Assessing the Efficient Cost of Sustaining Britain's Rail Network: Perspectives Based on Zonal Comparisons

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Abstract

The objective of this paper is to inform the debate on how efficiency targets for Network Rail (formerly Railtrack) should be set during the 2002/03 Interim Review and beyond. Given the problems experienced during the 2000 Periodic Review, which focused on external benchmarks, we propose an internal benchmarking approach, drawing on data for seven geographical Zones within Railtrack (over the period 1995/96 to 2001/02). Our approach mirrors the yardstick competition method used in other UK regulated industries. Three efficiency measurement techniques are applied to this data (DEA; COLS; SFA). Our results suggest that Railtrack (as a whole) delivered substantial improvements in productivity in the early years after privatisation, although these savings were largely offset by the post-Hatfield cost increases. However, looking forward, Zonal efficiency differences suggest that the company could make significant savings in future years by applying (its own) best practice consistently across the network.

JEL classification: L51; L92

Key words: corrected ordinary least squares; data envelopment analysis; efficiency analysis; internal benchmarking; railway; stochastic frontier analysis

Assessing the efficient cost of sustaining Britain's rail network: perspectives based on Zonal comparisons.

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1. Introduction

The 2000 Periodic Review of Railtrack's[1] access charges saw considerable debate about the scope for the company to deliver efficiency savings during the second control period (CP2)[2]. To inform the debate, comparisons were made with a number of external benchmarks (international railway companies and other UK privatised industries). However, none of these comparisons proved completely satisfactory. NERA (2000) found a lack of international railway (infrastructure) data to make meaningful comparisons with Railtrack. At the same time, the experience of privatised industries in the UK produced a wide range of potential efficiency targets for the company, and there was disagreement over which industry was most comparable with the railways.

Of course, the two years following the Periodic Review conclusions (October 2000) have seen considerable change in the industry. In October 2002, a new company, Network Rail, emerged as the owner and operator of Britain's rail network, having agreed

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[1] Britain's rail infrastructure provider (April 1994 to October 2002). See Section 2.
[2] Covering the period 2001/02 to 2005/06.

to purchase Railtrack PLC (in administration) from the parent company[3]. Network Rail is a company limited by guarantee (CLG), owned by members, rather than shareholders. Nevertheless, the question of efficiency remains of central importance in the regulation of the new company. In September 2002, the Office of the Rail Regulator (ORR) announced an (interim) review of Network Rail's access charges[4] (to be completed by December 2003); and stated the need, during that review, to consider the scope for realistic but challenging efficiency improvements.

The objective of this paper is to inform the debate on how efficiency targets for Network Rail should be set at the 2002/03 Interim Review of the company's access charges; and beyond. Given the problems experienced during the 2000 Periodic Review, which focused on external benchmarks, we propose an internal benchmarking approach, drawing on data for seven geographical Zones (see Figure 1 below) within Railtrack (over the period 1995/96 to 2001/02). Our approach mirrors the yardstick competition method used in other UK regulated industries[5]. Of course, such analysis does not address the wider question of the company's efficiency relative to international or other comparators. However, it does indicate the potential for Network Rail to reduce costs by applying (its own) best practice consistently across the network.

The period of our analysis, 1995/96 to 2001/02, captures the initial efficiency gains achieved after privatisation (Pollitt and Smith, 2002), the sharp increase in costs between 1999/00 and 2001/02, as well as the deterioration, and subsequent recovery, of some of the output / quality measures since the Hatfield accident (October 2000)[6]. The analysis predates the acquisition of Railtrack PLC by Network Rail, but is intended to illustrate the possibilities for Zonal yardstick comparisons going forward[7]. The paper is arranged in six sections. Section 2 provides some background to Railtrack's organisation structure, and the efficiency debate which took place during the 2000 Periodic Review. Section 3 details the methodology. Section 4 describes the data and model specifications used in the empirical analysis. Section 5 presents the results and Section 6 offers some conclusions.

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[3] In administration from October 2001. Railtrack Group PLC is the parent company.

[4] This announcement was made on September 25, a few days before Network Rail actually took over from Railtrack. See ORR (September 2002).

[5] See, for example, Shleifer, 1985; and OFWAT, 1998. We further note the ORR's reference to Zonal efficiency analysis in his September 2002 statement.

[6] A train derailment resulting from defective track, which resulted in four people being killed.

[7] Or, more generally, at business unit level (since it is possible that Network Rail may change the organisational structure).

2. Background

2.1 The structure of Railtrack

The separation of infrastructure management from train operation was one of the most significant, and controversial, elements of Britain's rail privatisation programme. In 1994, the fixed railway infrastructure assets were transferred to a new company, Railtrack, separate from British Rail (BR), but still wholly-owned by Government. The company was sold by public offer in 1996. Contracts were put in place between Railtrack and BR (and later the privatised passenger and freight operators), governing the charges for (and general terms of) access to the rail infrastructure.

At the same time, it was also decided that the infrastructure maintenance and renewal activities, previously undertaken by BR, would not be transferred to Railtrack; instead, these activities were reorganised into separate infrastructure maintenance companies (IMCs) and track renewal companies (TRCs), and privatised by trade sale. These companies provide maintenance and renewal services to Railtrack based on medium term contracts. The initial maintenance contracts were output-based, and were set to decline each year by RPI-3%; these contracts have recently been re-negotiated (completed in 2002). Track renewals were to be negotiated on a case-by-case basis[8].

At privatisation (1996) the organisation structure of Railtrack was based around seven[9] geographical Zones (see Figure 1 below), with a corporate centre. The functions of the corporate centre include strategy, financial control, safety assurance, procurement and R&D. The Zones are responsible for managing the maintenance / renewal contracts within their area, subject to direction from the centre[10]. Expenditure plans are formulated at the Zonal level, although financial and other targets are determined centrally.

2.2 Previous studies of Railtrack's efficiency

As a monopoly provider of rail infrastructure, it was clear from the outset that Railtrack's charges (to train operators) for access to the network would need to be regulated. The original level of "access charges" was determined by the Department of Transport. These charges were later reduced by the ORR, to reflect the expectation that Railtrack would be

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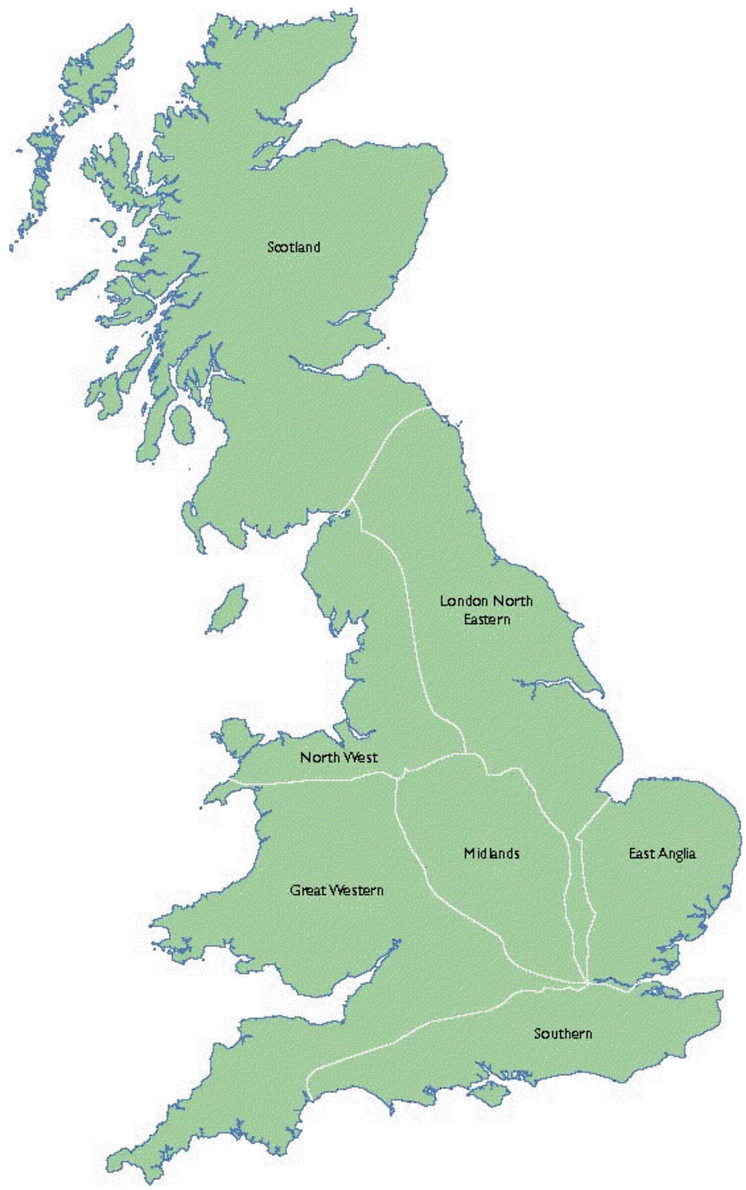
[8] Though Railtrack retained the option to (periodically) tender for renewals in order to test the market.

[9] On formation, in 1994, the company was arranged into ten Zones. The ten Zones included (in addition to the seven shown in Figure 1): West Coast, East Coast and South West. West Coast was divided into Scotland, Midlands and North West Zone. East Coast was divided into LNE and Scotland Zones. South West was combined with Southern Zone. This process started on 26 June 1995, when the number of Zones was reduced to eight. See Railtrack Annual Report 1994/95. Railtrack data on a seven-Zonal basis is available from 1995/96 (financial year) onwards.

