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Do network industries plan to eliminate inefficiencies in response to regulatory pressure? The case of railways in Great Britain

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Abstract

This paper outlines an econometric analysis of business planning data examining the scope for efficiency improvements of regulated firms in regulatory price reviews. Historical data may not fully reflect current industry cost structures, whereas forecast data offers evidence on cost evolution. Business Plans can provide useful information on planned elimination of inefficiencies in response to regulatory pressure. Network Rail submitted such data to the British railway regulator at the last Periodic Review (2013). Using a cost frontier model, the organisation's business units are analysed to determine the extent of their plans to eliminate internal inefficiencies and response to regulatory incentives.

Keywords
Network industries; benchmarking; cost-efficiency

1. Introduction

The elimination of cost inefficiency is important to ensure that network industries deliver services in a socially optimal manner. However, given the market failure of natural monopoly which afflicts most network industries, direct competition in the market is not optimal from the cost perspective. As such, economic regulation is required and price-cap regulation (Beesley and Littlechild, 1988) is the now standard means to achieve a cost efficient outcome. A key component of economic regulation is the establishment of the efficient cost level for the regulated firm(s). This requires data on the costs, outputs, quality and input prices to separate out the factors outside of the firm's control versus the residual inefficiency. Such data can often be difficult to collect in a form which is consistent across firms (or business units comprising a firm) and across time. In addition, in cases where an industry has recently undergone large capital investment or is expected to start large investments, historical data may be an inappropriate characterisation of the expected future costs of firms.

Importantly, and the subject of this paper, many regulatory review processes involve regulated firms outlining proposals for cost- and/or price-caps based on business planning data. This paper outlines an econometric analysis of such business planning data and discusses how this analysis can be a useful complement to the evidence base on the likely scope for efficiency improvements of regulated firms in regulatory price reviews. The approach could involve an individual network organisation submitting data on internal business units (e.g. British railway infrastructure), or it could involve multiple geographically separate firms submitting evidence on their operations (e.g. regional water companies and electricity distribution companies). Whilst this paper utilises an example from Britain, price-cap regulation is widely practiced across Europe and the wider world, so the approach to analysing business planning data by econometric methods as part of the regulatory process is equally applicable.

Our empirical illustration is the railway infrastructure manager in Great Britain, Network Rail, which has been set an ambitious revenue reduction profile of 18% for Control Period 5 from 2013/14 to 2018/19 (Network Rail, 2013a). This was based on a set of benchmarking evidence, both top down evidence from international comparators and bottom-up evidence (ORR, 2013). A control period is typically five years long and reflects Network Rail's time horizon for financial and operational planning under the regulation of the Office of Rail and Road (ORR). While international comparators were used to inform some of the scope for savings, a substantial body of evidence pointed to savings possible through dissemination of internal leading practice within Network Rail – see, for example, ARUP (2012).

The analysis in this paper seeks to determine if the regulated firm is planning for elimination of these inefficiencies. A frontier efficiency model is estimated, using zonal business planning data produced by Network Rail, which examines the implied evolution of inefficiency within the subsequent Control Period. Failure to find convergence may indicate scope for further savings, whilst finding convergence indicates that the regulated firm is responding to incentives from regulators. Some evidence is found that Network Rail is responding to regulatory incentives and planning to reduce the degree of internal inefficiency in its business.

More generally, our approach illustrates the potential role of analysis of business planning data via econometric approaches in regulatory reviews. In particular we can identify several potential benefits of utilising this data rather than, or in complement to, actual cost and output data:

1) Historical data may not be fully reflective of the current structure of the industry, particularly in times where the industry has been responding to substantial cost or technology shock.
2) Business planning data should be consistently defined across firms or across zones within a company as it is being requested directly by a regulator at a given point in time. It will also typically comprise a panel dataset (in our empirical example, six years) as data will be requested for a set number of periods into the future. This can contrast with collections of either cross-sectional data or a short panel of actual data, given the difficulty in ensuring consistency of data and zonal structure over time. In the example of Network Rail, the zonal structure has changed at least once over the five-year period to the last Periodic Review in 2013. In contrast, the Business Plan data should have consistent definitions of costs across zones comprising Network Rail and across time.
3) The data is provided by the regulated company as the basis for a proposal to be evaluated by the regulator. Thus, analysis of this data provides a useful high level evaluation of a submission to reveal the implicit assumptions being made by the firm about its cost structure and efficiency variation over time.

The structure of this paper is as follows. Following this introduction section 2 outlines the precedent for using business planning data in regulatory reviews and why the approach is useful in the railway infrastructure context. Section 3 outlines the efficiency analysis methodology and section 4 outlines the data sources. Section 5 reports the results, focusing on the plausibility of the estimated frontier, the estimated frontier shift over time and the trends on efficiency. Section 6 concludes.

