Train Operators' Economies of Scale and Business Strategies

Working paper

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Abstract

Following the regulatory reform of the Swedish Railway, the passenger market has been opened and competition has been introduced in terms of public procurements. At the same time the market has been divided into smaller units, counties. In order to adapt to the new situation the incumbent firm has reorganised in strategic business units, SBU. The aim of our paper is to analyse the size and number of these SBUs. We estimate a translog cost function in order to measure scale economies. We conclude that there are substantial returns to density as well as returns to scale.

1 Introduction

1.1 Background

Since the late 1980s, starting in Sweden and Great Britain, the European railways have been subject to major deregulation activities. The motives behind these changes in railway policy are to be found in the negative development of the financial and market performance of the railways, some of which have been described in the European Commission's White Paper (EC, 2001).

Before the late 1980s, almost all European railways were organised as integrated national monopolies. Since then, the deregulation process has followed a certain pattern starting with vertical separation of infrastructure from traffic operations, either in terms of separate and transparent cost accounting or complete organisational separation. This first step was followed, in some countries, by a second step involving horizontal measures in order to introduce competition such as the division of train operations of existing railways into smaller organisational units and/or allowing new train operators access to the networks. In addition to these fundamental transformations, several other measures were also integrated into the policy changes such as attempts to stimulate private ownership in the railway sector or the separation and unbundling of service activities like for instance train maintenance.

1.2 Strategic Decision Problems

Given the first step in the deregulation process, the vertical separation of infrastructure from the operations of trains, there are important strategic decisions to be made in a second step, i.e. decisions about the horizontal organisational structure of train operations. The horizontal decisions take place at two levels. At the highest level, regulators are confronted with the question whether the horizontal strategy should be to restructure the market into more than one operator and if so, into how many? As discussed by Jensen, (1998), the regulator is confronted with two conflicting forces. On one hand, there are the possible gains from competitive pressure on costs from introducing competition in the railway sector by horizontal measures. On the other hand, there is the possible loss of scale advantages from splitting up the production of train services into smaller organisational units, which may lead to increased costs. It can safely be assumed that cost efficiency will be an important objective for public regulators.

At the next level, given a certain number of train operators, each operator has to develop a business strategy. The internal organisation of the production system for train services is an important element in the business strategy of an operator. Should there be division-like business units (Strategic Business Units, SBUs)? If so, how many should there be? For train operators, there are similar conflicting forces as for regulators. The possible loss of scale advantages from horizontal division into more SBUs, the cost side, must be compared with the possible revenue gains (net) from improving the quality and differentiation of train services, which may be facilitated by increasing the number of SBUs. In both cases, empirical measurements of various concepts of scale economies offer valuable knowledge to decision makers of train operators, since they shed some light on the cost side of organisational and marketing strategies.

1.3 Purpose

The focus of this paper is on passenger transportation. The purpose is to measure some concepts representing intra-operator economies of scale in the production of railway passenger services and to discuss the implication of the measurements for organisational and marketing strategy of the largest Swedish passenger service operator.

The analysis in this paper will be restricted to economy of scale concepts and their implications for the cost side of operators' business strategies. We will not study the gains from competitive pressure and from the revenue side (see discussion above). Within this frame, we will deal with the following questions:

- Should the efforts of existing SBUs be focused on increasing the penetration of their market potentials?

- What are the consequences of increasing or decreasing the number of SBUs?

2 The Swedish deregulation process

The Swedish deregulation process was described in Bruzelius et al., (1994) and later by Alexandersson and Hultén, (1999). Therefore, the process will only be described briefly in terms of events related to our paper. In 1988 a new transport policy decision was made by which the construction and administration of the railway infrastructure organisationally and legally were separated from the operation of trains. The responsibility for the infrastructure was placed in the Swedish National Rail Administration, Banverket (BV), which came in effective operation as from 1 January 1989.

The responsibility for train operations remained within SJ, the former vertically integrated state monopoly. From 1 July 1990, passenger transportation rights were exclusive for SJ on main lines, but on regional routes, local transport authorities (CPTAs) were given the responsibility. The local transport authorities define the services to be provided, and they contract operators, among them SJ, to run the services. If SJ or CTPAs ceased their train services, BV could give the transportation rights to a third party. In 1990, the first new entrant started passenger traffic, and since then, several small operators have started passenger services after tenders. The number of private train operators in passenger traffic between 1990 and 2001 is shown in Table 1. In 2001, SJ was split up into 6 State owned companies, among them SJ AB (passenger transport) and Green Cargo (freight transport).