[10] Each maintenance contract area was contained within the boundary of a single Zone.

Figure 1

Map of Zone Areas (1995/96 to 2001/02)



able to achieve significant efficiency savings over the first control period (or CP1;. covering the period 1995/96 to 2000/01). Railtrack therefore became subject to the "RPI-X" incentive-regulation used for other privatised utilities In December 1997 the ORR started consultation on the appropriate level of efficiency targets for the company over the second control period (or CP2; covering the period 2001/02 to 2005/06). The ORR's assessment of the scope for future efficiencies was based on evidence from a range of different sources[11] and was supported by four consultant reports: Booz-Allen and Hamilton,1999 and 2000; NERA, 2000; Europe Economics, 2000; and Horton 4 Consulting, 2000; described in turn below. It should be noted that the academic literature provided little evidence on this question, since most studies had focused on comparing the efficiency of railway systems, rather than rail infrastructure provision. We have identified only one academic study which considered rail infrastructure efficiency (Chapin and Schmidt, 1999), although their paper is concerned with the impact of mergers on efficiency (US Class I railroads), rather than on international comparison.

Booz-Allen and Hamilton (1999; 2000) adopted a "bottom-up" approach to assessing the potential for efficiency gains. They reviewed each of Railtrack's asset areas and functions, and identified specific efficiency opportunities in each area. At the overall level, Booz-Allen Hamiliton's work suggested efficiency targets of approximately 4% per annum. However, the ORR noted that this approach did not take account of the potential for savings from (as yet) unspecified efficiency initiatives.

The remaining three consultant reports were based on "top-down" methodologies. NERA (2000) examined the international evidence on rail infrastructure costs. They compared productivity levels across a number of countries (US, Canada, Japan, Australia and Europe), and also analysed productivity trends (US Class I railroads). In respect of productivity levels, NERA found that there was insufficient evidence in the public domain to draw meaningful conclusions. However, their trend analysis revealed that the US Class I railroads had achieved annual productivity growth (infrastructure only) of between 3.3% and 3.9% over the period 1986 to1998. NERA argued that this benchmark provided a realistic long-run target for Railtrack (and that the company may also be able to achieve additional "catch-up savings)[12].

NERA also reviewed a study by LEK (2000), prepared for English, Welsh and Scottish Railways (EWS), but largely dismissed the LEK findings. The LEK study (of US Class I railroads) reported rail infrastructure productivity gains of 6.7% per annum between 1980 and 1998, though NERA argued that the study failed to adjust for scale and density effects. LEK also showed Railtrack's freight access charges to be considerably higher than the infrastructure costs of the largest five US Class I railroads; though this finding was based on comparing Railtrack prices with US costs, and also focused on a single (partial) productivity measure.

Europe Economics (2000) argued that the experience of other UK privatised network businesses offered the best means of assessing the scope for Railtrack efficiency

[11] This assessment is set out in ORR (October 2000), ORR (July 2000) and ORR (December 1999).

[12] That is, catch-up to private sector practice, following the change from public to private ownership. NERA acknowledged that their US calculations excluded the sharp improvements in productivity which

improvements (in particular, water, sewerage, electricity transmission and distribution, and gas transportation). Based on this evidence, Europe Economics suggested that Railtrack's efficiency target should be in the region of 3 to 5% per annum (in real terms). Horton 4 Consulting (2000) supported the conclusions of the Europe Economics report, though did not present any new evidence[13].

In the event, Railtrack's efficiency target was eventually set at 3.6% p.a.[14], close to the lower end of the range suggested by Europe Economics. Railtrack commissioned its own consultants (OXERA, 2000), who argued for a target closer to 2% per annum. In essence, the dispute centred on the comparability of the benchmark information, for example, in terms of the scope for technical change; the extent of capital substitution; differences in volume growth and scale effects; and real wage inflation differentials[15].

Given the problems experienced during the 2000 Periodic Review, which focused on external benchmarks, the objective of this paper is to explore the use of internal (Zonal) benchmarking to inform the debate on future efficiency targets for Network Rail. Compared to external comparisons, our approach has a number of advantages. First of all, the data is consistent across Zones, and our analysis does not therefore suffer from the problems often experienced in international studies. Furthermore, differences in scale, technology or other environmental factors, which usually affect efficiency comparisons, are likely to be relatively small. Finally, we would expect the analysis of comparable, internal business units to provide clearer guidance on how savings can be achieved in practice.

3. Methodology

In this paper we apply three established techniques to assess the relative efficiency of Railtrack's Zones over the period 1995/96 to 2001/02: corrected ordinary least squares (COLS); stochastic frontier analysis (SFA); and data envelopment analysis (DEA). These techniques have been widely applied to the study of productivity and efficiency measurement in the railway industry (see Affuso, Angeriz and Pollitt, 2001 for a review of this literature). We note that the use of more than one approach enables the results of alternative methodologies to be compared. This section briefly describes each of the techniques in turn. The model specifications used in our empirical analysis are described in Section 4 below.

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occurred immediately after deregulation in 1980. NERA also recognised the problems of comparing a predominantly passenger railway (Britain) with a freight dominated railway (US).

[13] See ORR (July 2000) page 48.

[14] See ORR (October 2000), page 36. This is the underlying efficiency improvement on controllable costs, and is based on a simple average.

[15] Though note that the ORR adjusted Railtrack's efficiency targets to take account of this last factor in the final conclusions.

3.1 Parametric approaches (COLS and SFA)

In conducting parametric efficiency analysis there is a choice to be made regarding the function (or frontier) to be estimated. We follow Coelli and Perelman (1999) and estimate an input distance function (using both the COLS and SFA techniques). Coelli and Perelman find distance function estimation to offer a convenient way of handling multiple inputs and outputs without the need to impose restrictive behavioural assumptions. They applied this method to the study of seventeen European railways over the period 1988-1993. We consider that this approach is applicable to the question presently under analysis (as explained in Section 4.2 below). Coelli and Perelman (1999) define the (translog) input distance function for M outputs and K inputs as[16]:

$$\ln D_{Ii} = \alpha_0 + \sum_{m=1}^{M} \alpha_m \ln y_{mi} + 1/2 \sum_{m=1}^{M} \sum_{n=1}^{M} \alpha_{mn} \ln y_{mi} \ln y_{ni} + \sum_{k=1}^{K} \beta_k \ln x_{ki} + 1/2 \sum_{k=1}^{K} \sum_{l=1}^{K} \beta_{kl} \ln x_{ki} \ln x_{li} + \sum_{k=1}^{K} \sum_{m=1}^{M} \delta_{km} \ln x_{ki} \ln y_{mi}, i = 1,2,....N \quad (1)$$

where i denotes the ith firm in the sample, the y_i and x_i are the M outputs and K inputs respectively, D_{Ii} represents the input distance function, and α,β, and δ are parameters to be estimated. Coelli and Perelman impose homogeneity of degree one in inputs by dividing through by one of the inputs (arbitrarily chosen). After this transformation, equation (1) becomes:

$$\ln(D_{Ii} / x_{Ki}) = TL(y_i, x_i / x_{Ki}, \alpha, \beta, \delta), i = 1,2,....n \quad (2)$$

where TL represents the translog function. Equation (2) can be re-arranged to give:

$$-\ln(x_{Ki}) = TL(x_i / x_{Ki}, y_i, \alpha, \beta, \delta) - \ln(D_{Ii}), i = 1,2,....n \quad (3)$$

[16] See Coelli and Perelman (1999), page 329.

Equation (3) now shows the log of the Kth input as a function of the outputs, and the ratios of the other inputs (to the Kth input). The $\ln(D_{Ii})$ term is interpreted as the one-sided inefficiency term.

Equation (3) may be estimated using COLS or, with some alteration, SFA (see below). The COLS method, developed by Greene (1980)[17] proceeds by estimating equation (3) using OLS, and then adjusting the intercept by adding the largest positive residual. Efficiency scores are then calculated as the exponential of the adjusted residuals. The COLS method makes no allowance for noise, and assumes that all deviations from the frontier result from inefficiency (deterministic model). To overcome this problem, we also apply the SFA technique, developed (independently) by Aigner, Lovell and Schmidt (1977) and Meeusen and van Den Broeck (1977), to our data set. The stochastic frontier method adds an additional random error (v_i) to the deterministic frontier model in equation (3), and can be written as:

$$-\ln(x_{Ki}) = TL(x_i / x_{Ki}, y_i \alpha, \beta, \delta) + v_i - u_i, i = 1,2,....n \qquad (4)$$

where, the v_i terms represent random noise, and are assumed to be identically and independently distributed as $N(0,\sigma_v^2)$; the notation $\ln(D_{Ii})$ is changed to u_i, where the u_i terms reflect inefficiency, and are therefore constrained to be non-negative. The u_i are assumed to be distributed independently of v_i and the regressors, and are usually assumed to be drawn from a $N(0,\sigma_u^2)$ half-normal distribution.

The stochastic frontier approach applies maximum likelihood estimation to equation (4), and the efficiency scores are then calculated from the residuals using the procedure developed by Jondrow, Lovell, Materov and Schmidt (1982). The SFA technique has now been automated on many statistical packages, including FRONTIER (used in our analysis). Our parametric model specifications are described in Section 4.2 below.

3.2 Data envelopment analysis (DEA)

To supplement our parametric methodologies we also apply the (non-parametric) DEA technique to our data set, including a second-stage TOBIT analysis of gross efficiency scores.

[17] Building on the work of Aigner and Chu (1968), Afriat (1972) and Richmond (1974).