2. Regulatory Context

The use of business planning data in regulatory reviews is not without precedent although our understanding is that this has not been systematically reported in the academic literature. Ofgem, the British regulator of electricity and gas transmission and distribution, has considered the suitability of comparing total cost efficiency based on future plans/costs and historic costs in price control reviews. Analysis based on future plans was recommended for electricity and gas distribution, although gas distribution was thought to be more appropriate with supporting analysis of historic costs (Frontier Economics, 2010). Two subsequent reports have investigated how total cost benchmarking for price control reviews may be undertaken in practice (Frontier Economics, 2013a: 2013b). The key motivation for the use of future plans by Ofgem is consistent with the benefit of utilising business planning data, namely that Ofgem argued that the need for substantial capital investment meant that historical cost data would be of limited relevance with any changes in underlying network or cost structures considered to weaken the effectiveness of historical cost analysis. Subsequently Ofgem adopted statistical analysis of electricity distribution company's business plans as part of the evidence for the initial assessment of the proposals (UK Power Networks, 2014).

In railways in Britain, historical cost data is less useful for benchmarking Network Rail today given the large cost shock which affected the industry. Across the whole British railway sector, unit cost (cost per passenger km) measures of railway industry (Network Rail; passenger and freight operators; rolling stock leasing companies) efficiency has fluctuated since privatisation (McNulty, 2011). In the years 1996/97-1999/00, unit costs were declining before the Hatfield and Ladbroke Grove train incidents led to increases in costs owing to safety improvements and temporary speed restrictions. Unit costs rose to a peak in 2003/04 at approximately 35% higher than in 1996/97. However, to 2009/10 there has been an almost continual downward trend with unit costs returning to approximately 1996/97 levels. Accompanying this has been a 62% increase in passenger kilometres travelled.

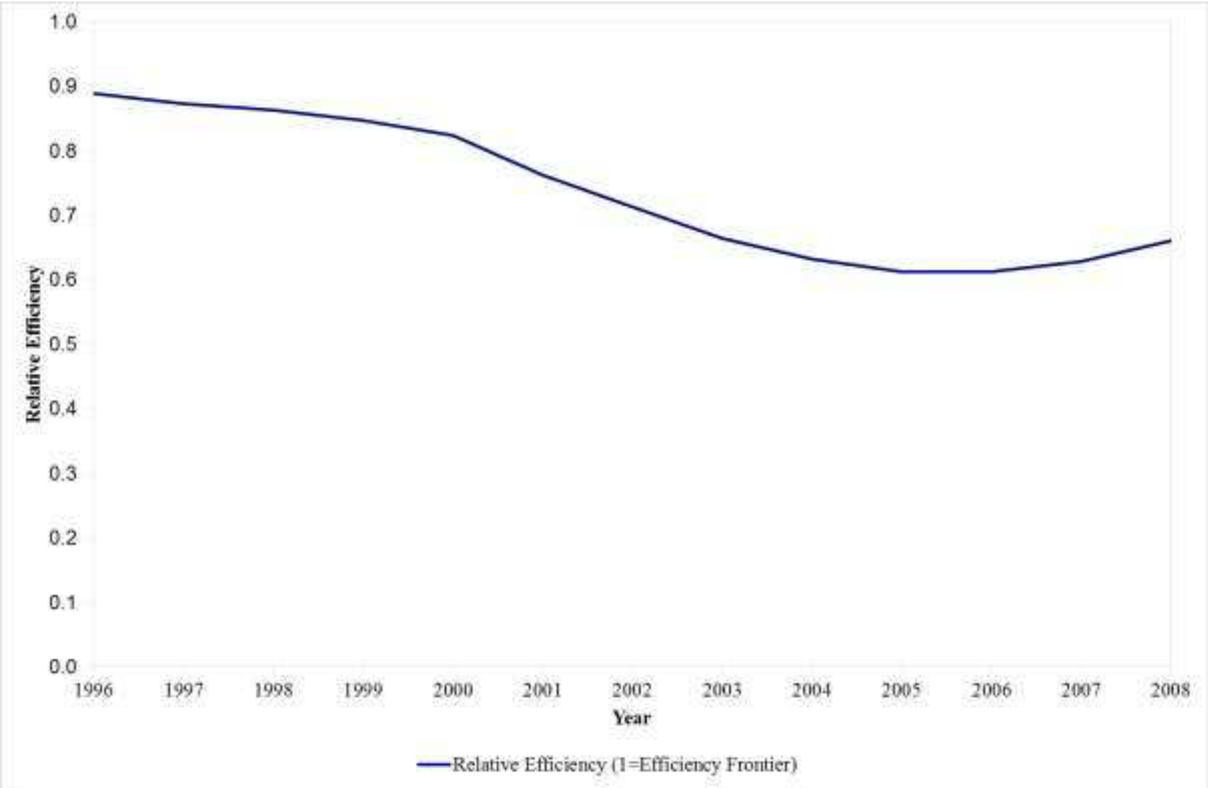
Absolute industry costs were estimated in McNulty as 30% (£2.5-3.5bn) above the efficient level as of 2008/09. International comparisons against France, Holland, Sweden and Switzerland revealed that this efficiency gap could potentially be as great as 40%. This gap remains despite 30% cost reductions during Control Period 3 (CP3: 2004/05 to 2008/09). Drawing on evidence from the previous 2008 Periodic Review (ORR, 2008), a significant proportion of the gap is attributed to Network Rail, which has a maintenance and renewals efficiency gap of 34% (Figure 1) in comparison to international benchmarks, although passenger operators and rolling stock leasing companies are also attributed responsibility.

