby a 1 per cent growth in productivity would correspond to a 1 per cent increase in output for the same level of inputs.

Adjustments for Factor Substitution

Partial productivity measures

A2.19 Factor substitution refers to the way in which changes in technology or working practices often leads to a re-allocation of resources away from some categories of inputs and towards other categories. In particular, economic progress is generally accompanied by a shift from labour inputs towards capital inputs.

A2.20 Factor substitution is at the origin of differences between total factor productivity and labour productivity. For example, in a two-factor model with labour x_L and capital x_K as inputs and one output *y*, the rate of growth of labour productivity can be expressed as:

$$g_{LP} = g(y) - g(x_L) = g_{TFP} + \alpha_K (g(x_K) - g(x_L))$$

A2.21 α_K was defined above as the marginal rate of substitution between capital and all inputs, so that α_L / α_K is the marginal rate of substitution between labour and capital: in other words, an α_L percentage increase in the quantity of labour used has the same effect on output as a α_K percentage increase in the quantity of capital services used. The firm will therefore be operating with an optimal combination of inputs if such a substitution at the margin leaves total cost invariant. Thus, provided that there are no constraints (e.g. fixed factors in the short run) preventing the adjustment of inputs used, α_K is also the capital share of total costs (sometimes called the capital share of value).

A2.22 Thus, on these assumptions, capital substitution leads to a faster increase in labour productivity than in total factor productivity, with the difference being calculated as the product of the capital share of total costs α_K by the increase in the volume of capital employed per unit of labour, $g(x_K) - g(x_L)$.

A2.23 Data from Englander and Gurney (1994) indicate that TFP growth had been 1.6 per cent a year, whilst capital productivity had risen by 0.4 per cent a year and labour productivity had risen by 2.1 per cent a year. This would tend to indicate that, for the economy as a

whole, the increase in the volume of capital employed per unit of labour, $g(x_K) - g(x_L)$, was 1.7 per cent a year (the difference between capital and labour productivity growth). In an industry with the same capital substitution trend as the economy as a whole, labour productivity growth would therefore exceed TFP growth by 1.7 per cent times that industry's capital share of value.

A2.24 The data presented in Section 5 for the economy as a whole are indicative of a somewhat greater capital substitution effect: the gap between labour productivity and TFP is found to exceed 1 per cent a year over the period 1950-1999 in the UK. Coupled with a typical labour share of value in excess of 60 per cent, this would lead to a factor of 3 per cent instead of the 1.7 per cent extracted from Englander and Gurney. However, data for other periods (see Table 5.1 and Table 5.2) are consistent with lower factors. Data for the nature of work comparators shown in Table 6.13 are consistent with a factor of 2 per cent, assuming a labour share of value of about 50 per cent for the nature of work comparators. Whilst we recognise the high level of uncertainty attached to the methodology for adjusting for capital substitution, and the wide range of values quoted above, it is clear that some form of adjustment is necessary before the scope for expenditure reduction can be estimated for the water and sewerage industries. In the remainder of the report, we assume that the gap between TFP and labour productivity growth is 2 per cent times the relevant industry's capital share of value.

Partial cost measures

A2.25 Another (closely related) effect of factor substitution is differential rates of reductions for different categories of expenditure (on top of the effect of differences in the rates of change of input prices in these categories). This is particularly relevant to the present study since data for the UK privatised infrastructure company comparators relates to operating expenditure, and the output sought from the study is the scope for reduction in operating and capital maintenance expenditures.

A2.26 At least as a first approximation, it seems reasonable to use the rate of substitution from labour to capital estimated above as a proxy for a rate of substitution between all operating expenditure inputs and all capital inputs. Thus, once any differences in input price growth have been taken into account, the gap between TFP and reductions in unit operating expenditure may be estimated as 2 per cent times the relevant industry's capital share of value.

A2.27 However, practical application of these assumptions requires a careful definition of the capital and operating inputs of the water and sewerage industry, and of the relevant comparators.

A2.28 There are in fact several possible delineations of the boundary between operating and capital expenditure, and therefore between operating and capital inputs.

(a) At one extreme is the usual accounting convention whereby capital maintenance expenditure — the replacement of assets on the network to maintain the network's

overall serviceability — is capitalised. We assume that this narrow definition of operating expenditure is the one that matches best the whole-economy data that led to the 2 per cent estimate above.

(b) At the other extreme is an economic definition of operating expenditure that would *include* capital maintenance expenditure. The rationale for such a definition would be that capital maintenance expenditure is expenditure undertaken to maintain the performance on the network seen as a whole entity, even if it amounts to the replacement of an asset within that network. Thus, from a top-down economic perspective, this alternative "broad" definition of operating expenditure is also a legitimate concept of operating expenditure that can be considered within a simplified model with two factor categories (operating inputs and capital inputs).

A2.29 A key difference between these two approaches relates to the impact of capital substitution. With the broad definition of operating inputs, some of the substitution from operating to capital inputs becomes substitution from one type of operating input to another type of operating input. Thus, the capital substitution effect should be scaled down.

A2.30 Thus, for example, if under the narrow definition operating expenditure amounts to 40 per cent of costs, and under the broad definition it amounts to 60 per cent of costs, and if capital substitution under the narrow definition is estimated at 2 per cent, then the capital substitution under the broad definition may be of the order of 2 per cent multiplied by (0.4/0.6) or 1.3 per cent. Disregarding input price effects, the difference between reduction in operating expenditure and TFP growth would therefore be 1.2 per cent (2*0.6) under the narrow definition of operating expenditure and 0.8 per cent (2*0.4) under the broad definition.

The case of monopoly infrastructure networks

A2.31 A further issue arises in the case of monopoly infrastructure networks. Some of the assets used by such businesses do not fit within the framework outlined above based on the assumption that the volume of capital inputs can be varied continuously and that there is scope for substitution at the margin between capital and operating inputs. A clear counter example would be, for example, a rail tunnel. It would not be possible to deliver the services that a rail infrastructure provides supplies using a tunnel by using a little bit less tunnel and a little bit more labour or materials. It would of course be possible to deliver these services with different combinations of the quality of the tunnel lining (capital input) and the amount of work spend on maintenance (operating input), but this would be substitution between tunnel lining and labour/materials, which does not involve the tunnel itself.

A2.32 Thus, the capital inputs of monopoly infrastructure networks normally include the use of some special assets which we term "basic monopoly assets" for which the substitution and share of cost concepts set out above cannot make sense. A natural and practical approach is therefore to exclude these assets from the measurement of productivity:

productivity is about the efficiency of the management of processes involving labour, materials, energy, plant, machinery, generic land space, skills and know-how, etc, and should not be distorted by the costs of these very specific assets that are only needed as the background against which monopoly infrastructure providers perform their activities.

A2.33 A complementary feature of these basic monopoly assets is that many are very old, and many have been inherited from the company's predecessor at the time of privatisation. This means that there are no reliable records of the cost of their construction, and instead they are taken into account in the regulatory regime through the regulatory capital value. It would clearly be inappropriate to use regulatory capital value — effectively the result of a deal between public and private sectors at privatisation — as part of an economic measure of productivity improvement.

A2.34 Thus, for water and sewerage and for the monopoly infrastructure network comparators, the shares of costs mentioned above should be calculated as shares of the total costs *excluding* the return on basic monopoly assets. This is of course extremely difficult to estimate with precision, but it seems likely that the relevant total cost figure will lie somewhere between total expenditures (without any return on capital) and total revenues (which are broadly equivalent to total expenditure plus a return on the regulatory capital value, and include some capital costs attributable to basic monopoly assets).

Application to water and sewerage

A2.35 Operating expenditure amounts to about 60 per cent of total operating costs in the water industry, and 50 per cent in sewerage. Operating costs (which include depreciation and the long-term infrastructure renewals charge, and are therefore a proxy for total base service expenditure) represent 75 per cent of revenues in water and 65 per cent in sewerage. Thus, the relevant adjustment to estimate the scope for base service operating expenditure reductions is of the order of 1 per cent in water and 1.3 per cent in sewerage, whilst the adjustment to estimate the scope for base service operating and maintenance expenditure reductions is about 0.5 per cent in water and 0.7 per cent in sewerage.

A2.36 These figures imply reductions in capital maintenance expenditure consistent with TFP growth in sewerage, but somewhat slower than TFP growth in water (in both cases subject to adjustments for whole-economy TFP growth and other input price effects). This means that substitution from operating expenditure inputs to broadly-defined capital inputs (which include capital maintenance) more than offsets substitution from capital maintenance expenditure (as well as from operating expenditure) to the use of a proportionately greater stock of capital.

A2.37 These assumed trends for capital substitution also imply that capital productivity (the volume of output relative to the volume of capital inputs employed) would rise slower than TFP. In the case of water, the difference would be about 1 per cent in water and 0.7 per cent in sewerage using the narrow (traditional) definition of opex; and 1.5 and 1.3 per cent respectively if capital maintenance is included in the operating input measure.

A2.38 It will be for Ofwat to ensure consistency of the capex allowances set for companies with the investment requirements implicit in the capital substitution component of the scope for efficiency improvement on operating and capital maintenance expenditure. Including no capex beyond the incremental investment required to deliver new outputs would be consistent with constant capital productivity (i.e. constant volume of capital inputs for the provision of the base service), which would only be consistent with our capital substitution assumptions if the scope for annual TFP improvement were, on the basis of the above figures, 1.5 per cent in water or 1.3 per cent in sewerage.

A2.39 If it is assumed that privatised infrastructure companies have not significantly increased capital productivity (other than land disposals, it can be argued that their only opportunity to do so was when they have been able to use constant capital inputs to produce more output), then the significant reductions in operating expenditure achieved since privatisation would be partially attributable to exceptionally high rates of capital substitution, which would be consistent with a hypothesis that nationalised industries had, in relative terms, too few capital inputs and too many non-capital inputs. This effect is taken into consideration in Section 7.

Adjustments for Input Prices

Use of whole-economy estimates

A2.40 Both the RPI and the GDP deflator are output price indices. However, the basket for the GDP deflator is wider, as it includes non-market services (e.g. government services) as well as some intermediate goods (there are also differences in terms of the inclusion of imported goods). The prices for both types of products would be expected to increase faster than retail prices:

(a) output for non-market services often has to be measured in terms of inputs (staff time), leading to low apparent productivity growth; and

(b) price growth for intermediate goods is offset by productivity improvements in the processes that convert these goods into final consumer goods, and inflation for intermediate goods should therefore be expected to be somewhat faster than the RPI.

A2.41 In practice, the analysis of Section 5 shows that the difference in trend between the RPI and the GDP deflator is extremely small, making it appropriate to treat the out-performance of a sector's TFP compared to whole economy TFP growth as an indicator of the change in real unit total costs for that industry.

Differences in relevant input price basket

A2.42 The relevant input price basket for operating and capital maintenance expenditure will have a disproportionate contribution from labour compared to a total cost input price basket (which includes a significant capital element). Given that wages are normally one of the fastest rising input prices in the economy, this will mean that the scope for operating

and capital maintenance expenditure reduction is somewhat less than it would be for a measure of total costs, to which TFP is most directly relevant.

A2.43 Only an approximate estimate of this effect can be obtained on the basis of the data available to us. In broad terms (and by reference to the GDP deflator), labour prices rise by 1.8 – 2 per cent a year (the Average Earnings Index has grown by 1.9 per cent a year between 1968 and 2001, but this is an imperfect proxy as it does not take account of changes in working hours or of part-time work). Labour constitutes two thirds of an economy-wide input price basket which (according to the data reported in Section 5) grows by about 1.2–1.4 per cent a year (the whole-economy trend rate of TFP improvement). This indicates that input prices other than for labour rise on average by 0 – 0.5 per cent a year.

A2.44 If the relevant input price basket for operating and capital maintenance expenditure were exclusively composed of inputs with the same trend growth rate as labour, a downward adjustment of 0.4 – 0.6 to the scope for efficiency improvement would be required. In practice there are some capital and materials input involved in operating and capital maintenance expenditure (raw materials used for asset maintenance and replacement, use of ordinary machinery, etc) and the adjustment would therefore be less, perhaps 0.3 per cent.

Methodology for RUOE Analysis

A2.45 This section sets out the methodology used to provide the direct analysis of real unit operating expenditure (RUOE) reductions in the privatised infrastructure companies discussed in Section 4.3.

A2.46 To compile a data series that allows estimation of trends in RUOE, we must divide the real operating expenditure in a year by an appropriate output measure. The following paragraphs describe the methodology used to determine output measures for electricity network, water and sewerage comparators. We then discuss the methodology used for the determination of trends for the privatised infrastructure companies.

Electricity networks

A2.47 The main output measure used for electricity transmission and distribution is the number of units carried on the network. This forms the basis of the "unadjusted" RUOE figures.

A2.48 The figures adjusted for economies of scale are determined by using the square root of the number of units carried as the output measure. This reflects the usual regulatory assumption for electricity network that a one per cent growth in volumes leads to a 0.5 per cent growth in costs, and usually gives rise to a 0.5 per cent increase in revenues through the operation of the price control formula.

Water and sewerage

A2.49 For the water and sewerage industries the output measure is arguably more complex than in some of the other sectors studied. However, because of the availability of data pertaining to base service, we are able to obtain a reasonable dataset of RUOE where the unit in question is effectively taken as a constant base service.

A2.50 The output of water companies has varied over time, and substantial investments have been undertaken to improve quality. While many of the quality and volume enhancements will fall under capital investment investments, there also increases in operating expenditure over time associated with increases in quality and volume. The perfect output measure would therefore capture all changes in volume and quality of service / quality of supply that are delivered by the companies over the period. No such volume measure exists.

A2.51 One way around the problem is to concentrate on base service. This measure has interest for the current study simply because we are concerned with the scope for efficiency improvement in base service. It is possible to construct an implied output index that reflects the difference between base service operating expenditure and total operating expenditure (note that in the base year, this ratio is 1). We can then estimate RUOE by dividing total operating expenditure by this output index, and then adjusting for inflation.

A2.52 Owat provided Europe Economics with data for water and sewerage industry operating costs over the period year-ending April 1993 to year-ending April 2002. (We understand that no reliable and consistent operating cost data exists for the period immediately after privatisation to 1992.) This data provides total operating expenditure and base service operating expenditure (in actual prices).

A2.53 However, the definition of the base year changes over the data period because the base is reset in 1997/1998. Thus it is necessary to chain-link the output index at the time of the switch. Having made this correction, an output index is obtained that, when used as the denominator in RUOE calculations, should provide a series of base service operating expenditure for a consistent measure of base service over time. The intuition behind this output index is simply that it is functional: it provides an output measure for which RUOE calculations will reflect changes in base service operating expenditure.

Determination of trends

A2.54 This section discusses the methodology used in the direct analysis for the determination of trends for the privatised infrastructure companies.

A2.55 A particular problem with the direct analysis of the record of changes in real unit operating expenditure by UK privatised infrastructure companies arises from the nature of the statistical noise present in these data: there are frequent shocks amounting to 10-20 per cent, which can be assumed to be the result of exceptional costs, whether reported as such or not.

A2.56 The simplest way of estimating the trend is to calculate the compound annual growth rate (CAGR) across the period for which data are available. Such a methodology effectively amounts to taking the average of the change in the logarithm of unit expenditure for each year to the next: it will therefore be a valid estimate of the trend if the noise is assumed to affect productivity improvement similarly and independently in each period, in other words if unit costs (in logarithms) are assumed to follow a drifting random walk.

A2.57 However, this is unlikely to be a valid assumption, if — as suggested above — the main source of noise is the re-timing of expenditure through exceptional costs (e.g. business reorganisation or redundancies).

A2.58 Given this, we have developed an alternative estimation technique which assumes the following structure for statistical noise:

$$\ln(RUOE_t) = a + bt + \varepsilon_t - \alpha\varepsilon_{t-1}$$

where the time variable *t* is expressed in years

a is a constant;

b is the trend, expressed in logarithms (i.e. the annual growth trend is $(e^b - 1) * 100\%$);

ε_t is a random noise variable;

α is a discount factor.

A2.59 In other words, the residual in each year $u_t = \ln(RUOE_t) - a - bt$ is expressed as a combination of random shocks in consecutive years: $u_t = \varepsilon_t - \alpha\varepsilon_{t-1}$.

A2.60 In effect, we are assuming that noise takes the form of re-allocation of expenditure from one year to the previous one, subject to a discount factor: for example, the company may bring forward expenditure of £1 million to the present year, thus reducing next year's expenditure by £1.05 million. (For simplicity, we are applying a discount factor to the logarithm of RUOE rather than to total expenditure, but this approximation is unlikely to have a significant effect provided that volume growth is relatively limited.)

A2.61 We have estimated the trend by minimising the sum of squares of the true noise variables ε_t. Once expressed in terms of the residuals u_t this gives rise to a generalised least squares model, which is straightforward to solve as there are only two parameters (the constant *a* and the trend *b*) to be estimated.

A2.62 In using this methodology to estimate the "trend" figures quoted in Section 4 of the report we have found relatively little sensitivity of the results to the value of α assumed. The trend estimates quoted in Section 4 are for $\alpha = e^{0.05}$.

APPENDIX 3: PRIVATISED INFRASTRUCTURE COMPANIES DATA

A3.1 This appendix provides results to the direct analysis of efficiency improvements achieved by UK privatised infrastructure companies since privatisation. Its supports the discussion provided in Section 4.3.

Overview of Estimated RUOE Reductions

A3.2 Table A4.1 provides, for each of the companies analysed, estimates of both compound annual reductions in real unit operating expenditure (RUOE) and of the trends for ROUE reductions estimated according to the methodology described at the end of Appendix 2.

A3.3 The output measure used for electricity wires network is the number of units of electricity carried; figures are shown below both on that basis and with an adjustment for economies of scale which relies on the assumption that 50 per cent of the costs are variable (see Appendix 2 for details).

A3.4 For water and sewerage companies, a notional output measure derived from base services expenditure figures has been used (see Appendix 2 for details).

A3.5 For Railtrack and BT, two potential output measures are used; in both cases, it is likely that one of the measures understate the impact of volume growth on operating expenditure whilst the other is likely to overstate that impact.

Table A3.1
RUOE reductions for privatised companies

Company	Data period (FYEs)	CAGR	Trend
Electricity wires network (units carried)			
EME (East Midlands)	1991-2001	4.8%	1.6%
EPN (Eastern)	1991-2001	10.1%	9.3%
LPN (London)	1991-2001	11.6%	10.5%
Manweb	1991-2001	5.4%	4.6%
MEB (Midland/Aquila)	1991-2001	6.2%	6.6%
NEDL (Northern)	1991-2001	7.5%	4.3%
NGC	1991-2001	1.2%	5.2%
NIE	1993-2001	5.6%	6.2%
SHD (Hydro-Electric Distribution)	1991-2001	5.2%	0.4%
SHT (Hydro-Electric Transmission)	1991-2001	9.9%	6.3%
Southern Electric	1991-1994	11.1%	11.3%
SP Distribution	1991-1994	4.5%	0.4%
SPN (SEEBOARD)	1991-1994	9.2%	10.0%
SP Transmission	1991-1994	4.3%	5.9%
SWALEC (WPD)	1991-1994	6.3%	6.5%
SWEB (WPD)	1991-1994	8.1%	9.3%
UUE (Norweb)	1991-2001	10.0%	6.7%
YEDL (Yorkshire)	1991-2001	7.6%	7.3%

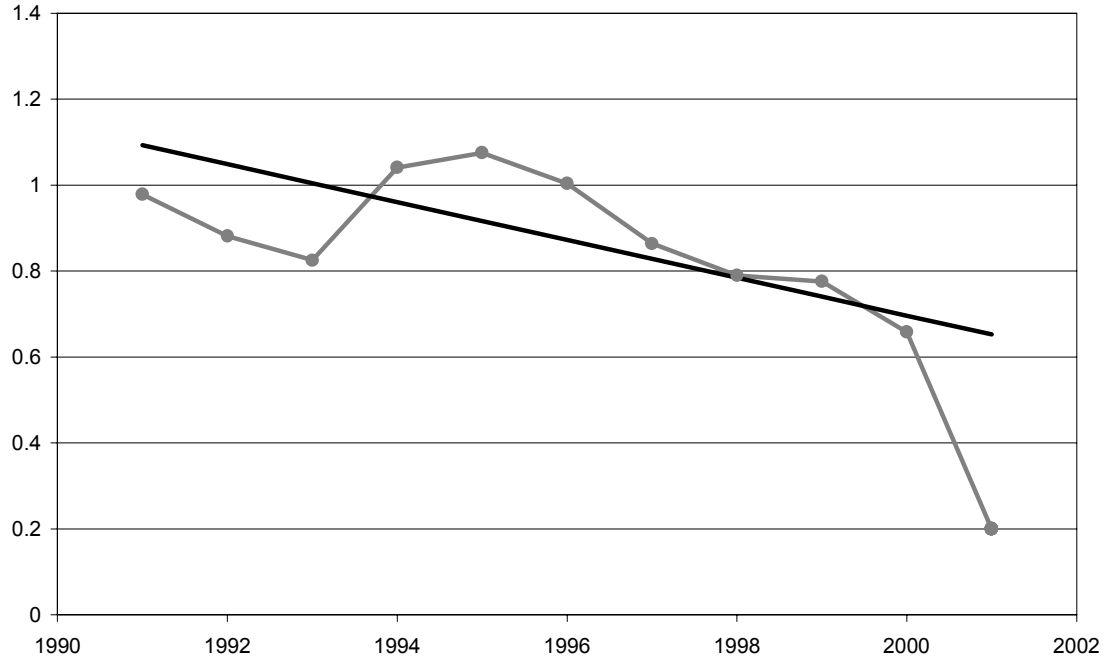
Company	Data period (FYEs)	CAGR	Trend
Electricity wires network (adjusted for economies of scale)			
EME (East Midlands) adjusted	1991-2001	3.9%	0.6%
EPN (Eastern) adjusted	1991-2001	9.4%	8.6%
LPN (London) adjusted	1991-2001	10.5%	9.4%
Manweb adjusted	1991-2001	5.5%	4.7%
MEB (Midland/Aquila) adjusted	1991-2001	5.5%	5.7%
NEDL (Northern) adjusted	1991-2001	6.8%	3.7%
NGC adjusted	1991-2001	0.4%	4.4%
NIE adjusted	1993-2001	4.4%	5.0%
SHD (Hydro-Electric Distribution) adjusted	1991-2001	4.5%	-0.4%
SHT (Hydro-Electric Transmission) adjusted	1991-2001	8.0%	4.2%
Southern Electric adjusted	1991-1994	10.1%	10.4%
SP Distribution adjusted	1991-1994	3.9%	-0.2%
SPN (SEEBOARD) adjusted	1991-1994	8.4%	9.2%
SP Transmission adjusted	1991-1994	2.3%	3.6%
SWALEC (WPD) adjusted	1991-1994	5.6%	5.6%
SWEB (WPD) adjusted	1991-1994	7.3%	8.4%
UUE (Norweb) adjusted	1991-2001	9.3%	6.0%
YEDL (Yorkshire) adjusted	1991-2001	7.2%	6.9%
Water companies (with base service adjustment)			
ANH.w Anglian & Hartlepool (water)	1993-2002	3.7%	4.9%
WSH.w Dwr Cymru (water)	1993-2002	4.1%	5.6%
NWT.w North West (water)	1993-2002	3.0%	2.0%
NES.w Northumbrian and Essex & Suffolk (water)	1993-2002	4.0%	4.4%
SVT.w Severn Trent (water)	1993-1994	4.3%	5.0%
SWT.w South West (water)	1993-2002	5.1%	5.6%
SRN.w Southern (water)	1993-1994	4.3%	6.1%
TMS.w Thames (water)	1993-2002	2.9%	3.2%
WSX.w Wessex (water)	1993-2002	3.9%	4.2%
YKY.w Yorkshire & York (water)	1993-2002	4.1%	5.1%
BWH.w Bournemouth and West Hants (water)	1993-2002	2.4%	2.0%
BRL.w Bristol (water)	1993-2002	2.5%	3.0%
CAM.w Cambridge (water)	1993-2002	2.5%	1.6%
DVW.w Dee Valley (water)	1993-2002	3.7%	5.6%
FLK.w Folkestone (water)	1993-2002	2.9%	1.9%
MKT.w Mid Kent (water)	1993-2002	5.5%	4.1%
PRT.w Portsmouth (water)	1993-2002	2.4%	3.0%
MSE.w South East (water)	1993-2002	3.6%	3.1%
SST.w South Staffordshire (water)	1993-1994	1.9%	2.0%
SES.w Sutton & East Surrey (water)	1993-2002	2.5%	3.1%
THD.w Tendring Hundred (water)	1993-2002	2.6%	1.5%
TVN.w Three Valleys & North Surrey (water)	1993-2002	2.3%	1.7%
TOT.w Total water industry	1993-2002	3.6%	4.0%

Company	Data period (FYEs)	CAGR	Trend
Sewerage companies (with base service adjustment)			
ANH.s Anglian & Hartlepool (sewerage)	1993-2002	2.3%	3.8%
WSH.s Dwr Cymru (sewerage)	1993-2002	1.7%	4.0%
NWT.s North West (sewerage)	1993-2002	4.7%	3.9%
NES.s Northumbrian (sewerage)	1993-2002	6.2%	6.5%
SVT.s Severn Trent (sewerage)	1993-1994	2.7%	2.3%
SWT.s South West (sewerage)	1993-2002	3.3%	4.9%
SRN.s Southern (sewerage)	1993-1994	4.0%	5.8%
TMS.s Thames (sewerage)	1993-2002	3.7%	4.1%
WSX.s Wessex (sewerage)	1993-2002	4.4%	5.0%
YKY.s Yorkshire & York (sewerage)	1993-2002	3.3%	3.8%
TOT.s Total sewerage industry	1993-2002	3.5%	4.0%
Other			
Railtrack (using passenger numbers)	1995-2002	1.2%	4.8%
Railtrack (using route length)	1995-2002	-3.2%	0.0%
BT Group (using exchange lines)	1988-2002	-2.4%	-1.1%
BT Group (using call minutes)	1993-2002	2.9%	1.9%

Company-Level Results

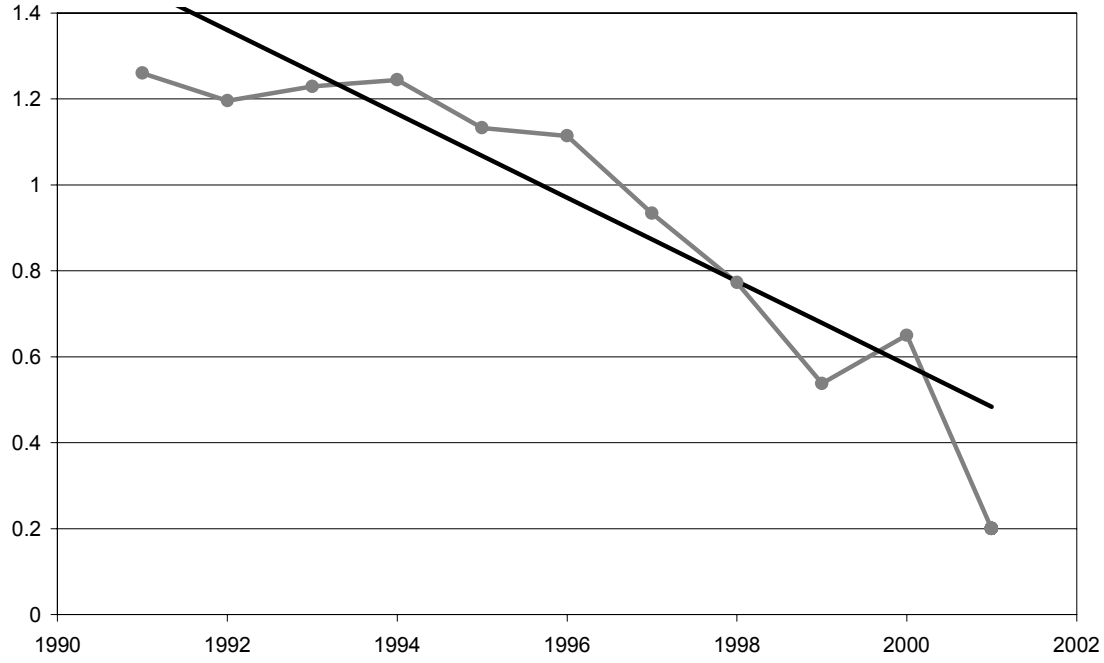
A3.6 The remainder of this appendix presents a chart for each company/output measure combination listed in the above table, showing in each case the CAGR in RUOE and the trend in RUOE that has been estimated following the methodology described in Appendix 2 (in both cases these are shown as a percentage reduction in real unit operating expenditure per annum). All the diagrams are shown in logarithms and unit expenditure values have been normalised to enable comparisons to be made between rates of change in RUOE.