(a) Single-stage DEA

The DEA method was first introduced by Charnes, Cooper and Rhodes (1978). Their paper re-presented and operationalised the work of Farrell (1957) using linear programming techniques[18]. The Charnes, Cooper and Rhodes (CCR) model may be shown in either its envelopment or ratio form. These approaches produce the same efficiency scores, but have different economic interpretations. The ratio form DEA linear programming problem can be written as (for each DMU; M outputs and K inputs)[19]:

$$\text{Maximise} \qquad h_0 = \frac{\sum_{m=1}^{M} u_m Y_{m0}}{\sum_{k=1}^{K} v_k X_{k0}}$$

$$st. \qquad \frac{\sum_{m=1}^{M} u_m Y_{mj}}{\sum_{k=1}^{K} v_k X_{kj}} \leq 1 \quad j = 1,2,\ldots n; \qquad u_m, v_k \geq 0, \tag{5}$$

where h_0 denotes the (computed) efficiency score for DMU_0, the Y_{mj} and X_{kj} are the observed outputs and inputs for the jth DMU, and the u_m and v_k are the output and input weights to be determined, which are assumed to be non-negative[20]. This is the linear programming solution for the input-oriented view of efficiency (as adopted in this paper; see Section 4.2 below).

In its ratio form, the DEA method finds the maximum ratio of weighted (or virtual) outputs to inputs for each DMU, subject to the constraint that all ratios, or efficiency scores, are less than or equal to one. However, in practice, most DEA packages use the envelopment form of the linear programme, since this involves fewer constraints, and is therefore easier to solve. The envelopment form programme finds the maximum radial contraction of the input vector (of each DMU) whilst still remaining within the feasible input set. Those firms on the boundary of the feasible input set (for which further contraction is not possible), are considered efficient, and obtain a score of unity. We describe our DEA model specifications in Section 4.2 below.

[18] Pollitt (1995) notes that Farrell's work had been largely ignored in the literature prior to 1978.
[19] See Charnes, Cooper and Rhodes (1978), page 430, and Charnes and Cooper (1985), page 63.
[20] Note that this form of the problem has an infinite number of solutions and requires modification prior to implementation.

(b) Two-stage (TOBIT) DEA
Many DEA applications adopt a two-stage methodology, in which regression analysis is used to explain the variation in "gross" efficiency scores generated by the first-stage DEA analysis. A TOBIT regression is used (in place of OLS), because the gross efficiency index is constrained to take values between zero and unity, making it a limited dependent variable. The use of second-stage, TOBIT regression analysis, serves two purposes. First of all, the drivers of gross efficiency can be identified. Second, "net" or "residual" efficiency scores can be computed from the residuals of the TOBIT regression. For more on this method, and its application in the railway industry, see Oum and Yu (1994) and Productivity Commission (1999).

4. Data and model specifications

This section describes our data set, as well as the model specifications used in the analysis presented in Section 5.

4.1 Data description
The data set used in this study covers seven Zones over the period 1995/96 to 2001/02, and was collected through fieldwork at Railtrack between February and August 2002. The data is shown in Table 1 (period averages), and includes:

- maintenance costs (MAIN);
- total costs (TOTC), which is the sum of maintenance and track renewal costs (REN);
- passenger train miles (PTM);
- passenger tonne miles (PTON);
- freight gross tonne miles (FTON);
- track miles (TRAC);
- Railtrack-caused delays (DELS); and
- broken rails (BRLS).

Table 1
Inputs and outputs (averages 1995/96 to 2001/02)

2000/01 £m*	Inputs (costs)			Inputs (quality)		Outputs			
	MAIN	REN	TOTC	DELS	BRLS	PTM	PTON	FTON	TRAC
	£m	£m	£m	000 min	number	million	million	million	miles
East Anglia	76.2	38.4	114.6	882	68	24.5	5,093	1,155	1,414
Great Western	108.3	57.3	165.6	1,671	90	32.0	6,903	4,452	3,136
LNE	114.4	63.4	177.7	1,958	213	37.3	8,114	6,169	3,448
Midlands	137.4	126.0	263.4	2,599	132	43.5	9,662	5,154	3,096
North West	94.7	50.2	144.9	1,425	95	29.0	4,115	2,564	2,638
Scotland	83.6	39.6	123.2	794	62	24.6	4,269	2,288	2,541
Southern	149.7	57.2	206.8	2,113	104	64.4	15,100	1,617	3,017
Network	**764.3**	**432.1**	**1,196.4**	**11,442**	**763**	**255.1**	**53,255**	**23,398**	**19,290**

* Where monetary values are used.

The variables, PTM, PTON, FTON and TRAC are all measures of volume. The DELS variable measures asset performance, whilst the inclusion of BRLS in the data set provides a measure of asset condition (and, in turn, safety). Our cost variables, maintenance (MAIN) and track renewal costs (REN), accounted for £1.7bn, or roughly 45% of Railtrack's total cash expenditure in 2001/02[21]. Further details about the data and sources are provided in Appendix 1.

4.2 Model specifications

Before describing the model specifications used to measure relative efficiency for Railtrack's seven Zones, we first outline our treatment of general changes in productivity (or frontier shifts) which have occurred since privatisation (Hatfield and time trend effects). Note for both our parametric and DEA approaches the data is pooled, to create 49 observations (seven Zones over seven years).

(a) Modelling frontier shifts (Hatfield and time trend effects)

It is well known that the cost of maintenance and renewal activities has increased sharply since the Hatfield accident in October 2000 (see Figure 5 below). To reflect this structural break in the data, we have divided the analysis in Section 5 into two parts: (1) the period 1995/96 to 1999/00; and (2), the full seven year period from 1995/96 to 2001/02. In respect of the latter we have included a Hatfield dummy variable in the parametric regression equations described below (see Tables 2 and 3). For the total cost regressions this dummy takes the value 0.5 in 2000/01; unity in 2001/02; and zero elsewhere (the

[21] Defined as: (maintenance and track renewal expenditure) divided by (operating costs less asset maintenance plan (AMP) charge and depreciation plus total renewal expenditure). The remaining 55% comprises non-track renewal costs, signaling operations, traction costs and overheads.

Hatfield accident took place mid way through the financial year 2000/01). For the maintenance cost regressions, the dummy variable takes the value unity in 2001/02; and zero elsewhere (since unit maintenance costs did not start to rise sharply until 2001/02).

We also include a time trend variable in all of our models in order to test for the existence of a general improvement in productivity (across all Zones) over time[22]. Of course, productivity did improve in the early years after privatisation, before falling back sharply in the years following the Hatfield accident. The latter effect is captured by the Hatfield dummy variable[23].

(b) Parametric model specifications

The specifications for the parametric (input distance function) models presented in Section 5 are shown in Table 2 below. These are identical for both the COLS and SFA approaches[24]. As noted in Section 3, our approach follows that of Coelli and Perelman (1999), who used distance function estimation in their comparison of European railway systems. We consider that the input distance function application is appropriate in the present context. Under this interpretation, the quality variables (delays and broken rails) are treated as traditional inputs. Railtrack Zones are then assumed to minimise inputs (costs, delays and broken rails) for a given level of (exogenously determined) output (track miles and traffic volume) [25]. The potential trade-off between cost and quality is therefore explicitly recognised in the distance function specification. We note that previous studies of international railway efficiency have been unable to adjust for quality differences due to the lack of comparable data.

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[22] This specification achieves the best fit with the data.

[23] We note that the COLS results (with no time trend included) indicate that average productivity is still higher in 2001/02 than in 1995/96. However, the regression performs less well in terms of overall fit; and the Hatfield dummy becomes insignificant when the time trend is absent. See Section 5 below.

[24] These approaches differ only in the method of estimation, and the calculation of the efficiency scores.

[25] Coelli and Perelman (1996) notes that the distance function specification avoids the problem of regressor endogeneity, since the ratio of the inputs are included as the relevant regressors. Coelli and Perelman argue that these can be regarded as exogenous, since the distance function is defined for radial reductions in all inputs, for given output levels.

Table 2
Parametric models (COLS and SFA)

	Model 1	Model 2	Model 3	Model 4
Inputs*	MAIN	MAIN	TOTC	TOTC
Input ratios	DELS/MAIN	DELS/MAIN	DELS/TOTC	DELS/TOTC
	BRLS/MAIN	BRLS/MAIN	BRLS/TOTC	BRLS/TOTC
Outputs**	TRAC	TRAC	TRAC	TRAC
	PTMD	PTOND	PTMD	PTOND
	FTOND	FTOND	FTOND	FTOND
Other variables	TIME	TIME	TIME	TIME
	DUMMY	DUMMY	DUMMY	DUMMY

* Arbitrarily chosen as the dependent variable
** Traffic volume measures expressed as densities (per track mile)

The output choices are derived from the alternative specifications used in the railway efficiency and productivity literature. The majority of previous studies include measures of passenger and freight volumes as railway outputs[26]. We use freight tonne miles (FTON) to represent freight traffic volumes. For passenger traffic, we use either passenger train miles (PTM; in Models 1 and 3), or passenger tonne miles (PTON; in Models 2 and 4). The comparison of these alternative specifications enables us to test whether taking account of the weight variation in passenger trains affects the "fit" of the parametric equations and, in turn, the relative efficiency scores of the Zones. We would expect Zones which handle heavier passenger trains to have higher maintenance and renewal costs (other things equal).