Finally, with respect to changes in the British rail industry that make historical data problematic for analysis is safety. The British railway system has become far safer since the 2000 Hatfield accident; it is now one of the safest railways in Europe. For example, in its 2015 Safety benchmarking report the ORR (2015a, p6) finds that the UK was the best performing EU member state (of 28) in 2013 (with 0.16 accidents per million train kilometres) and was second best over a four-year average (2010-2013). Whilst the industry is still trying to make gains in safety, the big challenges arising from an incomplete asset register and asset renewals backlog have been cleared. This should make projected cost data more comparable (the data used in this paper), but presents challenges with utilising historical data as this will clearly contain an element of catch-up expenditure. Given that the safety situation for Network Rail has stabilised we do not include measures of safety in our model for each zone. This is of course also pragmatic given the lack of projected data, which would have a large degree of uncertainty associated if it were available.

In terms of how Network Rail is regulated, revenue profiles (funding profiles), as opposed to purely price profiles, are set by the regulator at each review period since Network Rail receives a substantial amount of funding, through a lump sum transfer from Government and from other borrowing. This is in addition to prices charged to train operators, which are also subject to the reduction profile in the usual price-cap profile. Further Network Rail is free to retain the profit (for reinvestment) of any over performance on the cost side within the control period. As such the regulation of Network Rail is more akin to price cap regulation than rate of return regulation.

Given that price-cap regulation incentivises the regulated firm to outperform the price cap target, using business planning data could be deemed to be 'micro-managing' the firm rather than allowing it discretion to outperform the target set by the regulator. However, this misunderstands the role of business plans in the regulatory process (see for example Ofgem (2010) for an understanding of how British regulators use business planning data in the periodic review process). Such business plans in either rail or electricity are used as part of the information inputs into the regulatory determination. Since historical data is not fully representative of the future cost structure of the firm, it necessitates some allowance for future business plans of the firm. Irrespective of whether formal statistical analysis of the business plans is undertaken (which this paper advocates), regulatory determinations take into account the investment plans of the firm early in the process when setting price caps. Such information comes from the business plans submitted by firms. As such statistical analysis using efficiency techniques is simply a more formal tool to interrogate the implicit efficiency assumptions underpinning this initial submission by the firm. This is still 'top-down' in nature i.e. uses a prediction of outturn cost rather than determining whether the firm is doing specific activities in the 'best practice' manner. Thus the firm still has a large implicit discretion as to how to achieve any cost reductions that they are proposing in the aggregate to the regulator.

Figure 1: Relative Efficiency of Network Rail (International Benchmarking)



Source: ORR (2010)

3. Methodology: Efficiency Analysis

Cost (or economic) efficiency analysis is a set of techniques which seek to compare the costs of different firms to establish if there is scope for savings from a firm adopting leading practice. A key element of the analysis is to recognise that costs and average costs per output will differ between firms due to factors beyond their control. This includes differing input prices (cost of factors of production) as well as productivity changes through scale economies and technological advancement which impact on the costs of an organisation (Kennedy and Smith, 2004; Smith et al, 2001). Efficiency analysis is required to separate the impacts of these on costs and determine the effect cost-efficiency alone is having.

In this application, we undertake internal efficiency analysis as we have data on business units comprising a single (nationwide) infrastructure company. Such analysis is also referred to as yardstick competition (Kennedy and Smith, 2004; Smith et al, 2010). This catch-up efficiency approach enables clearer guidelines on achievable efficiency gains than external analysis offers. However, internal comparators may be below the highest attainable efficiency level potentially observable through external or international comparisons. Nevertheless, internal data is likely to be more consistent and avoid measurement inaccuracies present in external or international studies. Furthermore, variations in scale, technology or environmental factors are likely to be smaller between internal units.

3.1.Techniques

Corrected Ordinary Least Squares (COLS) estimates a deterministic model of efficiency (Perelman and Pestieau, 1988). Studies using COLS in railways include Coelli and Perelman, (2000); Kennedy and Smith (2004) and Perelman and Pestieau (1988). Under OLS estimation a function passes through the centre of the observed data points. COLS then adjusts the model by adding the largest negative OLS residual to the estimate of the intercept parameter. The result is the elimination of positive residuals and the presence of at least one residual equal to zero to produce the frontier. Under this frontier the distance from it for each firm captures inefficiency (Coelli and Perelman, 2000; Perelman and Pestieau, 1988).

Alternatively, Coelli et al (2005), Cowie (1999) and Oum and Yu (1994) adopt a non-parametric estimation of a frontier through use of Data Envelopment Analysis (DEA). This is a linear mathematical programming technique that approximates the frontier through fitting a piece wise linear hull enveloping the data points. Inefficiency can be identified by computing the distance from the frontier of an individual firm at a specific point in time.