Table 1 Number of private entrants in passenger transports

Year	Number of operators
1990	1
1991	1
1992	1
1993	4
1994	2
1995	3
1996	4
1997	4
1998	4
1999	5
2000	-[1]
2001	13[2]

In 1993, SJ was reorganised into divisions, one of which was SJ passenger division. SJ passenger division was decentralised into “businesses”. The businesses are based on the traffic they produce. Each business runs one or more railway lines. The businesses are responsible for revenues and costs, and they have strategies of their own within the division strategy of SJ. They

[1] No report
[2] 9 operators in railway and 4 operators in tram and metro traffic

are strategic business units (SBUs) in the terminology of business strategic management (see Johnson and Scholes, (1999)). The business units run both own traffic and contractual traffic. The latter represents interregional traffic purchased by the State, which SJ cannot run at a profit, and regional and local traffic purchased by the CTPAs.

3 Method

We have chosen an econometric method using a translog cost function. The model is specified below together with the data available to us.

3.1 Output variables

As mentioned above, we will design our data analysis with the following business strategic questions in mind:

- Should efforts be focused on increasing the penetration of the market potentials of the existing SBUs?
- What are the consequences of increasing or decreasing the number of SBUs?

Variables related to economy of density are relevant for analysing the first question, while variables related to economy of network or economy of size will be important for analysing the second question. These variables will be treated as output variables in the translog model.

3.2 SBU cost structure

Firstly, the vertical separation of infrastructure from the operation of trains implies that costs that were fixed and sunk for the integrated railway firm have been converted to variable and avoidable costs for the train operator, since the operator will be charged for infrastructure use in proportion to some measure of traffic. This goes for what is here called strategic business units (SBUs) as well. Secondly, the SBUs are leasing locomotives and coaches on a short term basis from the central passenger division of SJ, so they have no major fixed and potentially sunk capital costs for rolling stock. Remaining costs are in principle variable and avoidable for the SBUs such as the costs of maintenance, energy, and labour. All this means that the SBUs, in their strategic business framework, have few restrictions from fixed factors of production.

3.3 Data

The question of what variables to include in a study and which ones to exclude, is a question of theory, time horizon, data availability, and innovation. Theory states the basic structure of cost models in transportation as a function of vectors of input factor prices, output measures, input quantities and network factors. The variables used in this study are stated in Table 2. Data from 12 SBUs are available for the time period from 1993 to 2002. However, the data set was not complete, leaving 9 SBU to be studied. In all, there were 70 observations.

The cost function is measuring total costs of the SBUs. The cost items are classified according to inputs and consist of cost of electricity cost, infrastructure charges, rent rolling stock, maintenance, personnel, indirect and other direct costs. All cost figures are expressed in 2002 value. The output items are train kilometres, passenger kilometres and seat kilometres. In addition, there is a variable purchased train kilometres. The data set also contains specifications on operated line length, number of lines, number of points served (stations were the train stops) as well as train types operated on the different lines.

The input factors used in the study are energy, infrastructure, labour, materials, maintenance and others. The prices of the inputs were not available. Therefore, outlays of the respective input are divided by train-kilometres, an approach often adopted when real input factor prices are unknown. In our study, we have chosen to treat electricity and infrastructure in a joint variable, “ei”, since part of the data was grouped in this way, as recorded from SJ. Further, labour and other direct costs are also treated as one variable, due to the fact that there is an internal market for personnel between the SBUs, where sales and purchasing of labour is recorded in such a way that it makes sense to treat them as a joint variable. In our study, the network variables consist of operated line length, which is the sum of the lengths of the lines run by the SBU, and the number of stations with train stops, which is the sum of the number of stations at lines run by the SBU.