In line with previous studies, the traffic volume variables are expressed as densities (PTMD, PTOND and FTOND) and combined with the track miles variable (TRAC) in order to distinguish between economics of scale and density[27], whilst avoiding potential

[26] See, for example, Caves, Christensen and Swanson (1980).
[27] See, for example, Caves, Christensen, Tretheway and Windle (1985).

multicollinearity problems[28]. As explained above, a time trend is also included in each of our specifications, along with a "Hatfield" dummy variable (full seven year data regressions only).

(c) DEA model specifications

The DEA models analysed in this paper are shown in Table 3 below. The input and output choices follow those of our parametric models (see Table 2 above). However, the quality variables, delays and broken rails, are included (in normalised form[29]) as regressors in a second-stage TOBIT regression, since their treatment as inputs in the DEA linear programme is problematic[30]. The inclusion of track miles as an output follows Chapin and Schmidt (1999); the only academic study we have identified which considers the question of rail infrastructure efficiency, as noted above in Section 2. We would expect the inclusion of track miles as an output to enable the (first stage) DEA model to make some allowance for density effects, compared to models which use only traffic volume measures as outputs.

The second-stage TOBIT regressions include density variables (PTMD or PTOND and FTOND) in order to test the extent to which the first stage DEA scores are correlated with density. A time trend is also included, together with a Hatfield dummy (full, seven-year regressions only), in line with our COLS/SFA methods. Net efficiency scores are calculated from the residuals[31]. Note that in all the models shown in Table 3 we adopt the usual input-oriented approach, which assumes that the Railtrack Zones have greater control over their inputs (costs), than over the outputs (track miles and traffic volumes) [32]. We also run all of our DEA models under the alternative assumptions of constant (CRS) and variable returns to scale (VRS).

[28] Which may occur when TRAC, PTM and FTON are included together as independent variables.
[29] That is, divided by total train miles in order to correct for Zone size.
[30] In this paper we consider that the quality variables can best be interpreted as inputs for both our DEA and parametric approaches (see Section 4.2 (b) above). However, when these variables are included as inputs in a first stage DEA, all the efficiency scores are equal to (or close to) unity. The alternative treatment, where the inverse of the quality measures are included as outputs in the DEA programme, is also problematic due to the difficulty of finding an appropriate normalisation for the variables (dividing through by train miles does not work in this case).
[31] See Oum and Yu (1994) and Productivity Commission (1999).
[32] This assumption is normally based on regulatory restrictions on service and line closures.

Table 3
DEA Models

	DEA1	DEA2	DEA3	DEA4
Inputs (in first stage DEA)	MAIN	MAIN	TOTC	TOTC
Outputs (in first stage DEA)	PTM FTON TRAC	PTON FTON TRAC	PTM FTON TRAC	PTON FTON TRAC
Inputs (included in TOBIT regression)	DELS* BRLS*	DELS* BRLS*	DELS* BRLS*	DELS* BRLS*
Other TOBIT regressors	PTMD** FTOND** TIME DUMMY	PTOND** FTOND** TIME DUMMY	PTMD** FTOND** TIME DUMMY	PTOND** FTOND** TIME DUMMY

* These variables are normalised by total train miles
** Measured as densities (per track mile)

5. Results

This section is divided into three sub-sections. Section 5.1 shows the trends in the input, output and partial productivity measures (at the network level) over the period 1995/96 to 2001/02. Section 5.2 presents the results of our efficiency analysis for the period before the Hatfield accident (1995/96 to 1999/00). Finally, Section 5.3 looks at how the post-Hatfield environment has impacted on absolute productivity levels and the relative efficiency positions of the seven Railtrack Zones.

5.1 Network level trend analysis

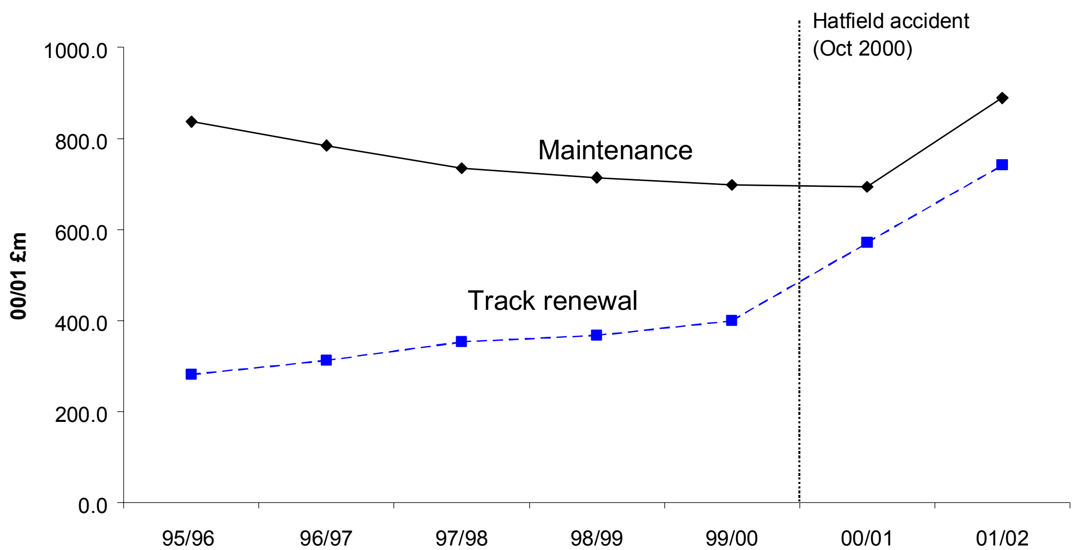
Figures 2 to 5 outline the trends in inputs, outputs and partial productivity measures (network level) over the period 1995/96 to 2001/02[33]. The quality measures are shown on a normalised basis (per train mile). Figure 2 shows that maintenance costs have fallen steadily over the period to 2000/01. However, in the aftermath of the Hatfield accident, maintenance and track renewal costs have risen sharply. Figure 3 illustrates the now familiar growth in passenger and freight traffic, partially halted in 2000/01, as a result of the speed restrictions imposed post-Hatfield.

Figure 4 shows the significant reduction in delays achieved over the period to 1999/00. Delays have now resumed a downward path, following the sharp increase in 2000/01. Figure 4 also shows that broken rails have fallen significantly over the period since privatisation, following an initial increase during the early years prior to 1999/00. Taking account of both cost and volume changes, Figure 5 shows that unit maintenance and total costs (per total tonne mile) fell significantly after privatisation, before rising again post-Hatfield.

Figures 2 to 5 show a clear structural break in the data after the Hatfield accident in October 2000. Maintenance and renewal costs have since increased sharply, along with Railtrack-caused delays. Passenger and freight volume growth was also partially interrupted by the Hatfield accident; and broken rails fell sharply over the period 1999/00 to 2001/02 (though the fall in broken rails began one year earlier). The remainder of the analysis in this paper is therefore split into two time periods; before and after Hatfield.

Figure 2

Inputs: Maintenance and Track Renewal Costs



[33] Note that the track miles variable is not shown since it has remained broadly constant over the period.