Stochastic Frontier Analysis (SFA) estimates, parametrically, a frontier of efficiency and examples in railways include Kennedy and Smith (2004), Smith et al (2010), and Smith and Wheat (2012). SFA, unlike COLS or DEA, is able to differentiate between deviations from the frontier into two separate components of inefficiency and random (stochastic) noise. With panel data there are a number of ways to model inefficiency that use both maximum likelihood estimation and least squares estimation; the latter being used in this study (see Kumbhakar and Lovell (2000) for a discussion regarding estimation approaches to SFA models).

3.2.Efficiency Methodology: CSS-RE Cost Frontier Model

Of importance to this analysis is our application of an efficiency methodology that allows for variation in the efficiency performance of each zone over time, where the same variation is not imposed a priori on all zones. Indeed, the aim of the exercise is to see whether the business planning data supports convergence in efficiency over time across zones or whether there is a degree of divergence. To this end, we analyse internal benchmarking of cost-efficiency conducted in this study using the time-varying random effects model proposed by Cornwell, Schmidt ad Sickles (1990) – abbreviated to CSS-RE.

The model is estimated by least squares techniques, thereby dispensing with the strong distributional assumptions common to other stochastic frontier techniques (which tend to be estimated by maximum likelihood techniques). This aids statistical robustness of the model estimates. This modelling approach interprets variation in the residuals of the cost frontier for each firm as a pattern of (relative) efficiency variation.

The model can be written as:

$$y_{it} = \alpha_{it} + \beta_1 X_{1it} + \beta_2 X_{1it} + \cdots + \beta_k X_{kit} + v_{it} \quad i = 1, \dots, N; t = 1, \dots, T \tag{1}$$

Where

$$\alpha_{it} = \gamma_{1i} + \gamma_{2i} t \tag{2}$$

N and T are the number of zones and time periods, respectively. This model is as in Cornwell et al (1990) with the exception of a linear trend for each zone as opposed to the quadratic trend suggested by Cornwell et al (1990). Given the length of the panel (six years) we consider a linear trend to be adequate and this is supported by statistical tests with respect to estimated coefficients on possible quadratic terms.

The method proceeds in three steps. Step one involves estimating the cost frontier (equation 1) using least squares techniques. Both ordinary least squares and generalised least squares yield consistent estimates of the slope parameters. The residuals from this first regression are then recovered and a set of N further regressions are run on a constant and a time trend (as in equation (2), replacing (α_{it}) with the zone-specific residuals), one for each zone. Time-variant efficiency (μ_{it}) is estimated by creating a frontier of efficiency over time from equation (3) and subtracting the inefficiency of all other firms over time from the frontier (equation 4). The minimum in equation (3) is used to create the frontier as the most cost-efficient firm operates at minimum cost.

$$\hat{\alpha}_t = min_i(\alpha_{it}) \tag{3}$$

$$u_{it} = \alpha_{it} - \hat{\alpha}_{it} \tag{4}$$

Cost-efficiency for each firm (CE_i) is expressed as the ratio of the observed cost of each firm to minimum cost (Coelli et al, 2005) using equation (5), which constrains the level of cost-efficiency to between 0 and 1.

$$CE_{it} = \exp(-u_{it}) \tag{5}$$

While the fixed effects variant of CSS has been more widely used in past work, the random effects model has the advantage of maintaining no correlation between regressors and efficiency components which is appropriate for modelling cost efficiency, given, by definition, cost efficiency is not correlated with scale efficiency (for example). This assumption also permits more precise estimates of the cost frontier as the estimator can exploit both within and between variation in the data - see Cornwell et al (1990). Furthermore, the CSS-RE model has been used by ORR in PR2013 as one of a number of modelling approaches in the top-down international benchmarking using the LICB dataset (ORR, 2013).

4. Data

A panel data set is constructed for ten strategic operating routes[1] (zonal business units) over six years from 2013/14 (final year of historical data for Control Period 4) to 2018/19 (final forecast year of Control Period 5). Maintenance and renewals costs for Network Rail are extracted from submissions to the ORR (ORR, 2013). Output measures of passenger train and passenger train tonne kilometres are provided by Network Rail's Route Specifications (Network Rail, 2012), Route Plans (Network Rail, 2010) and Volume Incentive Baselines (Network Rail, 2014). Train and train tonne kilometres contain data for both freight and passenger train tonne kilometres. Passenger train tonne kilometres are not available beyond 2010/11 and are, therefore, assumed to grow in line with passenger train kilometres.

Input measures including route kilometres, track kilometres and electrified lines kilometres are collected from Network Rail's Route Specifications, Strategic Business Plans (Network Rail, 2013b) and ORR data (ORR, 2015b). There are several enhancements to the network planned over the period (Network Rail, 2011)[2]. To reflect this, input measures data (excepting route kilometres) are assumed to grow at a constant rate each year. This is undertaken to account for uncertainty in the actual year which enhancements become operational, whilst attempting to avoid unrealistic peaks in the data. Furthermore, this is considered appropriate as there is not anticipated to be any decline in output and the network.

