The Technical Efficiency of Public and Private Ownership in the Rail Industry

The Case of Swiss Private Railways

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Abstract
The Swiss rail industry is examined, and split between private and public ownership on the basis of a 30 per cent private share holding. Data Envelopment Analysis is used to estimate technical efficiency. Scale effects were found to be considerable, with most railways exhibiting increasing returns. Private railways were found to have a significantly higher level of technical, managerial, and organisational efficiency, although organisational efficiency differences were less pronounced due to some variation in the results.

1. Introduction
Throughout Europe, state railway operators have undergone radical change, with the injection of greater market forces into the organisation of the rail system. The European Union has actively encouraged such developments, with the passing in 1991 of Directive 91/440. This financially separated infrastructure from operations, partly removed state railways' legally protected monopoly, addressed the issue of outstanding debt (which would cripple any commercial operator), and encouraged joint ventures established on commercial grounds between state operators.

In the UK, British Rail has been separated into numerous autonomous units and individually sold off, or franchised, to the private sector. Other practical examples are visible elsewhere in Europe. Sweden, for example, was the first to separate infrastructure from services, franchise several branch passenger services to private sector companies, and open up freight services to the private sector (Jansson and Cardebrin 1989; Jansson and Wallin, 1991). Germany has similarly separated infrastructure from operations, increased regional responsibility for the provision of rail services, and divided the state operating company into two, which it is proposed will be privatised intact (Bowers, 1994, 1996). Like Sweden, Germany has also franchised regional passenger services.

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Unquestionably, such developments have been driven by budgetary considerations, with governments unable financially to sustain rail systems under current structures. The efficiency gains associated with private ownership through property rights theories (Parker, 1994) are viewed as one major way of resolving such problems without resorting to massive rail closures. All European governments, therefore, have carried out some form of privatisation, as defined in its broadest terms (Swann, 1988), upon their rail systems. It should be noted, however, that very little privatisation as defined in a narrow sense — that is, the transfer of assets (Swann, 1988) — has actually occurred. Even in Sweden and Germany, most services are still run by the state-owned company.

Examination of the academic literature provides limited evidence in support of privatisation of rail services. Most studies are based upon the North American experience (Boardman and Vining, 1989), where private and public ownership has tended to co-exist more frequently. In the only such studies to date upon the rail industry, Caves and Christensen (1980) examined the relative efficiency of Canadian railroads. They found no significant differences in total factor productivity growth over an eighteen-year period between the state owned Canadian National Railroad and the privately owned Canadian Pacific Railroad, findings updated and confirmed by Treheway et al. (1997) seventeen years later. These results suggest that privatisation will have little impact. Canadian railroads, however, operate over far larger distances, face an entirely different regulatory regime, particularly regarding subsidy, and are more freight-orientated than their European counterparts.

Within Europe itself, opportunities for direct comparisons of different forms of ownership are limited, particularly in transport industries, where publicly owned monopolies have tended to dominate. One notable exception is Switzerland, where public and private ownership has co-existed in the rail industry for many years. In the following analysis, the technical efficiency of these railways is compared, to determine if any efficiency disparities exist within a European setting. From a general economic perspective, technical efficiency is examined because it is of greater significance if private companies extract more from the inputs they obtain, than if they simply obtain their inputs at lower cost. For example, reducing salaries to enhance profits can be viewed simply as a transfer that, because of the different utility of money between the two groups, may actually be less efficient by reducing overall utility.

2. The Swiss Rail Industry

Within Switzerland there are some 70 railways, amalgamated into 50 groupings, operating over some 5,030 kilometres of track. The state operator, Chemins de Fers Fédéraux Suisses (CFF), mainly operates on the Intercity and Inter-regional networks, with two others, the Berne-Lötschberg-Simplon and the Rheian, operating substantial regional networks. These three railways have not been included in this analysis because of their considerably larger scale and type of operations. Most of the remainder are passenger-orientated, and all are relatively small, with networks under 100 kilometres.
A majority are owned by a combination of central and local government; however, a number have significant private share holdings of 30 per cent or above. In this analysis, the former are referred to as public railways and the latter as private railways. There are a number of other important differences in the commercial practices of the two groups that reflect their ownership structure. Prior to 1996, public railways received deficit financing in addition to federal grants, and major investments were funded through a combination of federal and cantonal funds. Many private railways, on the other hand, generally only received federal grants for supplying specific services, such as school transport or reimbursement for concessionary fares, primarily financed investment from profits and debenture issues, and usually paid out dividends — that is, operated like any other commercial company.