Chart A3.1: ROUE trend for EME (East Midlands)



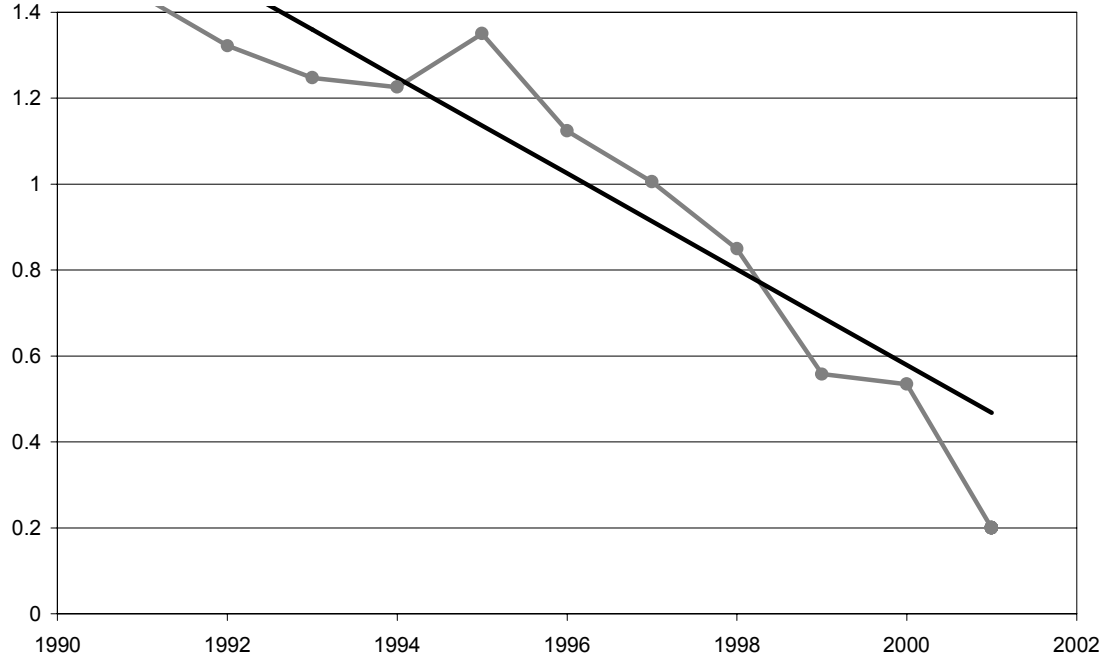
CAGR 4.8 per cent; trend 1.6 per cent.

Chart A3.2: ROUE trend for EPN (Eastern)



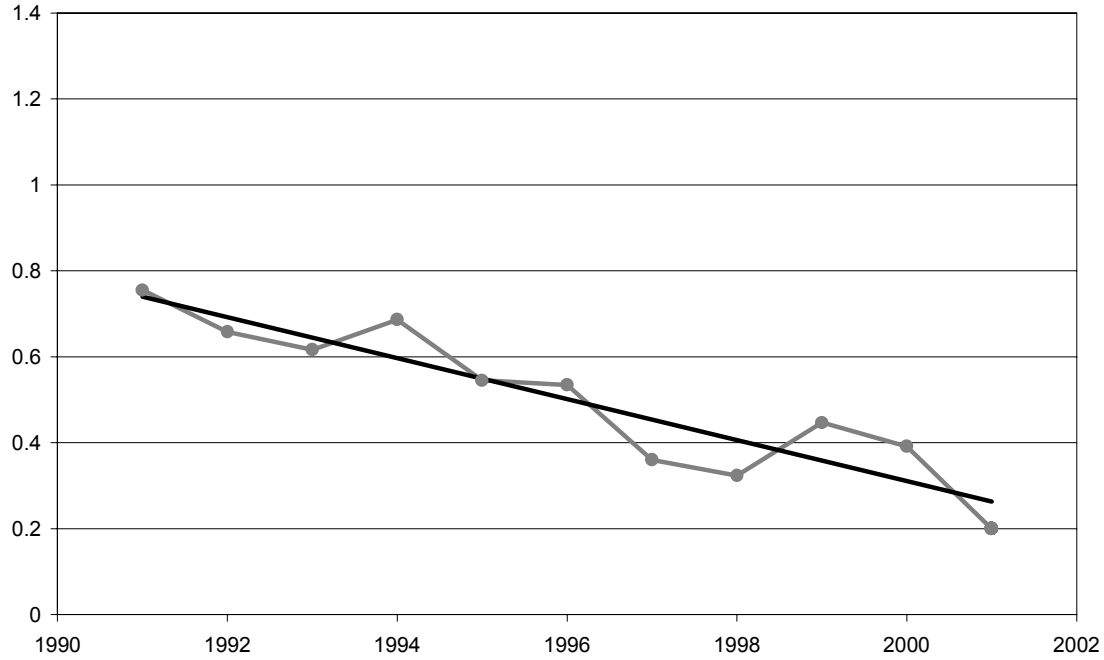
CAGR 10.1 per cent; trend 9.3 per cent.

Chart A3.3: RUOE trend for LPN (London)



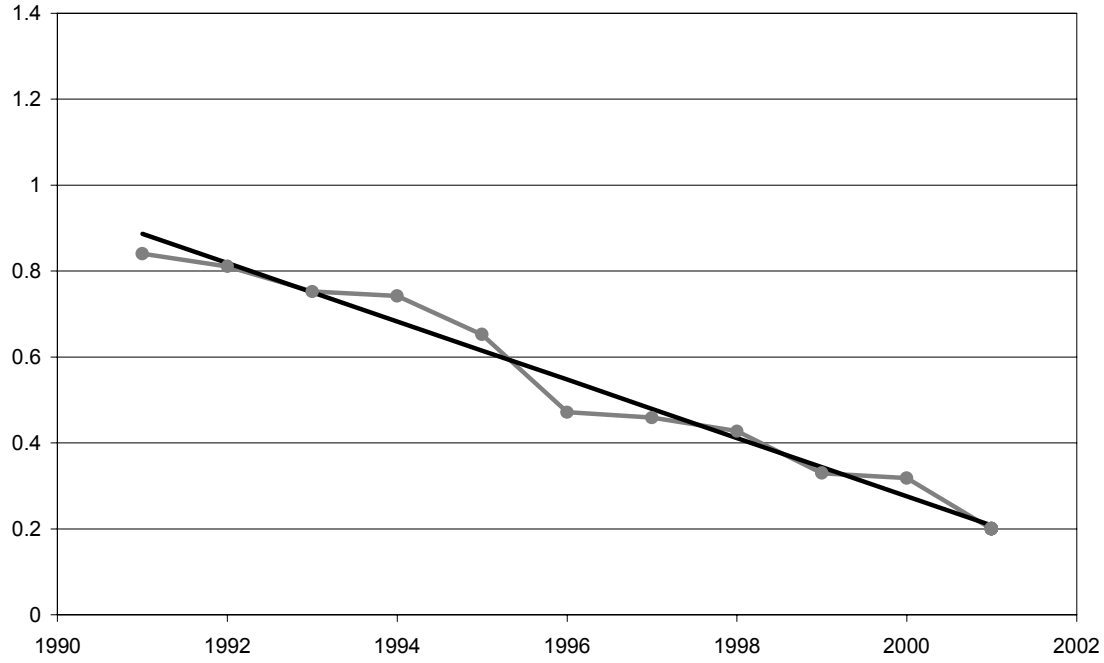
CAGR 11.6 per cent; trend 10.5 per cent.

Chart A3.4: ROUE trend for Manweb



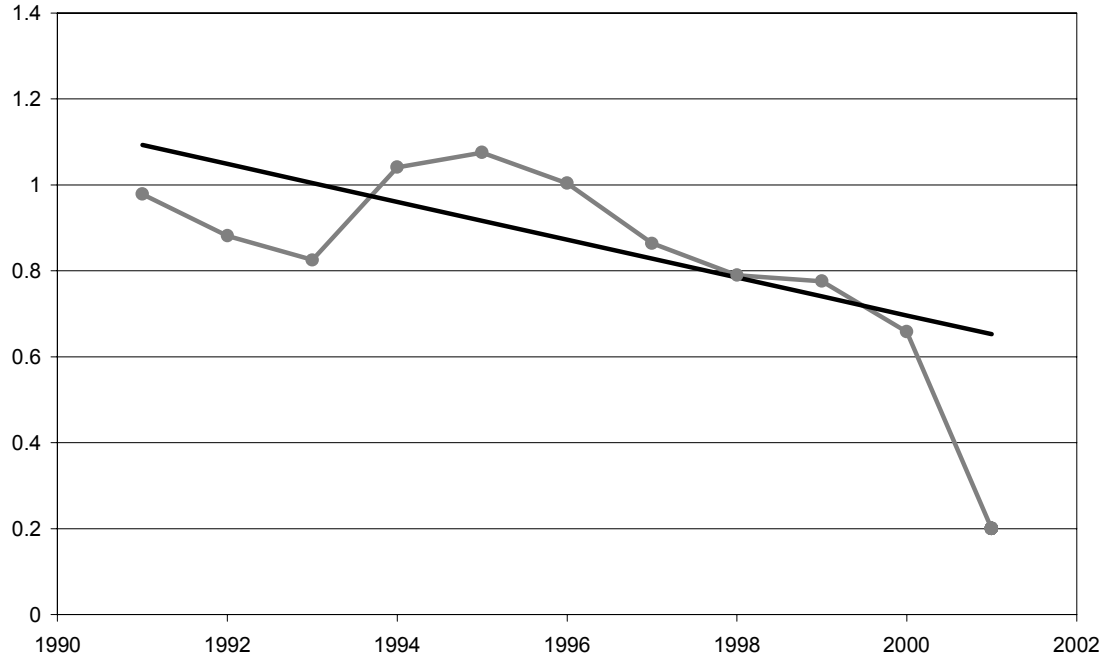
CAGR 5.4 per cent; trend 4.6 per cent.

Chart A3.5: RUOE trend for MEB (Midland/Aquila)



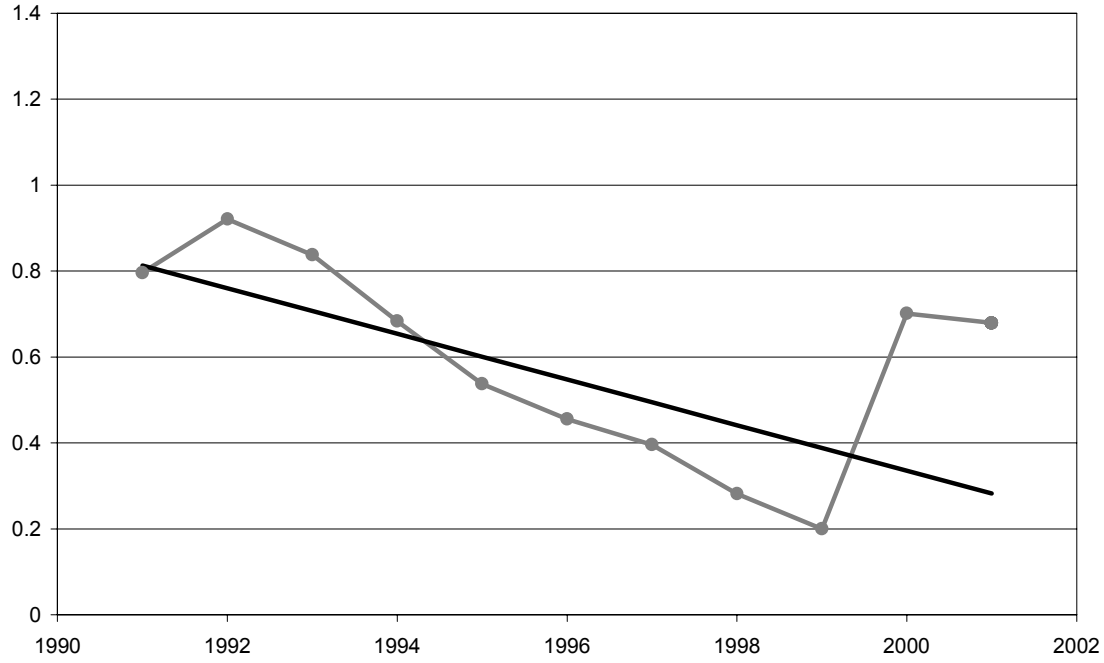
CAGR 6.2 per cent; trend 6.6 per cent.

Chart A3.6: ROUE trend for NEDL (Northern)



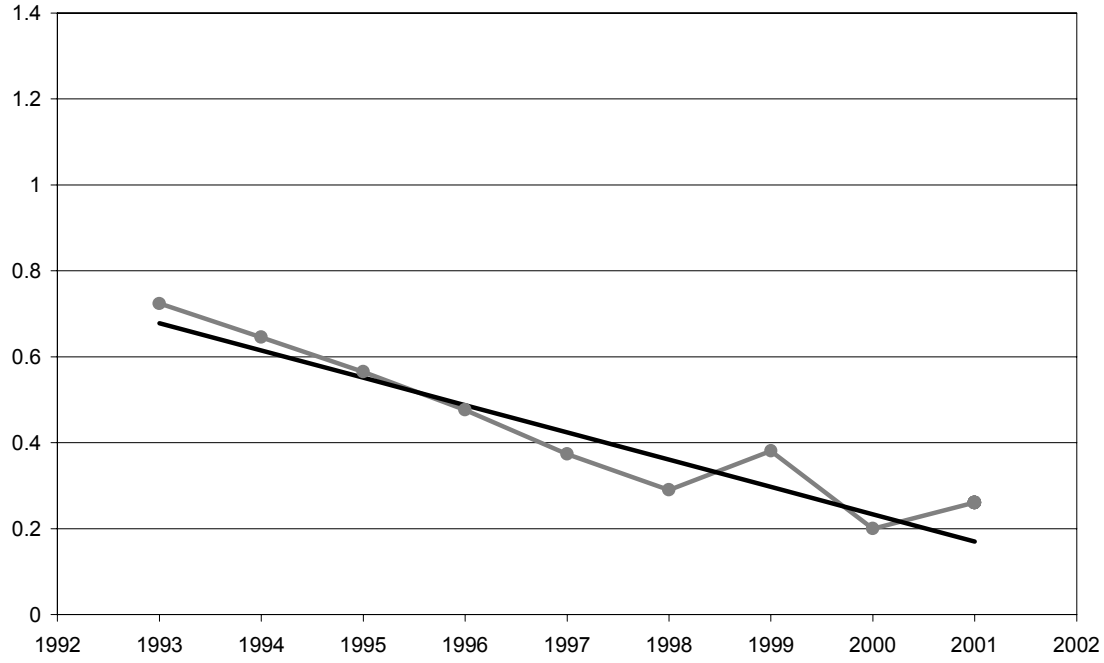
CAGR 7.5 per cent; trend 4.3 per cent.

Chart A3.7: RUOE trend for NGC



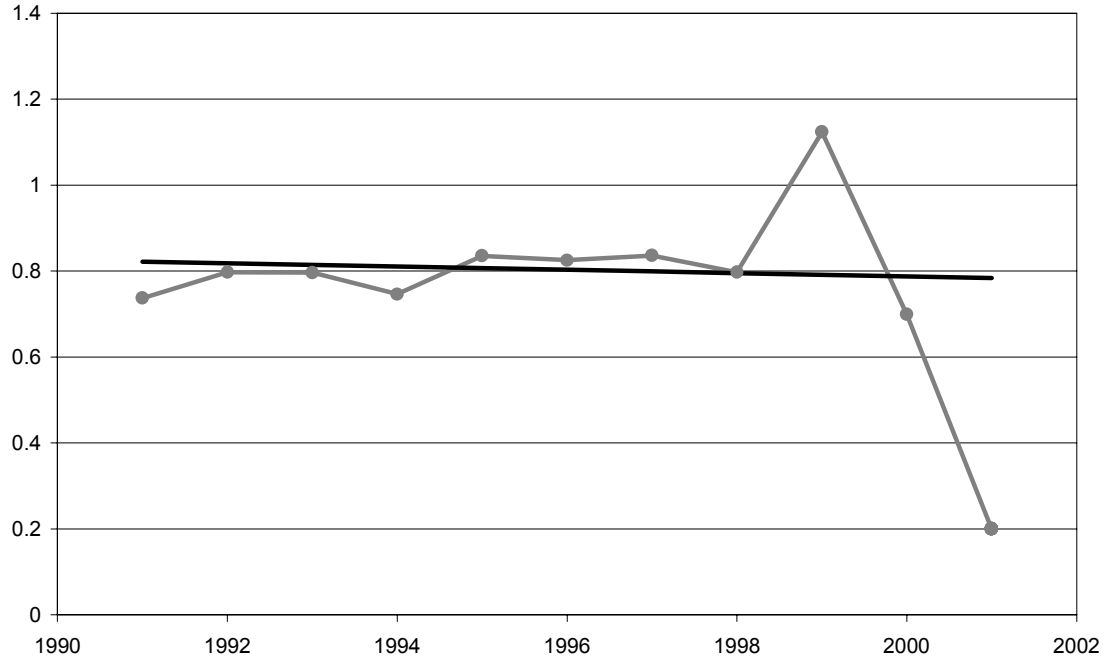
CAGR 1.2 per cent; trend 5.2 per cent.

Chart A3.8: RUOE trend for NIE



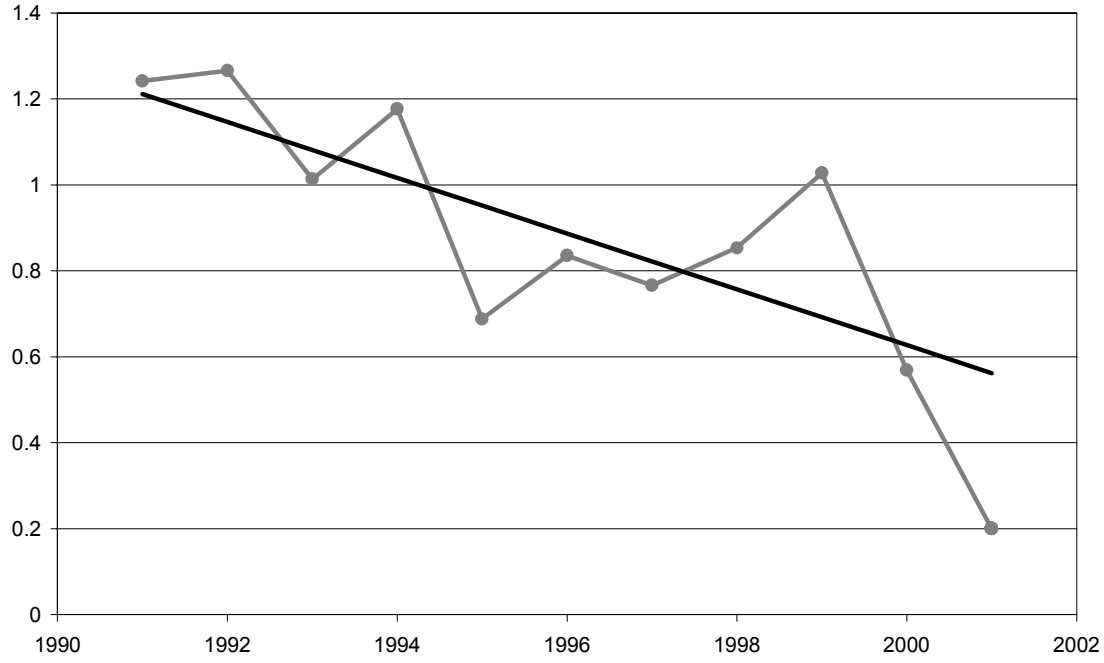
CAGR 5.6 per cent; trend 6.2 per cent.

Chart A3.9: ROUE trend for SHD (Hydro-Electric Distribution)



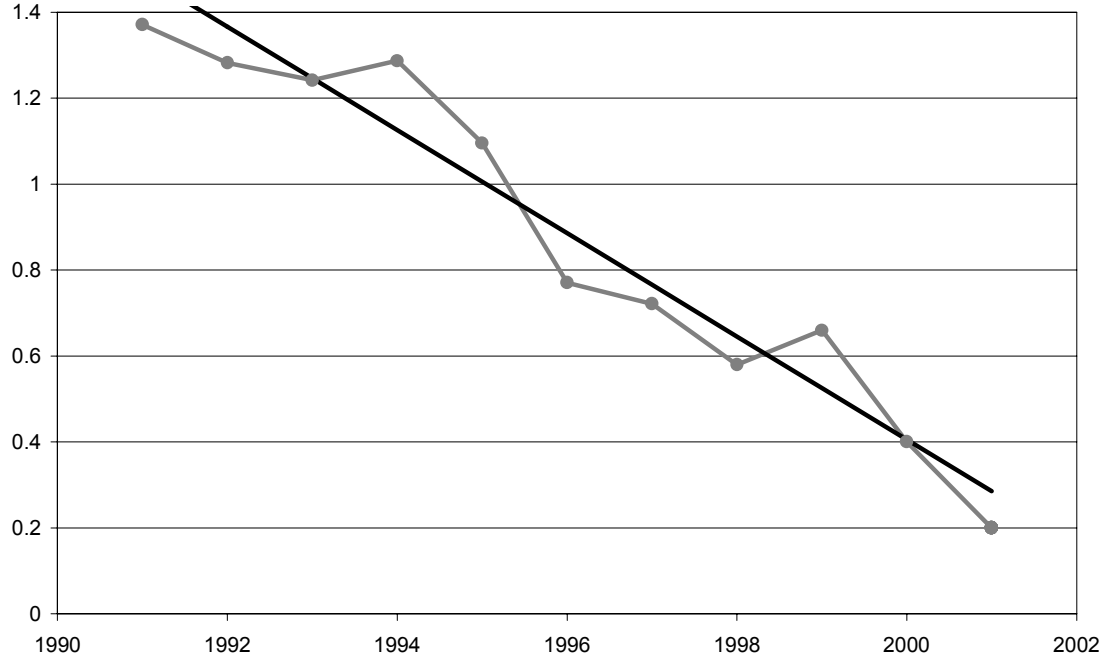
CAGR 5.2 per cent; trend 0.4 per cent.