[1] Anglia, East Midlands, Kent & HS1, London North-Eastern, London North-Western, Scotland, Sussex, Wales, Wessex and Western

[2] Borders Rail, Crossrail Programme, East-West Rail, Edinburgh-Glasgow Improvements Programme, Great Western Electrification, Intercity Express Programme, North-West Electrification and Thameslink Programme

Route kilometres have not been assumed to change over the period of analysis despite the enhancements, which is felt to be reasonable as the change in the size of operating routes is likely to be minimal.

Using the cost frontier approach discussed in Section 2.2, total maintenance and renewals costs (C_{TC}) and maintenance costs (C_{MC}) models are estimated. Total costs and maintenance costs for each operating route (i) and time period (t) are a function of track kilometres (Tr), train density (D), electrification (E), weight (W), track (R) and a time trend (t). The functional forms are as follows:

$$lnC_{TC,it} = \beta_1 + \beta_2 lnTr_{it} + \beta_3 lnD_{it} + \beta_4 E_{it} + \beta_5 lnW_{it} + \beta_6 R_{it} + \beta_7 t \quad (6)$$

$$lnC_{MC,it} = \beta_1 + \beta_2 lnTr_{it} + \beta_3 lnD_{it} + \beta_4 E_{it} + \beta_5 lnW_{it} + \beta_6 R_{it} + \beta_7 t \quad (7)$$

Train density reflects passenger train kilometres divided by track kilometres; electrification is the proportion of track kilometres that are electrified; weight is passenger train tonne kilometres divided by passenger train kilometres, thereby reflecting average train weight, and track represents track kilometres divided by route kilometres, thereby reflecting average numbers of tracks.

The specification of total cost and maintenance cost models with explanatory variables of track kilometres, passenger train density, the proportion of electrified track kilometres and a time trend is consistent with the received literature (Baños-Pino et al, 2002; Farsi et al, 2005; Gathon and Perelman, 1992; Kennedy and Smith, 2004; Smith et al, 2010). The choice of train density defined by train-km as opposed to tonne-km is due to the data available for the study, in that our train-km measure is more robust than the tonne-km measure., Discussed previously, passenger train tonne kilometres are assumed to grow in line with passenger train kilometres due to an absence of forecast data. Therefore, we include a separate weight variable to ensure this assumption is not detrimentally impacting on the estimation of the rest of the model.

In the previous studies reviewed, the number of tracks was not included as track kilometres per route kilometre but, rather, as a ratio of single to total track kilometres (Smith et al, 2010). A lack of data on single-track routes results in the choice of variable but it is considered that the two alternative measures are to a large extent substitutes, both demonstrating that operating routes with more tracks ease traffic flow and, therefore, pressures on costs.

It is anticipated that track kilometres, train density, electrification and weight will all positively impact on costs. A larger network, with heavier levels of traffic of greater weight and the additional resources required for electrification are expected to increase costs owing to the complexity of the network, impact on damage inflicted on the railway and also the potential life of the tracks. These expectations apply to both the total and maintenance costs models. A negative impact on costs is expected for average track numbers as more tracks allows for

Network Rail to undertake maintenance and renewals more easily. This is due to a larger number of tracks providing more flexibility to accommodate some traffic, thus reducing the impact on services (in contrast to a single track which with current health and safety regulations is likely to require line closure during the maintenance periods). This expectation applies to both models. Table 1 presents a summary of the data in 2013 prices:

Table 1: Summary of Data (2013 Prices)

Metric	Total	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19
Costs							
Maintenance (£m)	£6,258	£980	£1,102	£1,081	£1,057	£1,034	£1,004
Renewals (£m)	£16,340	£2,783	£2,741	£2,809	£2,769	£2,663	£2,575
Total (£m)	£22,598	£3,763	£3,843	£3,890	£3,826	£3,697	£3,579
Output							
Total Train km (000,000)	-	518.0	521.9	525.9	531.2	538.4	554.9
Total Train Tonne km (000,000)	-	148,201	150,731	152,289	155,060	157,649	162,699
Network							
Route kms	-	15,740.0	15.740.0	15.740.0	15.740.0	15.740.0	15.740.0
Track kms	-	31,085.7	31,196.9	31,308.2	31,419.5	31,530.8	31,642.0
Electrified Train kms	-	12,582.5	13,165.4	13,748.3	14,331.2	14,914.1	15,497.0

5. Results

Table 2 presents the results of the total maintenance and renewals costs (model 1) and maintenance costs (model 2) models. In each model, the explanatory variables for total track kilometres ($lnTr$), train density (lnD), average train weight (lnW) and the time trend (t) are significant to at least 5% and are of the expected sign discussed in Section 4. Electrification (E) is of the expected sign but, whereas in model 1 the variable is significant to 1%, in model 2 it is only significant to 10%. The average number of tracks (R) is of the expected sign but is only significant to 10% for model 1 and is not significant for model 2. The variable is, nevertheless, retained in the model as it is considered relevant, is of the expected sign and is not believed to be detrimentally impacting on the other explanatory variables.

We now consider the three key features of our model, namely, plausibility of the estimated minimum cost frontier and consistency with the received empirical literature; the frontier shift indicated by the model over time; and the behaviour of cost inefficiency over time for each of the zones.