Changes to federal railway law in 1996 amended the method of payment for the provision of services, so that federal and cantonal funds are entirely paid through grants and subsidies, with deficit financing now abolished. The period under analysis, however, predates these amendments.

The data set contains 57 small railways, split between 43 public and 14 private railways. Table 1 gives a brief summary of the major characteristics of the two groups.

For both groups operations tend to be small scale, with most railways operating line lengths of under 25km. At the time of nationalisation of the railways in 1902, only the major trunk routes were taken under federal control, with the remainder left in private hands, most subsequently coming under cantonal control. Furthermore, construction of many private lines postdates nationalisation.
Between the two groups, private railways tend to operate on an even smaller scale, with route lengths and annual train kilometres about half the size of public concerns, and three-quarters the size in terms of passengers. Two public railways operate freight-only services, and several public and private railways passenger-only services, hence the zero minimum values for passenger and tonne kilometres. Table 1 also reveals the high variance in scale of operations even within the public and private sub groups.

3. Methodology
Cowie and Riddington (1996) identify a number of possible methods for estimating efficiency. In this paper, Data Envelopment Analysis (Farrell 1957; Charnes et al., 1978) is used. While recognising the limitations of the approach (see, for example, Parkin and Hollingsworth 1997), in this context it provides an extremely useful framework.

A number of specifications exist within the general DEA framework to establish the level of technical efficiency (Golany and Roll, 1989); for example output maximisation, input minimisation, and the incorporation of variable scale effects. As there is strong evidence that variable returns exist at the lower end of the rail industry (Dodgson 1985; Preston 1994), the framework here utilises the approach outlined by Banker et al. (1984). If scale effects are present, this formulation attributes a degree of inefficiency to the actual size of the organisation.

The model specification for a given decision-making unit (DMU) \( k \) is given formally below:

\[
\text{Max: } h_k = \sum_{r=1}^{t} \mu_r y_{rk} - u_k \tag{1}
\]

\[
\text{S.T.: } \sum_{i=1}^{m} v_i x_{ik} = 1
\]

\[
\sum_{r=1}^{t} \mu_r y_{rj} - \sum_{t=1}^{m} v_i x_{ij} - u_k \leq 0,
\]

where:  
- \( j = \text{DMUs}, j = 1...n; \)
- \( r = \text{Outputs}, r = 1...t; \) and
- \( i = \text{inputs}, i = 1...m. \)

Therefore:  
- \( y_{rj} \) is the value of the \( r \)-th output of the \( j \)-th DMU;
- \( x_{ij} \) is the value of the \( i \)-th input for the \( j \)-th DMU; and
- \( \mu_r, v_i \) represent virtual multipliers of output \( r \) and input \( i \) respectively.

In equation (1), \( u_k \) is described as representing returns to scale, with values of less than zero indicating increasing returns, values greater than zero decreasing returns, and values equal to zero constant returns.
Technical efficiency is assessed by a comparison of all railways in the data set. Following Charnes et al. (1981), however, the level of managerial efficiency can be further isolated from overall technical efficiency. This is done by separating DMUs into different sets of interest (in this example two sets, publicly owned and privately owned), and applying equation (1) to each subgroup. The pooled results can then be compared.

By definition, managerial efficiency is the extent to which a decision-making unit follows best practice, given the organisational structure. In other words, the closeness of the individual DMU to the production possibility frontier as outlined by DMUs of a similar organisational structure. Hence, given the organisational constraints present in the subgroup, the decision-making efficiency of the DMU is measured. A degree of technical inefficiency may be attributed to the organisational structure, and consequently the remainder ascribed to the management of the organisation. Figure 1 illustrates this approach; for simplicity, the case for constant, not variable, returns is shown.