Figure 3

Outputs: Passenger train miles, Passenger tonne miles and Freight tonne miles

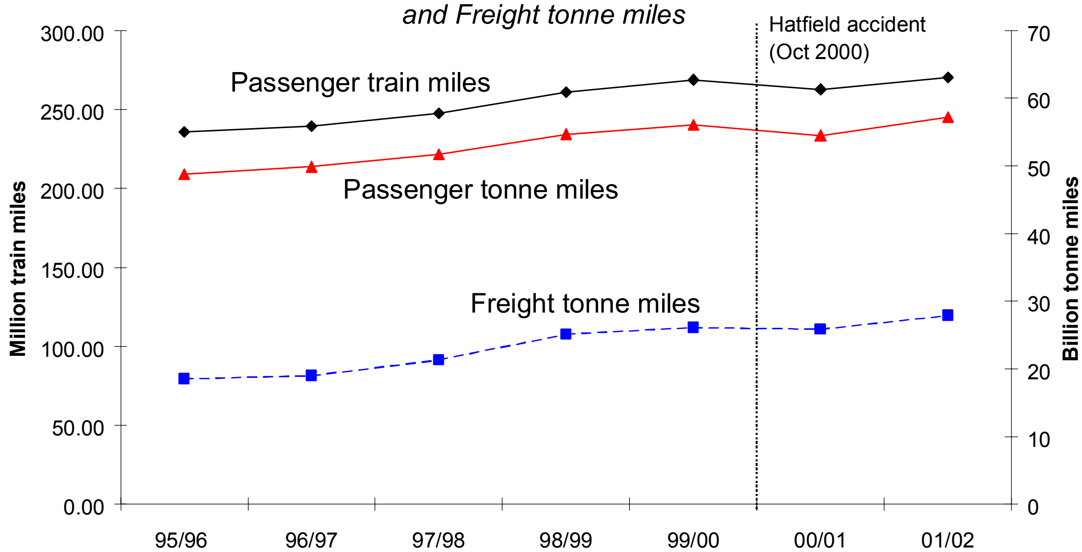


Figure 4

Quality (inputs): Delays and Broken Rails per train mile

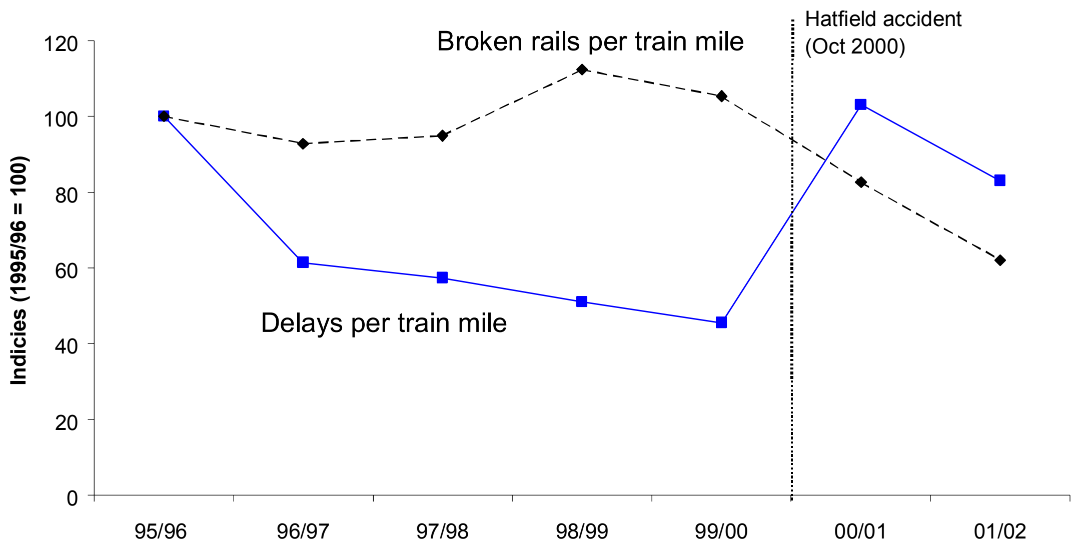
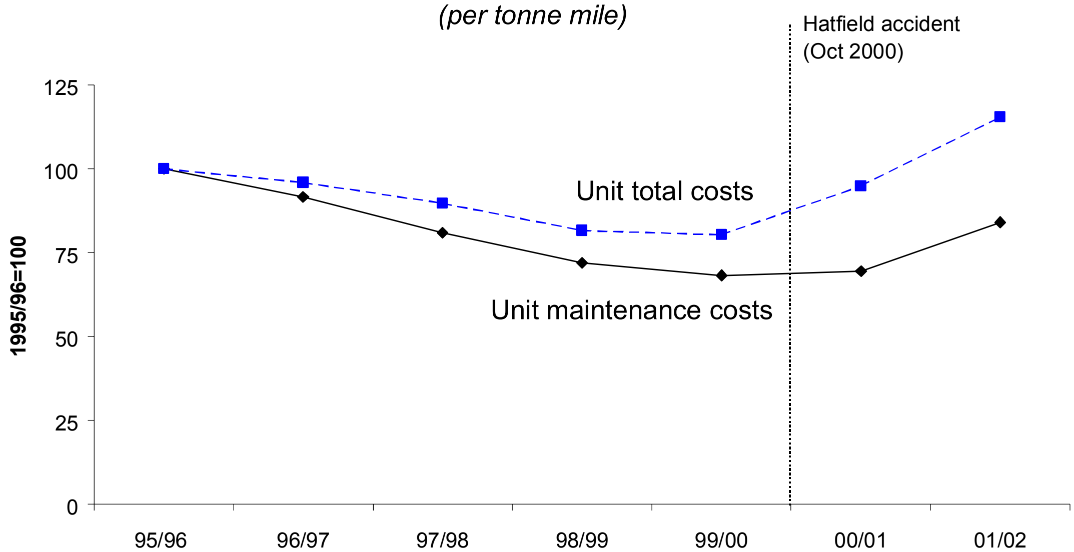


Figure 5

Productivity Indices: Unit Maintenance and Total Cost (per tonne mile)



5.2 Efficiency results (pre-Hatfield)

Below we present the results of our efficiency analysis covering the pre-Hatfield period (1995/96 to 1999/00). Note that, since data is not available on input prices, all of our techniques measure overall economic efficiency.

(a) Parametric results (COLS and SFA)

In Section 4.2 we identified four models to be estimated, based on the literature. The OLS estimates for these models are shown in Table 4 below. We have used a log-linear functional form, since our translog results performed poorly in terms of the significance of the parameters[34]. The signs of the coefficients have also been changed (compared to equation (3) above) for ease of interpretation, so that a positive coefficient indicates a positive relationship between cost and the other variables.

Our preferred models from Table 4 are COLS1 and COLS3, since these perform better than the other equations (overall fit; and significance of the variables). This finding indicates that Zonal maintenance and renewal costs exhibit a closer fit with the passenger train miles (rather than passenger tonne miles) data[35]. We further note that all of the coefficients in our preferred models have the expected sign (positive relationship between cost and outputs; negative relationship between cost and quality; and negative

[34] This is a common problem with translog estimation (multicollinearity between 1st and 2nd order terms).
[35] Which may reflect inaccuracies in the data used to convert PTM into PTON. See Appendix 1.

relationship between cost and time, indicating firm-wide productivity gains over time). All of the coefficients are also statistically significant (except the delays input ratio in COLS1)[36]. These results give us confidence in the efficiency rankings derived from the (adjusted) OLS residuals, to which we now turn.

Table 4

OLS Input Distance Function Regressions (log-linear; t ratios in brackets)*

Input**	COLS1 MAIN	COLS2 MAIN	COLS3 TOTC	COLS4 TOTC
Constant	2.571 (6.44)	2.917 (4.92)	1.028 (2.05)	1.155 (1.57)
TIME	-0.079 (-8.73)	-0.047 (-3.78)	-0.068 (-5.05)	-0.030 (-1.66)
TRAC	0.787 (19.41)	0.682 (11.62)	0.867 (15.67)	0.767 (9.86)
PTMD	0.692 (16.23)	- -	0.768 (13.20)	- -
PTOND	- -	0.381 (10.16)	- -	0.422 (8.41)
FTOND	0.200 (5.35)	0.032 (0.66)	0.364 (8.13)	0.210 (3.64)
DELS (ratio)	-0.053 (-1.17)	0.073 (1.14)	-0.134 (-2.20)	-0.015 (-0.18)
BRLS (ratio)	-0.121 (-3.92)	-0.083 (-1.83)	-0.217 (-5.49)	-0.199 (-3.52)
Adjusted R^2	0.959	0.909	0.936	0.870

* Positive coefficient indicates positive relationship. ** Arbitrary choice of dependent variable

[36] It is perhaps surprising that the total cost models (including annual renewal costs) are well behaved given the (potentially) lumpy nature of track renewal activity. Our results therefore suggest that some of this potential variation is smoothed out across the Zonal route portfolios. It is also possible that these findings reflect a reluctance within Railtrack to prioritise investment to particular areas of the network, and that, instead, each Zone has tended to receive its “historic” level of the company’s investment budget from year to year.

The efficiency scores resulting from the above OLS regressions, after applying the COLS transformation, are shown in Table 5 below. As noted above, our preferred models are COLS1 and COLS3[37]. However, we note that the COLS Zone rankings show a high degree of conformity across models (see Appendix 2). Table 6 shows that the SFA results produce virtually identical rankings to those generated by the COLS method. The gamma values[38] for the SFA models are high (between 0.956 and 1.000), indicating that the stochastic frontier model is not significantly different from the deterministic (COLS) model with no random error included. We note that Coelli and Perelman (1996) also reported extreme gamma values (either zero or greater than 0.99) in their analysis of European railways. The COLS/SFA results are discussed further in Sections 5.2 (c) and 5.2 (d) below.

Table 5

Summary of COLS efficiency scores*

		COLS1	COLS2	COLS3	COLS4
95/96	East Anglia	0.907 [4]	0.842 [6]	0.914 [3]	0.844 [3]
95/96	Great Western	0.997 [1]	0.996 [1]	0.996 [1]	1.000 [1]
95/96	London North Eastern	0.878 [7]	0.850 [5]	0.842 [6]	0.805 [5]
95/96	Midlands	0.881 [6]	0.822 [7]	0.872 [5]	0.804 [6]
95/96	North West	0.932 [3]	0.872 [3]	0.916 [2]	0.850 [2]
95/96	Scotland	0.886 [5]	0.867 [4]	0.838 [7]	0.816 [4]
95/96	Southern	0.947 [2]	0.888 [2]	0.874 [4]	0.797 [7]
	Average	**0.918**	**0.877**	**0.893**	**0.845**
99/00	East Anglia	0.959 [3]	0.909 [3]	0.954 [3]	0.899 [5]
99/00	Great Western	0.895 [4]	0.909 [4]	0.902 [5]	0.924 [3]
99/00	London North Eastern	0.988 [1]	0.939 [2]	0.994 [1]	0.942 [2]
99/00	Midlands	0.884 [5]	0.789 [6]	0.737 [7]	0.625 [7]
99/00	North West	0.854 [7]	0.761 [7]	0.852 [6]	0.753 [6]
99/00	Scotland	0.970 [2]	0.945 [1]	0.970 [2]	0.952 [1]
99/00	Southern	0.881 [6]	0.863 [5]	0.923 [4]	0.910 [4]
	Average	**0.919**	**0.874**	**0.905**	**0.858**

* Relative rankings (within each year) shown in square brackets

[37] Since these equations perform better than their counterparts Furthermore, the small changes in rankings between COLS2 and COLS1 (and COLS4 and COLS3), which reflect the difference between the choice of passenger tonne miles to measure passenger traffic volumes (rather than passenger train miles) do not appear to be intuitive. We would expect Zones with a high passenger tonnage per train to perform better under COLS2 and COLS4 (which is not the case).