5.1. The minimum cost frontier – Returns to Scale and Density

Whilst the ultimate aim of the analysis is to measure the extent of planned efficiency and frontier change implicit within the business plans of the company, to do this requires estimation of a cost frontier which accurately represents the underlying technology of the company. As such it is important to verify that the estimated frontier parameters are plausible.

We compare the estimated economies of scale (8) and density (9) from each model (Table 3) against previous literature (Table 4), which is summarised in Wheat and Smith (2008) and expanded upon in this paper.

$$Economies\ of\ Scale = \frac{1}{\beta_2} \tag{8}$$

$$Economies\ of\ Density = \frac{1}{\beta_3} \tag{9}$$

The elasticity of track kilometres (β_2) and train density (β_3) are also tested against the null of 1 (constant returns to scale or density). z-Test values are in brackets in Table 3. In each case, except for economies of scale in model 2, the z-values are beyond the -1.96 and 1.96 (95%) confidence interval indicating economies of scale and density. Model 2 exhibits constant returns to scale, therefore.

In comparison to the past literature, both models are consistent with previous findings on economies of scale. Economies of density in both models is lower relative to previous literature but this could be due to using a measure of train density using train kilometres rather than other past studies using train tonne kilometres. The model exhibits density economies and is, therefore, taken to provide consistency with the literature. Examination of the variable signs, statistical significance, and scale and density economies together provides confidence in the validity of the model for further analysis of the cost-efficiency of Network Rail.

Table 2: Estimation of Model Results

	Model 1 - Total		**Model 2 - Maintenance**	
Variable	**Coefficient**	**p-Value**	**Coefficient**	**p-Value**
C	-8.041	0.000	-11.053	0.000
$lnTr$	0.922	0.000	1.003	0.000
lnD	0.479	0.000	0.640	0.000
E	0.316	0.001	0.140	0.087
lnW	0.395	0.001	0.262	0.016
R	-0.155	0.057	-0.043	0.555
t	-0.031	0.000	-0.014	0.046

Table 3: Economies of Scale and Density (t-stat for Null Hypothesis: economies=1 in parenthesis)

Economies	**Model 1 - Total**	**Model 2 -Maintenance**

Scale	1.09 (-2.74)	1.00 (0.14)
Density	2.09 (-5.07)	1.56 (-3.88)

Table 4: Previous Estimations of Economies of Scale and Density

Study	Country	Economies of Scale	Economies of Density
Johansson and Nilsson (2004)	Sweden	1.26	5.92
Johansson and Nilsson (2004)	Finland	1.58	5.99
Tervonen and Idström (2004)	Finland	1.33	(5.71,7.52)
Mundoch et al (2002)	Austria	(1.45,1.62)	3.70
Booz Allen Hamilton (2005)	Britain	-	3.57
Wheat and Smith (2008)	Britain	(1.87,2.18)	(2.65,6.25)
Farsi et al (2005)	Switzerland	(1.09,1.74)	(1.91,8.18)
Gathon and Perelman (1992)	Europe	(0.92,1.18)	-

Source: Wheat and Smith (2008)

Notation (Min,Max) denotes minimum and maximum values in the above table.

5.2.Frontier shift

The linear time trend included in each model indicates how minimum costs (efficient costs) of producing a given output change as time increases. The negative sign indicates a predicted fall in costs and the statistically significant coefficient estimate of -0.031 in the total cost model and -0.014 in the maintenance only model indicate a 3.03% and 1.37% fall in costs per annum respectively[3]. This represents a 12.7% and 5.6% decrease in unit costs over the 5-year control period.

In contrast, Network Rail asserts that its Business Plan represented a 15.8% and 13.8%, respectively, efficiency saving over the control period (ORR, 2013: p323 and p327). These are greater than the frontier shift identified in the models, however this is to be expected if the efficiency performance is to be improved over the period and if traffic grows (which mean the estimated returns to train density will reduce unit costs further). Overall, the frontier shift in our model appears intuitive.

As outlined in Section 3.2, following the estimation of the two models reported in Table 2, auxiliary regressions are estimated using the residuals for each zone to relate them to a constant and a linear time trend, as given in equation (2). Only a linear trend is included in the auxiliary regressions as only six years of data are available, which is a short time span to justify the use of a quadratic time trend (which would enable the direction of the impact of time on cost to change)

5.3.Efficiency variation

[3] Calculated as 1-exp(coeff. on time)

Following the methodology outlined between equations (2) to (5), the (α_{it}) firm specific time values are converted into relative cost-efficiency scores of between 0 and 1 (best-performing) for each operating route and time period. Figures 2 and 3 present the relative cost-efficiency for models 1 (total costs) and 2 (maintenance costs), respectively. In 2013/14, the worst-performing route for total costs is Wales, which has a score of 0.62, whereas the worst-performing route by 2018/19 is Western with a score of 0.84. Figure 3 demonstrates that in 2013/14, the worst-performing route for maintenance costs is London North-Western with a score of 0.75, continuing to 2018/19 but with a higher relative efficiency score of 0.82. In each model, the gap in relative efficiency is reduced in 2018/19 when compared to 2013/14 and demonstrates convergence in the cost-efficiency of Network Rail's operating routes. Therefore, Network Rail appears to be responding to regulatory pressures.