The output variables can be divided into two main categories according to Small (1992), final and intermediate outputs. Final outputs are demand orientated, such as number of trips, passenger miles, revenue passenger, or ton-miles, whereas vehicle miles, vehicle-hours or seat miles are intermediate output or technical orientated. What output measure to use, depends on the purpose of the study. A study of technical efficiency would use intermediate output measures and a study of marketing or service effectiveness would use final output measures. In railway studies, output is often stated in passenger-miles, ton-miles, and average trip length. However, train kilometres or vehicle kilometres are not uncommon. Given the purpose of our study, we have chosen to use passenger kilometres as output variable.

Further, there is usually some kind of variable expressing the technology, for instance a time trend or firm specific dummy variables if cross-section data material is used. In this study, we have included a time variable and variables stating what train types are run by the SBU. Finally, we add a variable measuring the effect of public procurement of train services.

Costs are deflated by PPI (producer price index). Cost, price, output, and network variables are normalised around their mean values.

This TSCS data set contains, in total, the following variables (Table 2):

Table 2 Variables

Category	*Label*	*Variable*	*Unit*
Output	pkm	Passenger kilometres	Thousand
Network	km	Operated line length	Kilometres
	sta	Number of stations	
Costs	tc	Total costs	Thousand SEK
Input factor prices	ei	Electricity and infrastructure cost/train kilometre	Thousand SEK
	rm	Rent rolling stock/train	Thousand SEK

		kilometre	
	u	Maintenance cost/train kilometre	Thousand SEK
	ind	Indirect costs/train kilometre	Thousand SEK
	po	Labour and direct costs/train kilometre	Thousand SEK
Technology/Train types	t	Time	year
	dk	Dummy variable for SBUs with procured traffic	
	icr	Dummy variable for intercity and regional trains	
	lt	Dummy variable for county trains	

3.4 Specification of translog model

The cost function that is estimated should fulfil certain assumptions and behave in expected manner. The model is stated as below.

Equation 1

$$\ln TC = \alpha_0 + \sum_i \alpha_i \ln Y_i + \sum_j \beta_j \ln P_j + \tfrac{1}{2}\sum_i \sum_k \delta_{ik} \ln Y_i \ln Y_k + \tfrac{1}{2}\sum_j \sum_m \gamma_{jm} \ln P_j \ln P_m + \sum_i \sum_j \phi_{ij} \ln Y_i \ln P_j + e$$

where

TC = total cost

Y_i = element in the output vector (Y_1 , Y_2 , ……, Y_N)

P_j = element in the input factor price vector (P_1 , P_2 , ……, P_L)

This is the general form, which is the basis from which other models are elaborated, to include dummy variables of competition, firm specific dummies or the like. For better estimates, the translog cost function is estimated jointly with the cost share functions.

For homogeneity of degree one in input prices, we require that the following restrictions should be satisfied:

$$\sum_j \beta_j = 1; \sum_j \gamma_{jm} = \sum_m \gamma_{jm} = 0; \sum_i \phi_{ij} = \sum_j \phi_{ij} = 0$$

Input cost shares can be derived using Shepard’s lemma. In general:

Equation 2

$$W_j = \frac{P_j X_j}{C} = \frac{P_j \partial C}{C \partial P_j} = \frac{\partial \ln C}{\partial \ln P_j}$$

where

W_j= cost share of input *j*

X_j= quantity of input *j*.

So, for the cost share equations:

Equation 3

$$W_j = \beta_j + \sum_m \gamma_{jm} \ln P_m + \sum_i \phi_{ij} \ln Y_i$$

calculation of scale economies is made according to:

Equation 4

$$RTS = \frac{1}{\sum_j \partial \ln C / \partial \ln Y_j} = \frac{1}{\sum_j \varepsilon_{y_j}}$$

where ε_{y_j} is the elasticity of cost with respect to output *j*.

In transport, where network effects are included in the analysis, RTS is defined as the proportional increase in outputs and network due to a proportional increase in all inputs, with input prices held constant;

Equation 5

$$RTS = \frac{1}{\sum_i \varepsilon_{y_i} + \varepsilon_n}$$

where ε_n is the elasticity of cost with respect to network (number of points served or similar). Returns to density, RTD, is the proportional increase in outputs, by a proportional increase in inputs, with input prices and network held constant;

Equation 6

$$RTD = \frac{1}{\sum_i \varepsilon_{y_i}} \quad j$$

where $\varepsilon_{y_i} = \alpha_i + \sum_j \delta_{ij} \ln Y_j + \sum_k \phi_{ik} \ln P_k$

The translog cost function and the cost share equations are estimated jointly and in order to fulfil the homogeneity restriction, one cost share equation is dropped (in our case labour).