Table 6
Summary of SFA efficiency scores*

		SFA1	SFA2	SFA3	SFA4
95/96	East Anglia	0.948 [3]	0.911 [3]	0.946 [3]	0.948 [2]
95/96	Great Western	0.989 [1]	0.997 [1]	0.988 [1]	0.997 [1]
95/96	London North Eastern	0.861 [7]	0.876 [5]	0.872 [6]	0.825 [6]
95/96	Midlands	0.869 [6]	0.826 [7]	0.893 [5]	0.798 [7]
95/96	North West	0.908 [4]	0.839 [6]	0.949 [2]	0.855 [4]
95/96	Scotland	0.900 [5]	0.882 [4]	0.863 [7]	0.843 [5]
95/96	Southern	0.954 [2]	0.964 [2]	0.925 [4]	0.855 [3]
	Average	**0.918**	**0.899**	**0.919**	**0.874**
99/00	East Anglia	0.975 [3]	0.954 [3]	0.967 [4]	0.979 [3]
99/00	Great Western	0.882 [4]	0.934 [5]	0.912 [5]	0.939 [5]
99/00	London North Eastern	0.975 [2]	0.994 [1]	0.985 [1]	0.974 [4]
99/00	Midlands	0.873 [6]	0.817 [6]	0.745 [7]	0.625 [7]
99/00	North West	0.846 [7]	0.777 [7]	0.873 [6]	0.786 [6]
99/00	Scotland	0.979 [1]	0.984 [2]	0.974 [2]	1.000 [1]
99/00	Southern	0.874 [5]	0.944 [4]	0.968 [3]	0.988 [2]
	Average	**0.915**	**0.915**	**0.918**	**0.899**
	Gamma	1.000	0.999	0.956	1.000

* Relative rankings (within each year) shown in square brackets

(b) DEA results

The DEA scores for the four models outlined in Section 4.2 are presented in Table 7 below. Only the CRS scores are shown since our VRS models produce high scale efficiency scores[39]. For each model, we show the net efficiency scores (where the latter are computed from the residuals of the TOBIT regressions specified in Table 3 above). For example, for DEA1, the TOBIT regression takes the form[40]:

[38] Defined as $\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$. See equation (4) above.

[39] Between 0.93 and 0.96; we note that this finding contradicts the results of the parametric regressions shown in Table 4 above. We also found that the DEA VRS were not internally consistent. For example under DEA1, Midlands Zone was found to be at optimal scale in 1998/99 (and previous years), but to have a scale efficiency score of only 0.84 in 1999/00.

[40] Note that, following Oum and Yu (1994), in the actual regression analysis we take the negative log of the efficiency score (so that the dependent variable is left centred at zero, and can therefore be estimated using the standard TOBIT model).

$$h_i = \alpha_i + \beta_{1i}(PTMD) + \beta_{2i}(FTOND) + \beta_{3i}(DELS*) + \beta_{4i}(BRLS*) + \beta_{5i}(TIME) \qquad (6)$$

where h_i denotes the gross efficiency score for each observation; the delays (DELS*) and broken rails (BRLS*) variables are normalised (divided by train miles) to adjust for Zone size; and α and the βs are parameters to be estimated. Our preferred models are DEA1 and DEA3, since these are analogous to our preferred parametric models (COLS1 and COLS3).

It should be noted that the TOBIT regressions (not reported) perform less well than the OLS results shown in Table 4 above. The (normalised) quality variables, delays and broken rails, are not significant in any of the models, and the density variables are insignificant in three out of the four cases. However, the time trend is significant in three out of the four regressions, indicating positive productivity growth over the period (as for the OLS results reported in Table 4 above). The DEA results are discussed further in Sections 5.2 (c) and 5.2 (d), and compared with the results of our parametric analysis.

Table 7
Summary of DEA (net) efficiency scores*

		DEA1	DEA2	DEA3	DEA4
95/96	East Anglia	0.740 [7]	0.700 [7]	0.744 [7]	0.731 [7]
95/96	Great Western	0.994 [1]	0.990 [1]	0.961 [1]	0.979 [1]
95/96	London North Eastern	0.882 [4]	0.883 [3]	0.812 [4]	0.830 [4]
95/96	Midlands	0.799 [6]	0.780 [6]	0.757 [6]	0.763 [6]
95/96	North West	0.896 [3]	0.882 [5]	0.912 [2]	0.909 [2]
95/96	Scotland	0.874 [5]	0.882 [4]	0.796 [5]	0.815 [5]
95/96	Southern	0.980 [2]	0.956 [2]	0.876 [3]	0.859 [3]
	Average	**0.881**	**0.867**	**0.837**	**0.841**
99/00	East Anglia	0.831 [7]	0.775 [7]	0.776 [6]	0.747 [6]
99/00	Great Western	0.904 [4]	0.920 [4]	0.880 [5]	0.908 [4]
99/00	London North Eastern	1.000 [1]	1.000 [1]	1.000 [1]	1.000 [1]
99/00	Midlands	0.847 [6]	0.823 [6]	0.593 [7]	0.567 [7]
99/00	North West	0.876 [5]	0.839 [5]	0.908 [4]	0.871 [5]
99/00	Scotland	1.000 [1]	1.000 [1]	1.000 [1]	1.000 [1]
99/00	Southern	1.000 [1]	1.000 [1]	1.000 [1]	1.000 [1]
	Average	**0.923**	**0.908**	**0.880**	**0.870**

* Relative rankings (within each year) shown in square brackets

(c) Comparison of methods

As noted above, the COLS and SFA methods produce virtually identical efficiency results. The DEA method also produces similar rankings for five out of the seven Zones, therefore providing some support for the parametric results. However, in 1999/00 the DEA method produces very different rankings for East Anglia (high rank under COLS; low rank under DEA) and Southern (low rank under COLS; high rank under DEA); see Tables 5 and 7. For East Anglia (the smallest Zone), the differences can be explained by scale and quality effects. The OLS results imply increasing returns to scale; whereas the DEA results implied constant returns to scale.[41]. In addition, the quality variables are insignificant in the DEA TOBIT results, which means that East Anglia's high quality performance is not properly accounted for in the DEA scores.

On the other hand, Southern has the lowest cost per passenger train mile in 1999/00 (across all Zones and time periods), and therefore obtains a (gross) score of unity under the DEA method (which cannot be reduced during the second-stage TOBIT method). However, Southern also has the highest cost per freight tonne mile, as well as one of the highest cost per track mile ratios. The COLS method enables the appropriate output weights (for track miles and volume measures) to be determined econometrically. In contrast, the DEA method enables Southern to gain the highest score by applying a 100% weight to one of outputs (without adequately correcting for scale and density effects).

Based on the above discussion, and given the high performance of the OLS regressions, we are most comfortable with the parametric efficiency scores (the DEA TOBIT regression results were less well behaved in comparison). From the parametric models we are inclined to accept the deterministic (COLS) results, based on the high gamma scores from the SFA approach (as described above). We therefore use the COLS results (COLS1 and COLS3) to draw conclusions about the relative efficiency performance of Railtrack's Zones over the period 1995/96 to 1999/00.

(d) Discussion of results

Starting with *maintenance activity*, our (COLS) results show that, at a firm-wide level, Railtrack delivered substantial productivity improvements in the early years after privatisation (7.9% per annum, based on the time trend coefficient from our preferred model, COLS1; see Table 4). This calculation takes account of quality, scale and density effects, which are captured separately in the regression equation. The Railtrack productivity gains compare favourably with the savings reported by other UK privatised

[41] As reflected by average scale efficiency scores of close to unity resulting from the VRS DEA results. However, the VRS DEA results did indicate that East Anglia was operating below optimal scale. However, we did not use the VRS DEA results, due to the reasons outlined above. See footnote 39.

industries (in the region of 5% per annum); and with the gains reported for the US Class I railroads following de-regulation in the 1980s (between 3.3% and 6.7%)[42].

In terms of relative efficiency, Table 5 shows that Great Western, Southern and North West were the most efficient Zones in 1995/96 (COLS1). However, by 1999/00, the rankings had changed significantly. London North Eastern (LNE), Scotland, and East Anglia moved up into the top three positions, whilst Great Western, Southern and North West fell back into 4th, 6th and 7th positions respectively. Scotland and LNE achieved the largest real cost reduction over the period (26%), whilst East Anglia improved its relative position due to strong improvements across all measures.

It was noted in Section 2 that between 1999 and 2002, Railtrack renegotiated and consolidated its (inherited) maintenance contracts. Contract re-negotiation would be expected to affect costs (either positively or negatively), and we therefore investigated the extent to which this process may have impacted on our reported efficiency scores. However, we were unable to find any systematic relationship between contract renegotiation and changes in relative performance. Of the four Zones which saw changes to some or all of their contracts, two saw their relative rankings improve (Scotland and Midlands), whilst two saw falls in their relative positions (Great Western and Southern). Of those Zones which saw no contract renegotiation, two moved up the rank orderings (LNE and East Anglia), whilst the other (North West) fell back from 3rd to 7th position.

At the *total cost level* (maintenance and renewals) our results imply firm-wide productivity gains of 6.8% per annum[43]; slightly lower than for maintenance-only activity. In 1995/96, the three most efficient Zones (total costs) were Great Western, North West and East Anglia. By 1999/00, LNE, Scotland and East Anglia had emerged as the top performing Zones, as for maintenance activity. However, the slight difference in the rankings of the other Zones (as between maintenance and total efficiency scores) indicates some degree of substitution between maintenance and renewal activity. We note that the West Coast Main Line Project[44] appears to have had a significant impact on the performance of Midlands Zone in 1999/00 (efficiency score reduced from 0.884 in COLS1 to 0.737 in COLS3)[45].