The average efficiency scores weighted by cost (to yield an overall Network Rail efficiency score) are shown for each year in Table 5. These show that in both models the overall efficiency of Network Rail has improved, with particularly large improvements in the total cost model (efficiency improvement of 10.6% over the period). Combining the frontier shift with the average change in cost efficiency yields an implied cost reduction over the period of 24.6% for the total cost model and 10.9% for the maintenance cost model.

Figure 2: Cost Efficiency of Operating Routes – Model 1 Total Costs

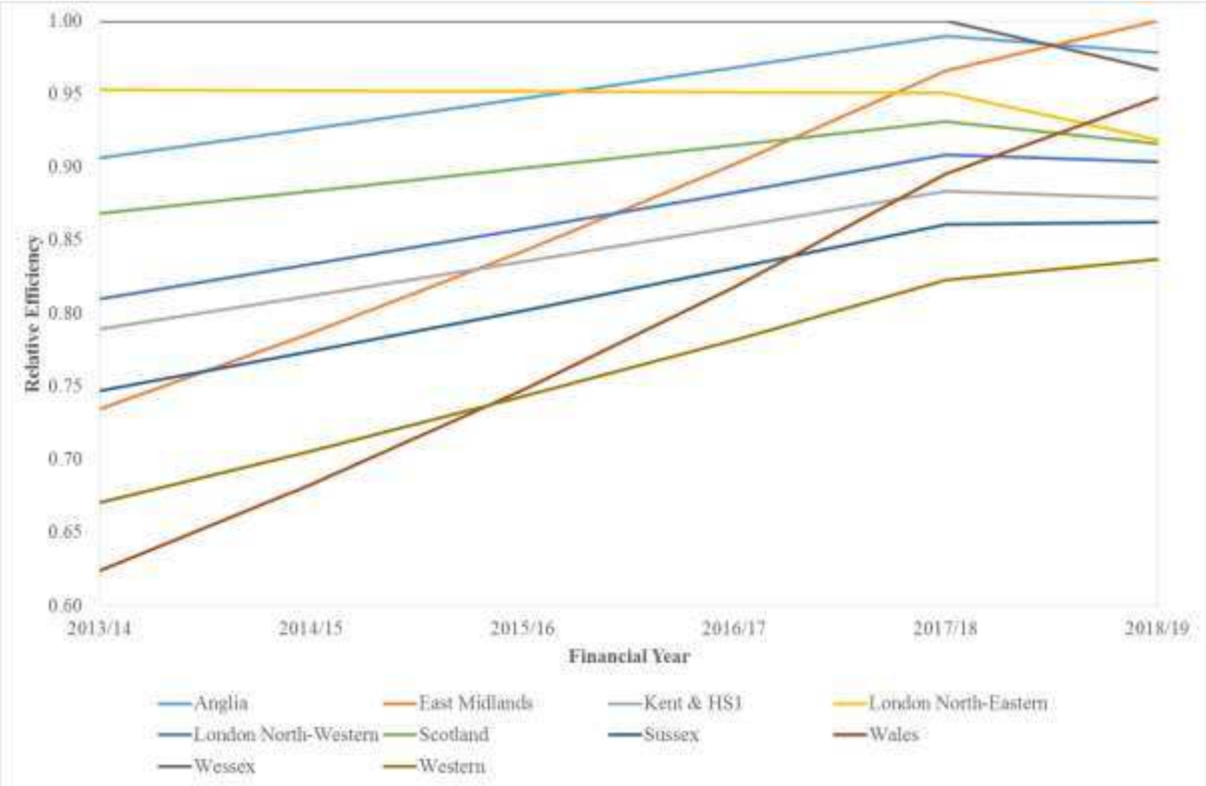


Figure 3: Cost Efficiency of Operating Routes – Model 2 Maintenance Costs

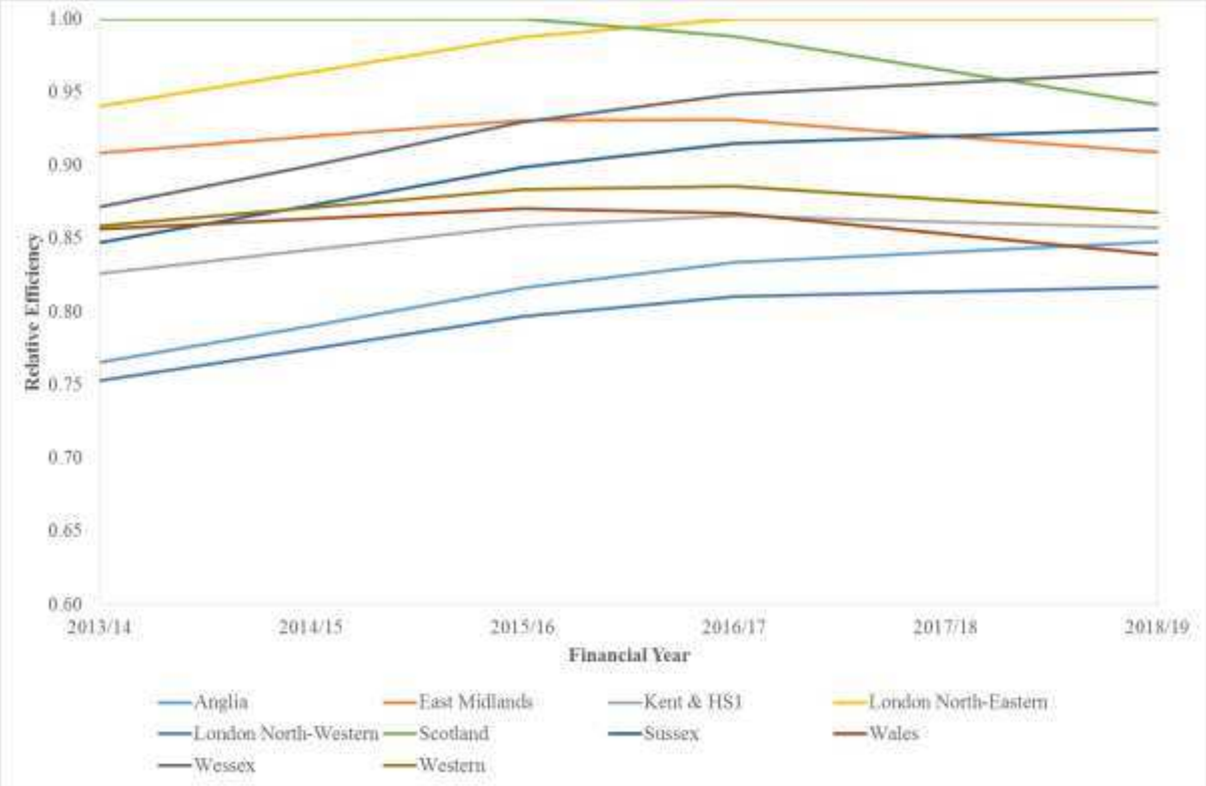


Table 5: Average cost efficiency and frontier shift for Network Rail

Year	**2013/14**	**2014/15**	**2015/16**	**2016/17**	**2017/18**	**2018/19**
Model 1 – Total Cost						
Average cost efficiency	83%	84%	87%	90%	92%	91%
Percentage change over period						10.6%
Frontier Shift over period						12.7%
Overall change over period						24.6%
Model 2 – Maintenance Cost						
Average cost efficiency	85%	87%	89%	90%	89%	89%
Percentage change over period						5.0%
Frontier Shift over period						5.6%
Overall change over period						10.9%

6. Conclusion

This paper has applied the frontier analysis technique demonstrated by Cornwell et al (1990) to total (maintenance and renewals) and maintenance costs for the British railway infrastructure manager Network Rail. The motivation was to demonstrate how regulators in network industries could examine the plans of an organisation or several organisations in an industry to determine whether or not the cost efficiency of business units is converging. If convergence in efficiency between business units is not found, then there is scope for further savings to be made over and above those proposed by the firm at the beginning of a regulatory review process. This paper provides a methodology to establish if such convergence is implied by the business plans.