This shows two inputs, X1 and X2, required to produce a single unit of output. The technically efficient frontier is given by the line TT', which represents the minimum combinations of X1 and X2 required to produce a single unit. It is estimated using the total data set. The line MM' is the managerial efficiency frontier, and is defined by the respective subset of decision making units. As some of the earlier points have been removed, this must lie either on or to the right of the technical efficiency frontier. In simple terms, the distance between the two frontiers represents the level of inefficiency attributed to the organisational structure.
Thus to assess technical, managerial and organisational efficiency for point \( a \), technical efficiency is calculated by the ratio \( o_c/O_a \), and managerial efficiency is similarly defined by the ratio \( O_b/O_a \). Finally, organisational efficiency is given by the ratio \( (O_c/O_a)/(O_b/O_a) \), or simply \( O_c/O_b \), the distance between the two frontiers. If the managerial point lies on the technical efficiency frontier, the DMU is said to be 100 per cent organisationally efficient; that is, all inefficiencies are attributable to management. Technical efficiency is thus given by:

\[
O_c/O_a = O_c/O_b. O_b/O_a
\]  

(2)

The final stage of this analysis is to test for significant differences between the efficiencies derived from the two subsets. As the distribution of efficiencies is unknown and difficult to describe (Brockett and Golany, 1996), both a Mann Whitney and a Median test are used to test for differences in the levels of technical, managerial and organisational efficiencies. The Median test examines the number of units above the pooled median value, while the Mann Whitney examines the sum of the ranks of the pooled efficiencies.

4. Data and Empirical Definitions

All data have been obtained from two main sources. First, they have been extracted from individual financial accounts, supplemented by direct approaches where the required information was not contained in the annual report. Second, data were obtained from the Swiss Federal Statistical Office (OFS, 1997). Results were confirmed by similar estimations for efficiencies using 1990 data.

One output was identified for each system; train kilometres. This represents the available supply to users (Oum and Yu, 1994), and, in part, the level of output contracted by government/canton as passenger service obligations.

The inputs to each system are the factors labour, capital, and land. Labour is simply the number employed in the provision of rail services. Capital is identified by traction stock levels, and specified as two separate inputs — first the addition of railcars and multiple units, and second the number of locomotives employed.

Most companies within the data set operate under similar terrain gradients. Nevertheless this can be a highly influential factor, particularly in a country such as Switzerland. This effect was therefore incorporated into the analysis as an exogenous factor by calculating the average gradient of line between stops. Railways in effect face a given land input.

5. Empirical Results

For each DMU, DEA defines a unique set of weights on the outputs and inputs. These maximise the efficiency of the DMU, subject to the constraint that no other DMU exceeds 100 per cent efficiency if that set of weights is applied. In this analysis, the tech-
Table 2
Virtual Inputs, Virtual Output, and Returns to Scale

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Model</th>
<th>Mean</th>
<th>Percentage Included in Assessment</th>
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<tbody>
<tr>
<td>Inputs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V1X1</td>
<td>Locomotives</td>
<td>Pooled</td>
<td>0.0333</td>
<td>72%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Public</td>
<td>0.0333</td>
<td>88%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Private</td>
<td>0.1154</td>
<td>79%</td>
</tr>
<tr>
<td>V2X2</td>
<td>Gradient</td>
<td>Pooled</td>
<td>0.3585</td>
<td>91%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Public</td>
<td>0.3319</td>
<td>95%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Private</td>
<td>0.3791</td>
<td>79%</td>
</tr>
<tr>
<td>V3X3</td>
<td>Railcars/EMUs</td>
<td>Pooled</td>
<td>0.4628</td>
<td>98%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Public</td>
<td>0.5037</td>
<td>58%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Private</td>
<td>0.2901</td>
<td>86%</td>
</tr>
<tr>
<td>V4X4</td>
<td>Labour</td>
<td>Pooled</td>
<td>0.1454</td>
<td>67%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Public</td>
<td>0.1135</td>
<td>42%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Private</td>
<td>0.2154</td>
<td>64%</td>
</tr>
<tr>
<td>Output</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U1Y1</td>
<td>Train Km</td>
<td>Pooled</td>
<td>0.7059</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Public</td>
<td>0.7059</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Private</td>
<td>0.7418</td>
<td>100%</td>
</tr>
<tr>
<td>Returns to</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scale°</td>
<td>U_r</td>
<td>Pooled</td>
<td>–0.0817</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Public</td>
<td>–0.1621</td>
<td>42%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Private</td>
<td>–0.2065</td>
<td>21%</td>
</tr>
</tbody>
</table>

*Figures in the final column for returns to scale refer to the percentage of DMUs that returned a positive $U_r$ figure, that is, were estimated as having decreasing returns to scale.*

The technical efficiency frontier was defined by 11 of the 43 public and 8 of the 14 private railways, the two managerial efficiency frontiers by 15 public and 10 private, and finally the organisational efficiency frontier by 21 public and 10 private railways.