Our translog cost function is specified to the following:

Equation 7

$$Ln\ TC = \alpha_0 + \beta_1 * \ln pkm + \beta_2 * \ln km + \beta_4 * \ln sta + \beta_5 * \ln P_{ei} + \beta_6 * \ln P_{rm} + \beta_7 * \ln P_{ind} + \beta_8 * \ln P_u + \gamma_1 * ½ * \ln pkm^2 + \gamma_2 * ½ * \ln km^2 + \gamma_4 * ½ * \ln sta^2 + \gamma_5 * ½ * \ln P_{ei}^2 + \gamma_6 * ½ * \ln P_{rm}^2 + \gamma_7 * ½ * P_{inds}^2 + \gamma_8 * ½ * \ln P_u^2 + \delta_1 * \ln pkm * \ln km + \delta_3 * \ln pkm * \ln sta + \delta_4 * \ln pkm * \ln P_{ei} + \delta_5 * \ln pkm * \ln P_{rm} + \delta_6 * \ln pkm * \ln P_{ind} + \delta_7 * \ln pkm * \ln P_u + \delta_9 * \ln km * \ln sta + \delta_{10} * \ln km * \ln P_{ei} + \delta_{11} * \ln km * \ln P_m + \delta_{12} * \ln km * \ln P_{ind} + \delta_{13} * \ln km * \ln P_u + \delta_{19} * \ln sta * \ln P_{ei} + \delta_{20} * \ln sta * \ln P_{rm} + \delta_{21} * \ln sta * \ln P_{ind} + \delta_{22} * \ln sta * \ln P_u + \delta_{23} * \ln P_{ei} * \ln P_{rm} + \delta_{24} * \ln P_{ei} * \ln P_{ind} + \delta_{25} * \ln P_{el} * \ln P_u + \delta_{26} * \ln P_{rm} * \ln P_{ind} + \delta_{27} * \ln P_{rm} * \ln P_u + \delta_{28} * \ln P_{ind} * \ln P_u + \sigma_0 * t + \sigma_1 * dk + \sigma_5 * icr + \sigma_6 * lt$$

Here TC is total operating costs, pkm is passenger kilometres, P_{ei} is price for electricity and infrastructure, P_{rm} is price for rolling stock, P_{ind} is price of other supplies, P_u is price of maintenance and P_{lo} is price of labour. t is a time variable, dk is a dummy variable for tendered traffic, icr is a dummy for intercity and regional trains and lt is a dummy for county local traffic.

The cost share equations are stated below.

Equation 8

$$share_{ei} = \beta_5 + \gamma_5 * \ln P_{ei} + \delta_4 * \ln pkm + \delta_{10} * \ln km + \delta_{19} * \ln sta + \delta_{23} * \ln P_{rmk} + \delta_{24} * \ln P_{ind} + \delta_{25} * \ln P_u$$

Equation 9

$$share_{rm} = \beta_6 + \gamma_6 * \ln P_{rm} + \delta_5 * \ln pkm + \delta_{11} * \ln km + \delta_{20} * \ln sta + \delta_{23} * \ln P_{ei} + \delta_{26} * \ln P_{ind} + \delta_{27} * \ln P_u$$

Equation 10

$share_{ind} = \beta_7 + \gamma_7 \; ln\, P_{ind} + \delta_6 * ln\, pkm + \delta_{12} * ln\, km + \delta_{21} * ln\, sta + \delta_{24} * ln\, P_{ei} + \delta_{26} * ln\, P_{rm} + \delta_{28} * \; ln\, P_u$

Equation 11

$share_u = \beta_8 + \gamma_8 * ln\, P_u + \delta_7 * ln\, pkm + \delta_{13} * ln\, km + \delta_{22} * ln\, sta + \delta_{25} * ln\, P_{ei} + \delta_{27} * ln\, P_{rm} + \delta_{28} * ln\, P_{ind}$

The results from the estimation are presented below.