Chart A3.10: RUOE trend for SHT (Hydro-Electric Transmission)



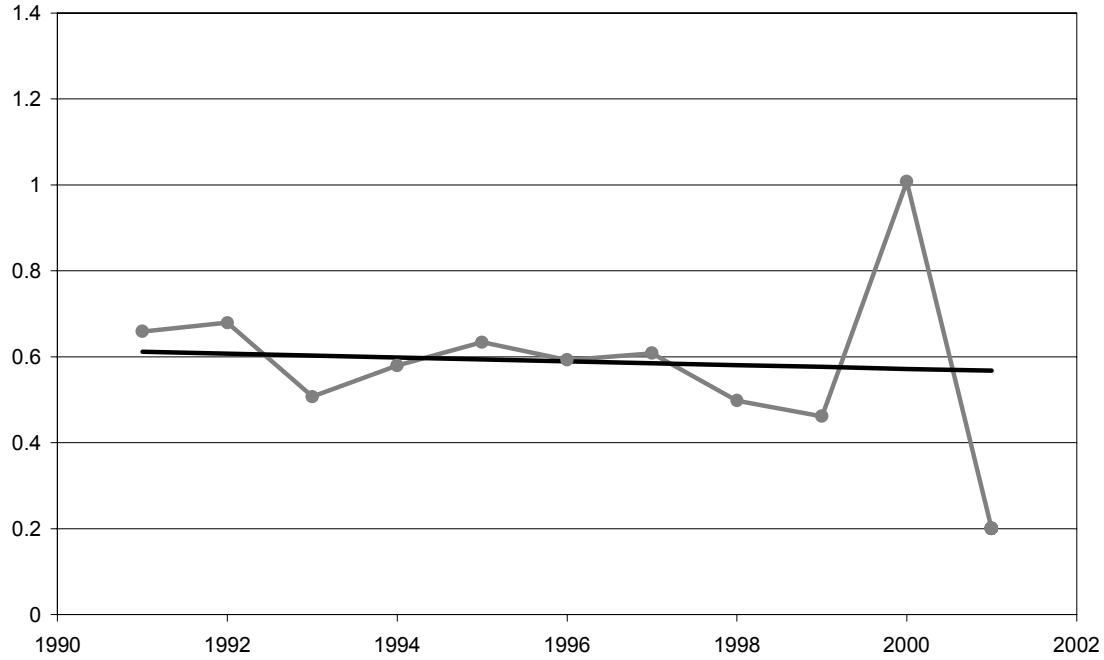
CAGR 9.9 per cent; trend 6.3 per cent.

Chart A3.11: RUOE trend for Southern Electric



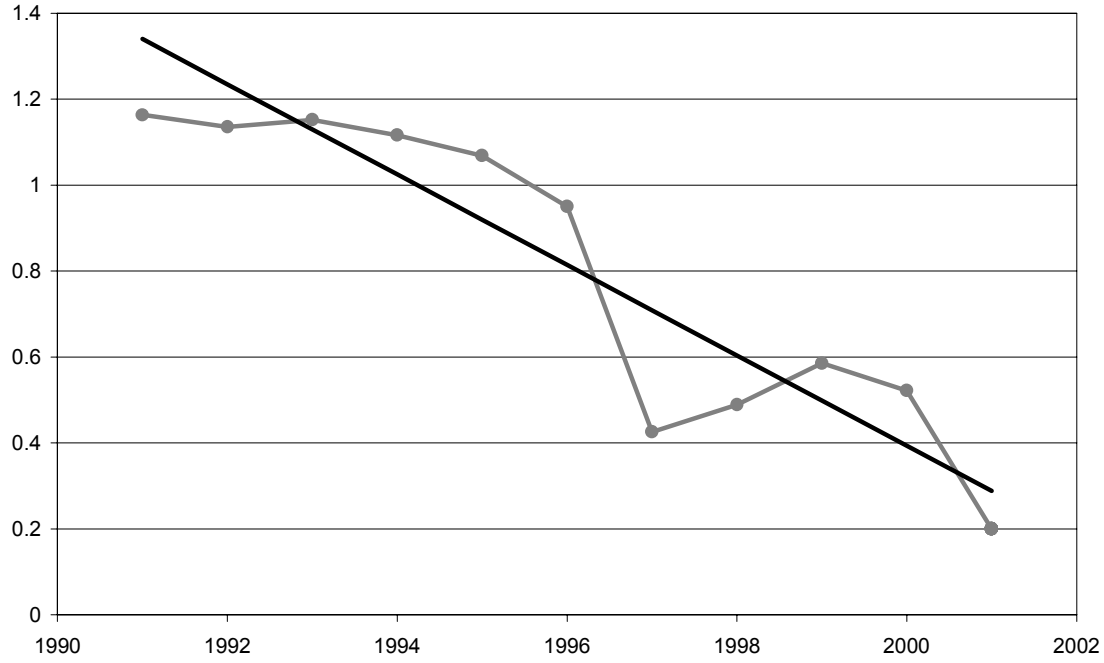
CAGR 11.1 per cent; trend 11.3 per cent.

Chart A3.12: RUOE trend for SP Distribution



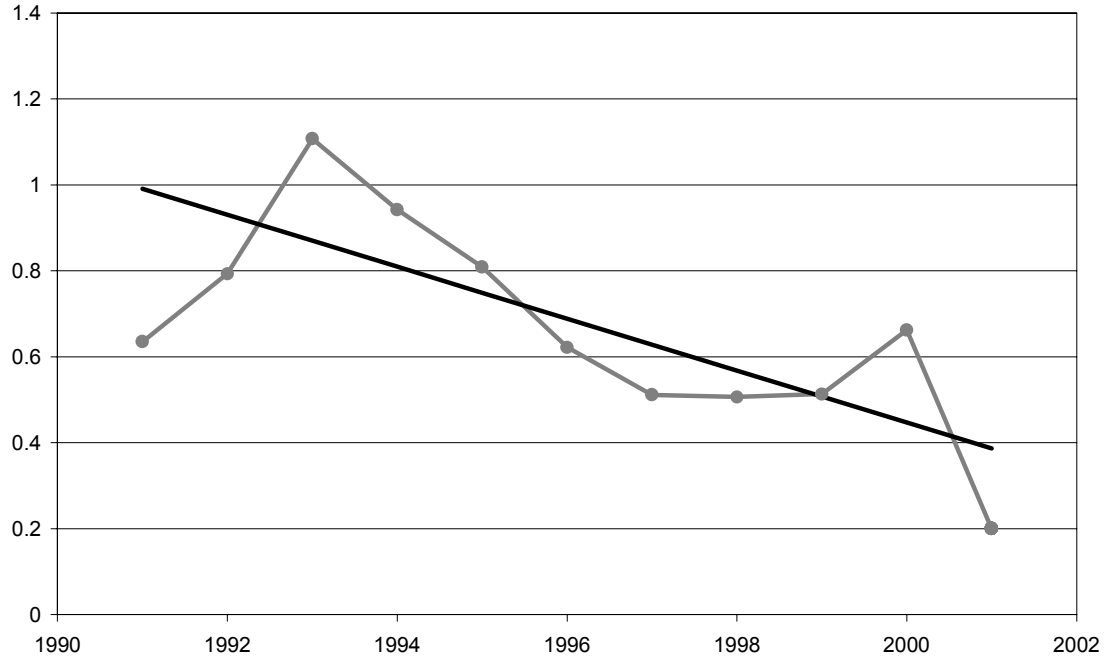
CAGR 4.5 per cent; trend 0.4 per cent.

Chart A3.13: RUOE trend for SPN (SEEBOARD)



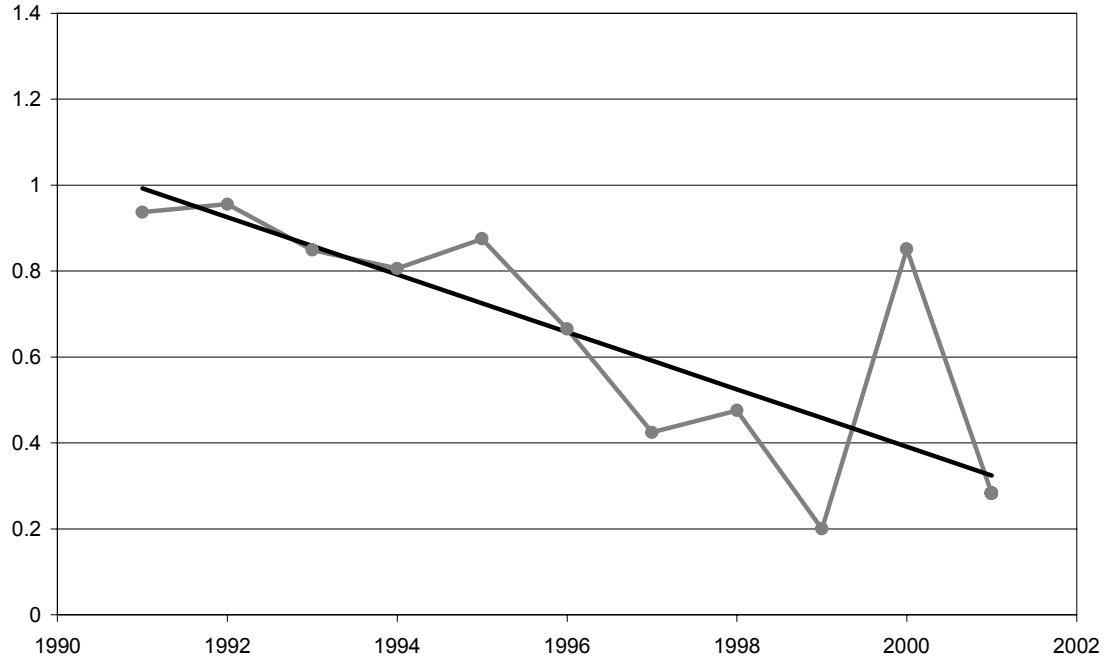
CAGR 9.2 per cent; trend 10.0 per cent.

Chart A3.14: ROUE trend for SP Transmission



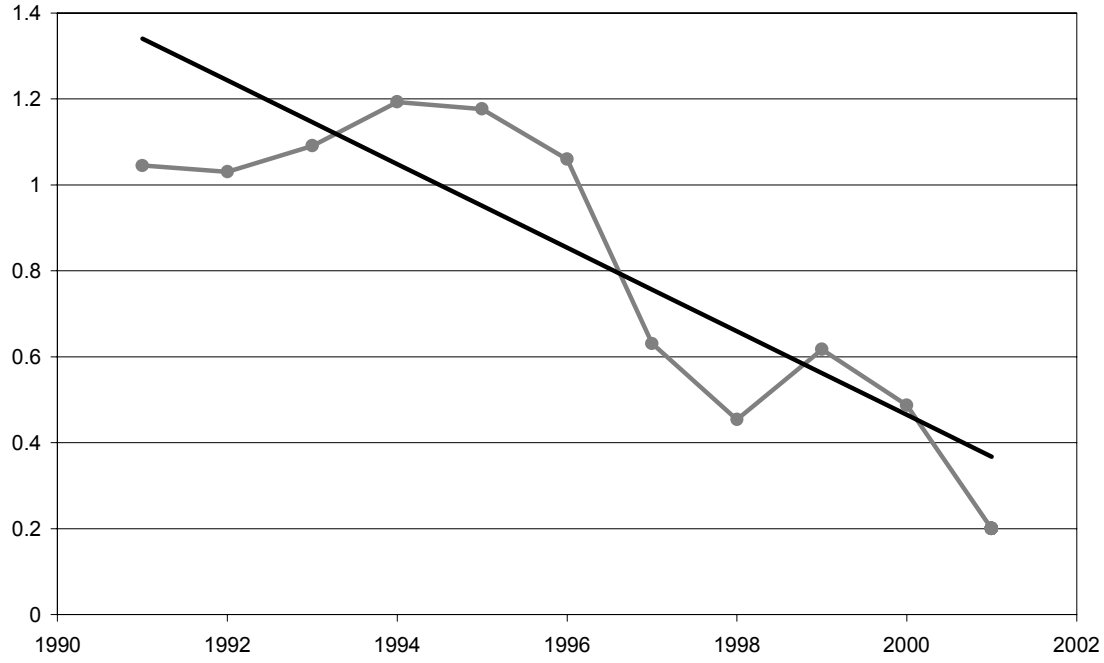
CAGR 4.3 per cent; trend 5.9 per cent.

Chart A3.15: RUOE trend for SWALEC (WPD)



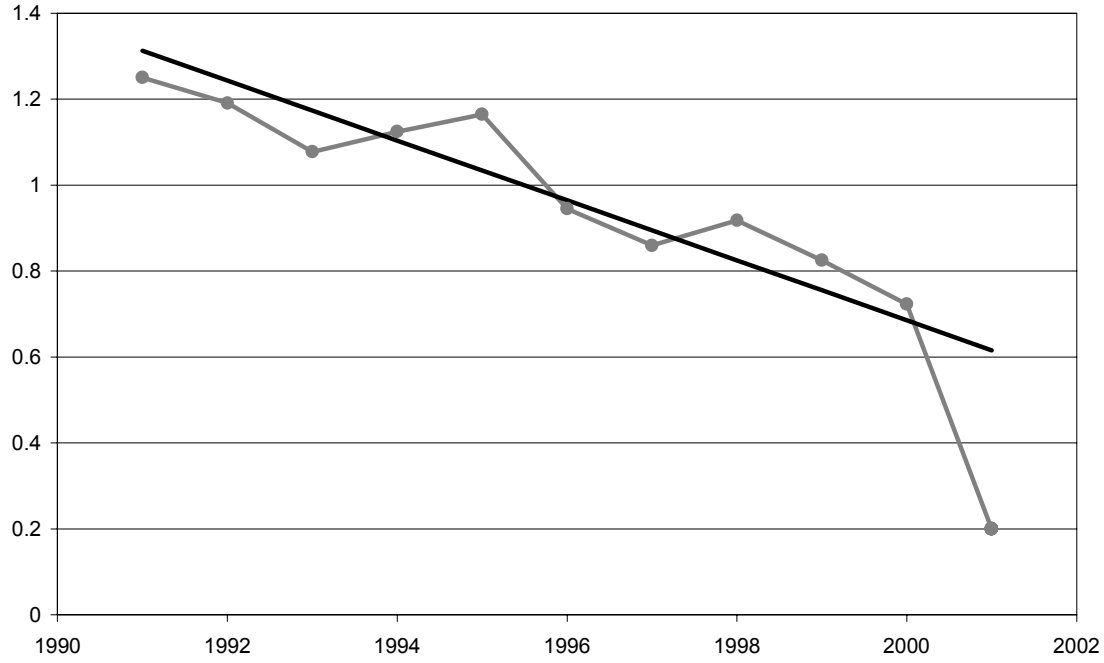
CAGR 6.3 per cent; trend 6.5 per cent.

Chart A3.16: RUOE trend for SWEB (WPD)



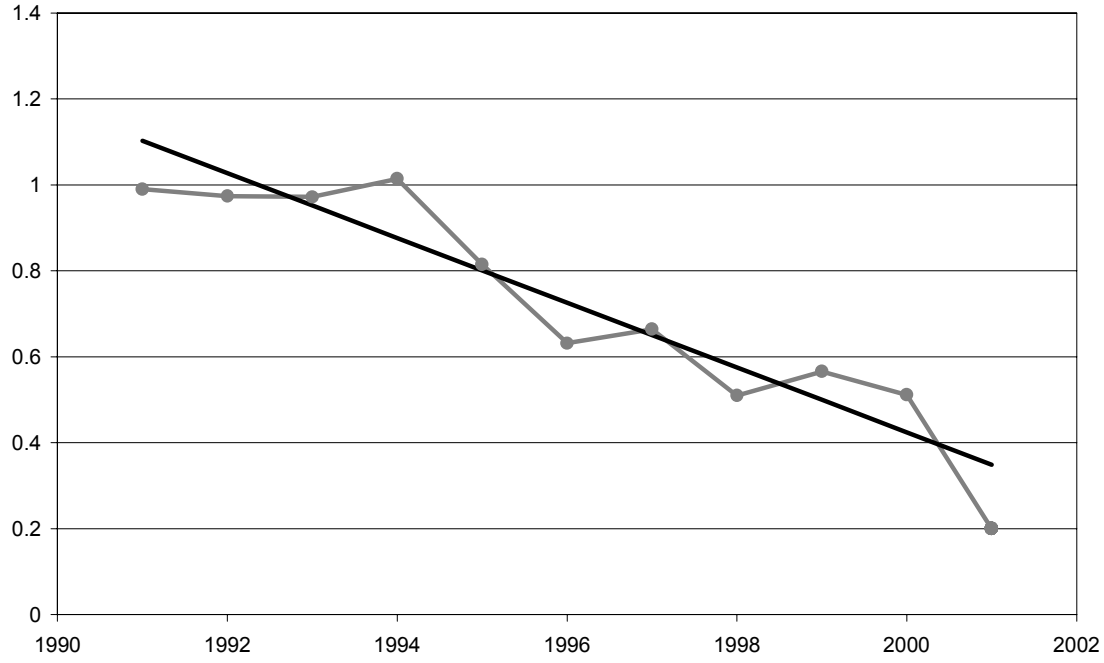
CAGR 8.1 per cent; trend 9.3 per cent.

Chart A3.17: ROUE trend for UUE (Norweb)



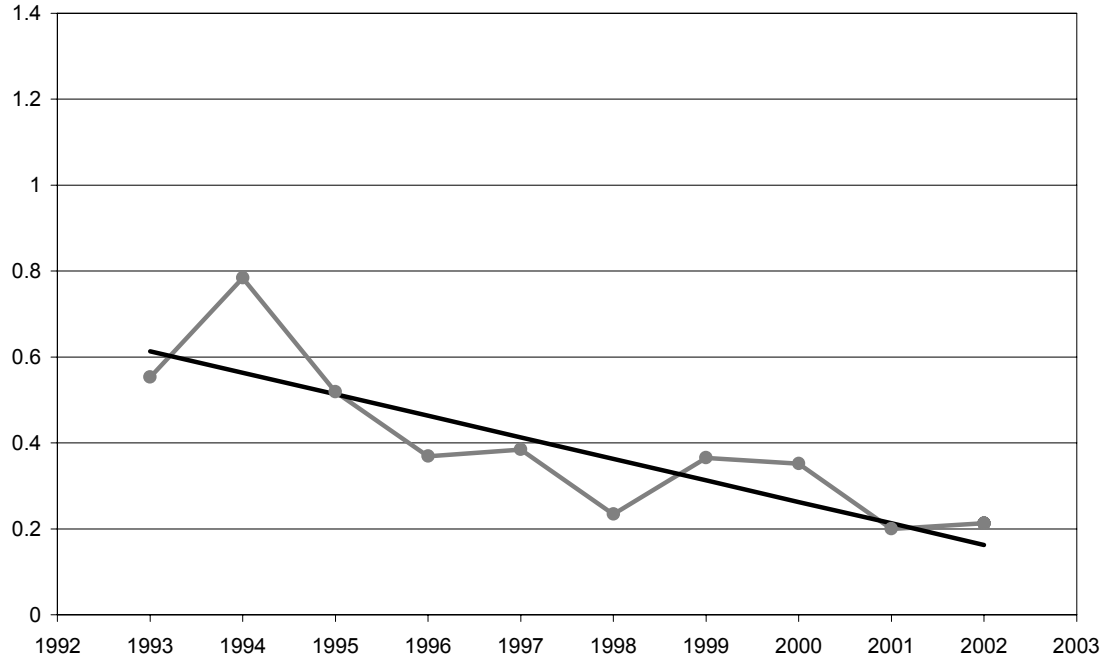
CAGR 10.0 per cent; trend 6.7 per cent.

Chart A3.18: RUOE trend for YEDL (Yorkshire)



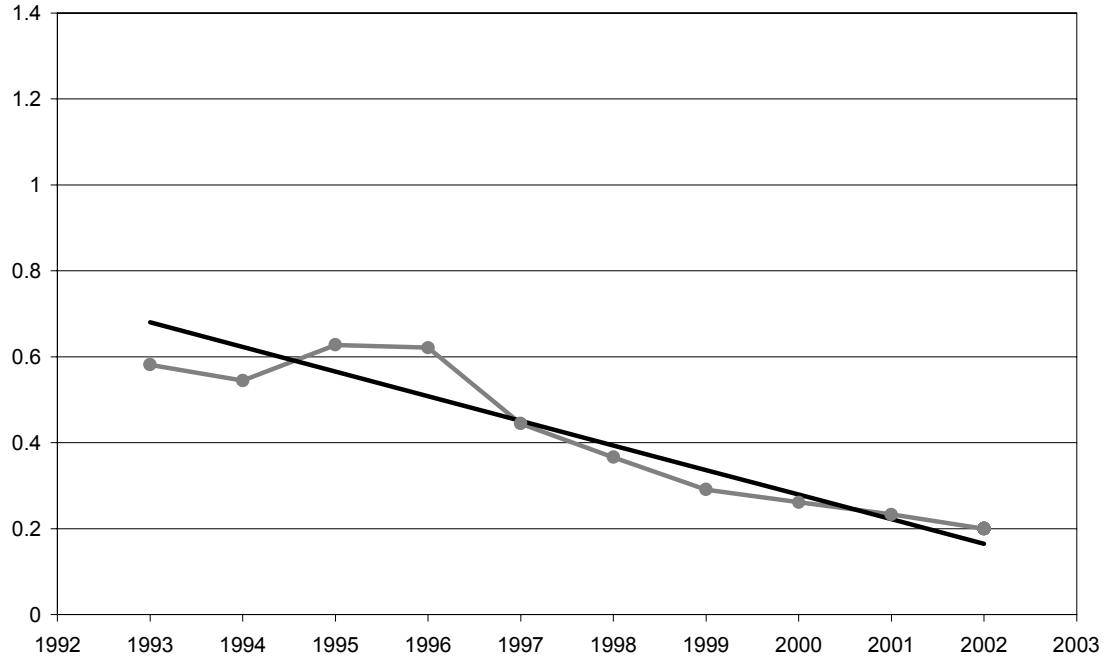
CAGR 7.6 per cent; trend 7.3 per cent.

Chart A3.19: RUOE trend for ANH.w Anglian & Hartlepool (water)



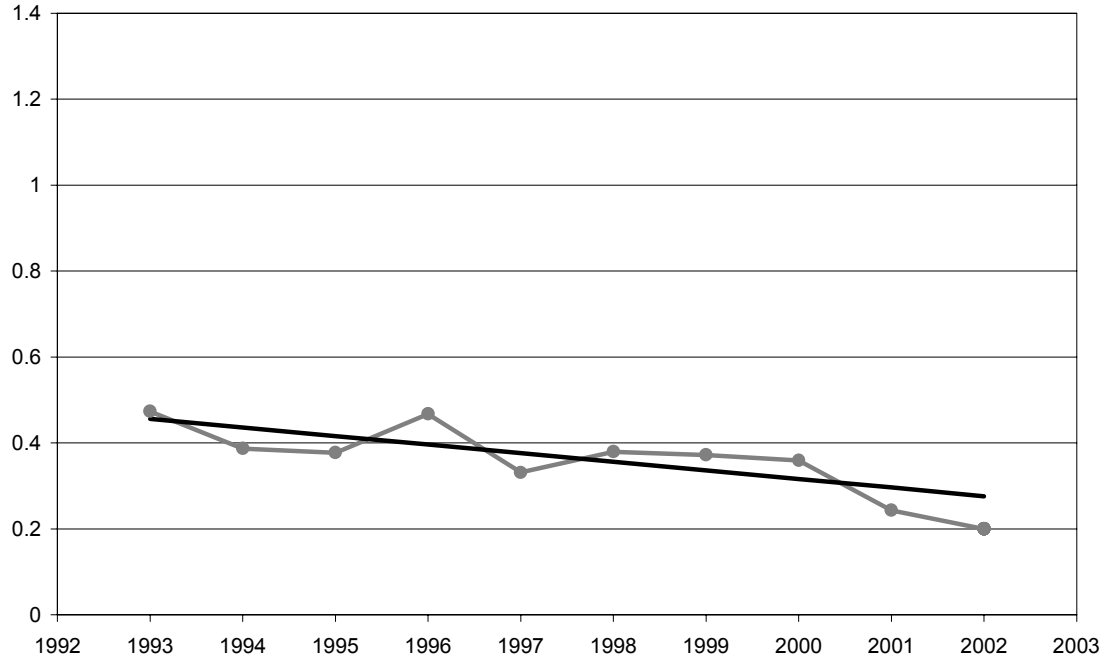
CAGR 3.7 per cent; trend 4.9 per cent.

Chart A3.20: RUOE trend for WSH.w Dwr Cymru (water)



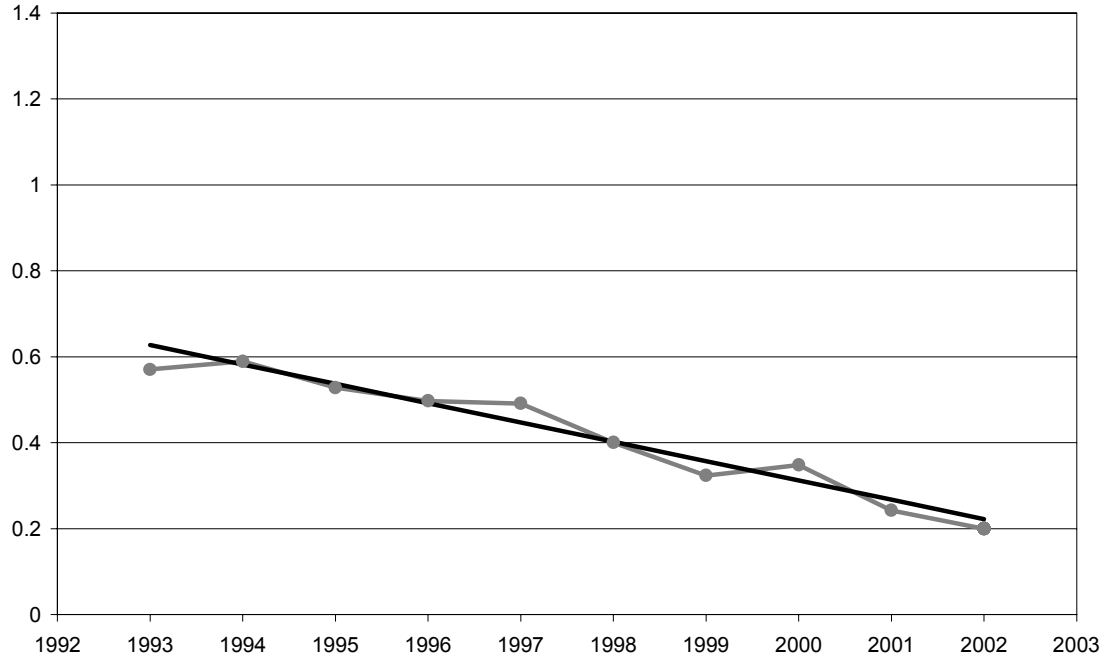
CAGR 4.1 per cent; trend 5.6 per cent.