The finding from the modelling of our rail example, is that convergence has been found such that Network Rail's internal business units have reductions in inefficiency over time relative to the best performing unit operating. Furthermore, our results on frontier shift (technical change) confirm that the most efficient unit is performing better as time progresses. The econometric models appear to be robust in terms of signs and statistical significance and by comparison against previous literature. On the basis of the summarised evidence for both cost models, it is possible to conclude that Network Rail is seeking to converge the cost-efficiency of both total and maintenance costs over the time period. Hence, cost inefficiency is being reduced in response to regulatory pressures.

Reflecting on the analysis leads to the recommendation that infrastructure regulators (rail or otherwise) can and should, evaluate the future plans of regulated firms in terms of anticipated effects on relative efficiency by means of econometric modelling. The key benefits of this approach are that: 1) the regulator can account for changes in the underlying cost structure of the regulated organisation in the future, which may not be reflected in historic data; 2) business planning data – in the case of internal analysis - at zonal level will naturally be a panel dataset and, also, should be consistently measured both across the zonal structure and over time (in contrast to a more historic dataset which is collected from numerous sources) and 3) the data is provided by the regulated company as the basis of a proposal to be evaluated by the regulator and, thus, analysis of this data provides a useful high level evaluation of a submission to reveal the implicit assumptions made by the firm about its cost structure and proposed efficiency variation over time.

Finally, we note that our analysis has utilised publicly available data and that in practice this presents some limitations (such as our traffic variable). Nonetheless, we were able to demonstrate the feasibility of this approach and reconcile our findings to best practice as identified in the relevant empirical literature. If in the future, regulators use these econometric techniques to analyse business plan data in the way we propose, then they can specify the requisite data to be submitted directly by the regulated firms. This in turn will improve the robustness of the analysis.

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