3.5 Estimated model

The model is estimated using iterated SUR. To avoid singularity the labour share factor is dropped. The results are presented in Table 3 and Table 4.

Table 3 Model summary

Equation	*DF Model*	*DF Error*	*SSE*	*MSE*	*Root MSE*	*R-Square*	*Adj R-Sq*	*Durbin Watson*
ltc	26	44	0.8664	0.0197	0.1403	0.9686	0.9508	1.2921
$Share_{ei}$	3.5	66.5	0.00125	0.000019	0.00434	0.9636	0.9622	1.4405
$Share_{rm}$	3.5	66.5	0.0745	0.00112	0.0335	0.7164	0.7058	1.3384
$Share_{ind}$	3.5	66.5	0.0149	0.000225	0.0150	0.9446	0.9425	1.0600
$Share_u$	3.5	66.5	0.00243	0.000037	0.00605	0.9214	0.9185	1.2080

Table 4 Results parameter estimates

Parameter	*Variable*	*Estimate*	*Std Err*	*t Value*
α_0		20.66269	19.1353	1.08
β_1	Log pkm	0.687056	0.0635	10.81
β_2	Log km	-0.60171	0.0980	-6.14
β_4	Log sta	0.695074	0.0826	8.41

β_5	Log ei	0.083584	0.000594	140.68
β_6	Log rm	0.221367	0.00438	50.56
β_7	Log ind	0.168245	0.00207	81.11
β_8	Log u	0.119948	0.000813	147.57
γ_1	Log pkm^2	0.304902	0.1075	2.84
γ_2	Log km^2	0.424868	0.4288	0.99
γ_4	Log sta^2	0.874919	0.2566	3.41
γ_5	Log Ei^2	0.074758	0.00143	52.15
γ_6	Log Rm^2	0.067932	0.00478	14.22
γ_7	Log ind^2	0.129583	0.00503	25.79
γ_8	Log u^2	0.102654	0.00129	79.31
δ_1	Log pkm*log km	0.045454	0.1591	0.29
δ_3	Log pkm*log sta	-0.06545	0.1204	-0.54
δ_4	Log pkm* log ei	0.003053	0.00104	2.95
δ_5	Log pkm*log rm	-0.02128	0.00667	-3.19
δ_6	Log pkm* log ind	0.00094	0.00376	0.25
δ_7	Log pkm* log u	0.004898	0.00135	3.62
δ_9	Log km* log sta	-0.65829	0.3050	-2.16
δ_{10}	Log km*log ei	-0.00341	0.00154	-2.22
δ_{11}	Log km * log rm	0.028019	0.0117	2.39
δ_{12}	Log km* log ind	-0.00993	0.00526	-1.89
δ_{13}	Log km* log u	-0.00267	0.00212	-1.26
δ_{19}	Log sta*log ei	0.003426	0.00152	2.25
δ_{20}	Log sta*log rm	-0.02615	0.0110	-2.37
δ_{21}	Log sta* log ind	0.010567	0.00535	1.97
δ_{22}	Log sta* log u	0.001159	0.00208	0.56
δ_{23}	Log ei*log rm	-0.00626	0.000713	-8.79
δ_{24}	Log ei*log ind	-0.01778	0.00122	-14.58
δ_{25}	Log ei* log u	-0.01251	0.00102	-12.23
δ_{26}	Log rm* log ind	-0.01013	0.00245	-4.14
δ_{27}	Log rm *log u	-0.01036	0.000924	-11.21
δ_{28}	Log ind*log u	-0.02599	0.00138	-18.81
σ_0	t	-0.01051	0.00958	-1.10
σ_1	Dk	0.241098	0.0491	4.91
σ_5	icr	-0.197	0.0759	-2.59
σ_6	lt	0.302402	0.0641	4.72

Table 5 shows scale economies estimated at total sample means and at the means of individual SBUs respectively.