The absolute weights attached to each input and output reflect both the different sizes of the DMUs and the relative importance of individual factors in each organisation. Consideration here is restricted to a brief overview of the “virtual” output and “virtual” inputs in the measure of efficiency. With just one output, the theoretical maximum of the virtual output is unity plus any economies of scale ($U_r$). Because the DEA programme constrains the sum of the virtual inputs to unity, the virtual inputs (that is, the values of the $\nu y_{ik}$ terms of equation (1)), are directly interpretable as the proportions of inputs represented in the individual DMUs’ efficiency score. The figures shown in Table 2 give the mean value obtained and the percentage of DMUs for which this factor was represented in the efficiency calculation.
Table 3

*Technical, Managerial, and Organisational Efficiency, Swiss Private and Public Railways, 1995*

<table>
<thead>
<tr>
<th></th>
<th>Technical</th>
<th></th>
<th>Managerial</th>
<th></th>
<th>Organisational</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Public</td>
<td>Private</td>
<td>Public</td>
<td>Private</td>
<td>Public</td>
<td>Private</td>
</tr>
<tr>
<td>Mean</td>
<td>75.5%</td>
<td>88.8%</td>
<td>81.4%</td>
<td>94.8%</td>
<td>92.3%</td>
<td>92.8%</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>20.3%</td>
<td>18.5%</td>
<td>17.9%</td>
<td>9.7%</td>
<td>11.1%</td>
<td>14.6%</td>
</tr>
<tr>
<td>Number</td>
<td>43</td>
<td>14</td>
<td>43</td>
<td>14</td>
<td>43</td>
<td>14</td>
</tr>
<tr>
<td>Median</td>
<td>74.0%</td>
<td>100.0%</td>
<td>80.2%</td>
<td>100.0%</td>
<td>98.1%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Median Test</td>
<td>T Calc:</td>
<td>1.9221</td>
<td>T Calc:</td>
<td>2.5376</td>
<td>T Calc:</td>
<td>1.4740</td>
</tr>
<tr>
<td>Probability:</td>
<td>0.0608</td>
<td></td>
<td>0.0146</td>
<td></td>
<td>0.1473</td>
<td></td>
</tr>
<tr>
<td>Mann Whitney</td>
<td>T Calc:</td>
<td>5.8397</td>
<td>T Calc:</td>
<td>5.9324</td>
<td>T Calc:</td>
<td>3.4111</td>
</tr>
<tr>
<td>Probability:</td>
<td>0.0000</td>
<td></td>
<td>0.0000</td>
<td></td>
<td>0.0008</td>
<td></td>
</tr>
</tbody>
</table>

Of the inputs, the combined mean for traction stock represents around half of the total inputs incorporated, suggesting that the use of traction stock is the largest determinant of efficiency. Labour levels are far less important, both in terms of the virtual input and its inclusion in the efficiency measure. As DEA is designed to weight inputs to maximise individual DMU efficiency scores (Thanassoulis et al., 1987), this suggests most variation occurs in labour productivity. As expected, gradient also has a large bearing on individual efficiencies. Comparisons between the two groups reflect small differences in the derivation of managerial efficiencies. Private railways tend to feature more locomotives and labour, but less DMUs/Railcars, which partly reflects subtle differences in operations.

More significant are the results relating to scale effects. In this single output case, the difference between the mean virtual output of 0.71 and mean pooled technical efficiency, which was found to be just under 79 per cent, is directly interpretable as the degree of inefficiency attributable to firms not operating at the optimum size. In this example, the 8 per cent difference equates with the mean $U_i$ value found. Overall, these results are broadly in line with Filippini and Maggi (1992), who estimated a returns to scale factor of 1.35 for the Swiss rail industry if network effects are not taken into consideration.