Chart A3.21: RUOE trend for NWT.w North West (water)



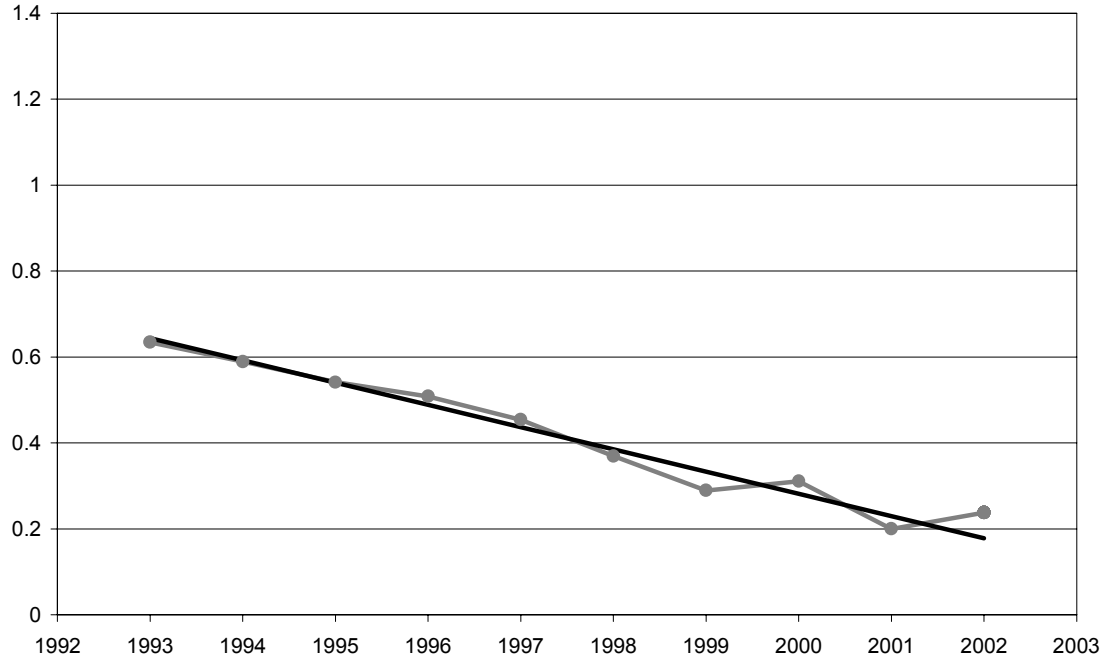
CAGR 3.0 per cent; trend 2.0 per cent.

Chart A3.22: RUOE trend for NES.w Northumbrian (water)



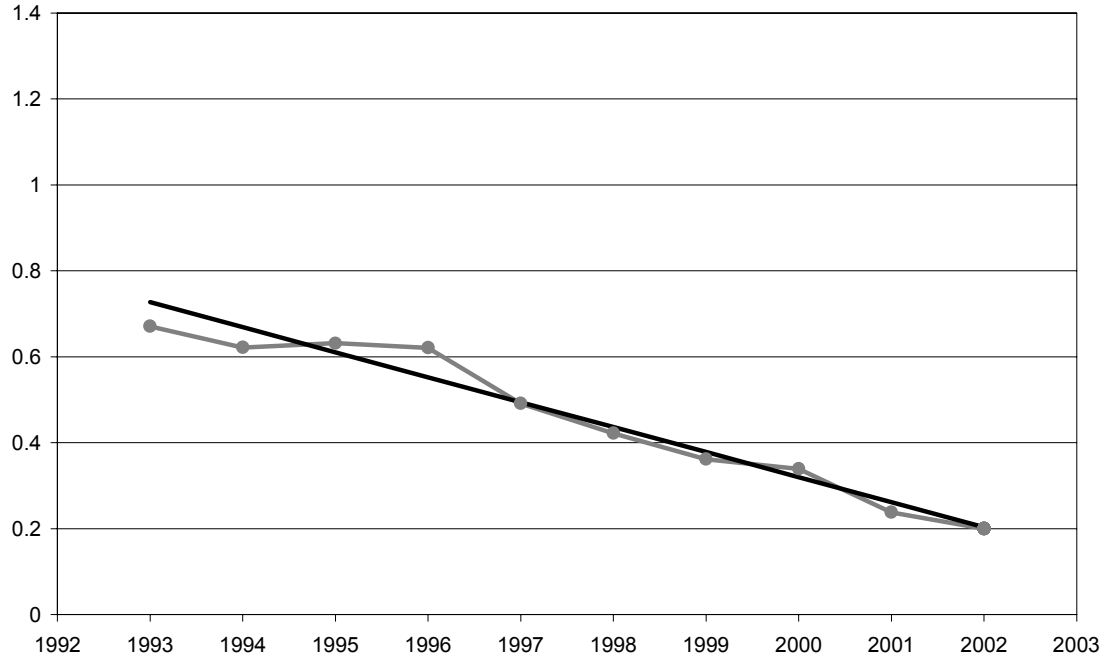
CAGR 4.0 per cent; trend 4.4 per cent.

Chart A3.23: RUOE trend for SVT.w Severn Trent (water)



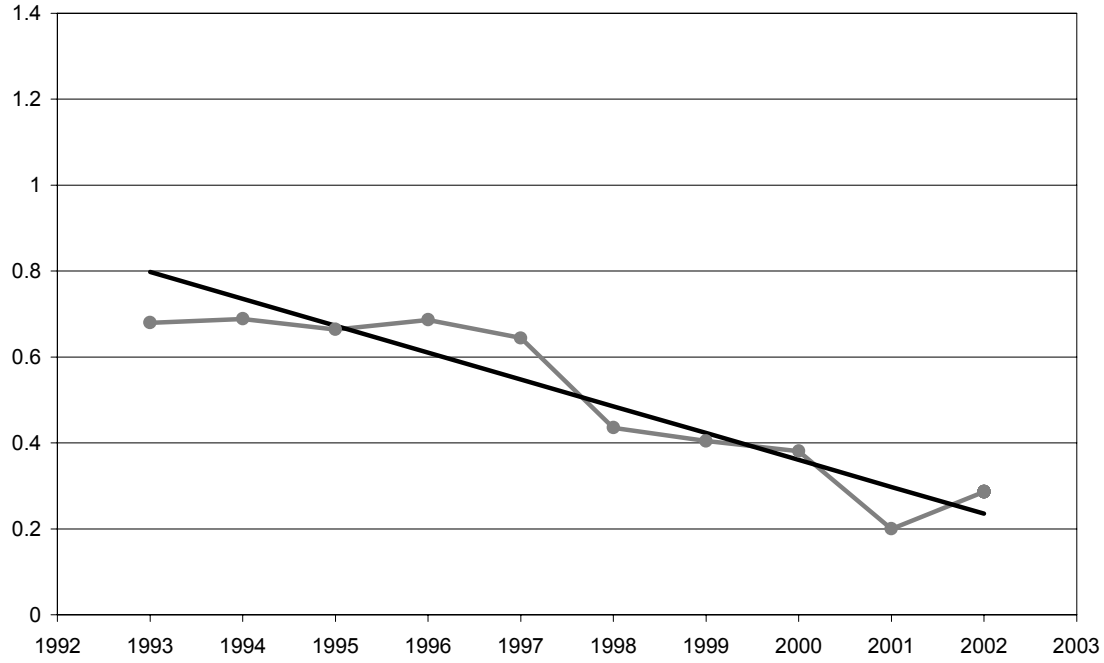
CAGR 4.3 per cent; trend 5.0 per cent.

Chart A3.24: RUOE trend for SWT.w South West (water)



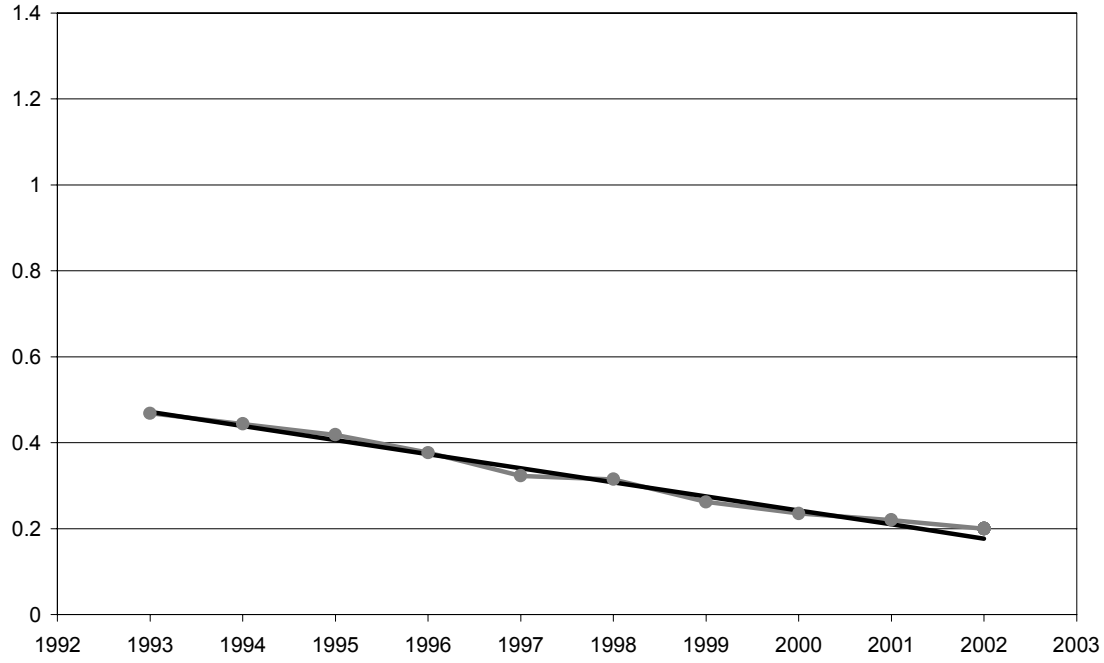
CAGR 5.1 per cent; trend 5.6 per cent.

Chart A3.25: RUOE trend for SRN.w Southern (water)



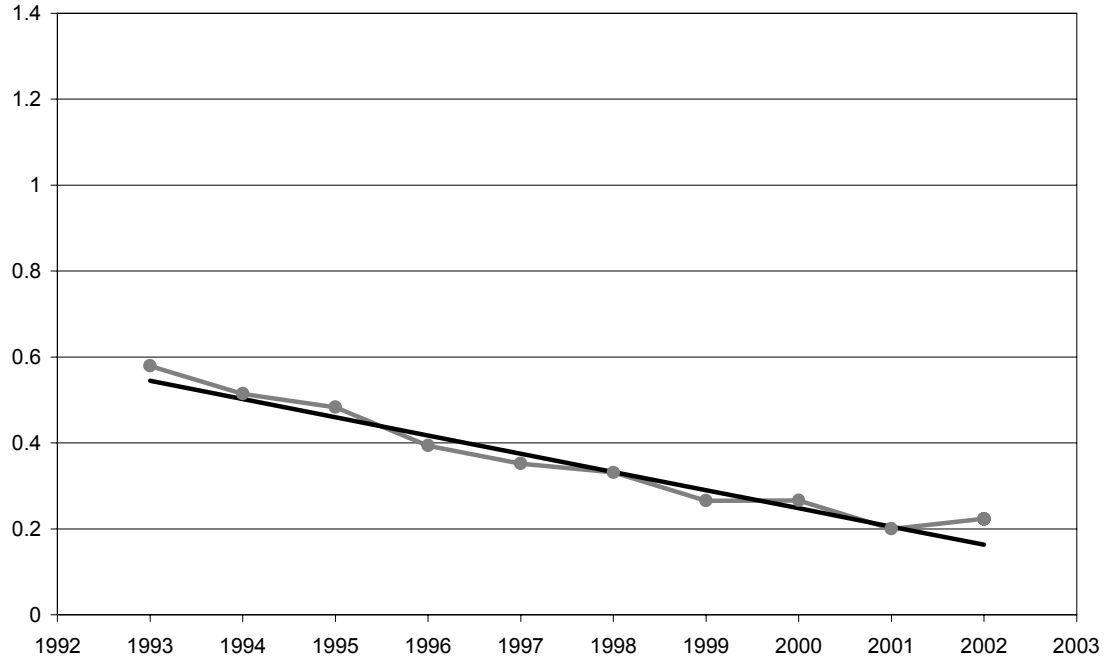
CAGR 4.3 per cent; trend 6.1 per cent.

Chart A3.26: RUOE trend for TMS.w Thames (water)



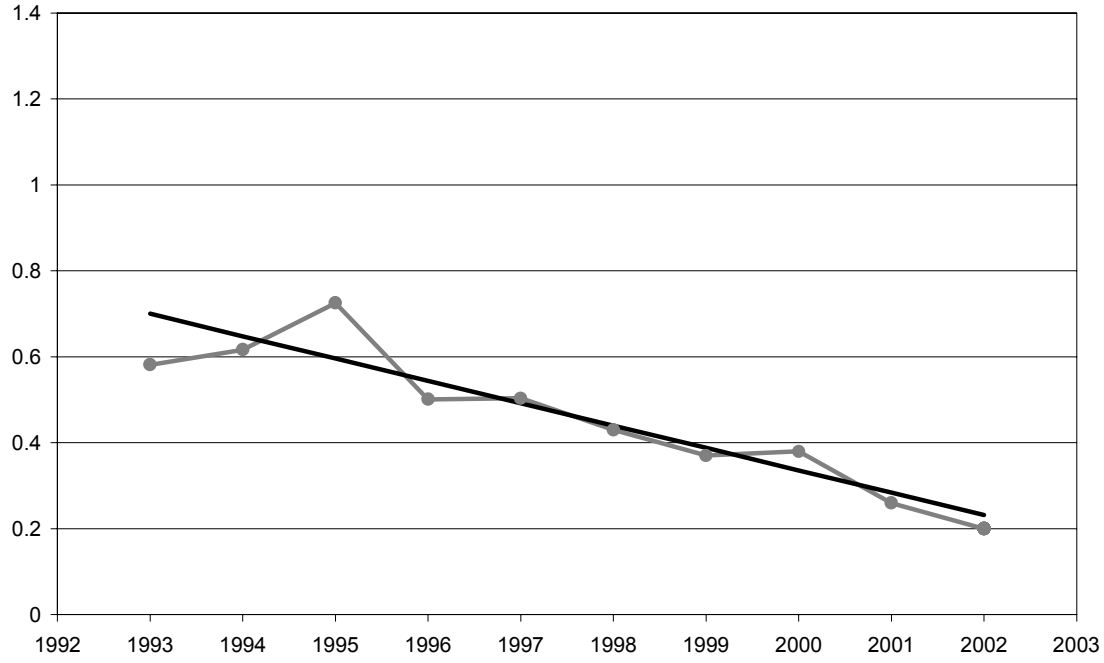
CAGR 2.9 per cent; trend 3.2 per cent.

Chart A3.27: RUOE trend for WSX.w Wessex (water)



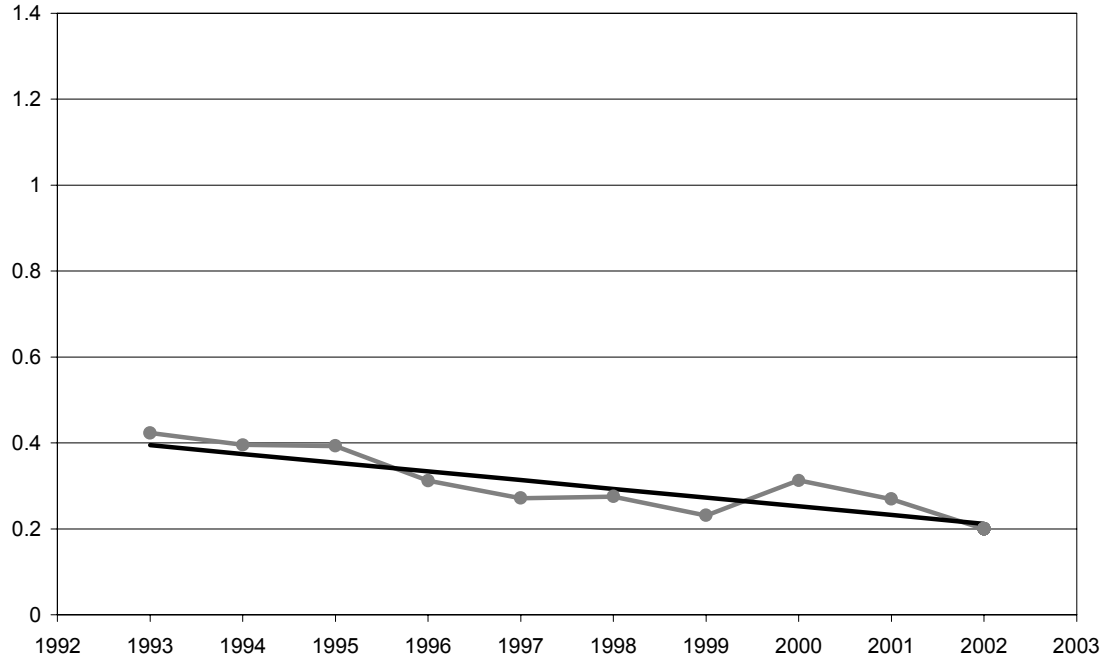
CAGR 3.9 per cent; trend 4.2 per cent.

Chart A3.28: RUOE trend for YKY.w Yorkshire & York (water)



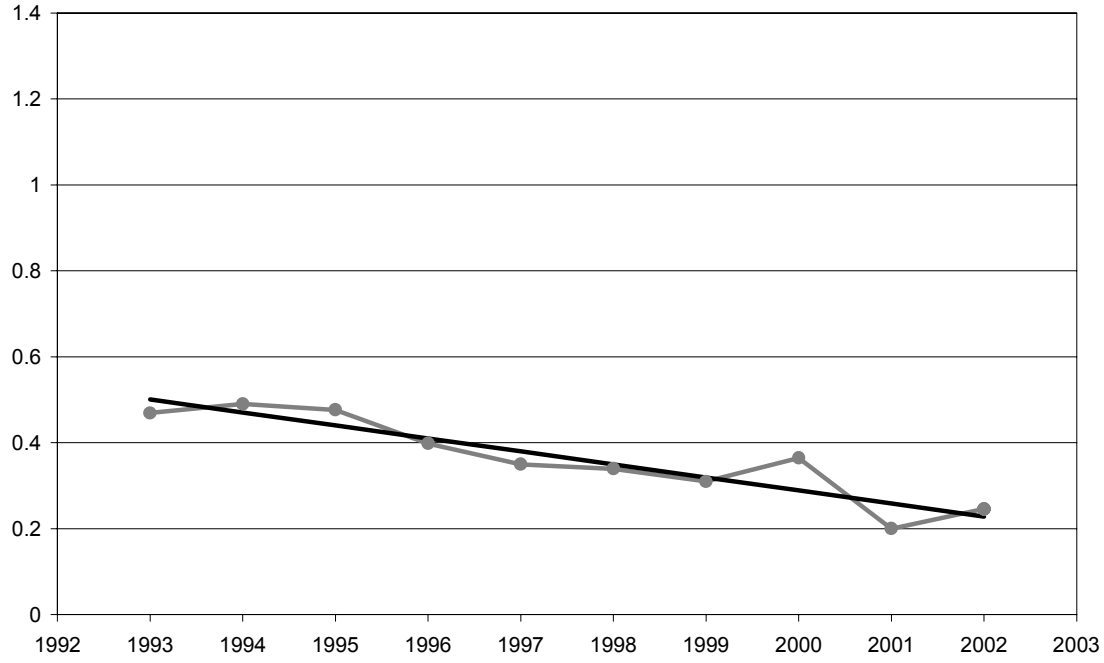
CAGR 4.1 per cent; trend 5.1 per cent.

Chart A3.29: RUOE trend for BWH.w Bournemouth and West Hants (water)



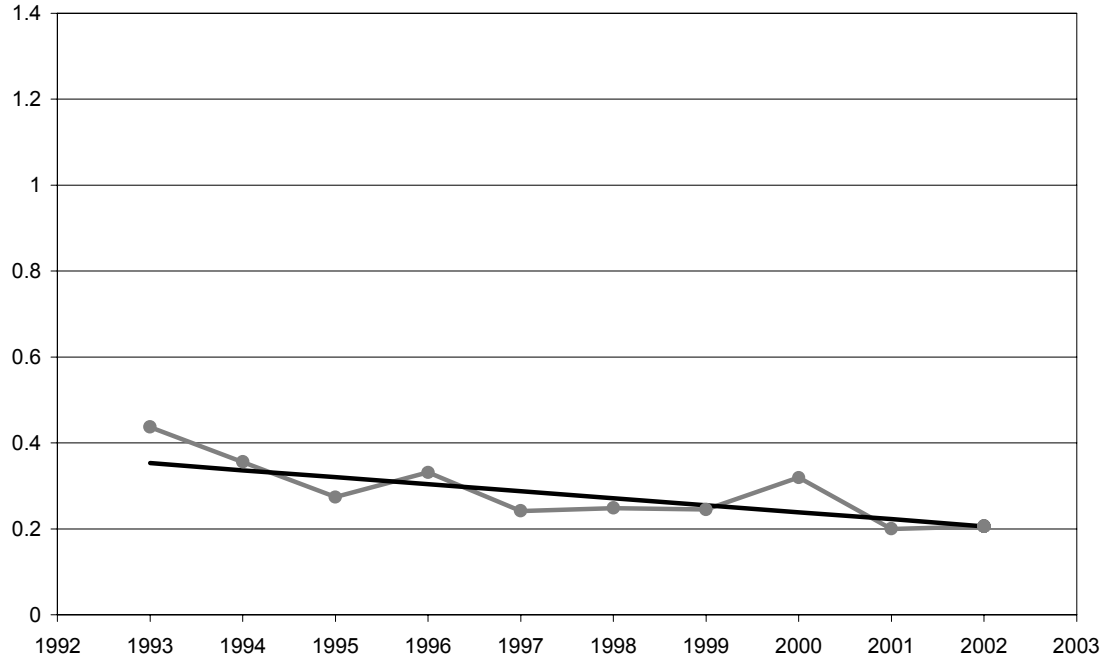
CAGR 2.4 per cent; trend 2.0 per cent.

Chart A3.30: RUOE trend for BRL.w Bristol (water)



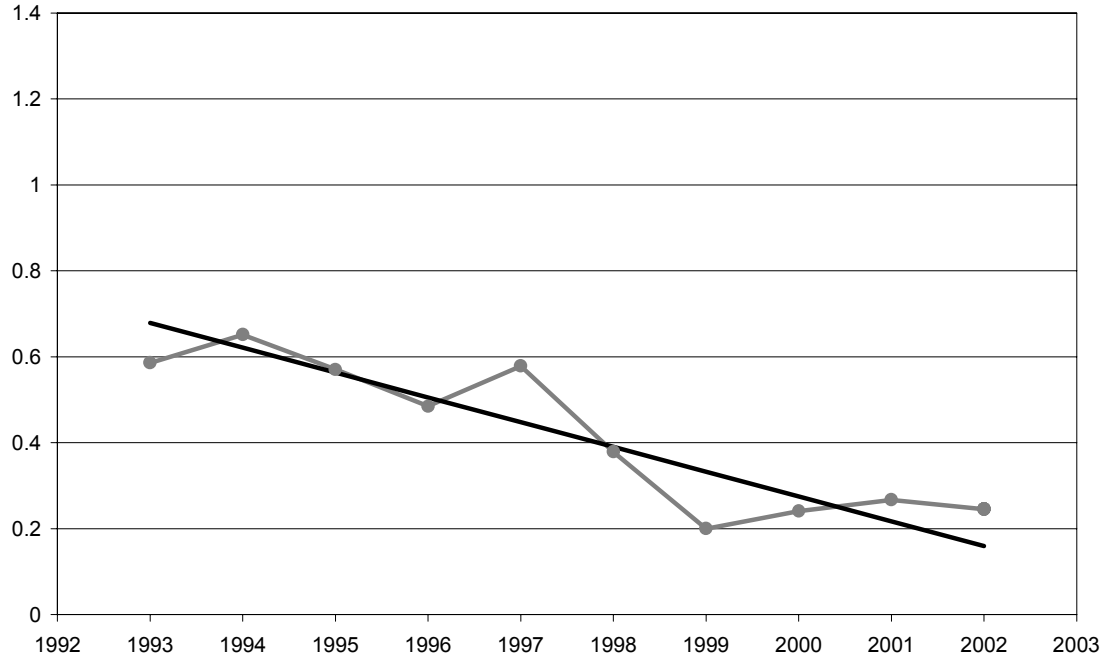
CAGR 2.5 per cent; trend 3.0 per cent.