Table 5 Scale Economies

Scale	Tot	SBU1	SBU2	SBU3	SBU4	SBU5	SBU6	SBU7	SBU8	SBU9
RTS	1,28	1,03	1,20	1,16	2,22	1,29	1,86	1,09	1,04	1,31
RTD	1,46	1,18	1,46	1,63	4,21	1,19	2,39	1,13	1,01	1,20

4 Implications for business strategy

4.1 Marketing strategy

The effectiveness of increasing the penetration of the market potentials of the SBUs is an important question in the business strategy of an operator. An analysis of this question involves the choice of marketing tools for increasing travel demand and all cost and revenue effects of their use and the cost effects of the increase in output. The effect on costs of increasing output can be analysed using the concept of returns to traffic density. Returns to traffic density represents the change in costs caused by a change in output-kilometres where the size of the railway network is held fixed. The coefficient $\beta_1 = 0.687$ in Table 4 is an estimate of the output elasticity of costs holding constant length of track operated, number of stations and other variables in the translog cost model. The coefficient is measured at the sample mean. In terms of elasticity, it implies that a 1% increase in output-kilometres leads to an increase in total costs by 0.687 %. Expressed as returns to density (RTD), which is given in Table 5 (column 1, line 2) by the inverted value of the elasticity, we get RTD = 1.46. This implies that there are increasing returns to traffic density for an "average SBU" within the operator's organisation. The term average refers to the point where the elasticity is measured, which is at the total sample average of output-kilometres, length of track operated, number of stations, and prices of inputs.

Table 5 also contains the RTD estimates of the indivual SBUs (line 2 in the table). All SBUs show increasing return to traffic density. These figures can give some guidance when ranking the SBUs according to potential gain in cost efficiency from increasing marketing efforts. The final decision will also have to consider the impacts on revenues and costs of the marketing activities themselves. SBU elasticities are estimated at the mean of the respective SBU. The precision of the estimate for a specific SBU is dependent on the difference between the overall sample means and the means of the SBU for relevant variables.

4.2 Organisational strategy

The size and the number of SBUs are a question for an operator's organisational strategy. These two factors are of course dependent, since changing the total size of a railway operator's production system is a decision problem that occurs infrequently. It will normally require participation in new tenders for traffic or loss of traffic. The translog cost function can give some information about the cost advantage of changing the size of a train operator's SBUs. An overall measure of economy of scale (elasticity) measured at the sample mean can be defined as the % impact on total cost from a 1% increase in output-kilometres, length of tracks operated, and number of stations while holding remaining variables fixed. This elasticity is equal to 0.687 – 0.602 + 0.695 = 0.780, which means that an increase by 1% of these three variables leads to an increase of cost by 0.780% while holding the remaining variables fixed. In terms of returns to scale, we get RTS = 1.28, which is another way of expressing increasing returns to scale. This result indicates that reducing the number of SBUs from the present level, given the same total size of the operator, could lead to a higher cost efficiency. The returns to scale for the individual SBUs are shown in Table 5, line one. These measures can give some hints about which SBUs should be given the highest priority for restructuring. However, once again, the precision of an individual SBU elasticity depends somewhat on the difference between the overall sample means and the means of the SBU in question along relevant independent variables.

The analysis of the returns to scale in total and for individual SBUs for other constructs than the two discussed here is still going on, but the results need a little more work and interpretation.

5 Conclusions

The regulatory reform of the railways has implied an introduction of competition. This means that the incumbent firm has to deal with a new environment. In order to adapt to the new situation, the incumbent has to react. This can be done in various ways, however given the division of the Swedish passenger market in different counties, the strategy of SBUs has been chosen by the incumbent firm. Our study aimed at analysing if these SBUs are appropriate in terms of size and number. Our analysis shows that there seems to be substantial economies of density in the Swedish rail passenger market. This is in accordance with other studies showing that rail transports in general are characterised by increasing returns to density (Preston, 1994, Keeler, 1974, Harris, 1977, Braeutigam et al., 1984, Friedlaender et al., 1993, McGeehan, 1993). These economies can be exploited either by longer trains or more frequent traffic. How to attract new travellers is a question of marketing.

Further our study points at increasing returns to size. This can be interpreted as if the SBUs are too many and too small. By merging some of the SBUs scale economies could be realised. This also gives a hint about the division of the market in counties. It might be that these counties should be larger regions instead. Other studies have concluded that the railways in general show constant or decreasing returns to scale, at least large railways. But these studies are based on cross-sections of national railways, which are much bigger in size than the SBUs in our study, so the comparison is not directly relevant. However, at some size also the scale of SBUs may become too big when balanced against other factors influencing organisational strategy.

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