[42] However, we note that the Railtrack productivity gains may be under or overstated to the extent that contractor costs differ from the amount paid by Railtrack under the lump-sum, output-based maintenance contracts inherited at privatisation. Under these contracts, Railtrack's suppliers may not have been fully compensated for increased costs resulting from traffic growth since privatisation (though there have been some volume-related payments). Alternatively, contractors may have cut costs faster than implied by the changes in contract prices. In any case, by 1999/00, many of the contracts had been renegotiated. We therefore consider that our analysis is not impacted significantly by departures of contract prices from costs.
[43] Based on COLS3.
[44] The renewal and enhancement of Britain's West Coast Main Line (linking London and Glasgow).
[45] This project included a large component of track renewals, which shows up as inefficiency in our analysis. However, this interpretation may be inappropriate to the extent that the renewals programme has been accelerated to capture scope economies between renewal and upgrade work. The project started in financial year 1998/99.

In addition to the changes in relative rankings noted above, the dispersion[46] of efficiency scores also increased between 1995/96 and 1999/00 (for both maintenance and total cost scores). In their study of UK and Japanese Electricity Distribution systems, Hattori, Jamasb, and Pollitt (2002) note a similar trend; and therefore question the effectiveness of incentive regulation in closing the efficiency gap among companies in the sector. However, in that case, the widening efficiency gap results from frontier firms increasing their lead over other companies. Our analysis suggests that the leading Zones in 1995/96 were instead over-taken by (previously) less efficient Zones.

5.3 Efficiency results (post-Hatfield)

As noted in Section 4, the cost of maintaining and renewing Britain's rail network has increased sharply in the last two years. In the post-Hatfield environment it became clear that a permanent increase in maintenance and renewal activity would be needed to sustain the network, given the substantial increase in passenger and freight traffic which had occurred since privatisation. However, it is possible that part of the increase has resulted from a number of temporary factors which are reversible over time (see below). In this sub-section we evaluate the impact of the Hatfield accident (and responses to it) on absolute productivity levels, and on the relative positions of the Zones.

(a) Efficiency scores

In order to keep the discussion manageable, we present only our COLS efficiency results[47], and also confine our analysis to the preferred model specifications (COLS1 and COL3). The OLS estimates for these two models are shown in Table 8 below. The COLS efficiency scores, based on these OLS results, are shown in Table 9 below (for 2001/02 only).

[46] Measured by standard deviation.

[47] As for the pre-Hatfield period, the COLS and SFA results are virtually identical. See Appendix 3. The DEA results (in 2001/02) also produce similar rankings to the other methods (in contrast to our earlier findings).

Table 8

OLS Input Distance Function Regressions (log-linear)*

Input**	Maintenance Costs (MAIN)		Total Costs (TOTC)	
	Coefficient	t ratio	Coefficient	t ratio
Constant	2.881	6.12	1.015	1.890
TIME	-0.059	-7.92	-0.064	-4.801
Hatfield dummy	0.235	5.08	0.321	3.874
TRAC	0.782	17.92	0.803	14.109
PTMD	0.640	13.11	0.808	13.302
FTOND	0.154	3.55	0.409	9.100
DELS (ratio)	0.000	0.00	-0.090	-1.775
BRLS (ratio)	-0.135	-3.55	-0.244	-5.571
Adjusted R^2	0.921		0.917	

* Positive coefficient indicates positive relationship. ** Arbitrary choice of dependent variable

Table 9

Summary of COLS efficiency scores (2001/02)*

		COLS1 MAIN	COLS3 TOTC
01/02	East Anglia	0.808 [5]	0.820 [6]
01/02	Great Western	0.788 [7]	0.914 [2]
01/02	London North Eastern	0.967 [3]	0.912 [4]
01/02	Midlands	1.000 [1]	0.822 [5]
01/02	North West	0.830 [4]	0.760 [7]
01/02	Scotland	0.987 [2]	1.000 [1]
01/02	Southern	0.795 [6]	0.913 [3]
	Average	**0.882**	**0.877**

* Rankings shown in square brackets.

(b) Discussion of results

As for the OLS results presented earlier (Table 4), the regression equations in Table 8 perform well in terms of overall fit, and the signs and significance of the variables. However, the delays variable is not significant in either of the equations, which may reflect that fact that, in the short-term, reduced renewal activity can actually result in lower delays, due to reduced need for access to the track (and vice versa, as experienced in the aftermath of Hatfield). The time trend coefficient is negative and significant in both equations, reflecting the general productivity improvements which occurred in the early years after privatisation (the time trend coefficients in Table 8 are broadly in line with those reported in Table 4). However, the positive coefficient on the Hatfield dummy variable indicates that "Hatfield effects" have led to a sharp reduction in productivity over the last two years (23% and 32% respectively for maintenance and total costs).

In addition to the change in absolute productivity levels, the relative positions of some of the Zones have also changed compared to the 1999/00 results. For *maintenance activity*, Midlands, Scotland and LNE emerge as the top three Zones (compared to LNE, Scotland and East Anglia in 1999/00). Midlands moved up from 5th position in 1999/00 (see Table 5) to first position in 2001/02; and was the only Zone to reduce maintenance costs over this period, whilst the other Zones saw increases of up to 48% in real terms. At the *total cost level*, the three top performing Zones in 2001/02 are shown to be Scotland, Great Western and Southern (compared with LNE, Scotland and East Anglia in 1999/00).

The changes to the Zonal rankings since 1999/00 suggest that different Zones have developed alternate responses to the Hatfield accident (or have been impacted to a greater or lessor extent)[48]. Furthermore, comparison of the maintenance and total cost rankings, before and after Hatfield, suggests that the relationship between maintenance and renewal activity has also changed (the correlation between COLS1 and COLS3 was much higher in 1999/00 than in 2001/02; see Tables 5 and 9).

To complete this sub-section, Table 10 shows the range of potential performance improvements[49] which less efficient Zones might be expected to deliver, based on replicating the practices employed by the most efficient Zone. Table 10 puts these potential improvements in the range of 1% to 21% for maintenance activity, and 9% to 24% for overall maintenance and renewal activity. These potential cost reductions translate into an overall, company-wide efficiency target of around 13% for both maintenance and total costs (based on a weighted average).

It should be noted that, in our analysis, we have treated post-Hatfield cost increases as a frontier shift. In other words, we assume that these cost increases are permanent – resulting from new information about asset degradation - and that there is no prospect of returning to the productivity levels recorded in earlier years. However, it is possible that part of the increase has resulted from a number of temporary factors which are reversible over time. For example: capacity constraints amongst Railtrack's supplier base; over-reaction and inefficiency in the response to Hatfield, given the lack of knowledge about asset condition; and a general switch in focus away from efficiency considerations,

[48] The dispersion of maintenance scores has also increased since Hatfield; though the dispersion of the total cost efficiency scores has remained virtually unchanged.
[49] Radial contraction of cost and quality inputs.

towards simply getting the railways working again. Further savings, over and above those shown in Table 10, may therefore be possible over time.

Table 10

Indicative potential cost reduction and/or quality improvement

	Maintenance costs	Total Costs
East Anglia	19%	18%
Great Western	21%	9%
London North Eastern	3%	9%
Midlands	-	18%
North West	17%	24%
Scotland	1%	-
Southern	20%	9%
Company weighted average	**13%**	**13%**

(c) Other factors affecting 2001/02 efficiency scores?

The above analysis has taken account of a number of factors in arriving at efficiency scores. In this sub-section we consider whether the Zonal efficiency rankings produced by our analysis can be explained by other operational factors: (1) track quality, measured by Level 2 Exceedences per track mile (L2Es) [50]; (2) track temporary speed restrictions per track mile (TSRs)[51]; (3) track category (where a high track category score indicates track which is capable of handling high train speeds and / or high tonnages)[52]; and (4) track asset age.

We were unable to include these factors in the parametric and non-parametric efficiency analysis detailed above, since a full seven year time series was not available. As a result, we carry out simple correlation analysis between the efficiency scores generated earlier, and the values of the above variables (for 2001/02 only). Our null hypothesis is that these four operational factors can explain some of the efficiency differentials reported above. If this hypothesis is true, we would expect high efficiency scores to be associated with high L2Es (that is, low track quality); high TSRs; low track categorisation (low linespeeds / tonnage capability); and low average asset age (newer assets). Based on one-year's data (2001/02), the results in Table 11 provide no evidence

[50] Level 2 Exceedence is a measure of the difference in the actual rail position from its "ideal" position.
[51] Temporary speed restrictions (TSRs) is a combined measure of the length (track miles) and duration (time) of TSRs imposed on the network due to concerns over the quality of track.
[52] Track category relates to the ability of a section of track to handle the highest train speeds and/or tonnages (on a scale of 1A to 6). Our track category measure is calculated as the percentage of track miles (by Zone) falling into the top four categories (1A to 3 inclusive); and a high percentage therefore indicates a high track category score.

in support of the above hypothesis[53]. This finding gives us further confidence in the robustness of the efficiency results presented earlier.

Table 11

Correlation between 2001/02 Efficiency Scores* and Four Operational Factors

	L2Es	TSRs	Track Category	Track Age
Correlation coefficents	-0.814**	-0.423	0.135	0.153

* Total cost efficiency scores. ** Significant at the 5% level.

To complete this sub-section, it is also of interest to examine whether the 2001/02 efficiency rankings can be explained according to the maintenance contractor (or contractors) operating in each Zone. Tables 12 and 13 compare maintenance and total cost efficiency rankings (most efficient Zone listed first) against maintenance contractor. However, this information does not indicate any clear relationship between efficiency measure and contractor, though analysis of efficiency by contractor may be an interesting area for future research.