Chart A3.31: RUOE trend for CAM.w Cambridge (water)



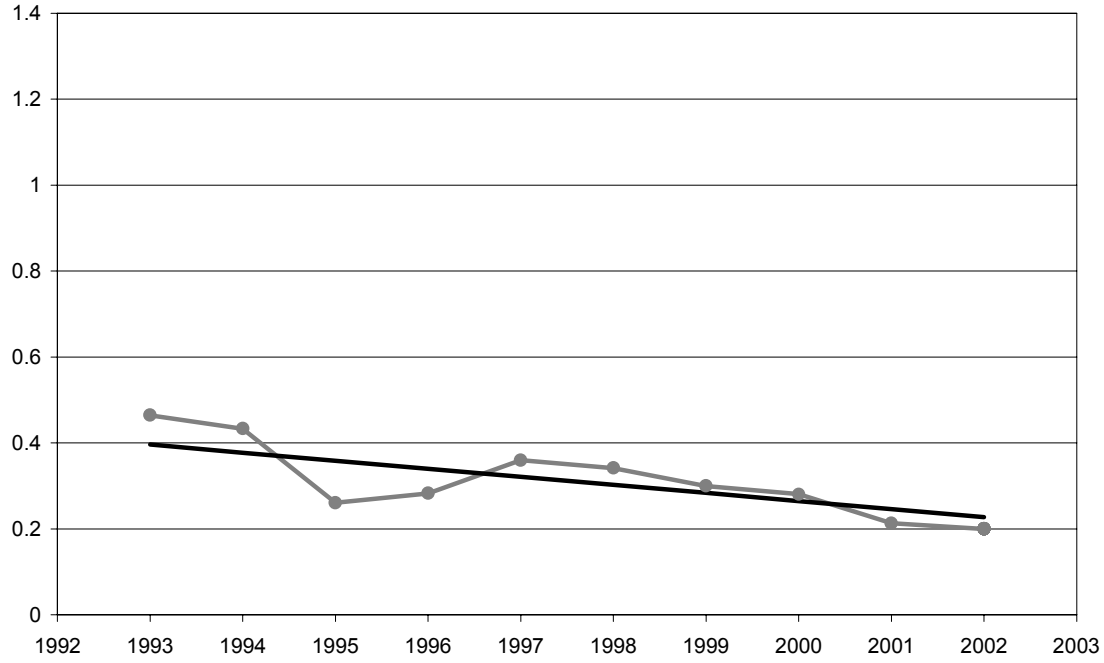
CAGR 2.5 per cent; trend 1.6 per cent.

Chart A3.32: RUOE trend for DVW.w Dee Valley (water)



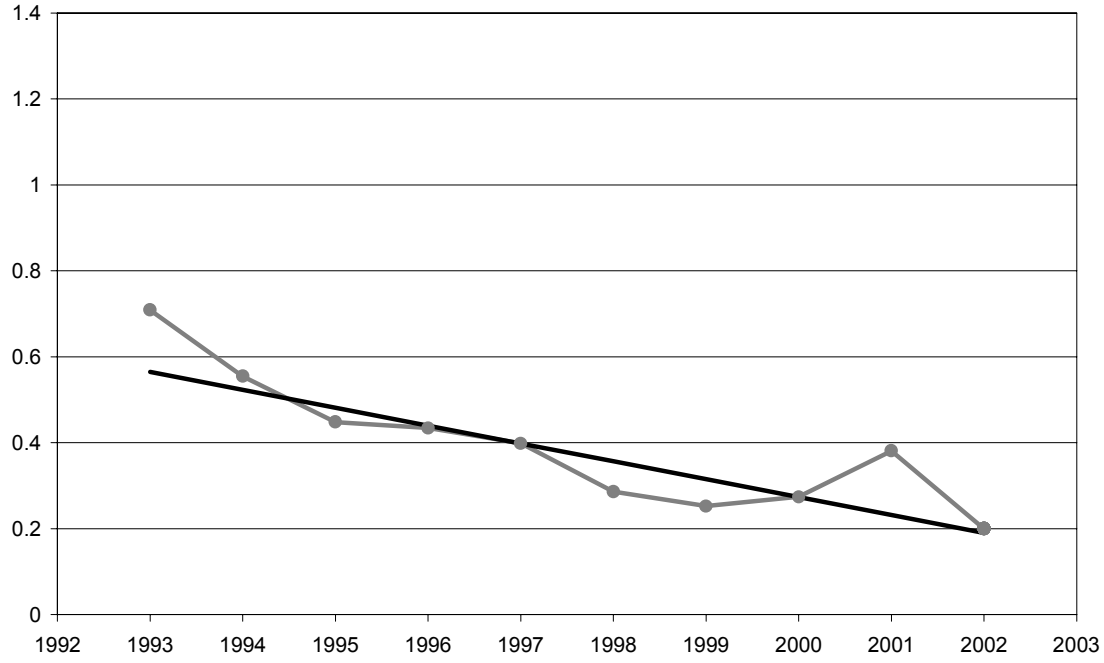
CAGR 3.7 per cent; trend 5.6 per cent.

Chart A3.33: RUOE trend for FLK.w Folkestone (water)



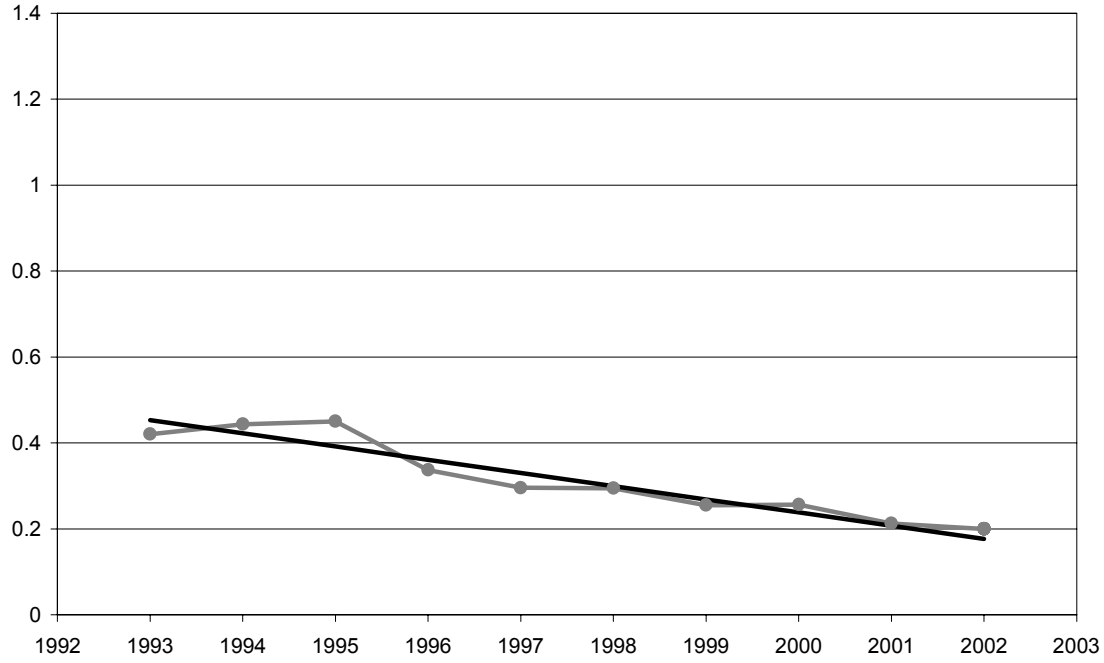
CAGR 2.9 per cent; trend 1.9 per cent.

Chart A3.34: RUOE trend for MKT.w Mid Kent (water)



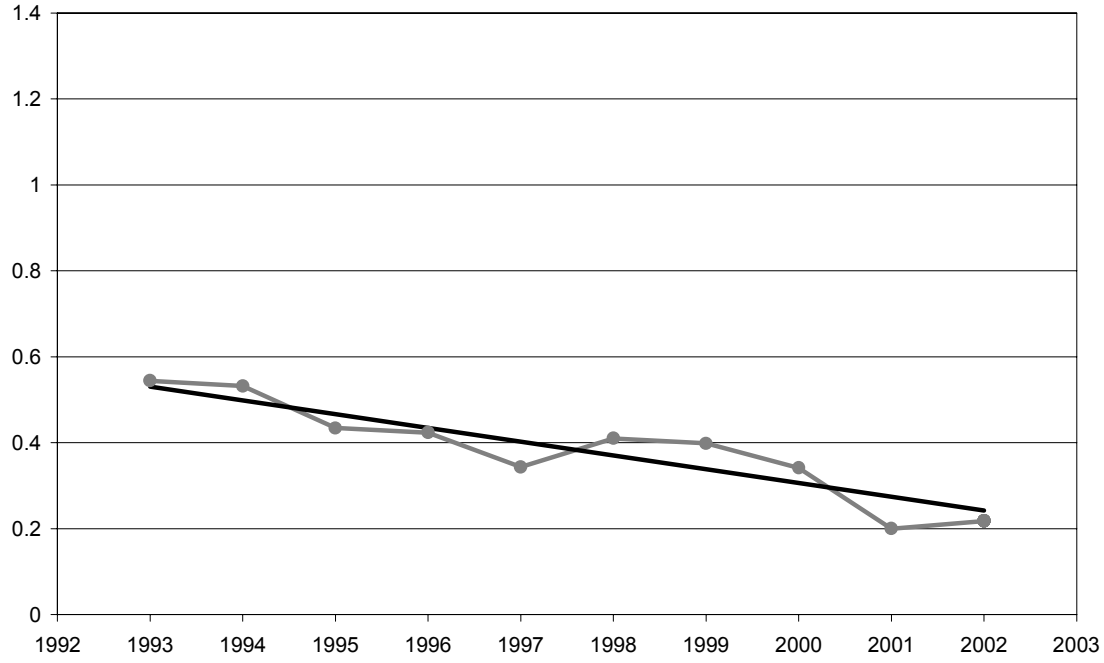
CAGR 5.5 per cent; trend 4.1 per cent.

Chart A3.35: RUOE trend for PRT.w Portsmouth (water)



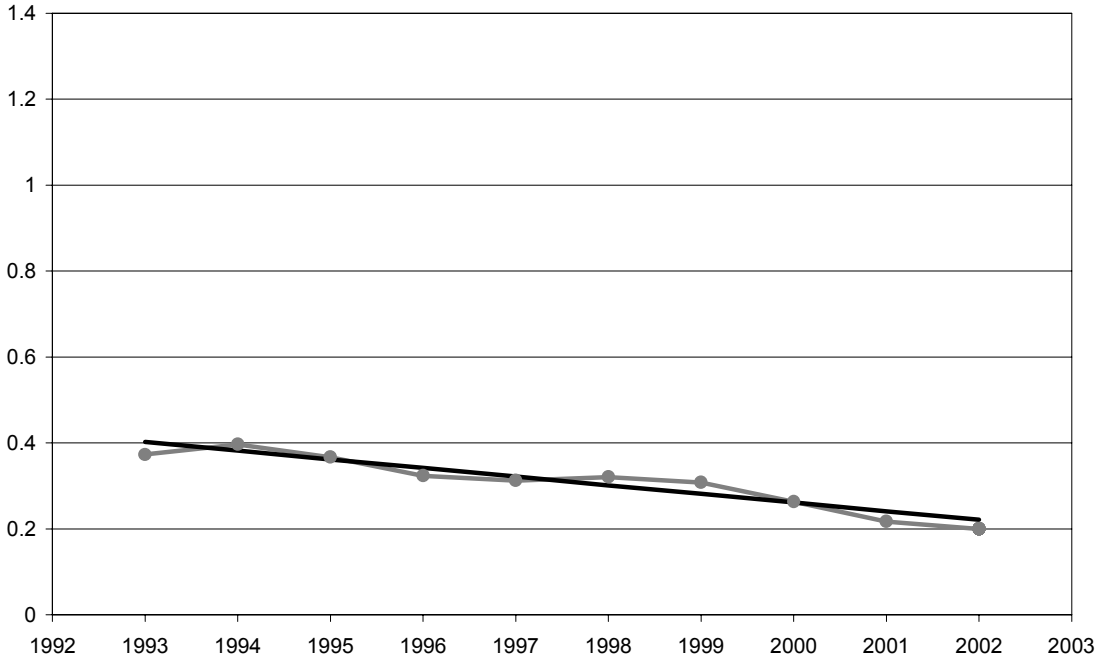
CAGR 2.4 per cent; trend 3.0 per cent.

Chart A3.36: RUOE trend for MSE.w South East (water)



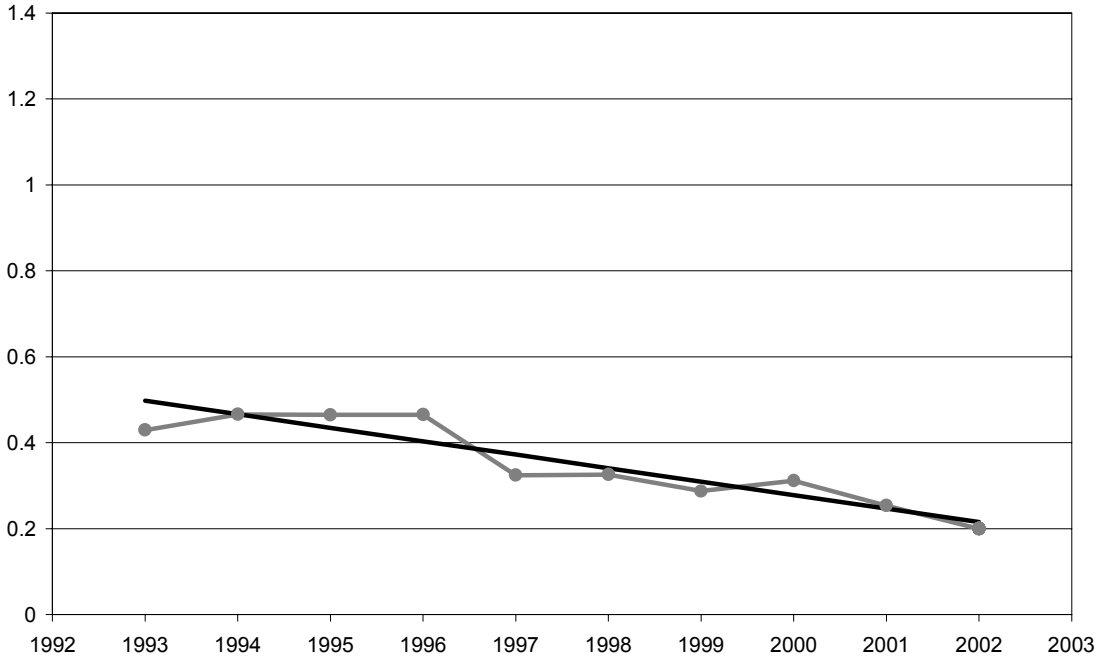
CAGR 3.6 per cent; trend 3.1 per cent.

Chart A3.37: RUOE trend for SST.w South Staffordshire (water)



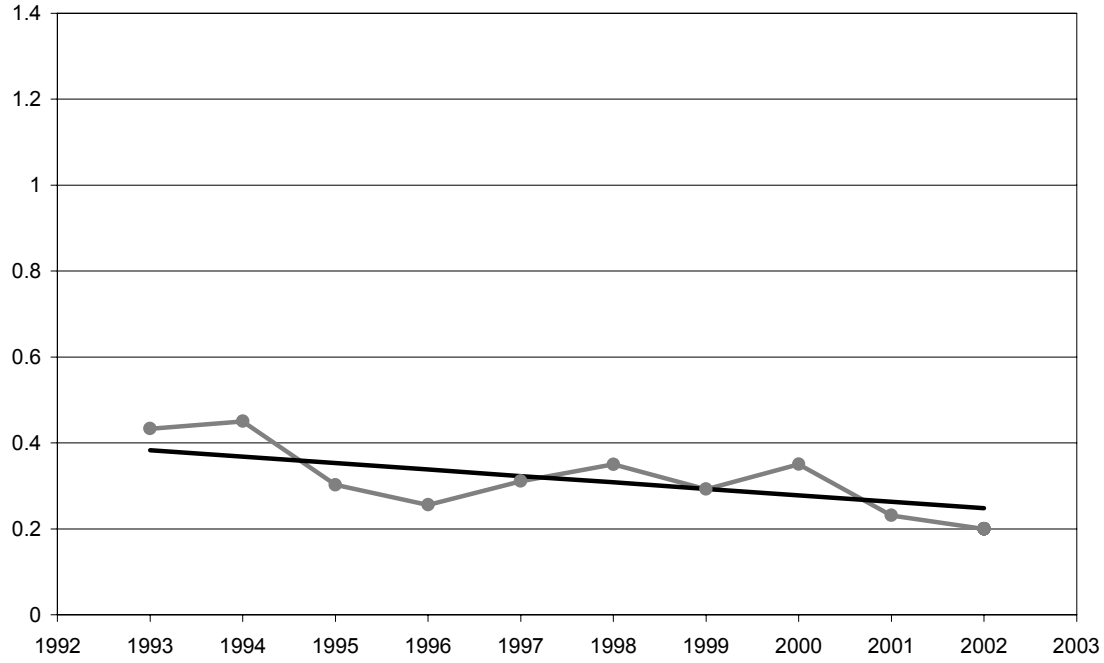
CAGR 1.9 per cent; trend 2.0 per cent.

Chart A3.38: RUOE trend for SES.w Sutton & East Surrey (water)



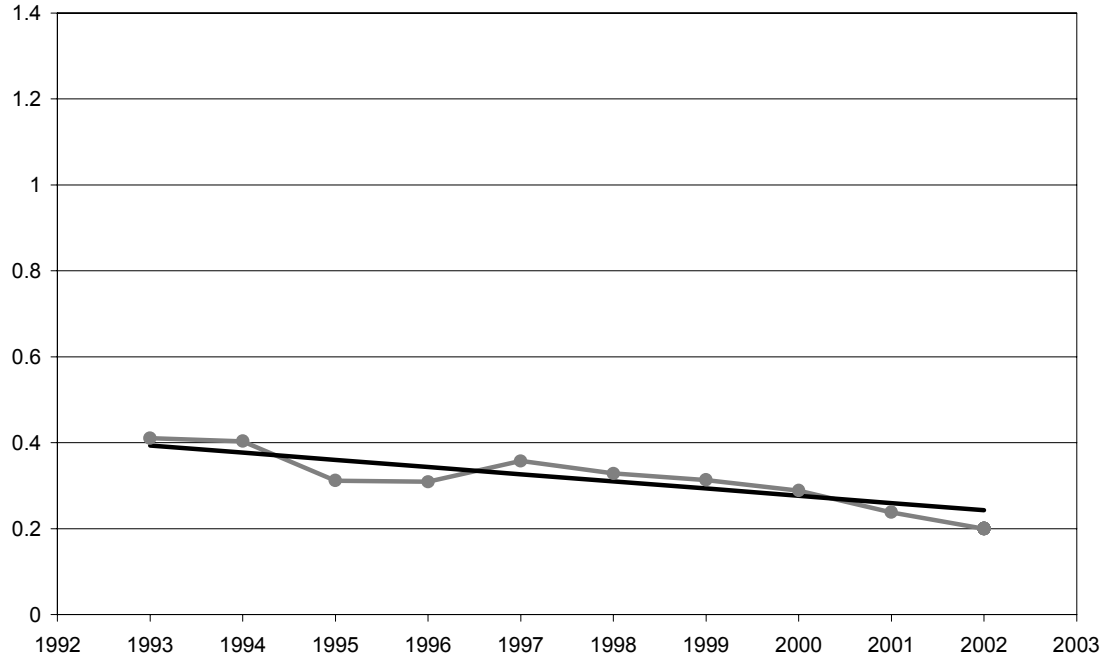
CAGR 2.5 per cent; trend 3.1 per cent.

Chart A3.39: RUOE trend for THD.w Tendring Hundred (water)



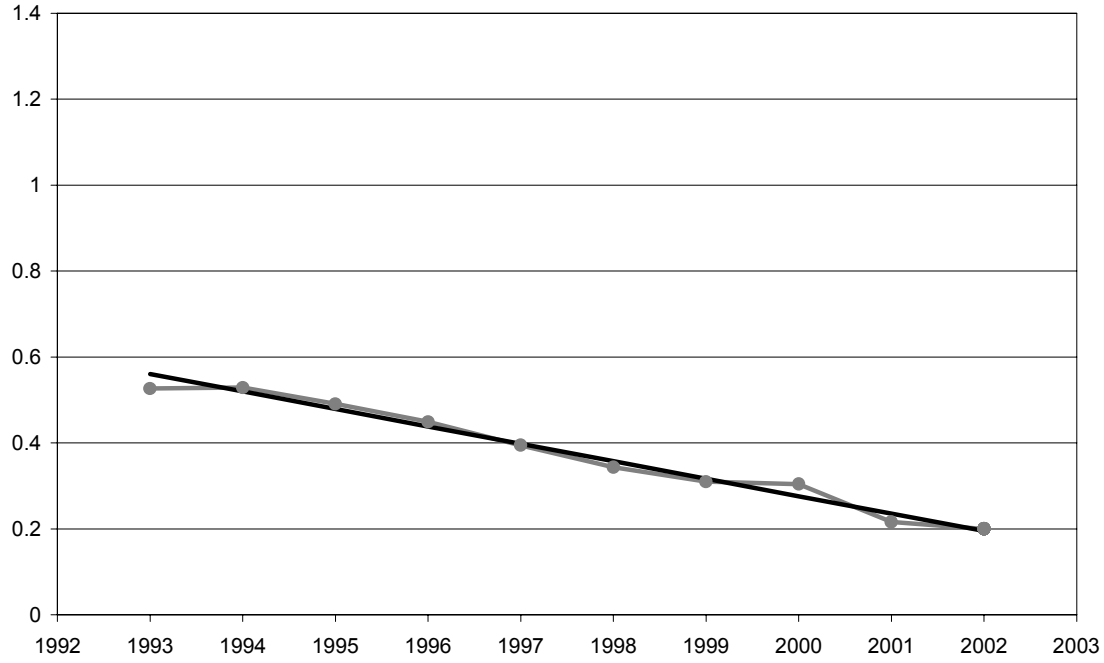
CAGR 2.6 per cent; trend 1.5 per cent.

Chart A3.40: RUOE trend for TVN.w Three Valleys & North Surrey (water)



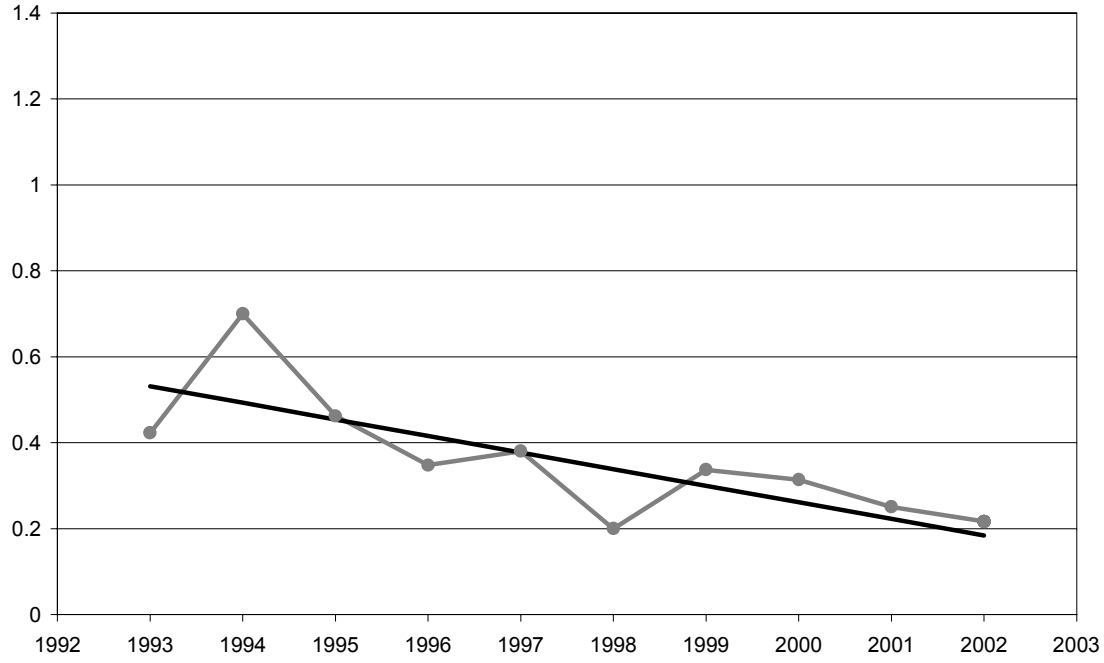
CAGR 2.3 per cent; trend 1.7 per cent.

Chart A3.41: RUOE trend for TOT.w Total water industry



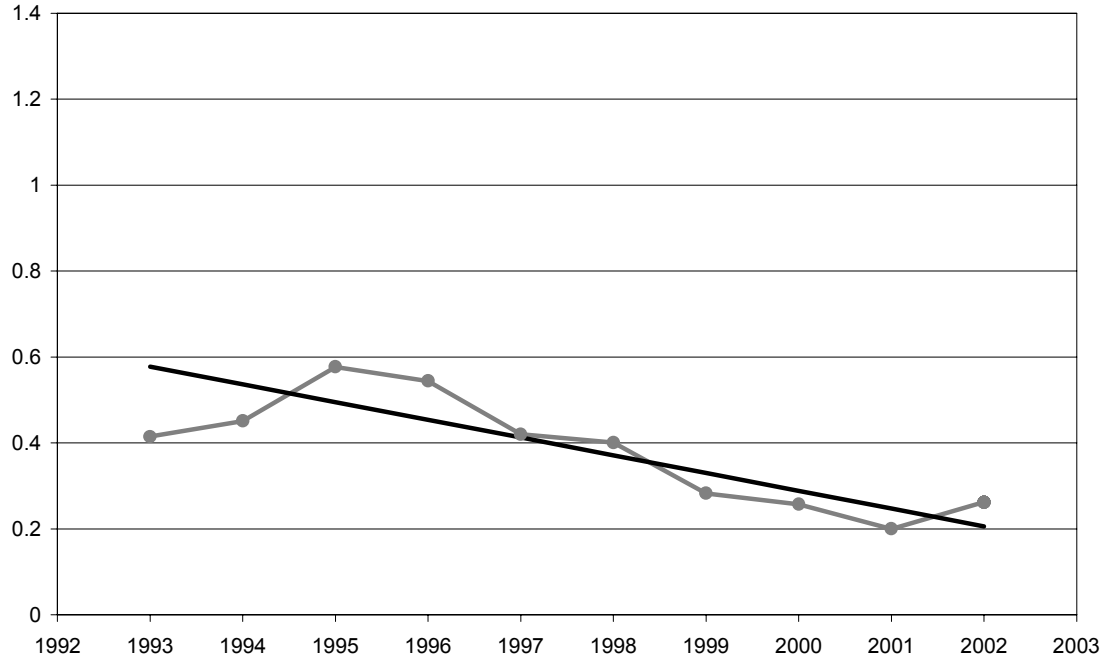
CAGR 3.6 per cent; trend 4.0 per cent.