Efficiency results derived from this model are shown in Table 3. The Median and Mann Whitney test statistics examine the hypothesis that private railways' efficiencies are significantly different from public railways, and are calculated as $T$-statistics. The probability gives an indication of the strength of the hypothesis against the null hypothesis of no difference. The results are detailed below.
5.1 Technical efficiency
Average technical efficiencies are high, with an overall mean for the two groups of just under 80 per cent. Private companies have a higher mean technical efficiency level, (89 to 76 per cent), and a substantially higher median (100 to 74 per cent). The test statistics reveal significant differences in the technical efficiency of private and public railways at the 10 per cent level for the Median test and the 1 per cent level for the Mann Whitney test.

The results on the averages occur because of substantial variation in the performance of private railways, which is also reflected in the difference in the level of significance in the test statistics. The Median test simply examines those above and those below the median; hence there is no consideration of how far from the median individual observations lie. The Mann Whitney test, on the other hand, because it operates on rankings, does consider this spatial factor. Where the performance of private railways is above the average (that is, the pooled median), it is well above the average, but observations tend to be slightly polarised (that is, there is a considerable gap between “good” performers and “poor” performers). Importantly, however, there are significantly more good performers in the private railway subgroup, at least at the 10 per cent level of significance.

5.2 Managerial and organisational efficiency
As expected, efficiency differences reduce once managerial effort is isolated. This is clearly revealed in the median scores. Nevertheless, management appears to be particularly efficient in private railways, with a mean efficiency of 95 per cent. The 13 per cent difference found in the mean between the two groups exactly reflects the difference in technical efficiency, suggesting that all of this difference can be accounted for by managerial effort. Both test statistics show this to be significant, at the 5 per cent and 1 per cent levels respectively for the Median and Mann Whitney tests.

Differences in organisational efficiency are considerably smaller, with little difference in the mean and just under 2 per cent for the median. Only the Mann Whitney test identifies a significant difference. This inconsistency between the two test statistics is again indicative of variable organisational efficiency in the performance of private railways, with no significant difference found in those above from those below the median, but significant differences in the ranking of the two groups. This may be as a result of the federal nature of Switzerland, with organisational constraints not being consistent across the country, and also the varying level of public ownership in the definition of the identified private railways. Furthermore, this accentuates the results for technical efficiency, suggesting that the overall higher managerial efficiency of private railways only has a significant impact on technical efficiency where organisational constraints permit.

It can be hypothesised that the results indicate that the majority of publicly owned railways are less organisationally efficient than their private counterparts, with technical inefficiencies primarily attributable to organisational constraints affecting public railways. These, however, are not uniform across the country.
6. Conclusions

The Swiss private railway industry can be divided between railways that are partly owned by private shareholders (private), and railways that are owned almost entirely by a combination of state, cantons and municipalities (public). Private railways were found to have a significantly higher level of technical efficiency of around 13 per cent, which was almost solely accounted for by a higher degree of managerial efficiency.

From the analysis, there is some evidence to conclude that railway operators in the private sector face reduced organisational constraints, and thus can achieve higher levels of technical efficiency. The differences, however, are not clear cut. The slight inconsistency of the test statistics for technical efficiency suggests variability in performance; hence private railways perform better than public railways where their performance is strong, but only similar to, or possibly even worse than, public railways where their performance is weak. This was very much reflected in differences in organisational efficiency, where even more variation in performance was found.

Ownership, however, is only one aspect of being in the public sector, and indeed may not be the main organisational constraint. Other elements, which arise as a consequence of being part of the public sector, may also have a significant impact. The difference in performance may also be a consequence of the difference in the form of subsidy paid to the two groups. This again, however, may be related to being part of the public sector, as the form of subsidy that can be paid to a given operator will be partly dependent upon its ownership form.

Policy prescriptions on the Swiss rail industry are that privatisation alone, in the form of transfer of assets, will not automatically lead to higher efficiency. Other elements, such as the form of subsidy paid to operators and organisational constraints arising from the public sector, also need to be taken into consideration.

References


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