Table 12

Maintenance cost efficiency rankings versus maintenance contractor*

Zone	Maintenance contractors
Midlands	SERCO; AMEY; Carillion.
Scotland	First Engineering.
London North Eastern	Jarvis.
North West	First Engineering; Jarvis; Carillion.
East Anglia	Balfour Beatty; AMEC.
Southern	Balfour Beatty; AMEC
Great Western	AMEY; Carillion.

* Most efficient Zone (in 2001/02) listed first, based on COLS1 in table 9.

Source: Data on contractor location provided by Railtrack.

[53] The only correlation which is statistically significant is that between efficiency and L2Es, but this coefficient is negative, indicating that firms with high efficiency also have low L2Es.

Table 13

Total cost efficiency rankings versus maintenance contractor*

Zone	Maintenance contractor (s)
Scotland	First Engineering.
Great Western	AMEY; Carillion.
Southern	Balfour Beatty; AMEC
London North Eastern	Jarvis.
Midlands	SERCO; AMEY; Carillion.
East Anglia	Balfour Beatty; AMEC.
North West	First Engineering; Jarvis; Carillion.

* Most efficient Zone (in 2001/02) listed first, based on COLS3 in table 9.

Source: Data on contractor location provided by Railtrack

We consider that the analysis presented in this paper has analysed the main factors which affect efficiency performance. In particular, we have taken account of quality measures (delays, broken rails, track quality, TSRs), and other potential cost drivers (track category and asset age), as well as the standard cost and volume indicators. We have considered the relationship between efficiency rankings and maintenance contractor, and also the maintenance contract renewal process. However, we recognise that there may be other factors affecting our efficiency comparisons which have not been accounted for. This possibility will be explored further as this approach is developed as an internal management tool for the company going forward.

6. Conclusions

Given the difficulties with previous attempts to benchmark Railtrack's efficiency performance, the objective of this paper was to explore the use of internal benchmarking to inform the debate on future efficiency targets for Network Rail. Our approach mirrors the yardstick competition method adopted in other UK regulated industries. Cost, output and quality data was collected on a consistent basis for seven geographical Zones within Railtrack, over the seven year period 1995/96 to 2001/02.

The results in Tables 4 and 8 show that Railtrack delivered substantial productivity improvements in the early years after privatisation (between 5.9% and 7.9% for maintenance activity; and 6.4% to 6.8% for overall maintenance and renewal activity). These productivity gains take account of quality, scale and density effects, which are captured separately in the regression equations. However, these improvements were largely offset by the post-Hatfield cost increases, which resulted in productivity falls of

24% and 32% for maintenance and overall (maintenance and renewal) activity respectively.

In terms of relative efficiency, the most efficient Zones in 2001/02 are identified as Midlands, Scotland, and LNE (maintenance only); and Scotland, Great Western and Southern (total costs). The post-Hatfield environment resulted in changes to the relative rankings, compared to 1999/00, indicating differing responses to Hatfield at the Zonal level. Since our efficiency scores and rankings take account of volume and quality measures, and cannot be explained away by Zonal differences in other operation factors (track quality; TSRs; track category and asset age; see Table 11) we consider these rankings to be robust given the available data. However, we recognise that there may additional variables which have not been not been accounted for in our analysis.

The relative efficiency scores in 2001/02 suggest the scope for less efficient Zones to make cost reductions and / or quality improvements of up to 24% if they can replicate the performance of the most efficient Zones (see Table 10). These potential savings at Zonal level translate into an overall company-wide (radial) efficiency target of 13% for both maintenance and total costs. Further savings may also be possible to extent that part of the post-Hatfield cost increases are temporary, and therefore potentially reversible in future years (although, as noted earlier, this cost increase may reflect a permanent change resulting from new information about asset degradation).

Our regression analysis also suggests that there are increasing returns to scale at the total cost level (1.15 to 1.24; see Tables 4 and 8), which in turn implies that fewer Zones may result in lower cost. From a regulatory perspective, this benefit would need to be weighed against the loss of yardstick information. Our finding of decreasing returns to density (0.82 to 0.88) may suggest that further traffic growth on the existing network will result in significantly higher maintenance and renewal costs if quality standards are to be maintained (given that capacity is now fully-utilised on some parts of the network). However, we note that our results on scale and density are based on the restrictive log-linear functional form.

We consider that the methodology and results detailed in this paper demonstrate the potential for using Zonal yardstick comparisons to set future efficiency targets for Network Rail. The analysis is based on a high quality, consistently-defined data set, which fits well with our parametric models. Zonal differences in scale, technology and other environmental factors are relatively small compared with external benchmarking studies. Our study identifies the most efficient Zones and indicates a set of efficiency targets for less efficient parts of the network. Furthermore, these targets are calculated relative to performance levels already being achieved elsewhere within the company. As a result, we argue that our approach, based on internal benchmarking, provides clearer guidance on how efficiency gains can be achieved in practice.

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Appendix 1
Data sources and definitions

Data	Source	Comments
Maintenance Costs	Railtrack (Finance)	All financial data reconciles with Railtrack's Statutory Accounts.
Renewal Costs	Railtrack (Finance)	Our renewals cost series includes track renewals only, since this measure was considered to be more comparable across Zones (in contrast to other renewals, such as structures or signaling). We have used annual track renewal costs (which are capitalised), in place of a capital stock series, since it was not possible to access Zonal renewal data prior to privatisation (and net book value is not an accurate measure of capital in this industry)[54].
Track Miles	Railtrack Network Management Statements	No significant changes to track miles over the period of our analysis.
Passenger train miles	Railtrack TOPS System; Railtrack (Performance)	Accurate data was available by train service code (groups of services) between 1998/99 to 2001/02 (TOPS system) Railtrack provided a mapping of train service code onto Zones for 1999/00 (based on samples of data taken from the summer and winter timetable). Given the stability of the relationship between train service code and Zones, the same mapping has been used for 1999/00, 2000/01 and 2001/02. The data for the period 1995/96 to 1997/98 was constructed using TOC data (which has a very strong correlation with the Zones in most cases), supported by additional information from Railtrack experts.
Passenger tonne miles	Railtrack (Regulation & Government)	The passenger tonne mile series was constructed using Railtrack data on average tonnage per train (by TOC).
Freight tonne miles	Railtrack (Freight)	The freight billing system data (1998/99 to 2001/02), was allocated from service group to Zones using the Railtrack Zone/service group mapping. 1995/96 to 1997/98 data was constructed using freight data by commodity.
Delays	Railtrack (Performance)	Includes Railtrack-caused delays only.
Broken rails	Railtrack (Regulation & Government)	
Level 2 Exceedences	Railtrack Annual Return, 2001/02	
Track TSRs	Railtrack Annual Return, 2001/02	
Track Category	Railtrack (Regulation & Government)	
Track age	Railtrack (Regulation & Government)	Track asset age is an average of the age of rail, sleepers and ballast.

[54] Our parametric models perform well using this track renewal cost series, without the need, for example, to construct a moving average renewal cost series.

Appendix 2
Correlations of Efficiency Scores
(1995/96 to 1999/00)

Rank Correlation Coefficients: Maintenance Efficiency Scores*

	COLS1	COLS2	DEA1	DEA2	SFA1	SFA2
COLS1	1.00	0.83	0.50	0.45	0.93	0.79
COLS2	0.83	1.00	0.60	0.60	0.76	0.94
DEA1	0.50	0.60	1.00	0.98	0.39	0.61
DEA2	0.45	0.60	0.98	1.00	0.35	0.62
SFA1	0.93	0.76	0.39	0.35	1.00	0.79
SFA2	0.79	0.94	0.61	0.62	0.79	1.00

* All significant at the 5% level

Rank Correlation Coefficients: Total Cost Efficiency Scores*

	COLS3	COLS4	DEA3	DEA4	SFA3	SFA4
COLS3	1.00	0.81	0.50	0.53	0.97	0.76
COLS4	0.81	1.00	0.56	0.64	0.78	0.91
DEA3	0.50	0.56	1.00	0.98	0.58	0.48
DEA4	0.53	0.64	0.98	1.00	0.60	0.53
SFA3	0.97	0.78	0.58	0.60	1.00	0.78
SFA4	0.76	0.91	0.48	0.53	0.78	1.00

* All significant at the 1% level

Appendix 3
Rank Correlations of Efficiency Scores
(1995/96 to 2001/02)

Rank Correlation Coefficients: Maintenance Efficiency Scores*

	COLS1	COLS2	DEA1	DEA2	SFA1	SFA2
COLS1	1.00	0.87	0.64	0.62	0.93	0.84
COLS2	0.87	1.00	0.66	0.68	0.80	0.96
DEA1	0.64	0.66	1.00	0.98	0.56	0.73
DEA2	0.62	0.68	0.98	1.00	0.52	0.74
SFA1	0.93	0.80	0.56	0.52	1.00	0.82
SFA2	0.84	0.96	0.73	0.74	0.82	1.00

* All significant at the 1% level

Rank Correlation Coefficients: Total Cost Efficiency Scores*

	COLS3	COLS4	DEA3	DEA4	SFA3	SFA4
COLS3	1.00	0.87	0.45	0.50	0.95	0.84
COLS4	0.87	1.00	0.54	0.62	0.80	0.93
DEA3	0.45	0.54	1.00	0.98	0.51	0.55
DEA4	0.50	0.62	0.98	1.00	0.55	0.63
SFA3	0.95	0.80	0.51	0.55	1.00	0.87
SFA4	0.84	0.93	0.55	0.63	0.87	1.00

* All significant at the 1% level