Chart A3.42: RUOE trend for ANH.s Anglian & Hartlepool (sewerage)



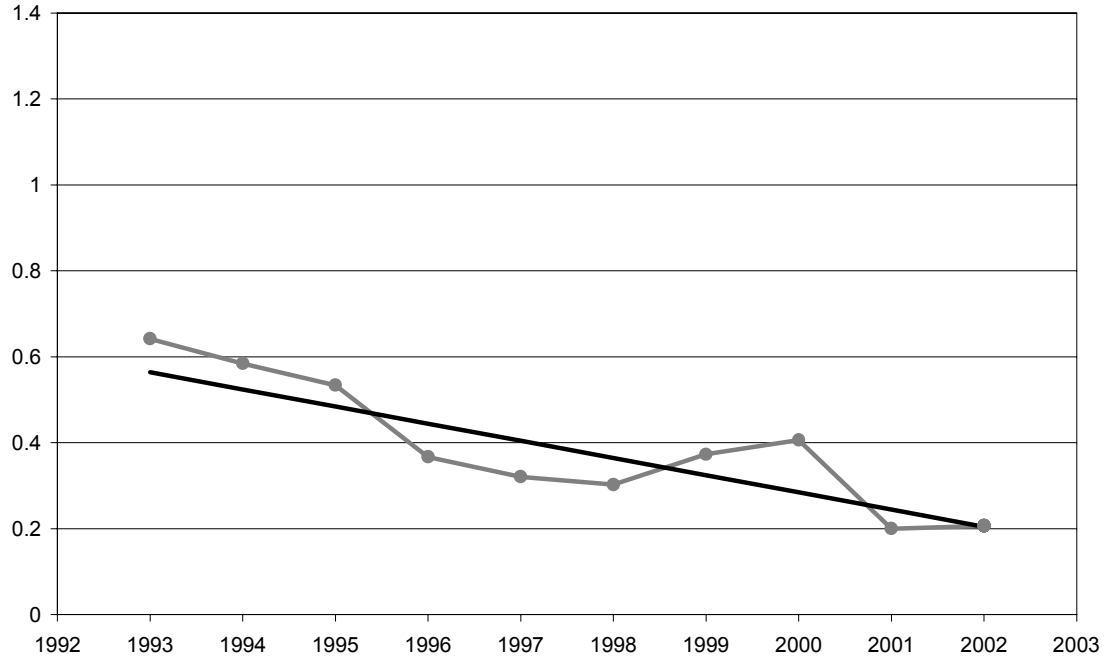
CAGR 2.3 per cent; trend 3.8 per cent.

Chart A3.43: RUOE trend for WSH.s Dwr Cymru (sewerage)



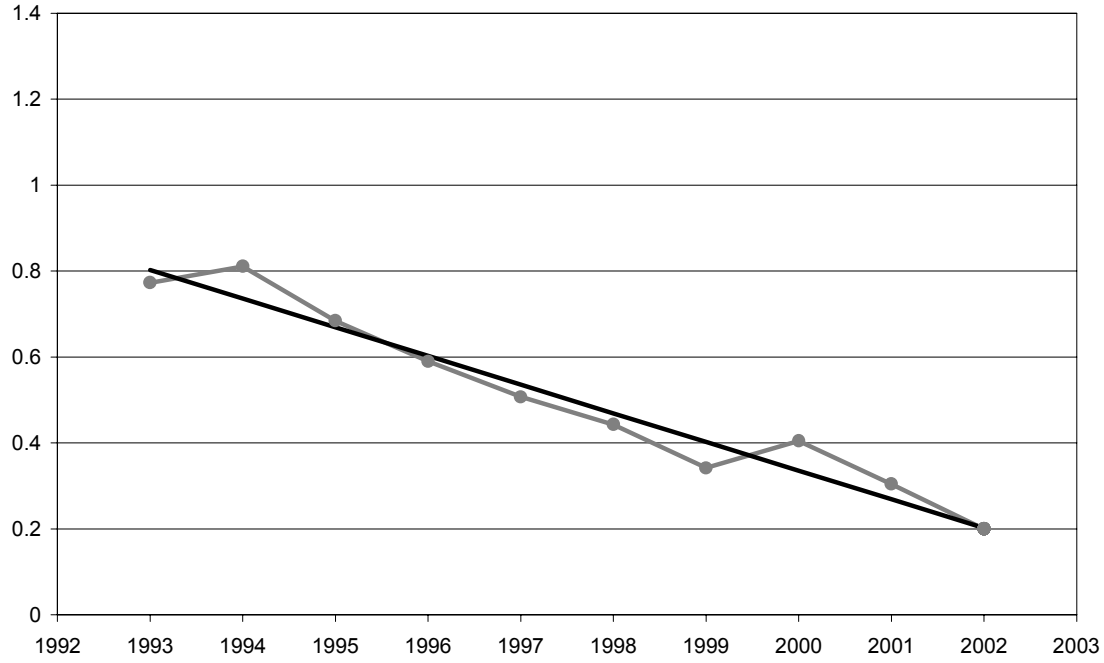
CAGR 1.7 per cent; trend 4.0 per cent.

Chart A3.44: RUOE trend for NWT.s North West (sewerage)



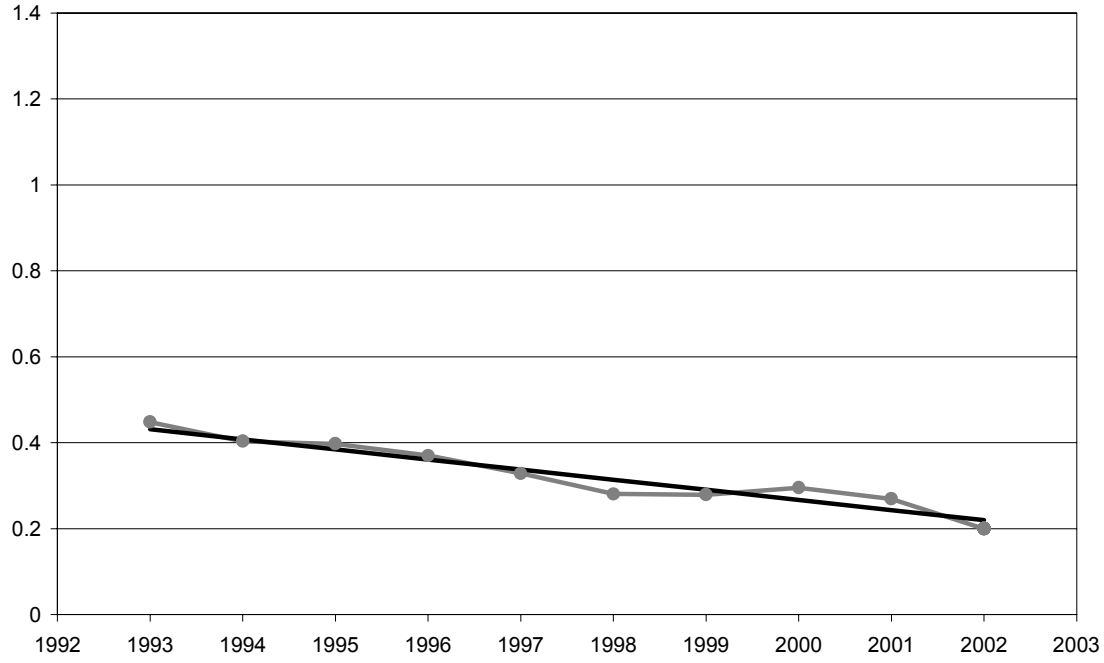
CAGR 4.7 per cent; trend 3.9 per cent.

Chart A3.45: RUOE trend for NES.s Northumbrian (sewerage)



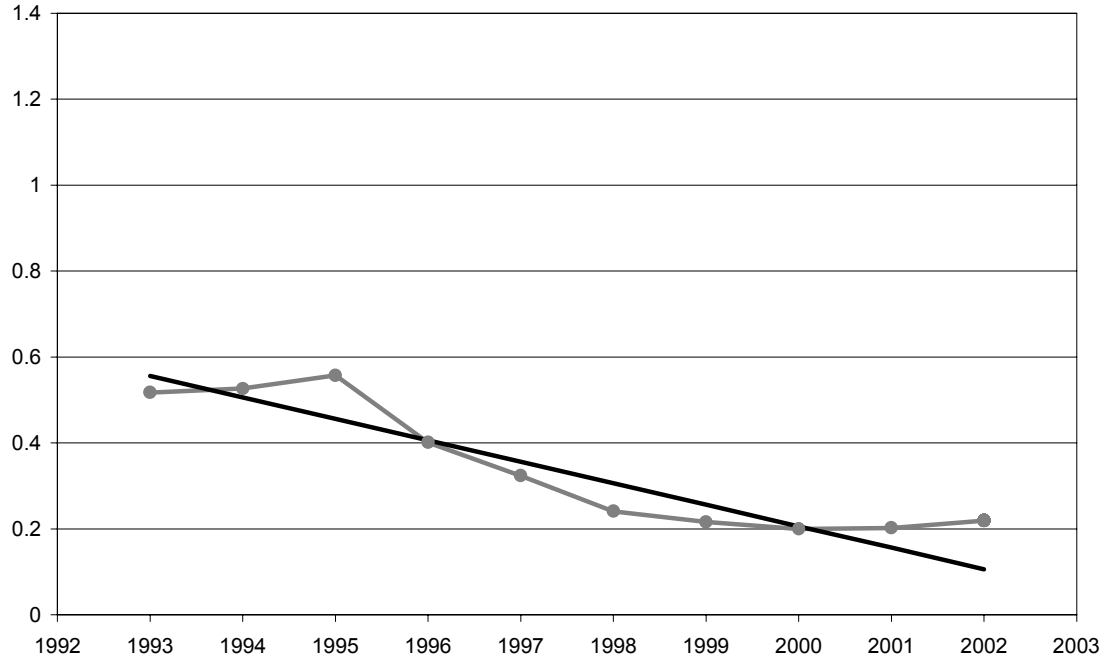
CAGR 6.2 per cent; trend 6.5 per cent.

Chart A3.46: RUOE trend for SVT.s Severn Trent (sewerage)



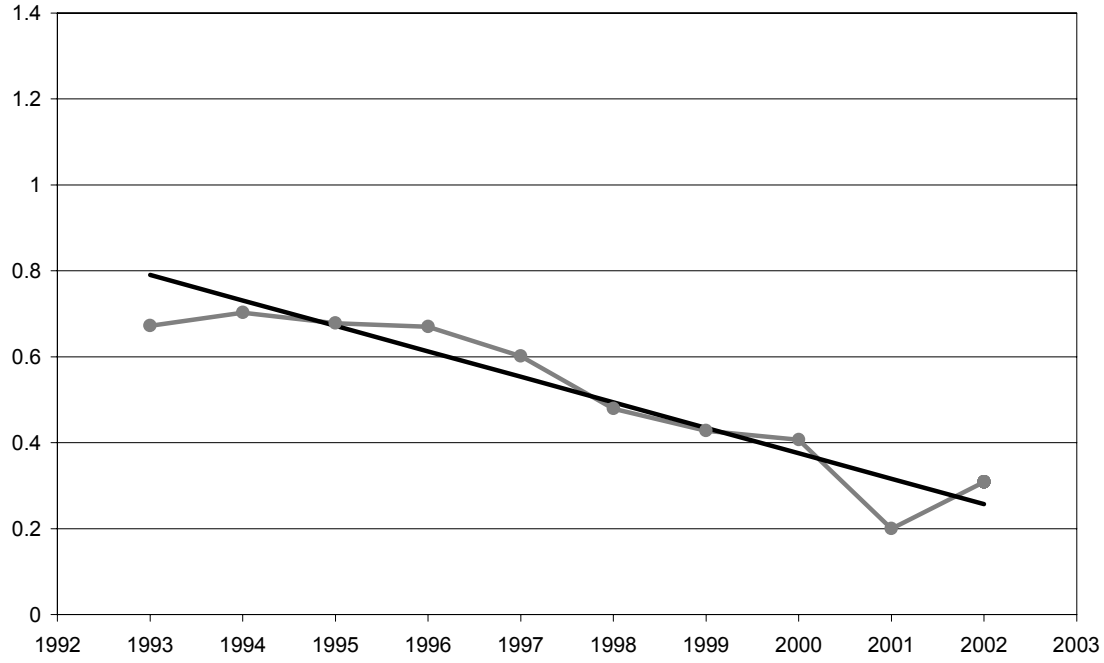
CAGR 2.7 per cent; trend 2.3 per cent.

Chart A3.47: RUOE trend for SWT.s South West (sewerage)



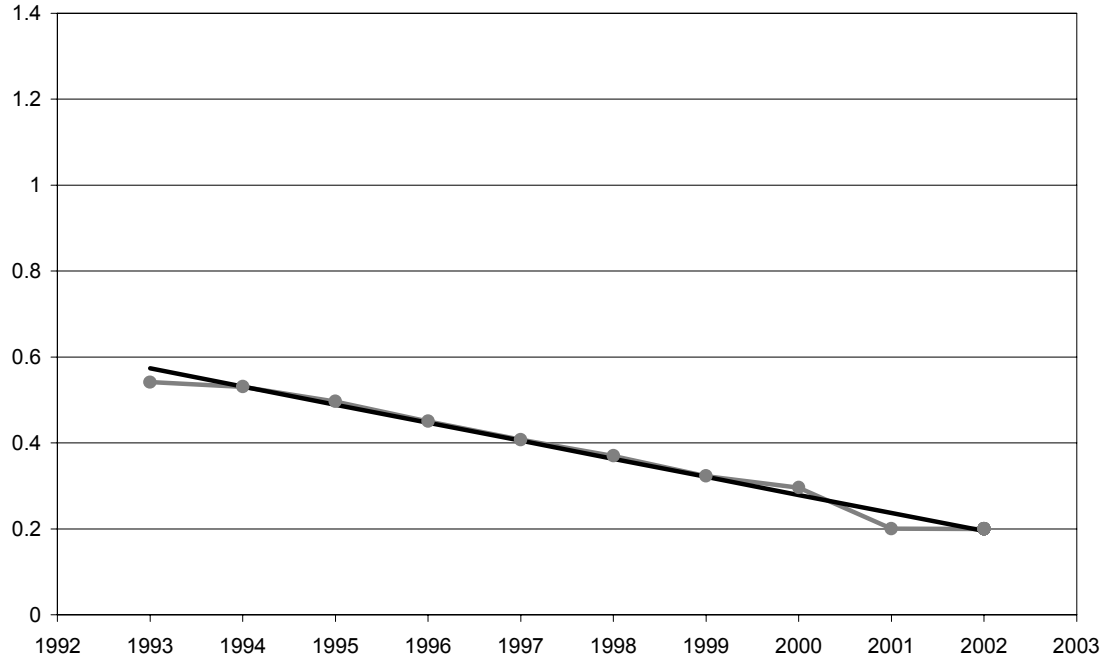
CAGR 3.3 per cent; trend 4.9 per cent.

Chart A3.48: RUOE trend for SRN.s Southern (sewerage)



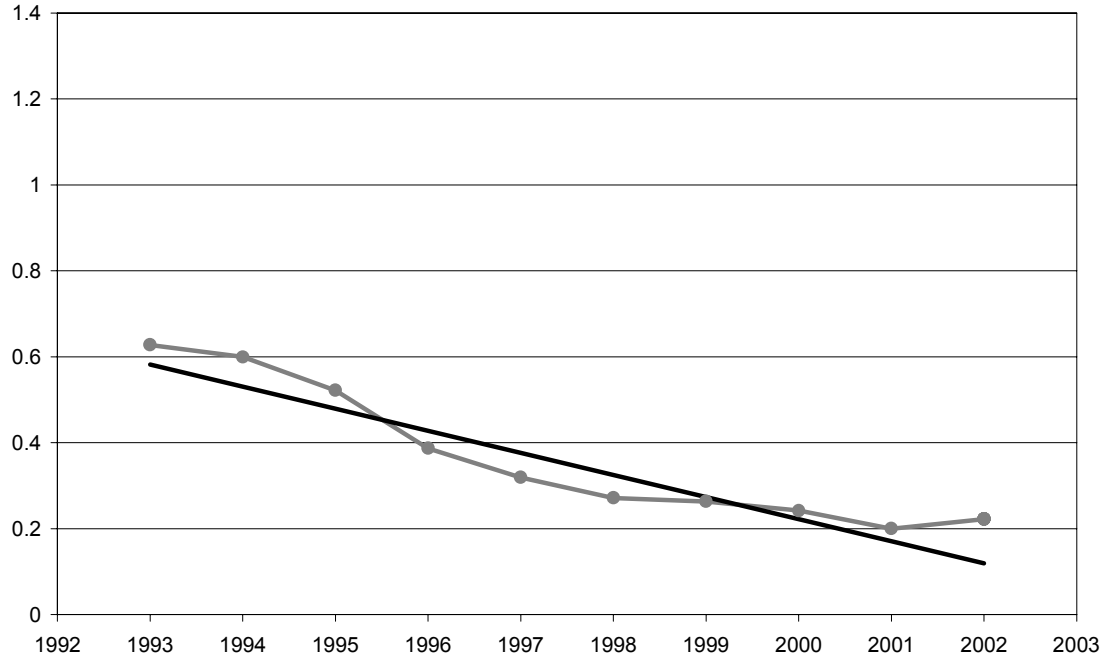
CAGR 4.0 per cent; trend 5.8 per cent.

Chart A3.49: RUOE trend for TMS.s Thames (sewerage)



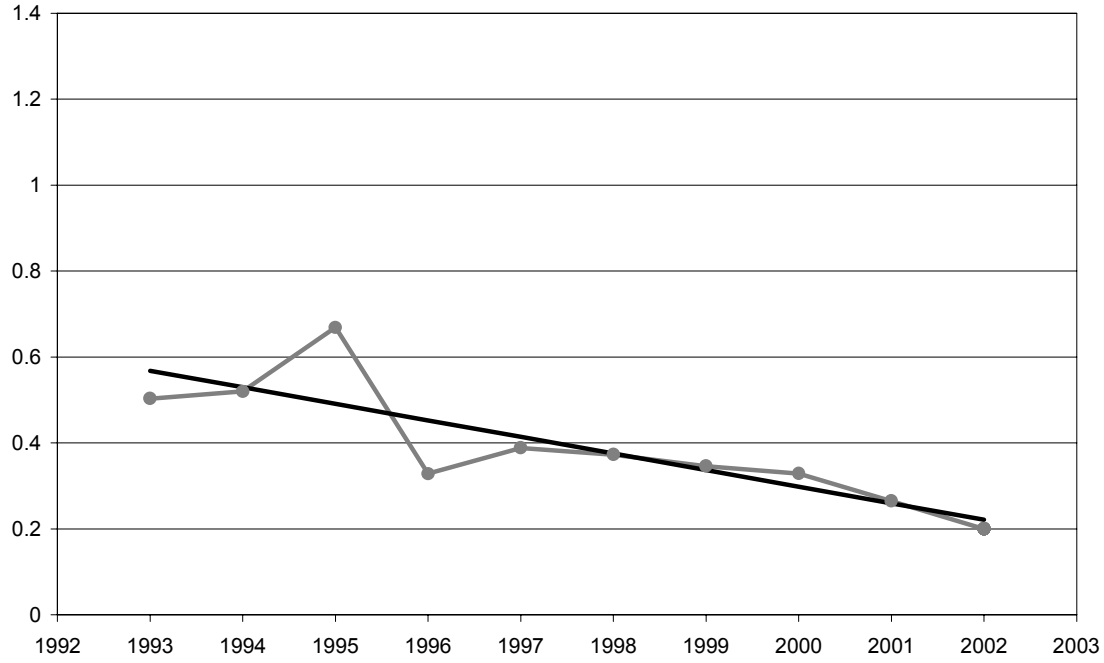
CAGR 3.7 per cent; trend 4.1 per cent.

Chart A3.50: RUOE trend for WSX.s Wessex (sewerage)



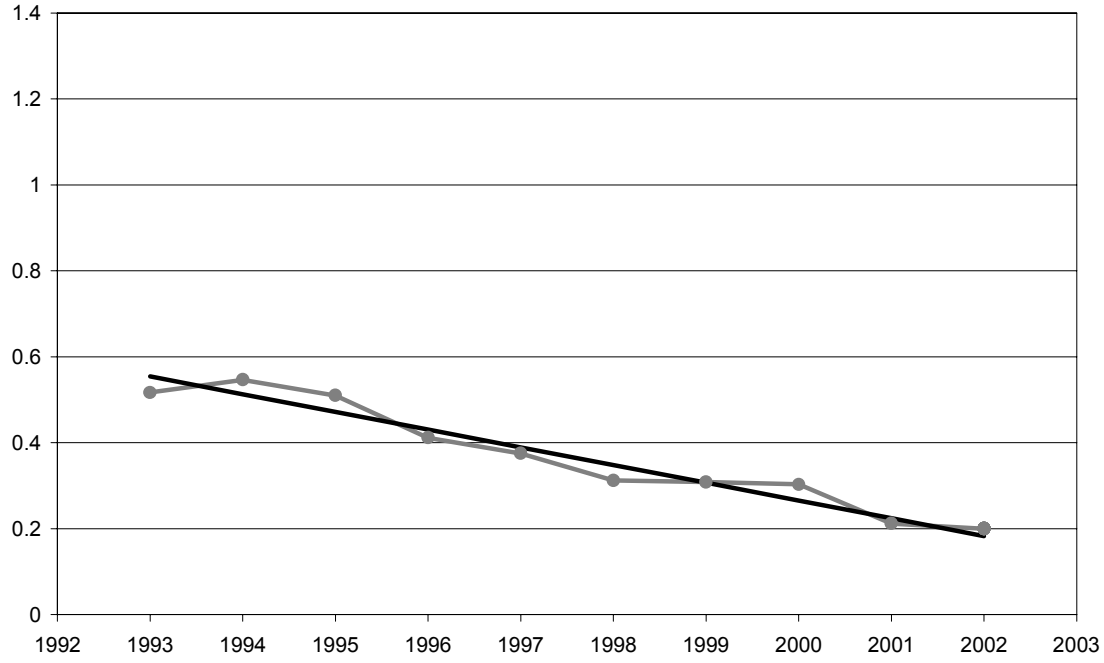
CAGR 4.4 per cent; trend 5.0 per cent.

Chart A3.51: RUOE trend for YKY.s Yorkshire & York (sewerage)



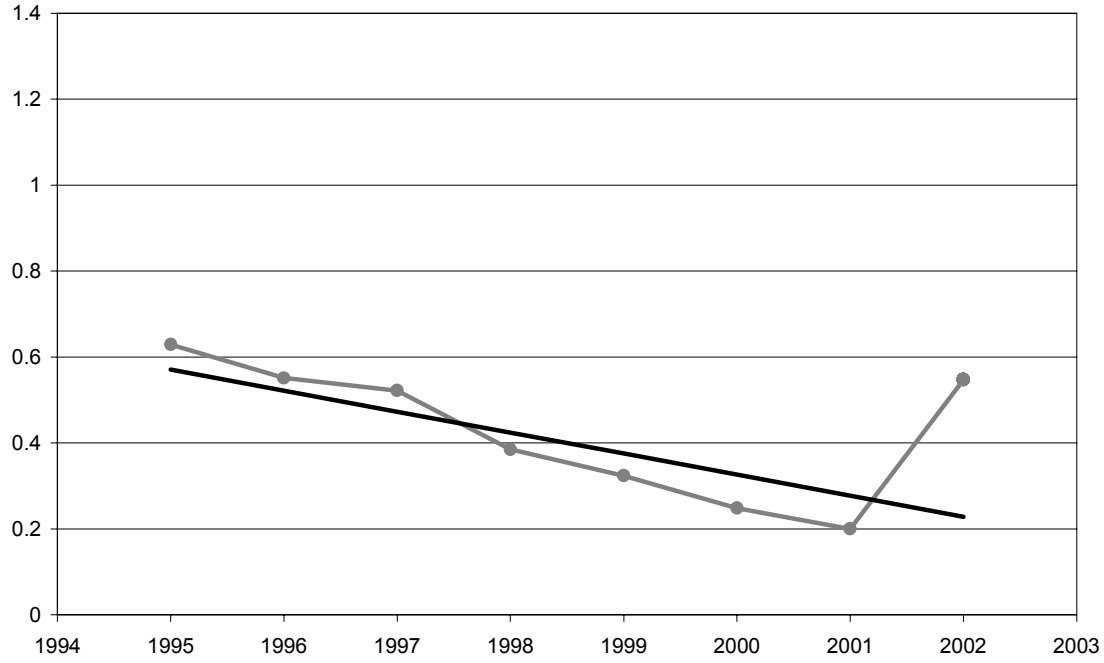
CAGR 3.3 per cent; trend 3.8 per cent.

Chart A3.52: RUOE trend for TOT.s Total sewerage industry



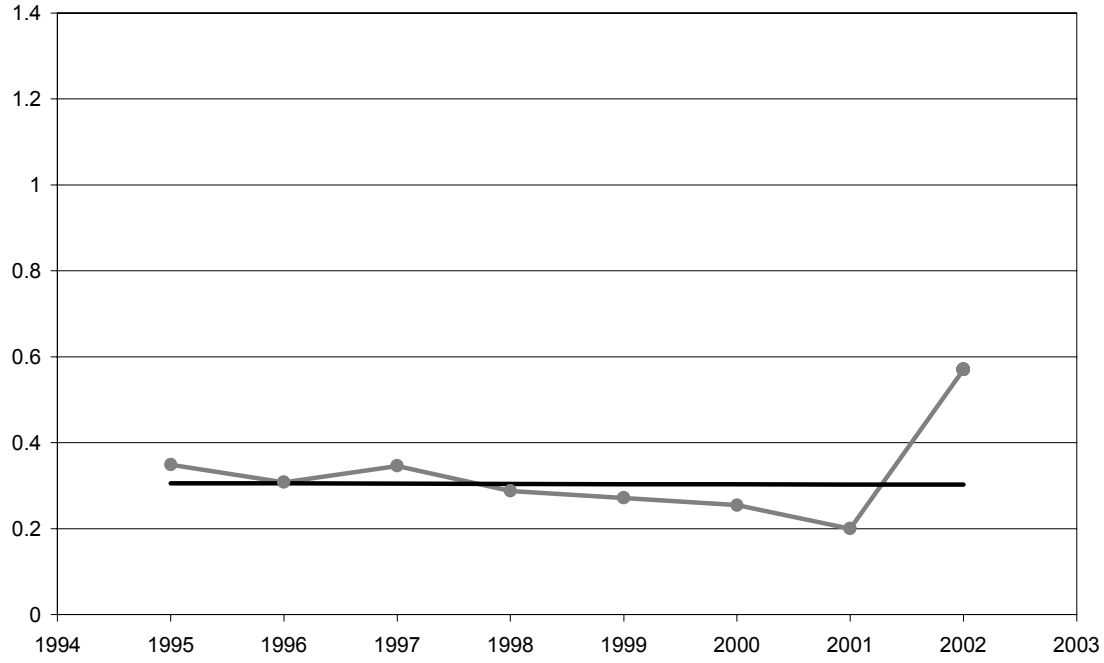
CAGR 3.5 per cent; trend 4.0 per cent.

Chart A3.53: RUOE trend for Railtrack (using passenger numbers)



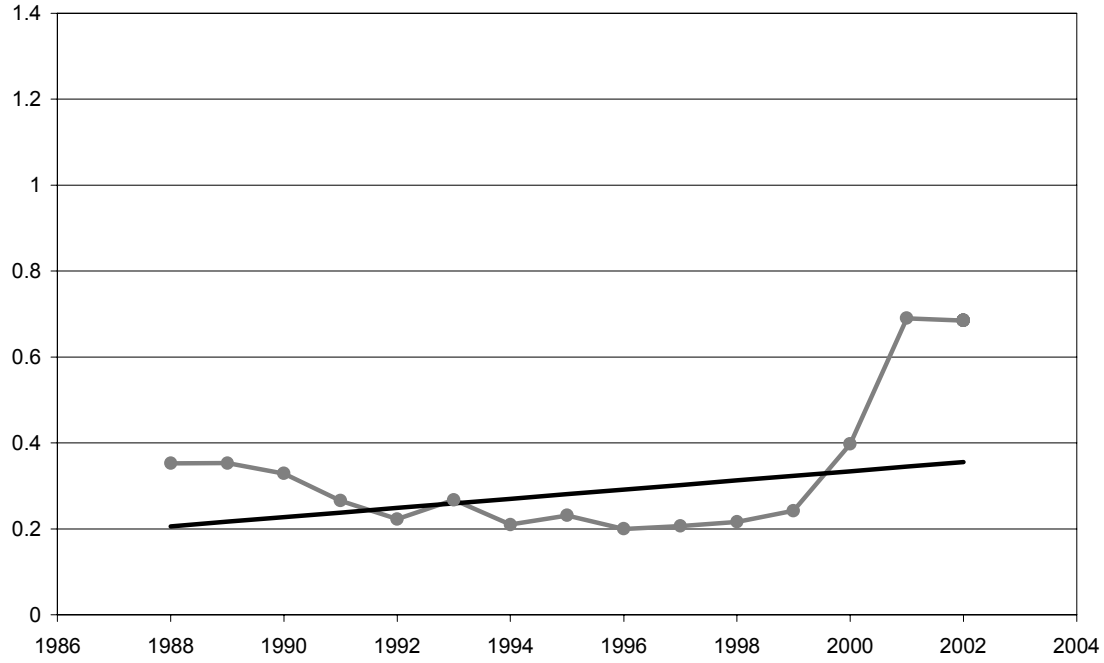
CAGR 1.2 per cent; trend 4.8 per cent.

Chart A3.54: RUOE trend for Railtrack (using route length)



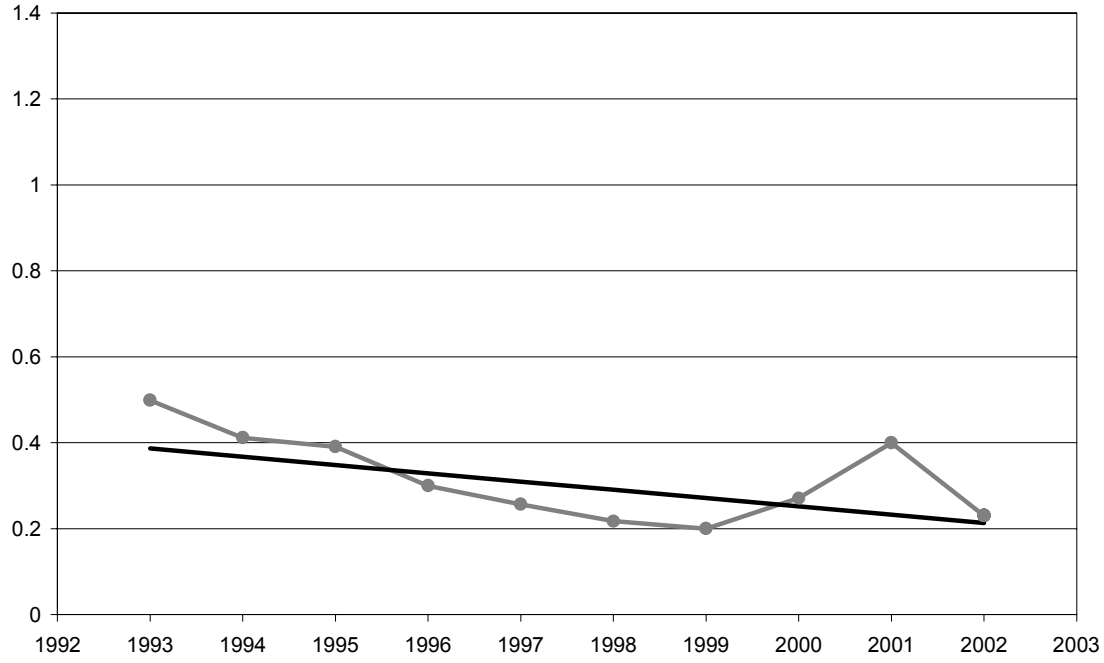
CAGR -3.2 per cent; trend 0.0 per cent.

Chart A3.55: RUOE trend for BT Group (using exchange lines)



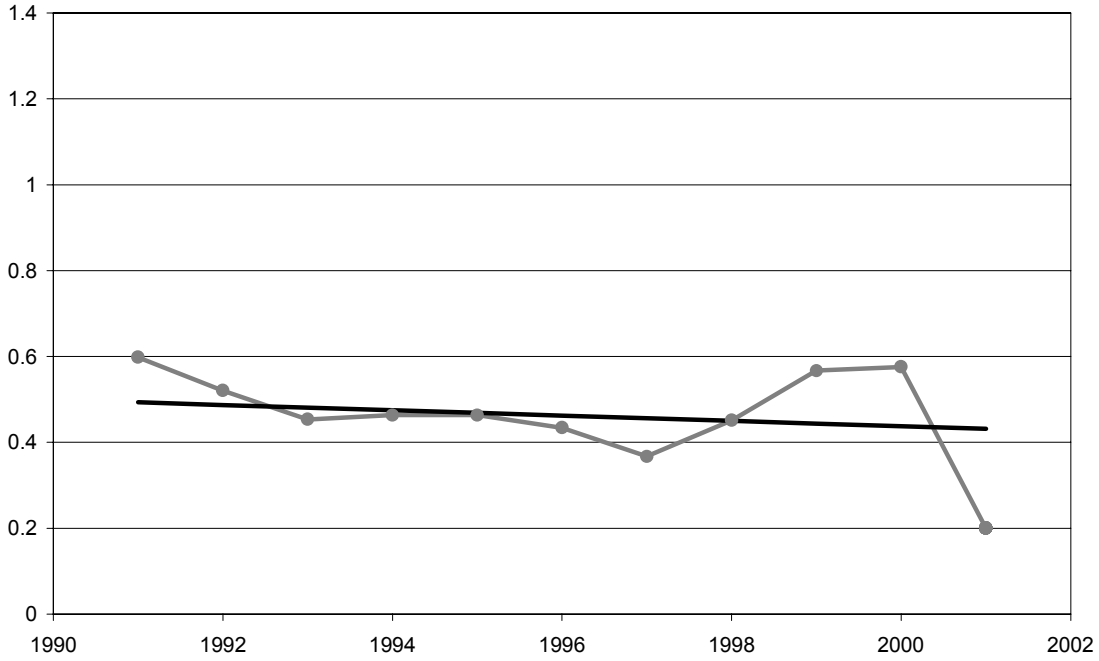
CAGR -2.4 per cent; trend -1.1 per cent.

Chart A3.56: RUOE trend for BT Group (using call minutes)



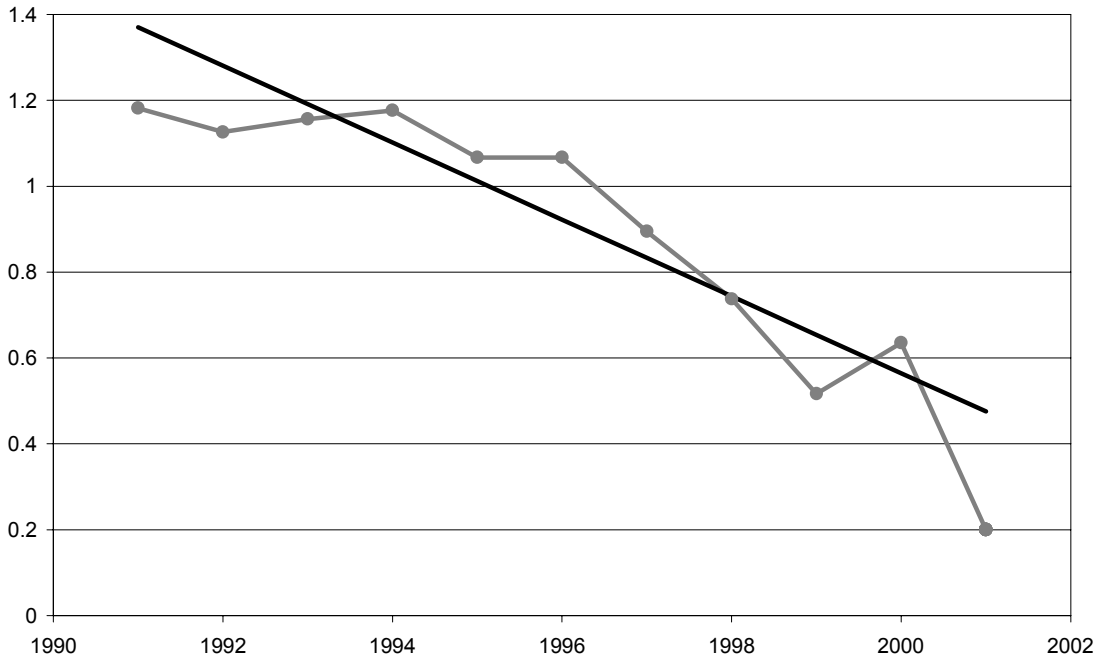
CAGR 2.9 per cent; trend 1.9 per cent.

Chart A3.57: RUOE trend for EME with economies of scale



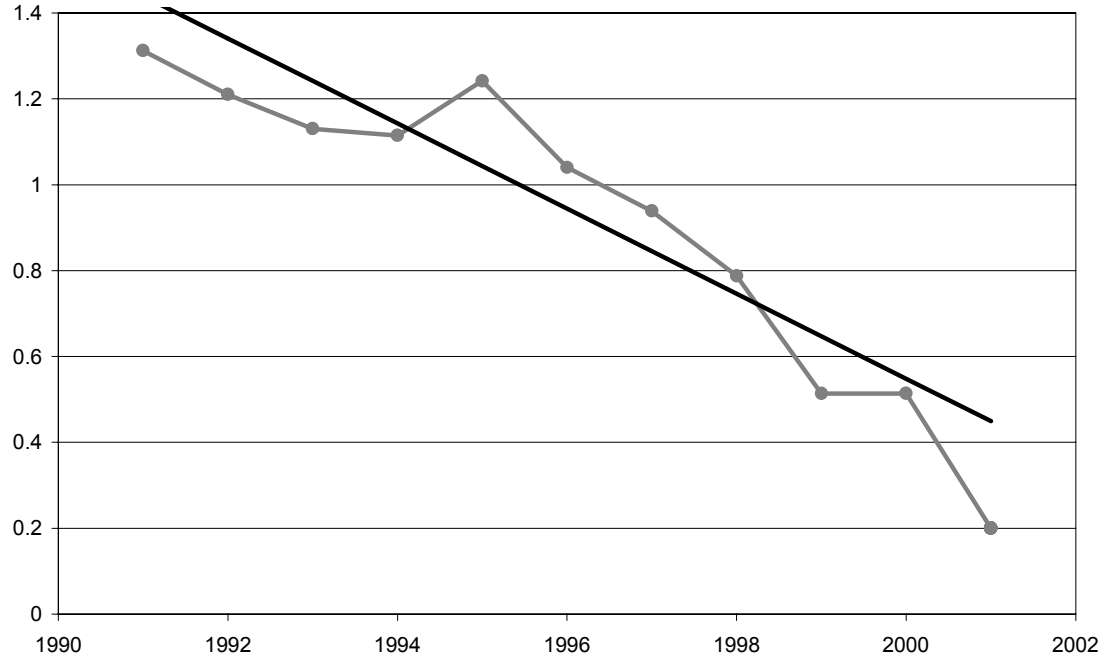
CAGR 3.9 per cent; trend 0.6 per cent.

Chart A3.58: RUOE trend for EPN with economies of scale



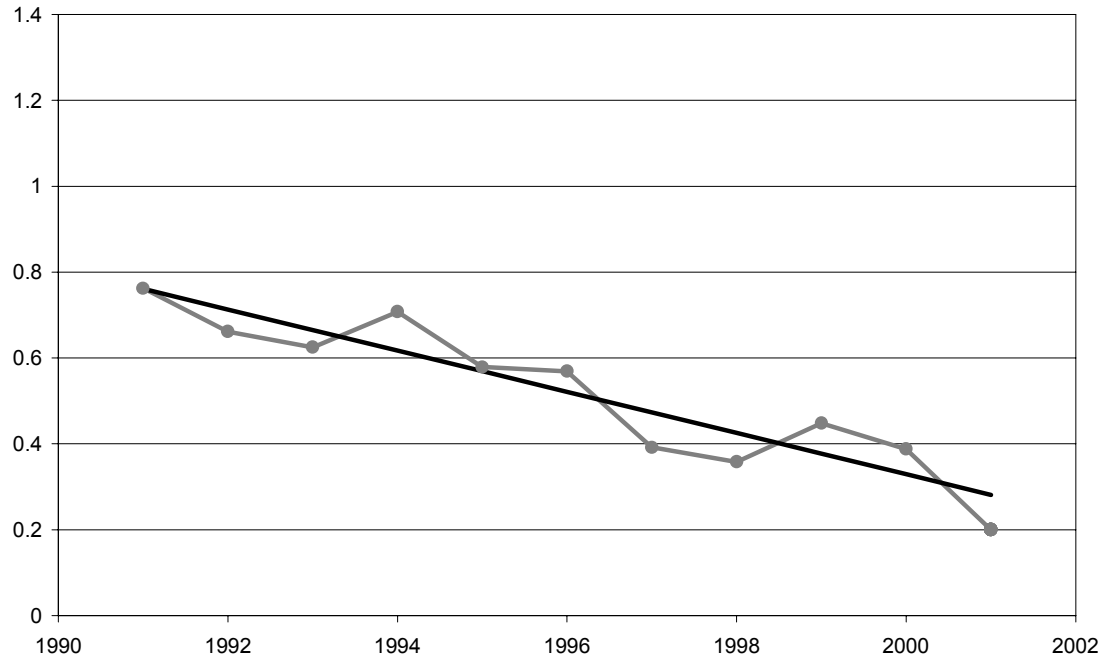
CAGR 9.4 per cent; trend 8.6 per cent.

Chart A3.59: RUOE trend for LPN with economies of scale



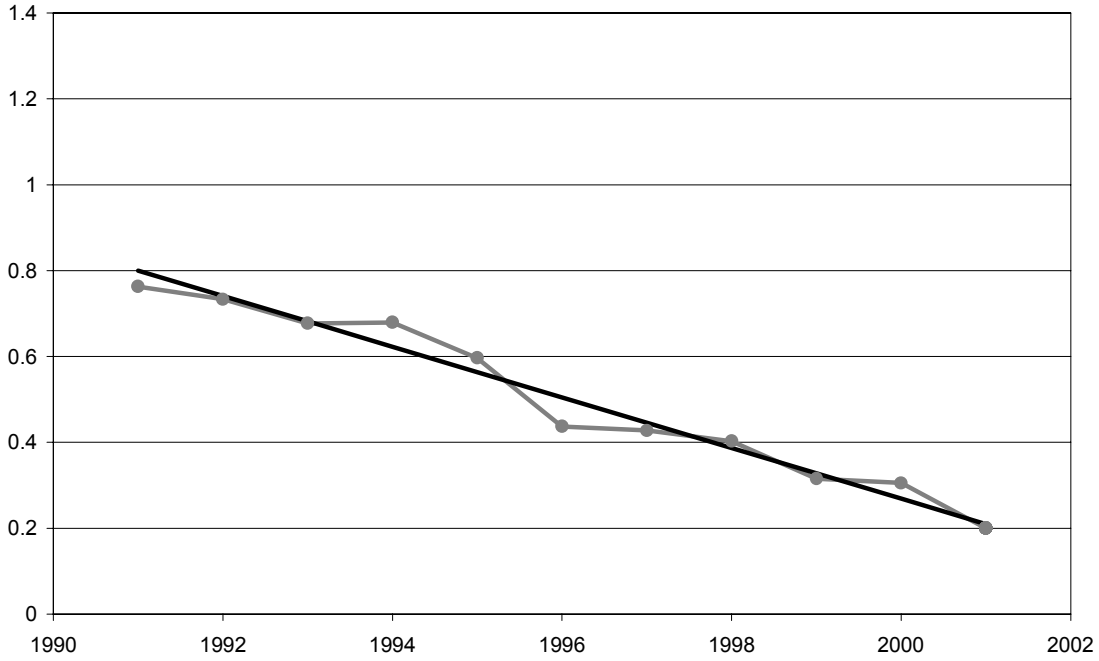
CAGR 10.5 per cent; trend 9.4 per cent.

Chart A3.60: RUOE trend for Manweb with economies of scale



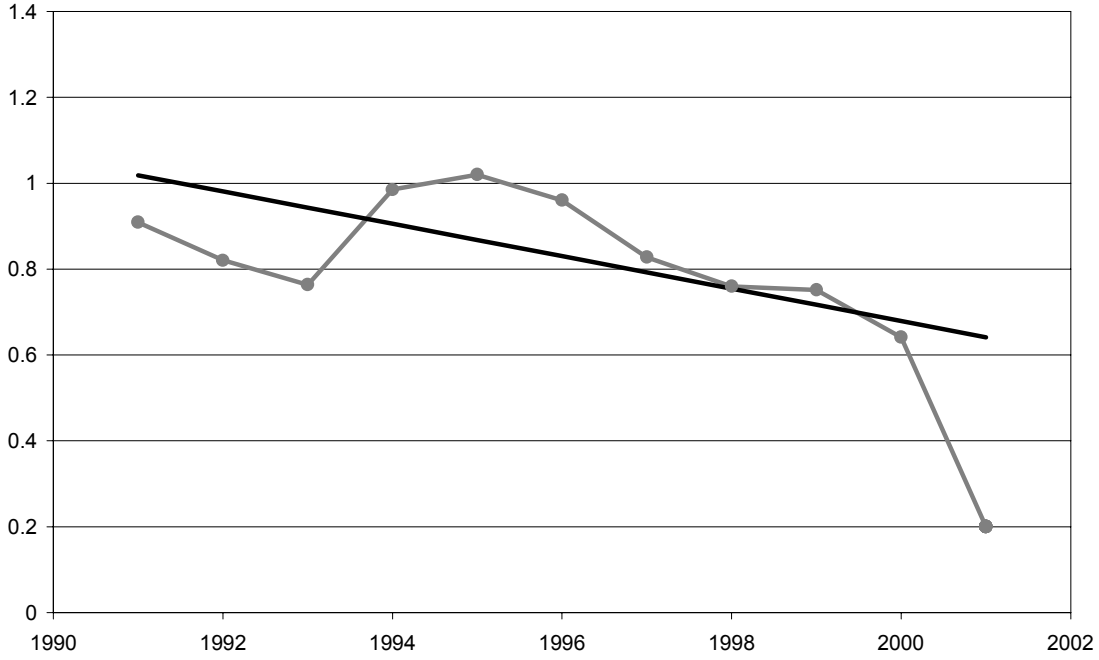
CAGR 5.5 per cent; trend 4.7 per cent.

Chart A3.61: RUOE trend for MEB with economies of scale



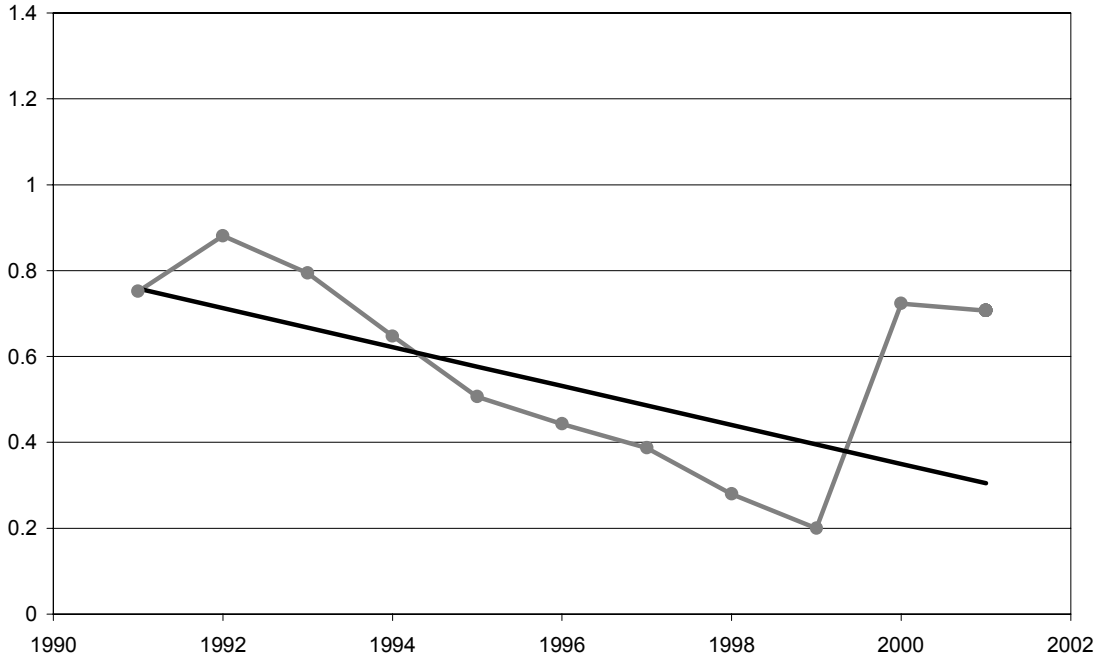
CAGR 5.5 per cent; trend 5.7 per cent.

Chart A3.62: RUOE trend for NEDL with economies of scale



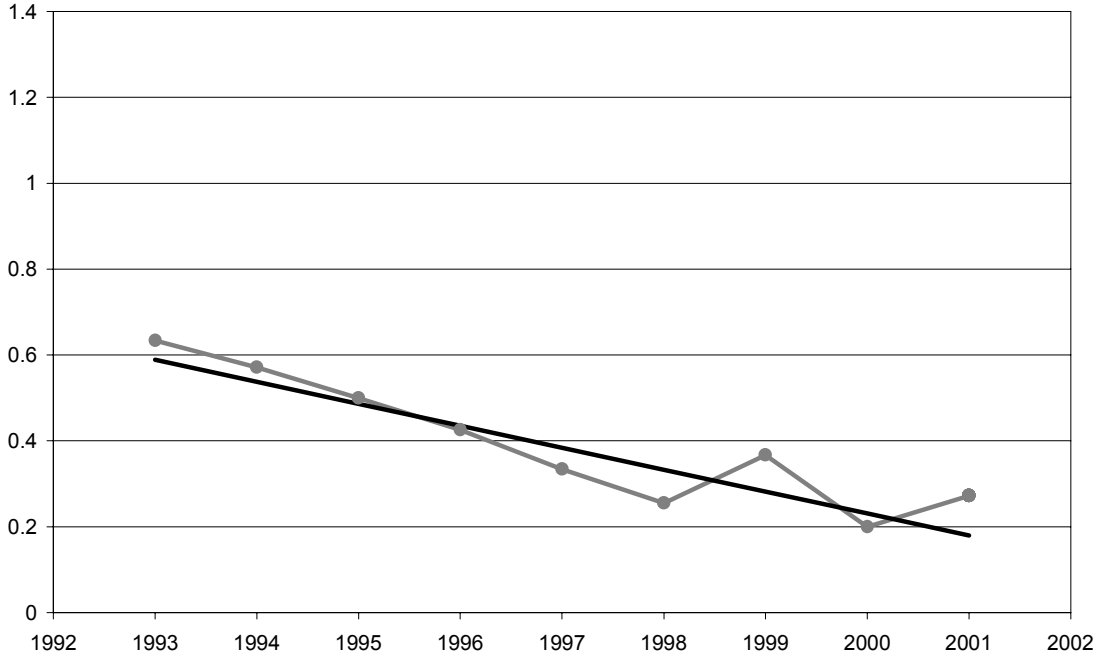
CAGR 6.8 per cent; trend 3.7 per cent.

Chart A3.63: RUOE trend for NGC with economies of scale



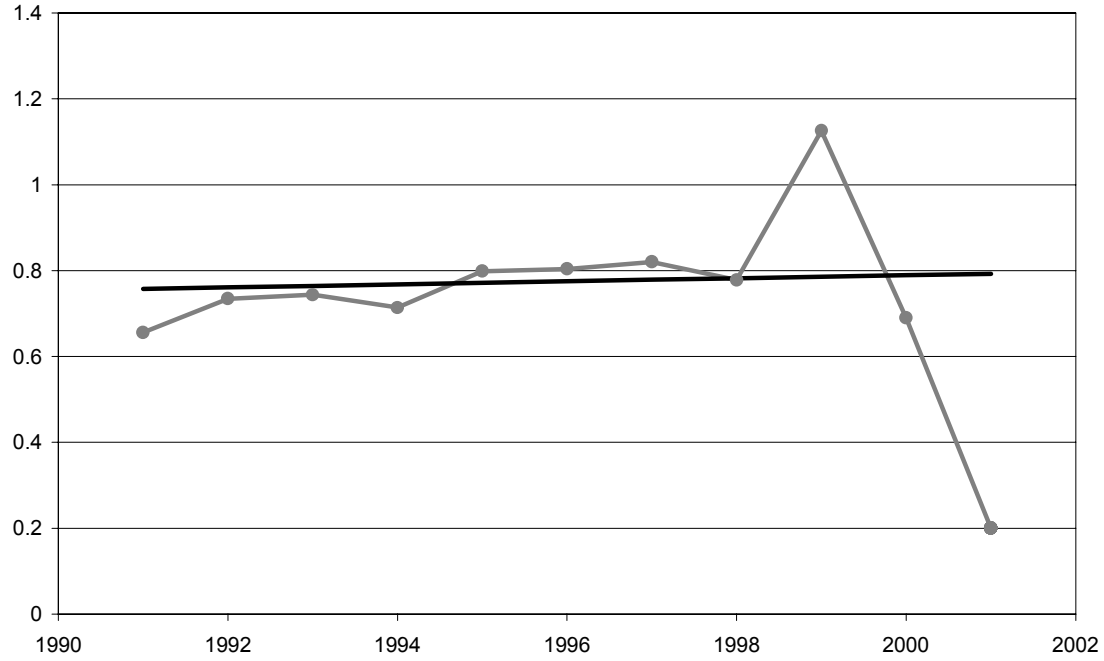
CAGR 0.4 per cent; trend 4.4 per cent.

Chart A3.64: RUOE trend for NIE with economies of scale



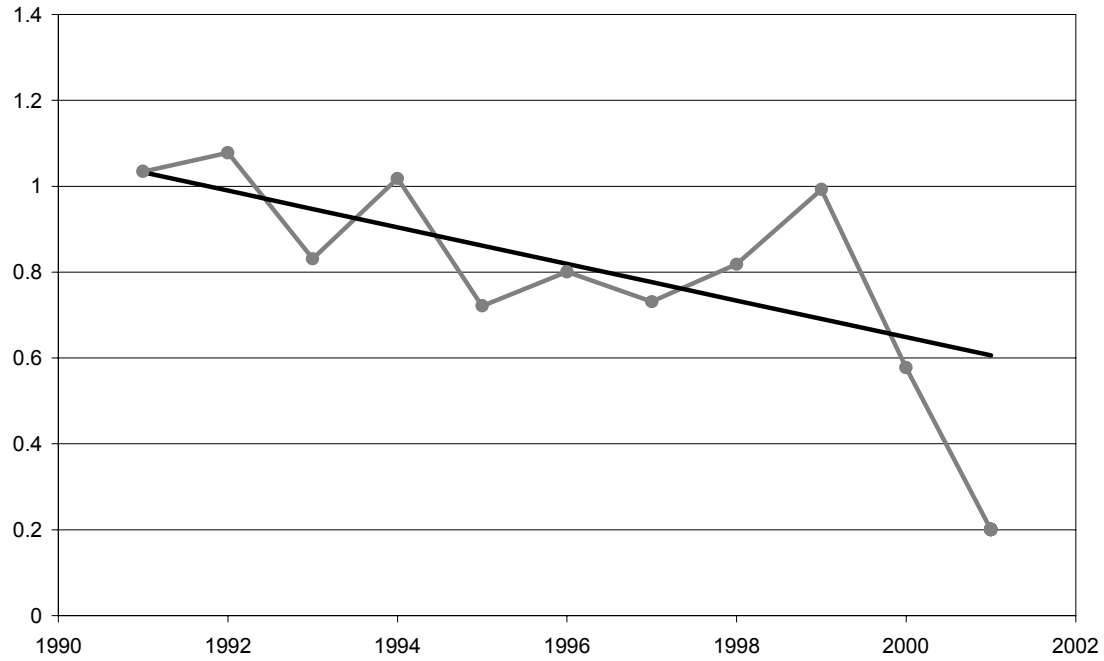
CAGR 4.4 per cent; trend 5.0 per cent.

Chart A3.65: RUOE trend for SHD with economies of scale



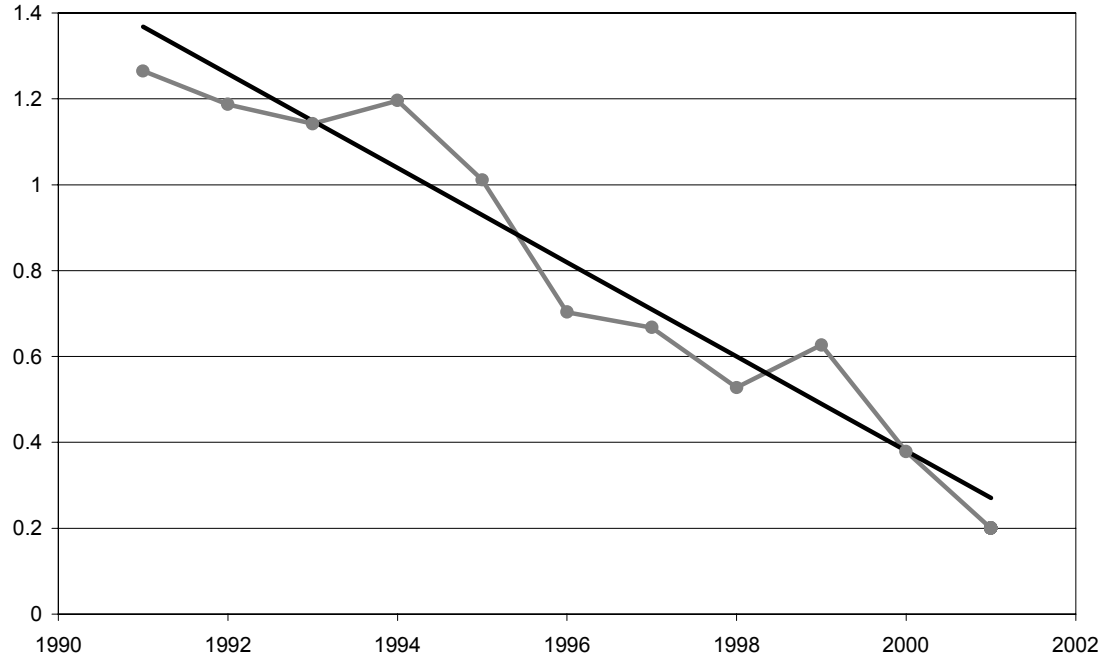
CAGR 4.5 per cent; trend -0.4 per cent.

Chart A3.66: RUOE trend for SHT with economies of scale



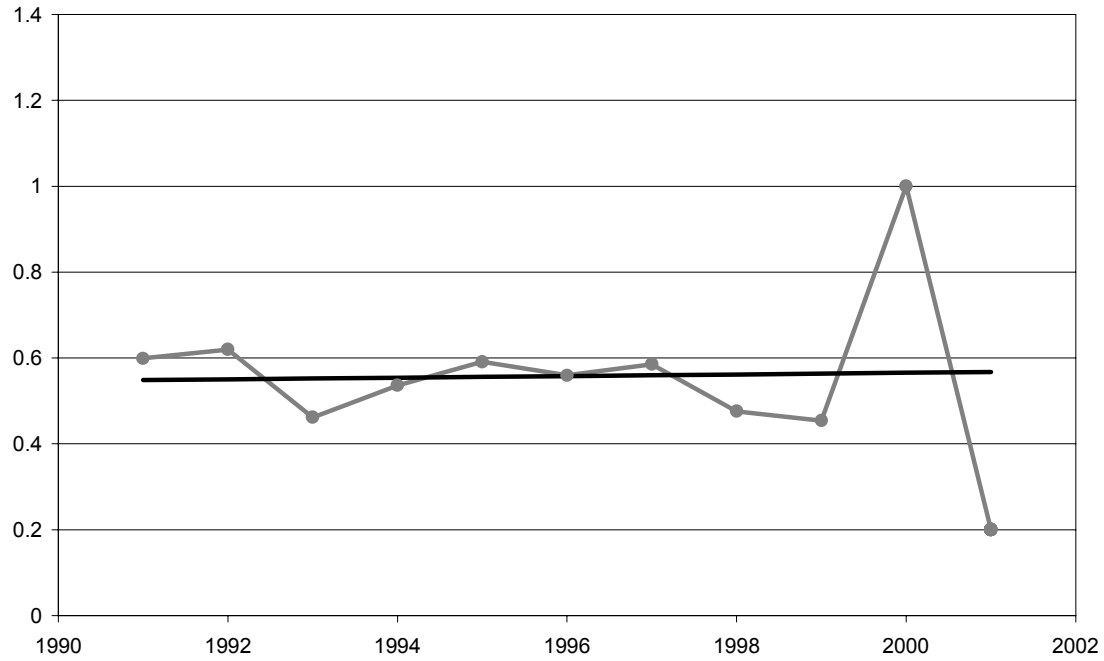
CAGR 8.0 per cent; trend 4.2 per cent.

Chart A3.67: RUOE trend for Southern Electric with economies of scale



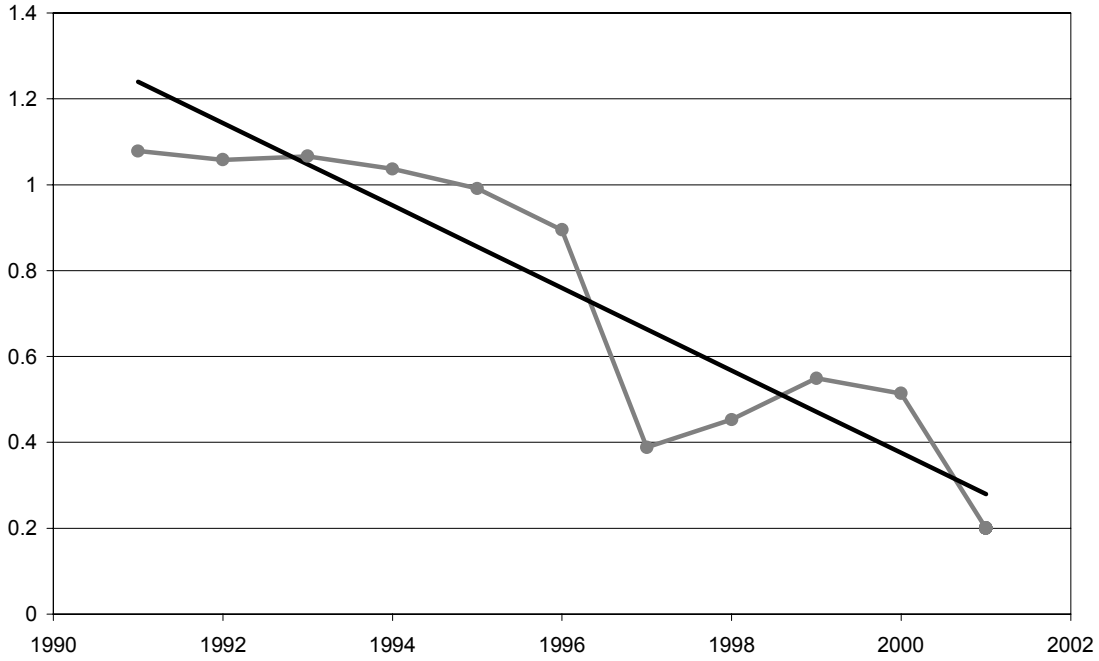
CAGR 10.1 per cent; trend 10.4 per cent.

Chart A3.68: RUOE trend for SPD with economies of scale



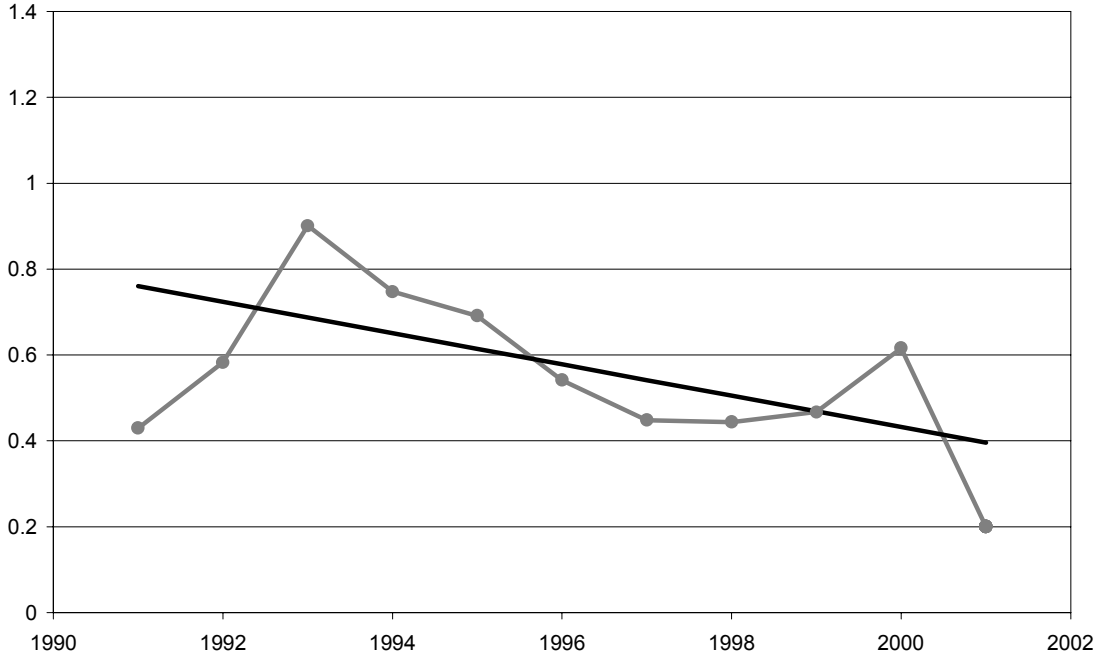
CAGR 3.9 per cent; trend -0.2 per cent.

Chart A3.69: RUOE trend for SPN with economies of scale



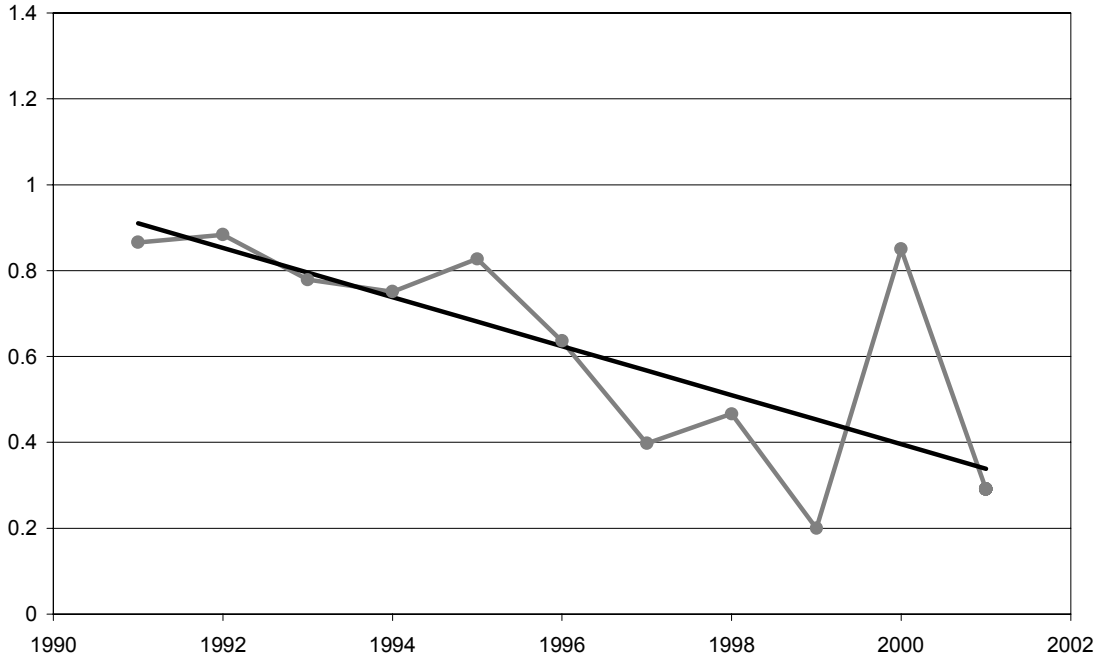
CAGR 8.4 per cent; trend 9.2 per cent.

Chart A3.70: RUOE trend for SPT with economies of scale



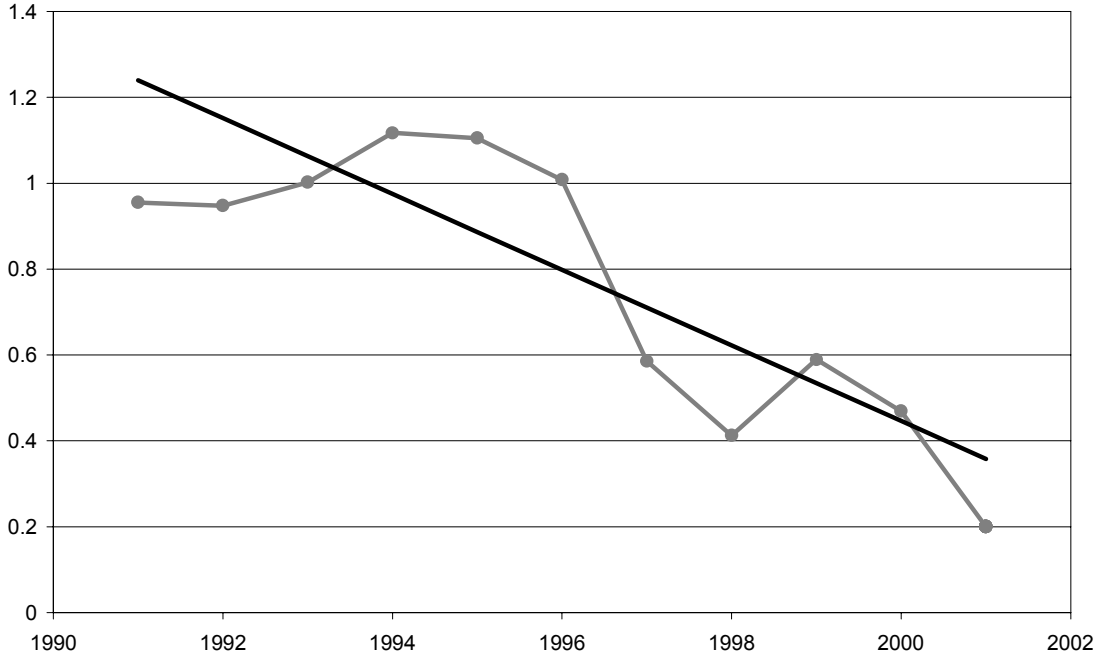
CAGR 2.3 per cent; trend 3.6 per cent.

Chart A3.71: RUOE trend for SWALEC with economies of scale



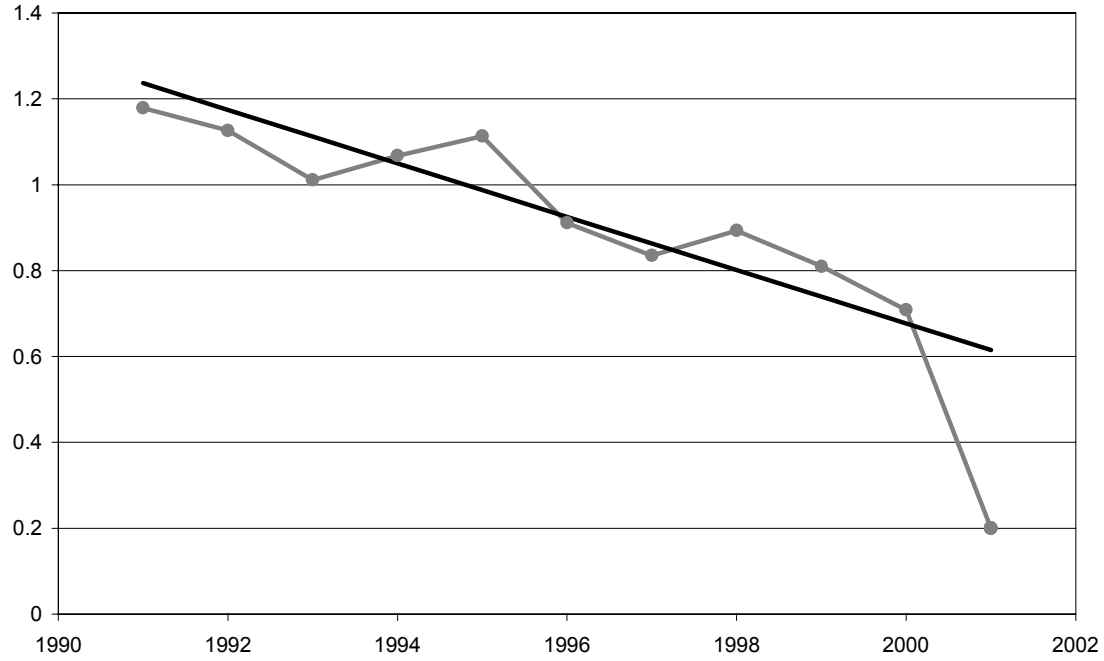
CAGR 5.6 per cent; trend 5.6 per cent.

Chart A3.72: RUOE trend for SWEB with economies of scale



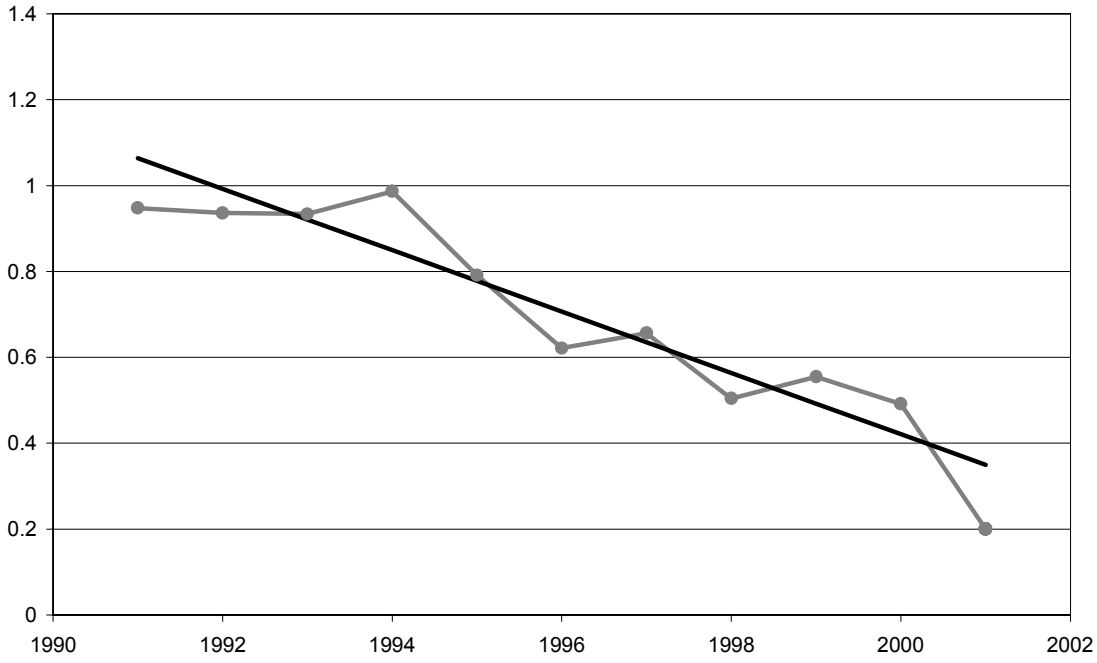
CAGR 7.3 per cent; trend 8.4 per cent.

Chart A3.73: RUOE trend for UUE with economies of scale



CAGR 9.3 per cent; trend 6.0 per cent.

Chart A3.74: RUOE trend for YEDL with economies of scale



CAGR 7.2 per cent; trend 6.9 per cent.

APPENDIX 4: REFERENCES

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