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A Longitudinal Study

By

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ABSTRACT

Vertical separation between infrastructure service provision and the operation of trains is one important element in the Swedish deregulation process. Another is the introduction of various forms of competition. In this paper, we study the economic development of the Swedish railway and explore if and how the deregulation has affected cost efficiency. We use a longitudinal econometric approach in our study and conclude that vertical separation raises costs, and also that the introduction of competition lowers costs. The combined effect seems to be an improvement in cost efficiency as an impact of the deregulation process. The study also gives some results on lagged relationships between output and costs in railways with mixed passenger and freight services and provides a methodological approach for causal research on the relationship between railway deregulation and costs.

Keywords: Railway deregulation impact, competition and cost pressure in railways, vertical separation in railway sectors, railway cost functions, railway deregulation cost effectiveness, railway cost determinants.

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1 Introduction

Many railways all over the world have been subject to various deregulatory activities during the last decades. The motives behind these changes in railway policy are often to be found in the negative development of the financial and market performance of the railways. The European Commission has described the development of the European railways in its White Paper (EC, 2001). Governments in Europe have made major changes in their railway policies since the late 1980s, a development that started in Sweden and Great Britain. Examples of important changes in policy are:

- Vertical separation of infrastructure from traffic operations, either in terms of separate and transparent cost accounting or complete organisational separation.
- Organisational and other measures to increase competition such as giving new train operators access to the railway network.
- Stimulation of private ownership in the railway sector.

The policy mix of these ingredients as well as the speed with which the changes are implemented varies considerably between countries. There are examples of both instant radical changes in regulation and of limited gradual changes over extended periods of time.

There may have been several goals for the deregulation of the railway sectors, and the goals may not have been completely clear at the outset. However, it can be safely assumed that improved *economic efficiency* in terms of reduced costs of producing a given output is one of the most important goals. Therefore, it is extremely important to undertake research aiming at analysing whether the deregulation policy really leads to improved economic efficiency or not and also to suggest concepts and methods for such research. In this paper, we interpret economic efficiency as cost efficiency expressed as the cost of producing a given output.

In Swedish railway policy (see Bruzelius et al., 1994), the importance of cost efficiency can be deduced from a Government directive to a special investigator appointed in the spring of 1992 in which the Minister of Transport and Communication says:

> "A predominant objective of the deregulation and of competition in general is to stimulate efficiency in utilisation of resources."
>
> *"My basic opinion is that an abolition of competitive limitations and in general a more severe legislation related to competition are an important prerequisite for increased cost efficiency within the sectors reporting to the Ministry of Transport and Communication."*

Cause-and-effect research in the railway sector encounters several difficulties. How can output be defined? Are costs empirically measurable? Can changes in costs be explained by the deregulation policy or are they caused by other factors? This paper deals with these difficult research questions, and our purpose is to explore how the deregulation of the Swedish railway sector has impacted its cost efficiency. The deregulation policy is composed of a number of more or less visible measures. Within our purpose, we will focus on three main issues:

- Is it likely that the deregulation policy as such, whatever it contains, has been effective in terms of improved cost efficiency?
- Are there any indications showing that the competition enhancing measures of the deregulation policy have been effective in terms of improved cost efficiency?
- How has the vertical organisational separation of infrastructure from train operations affected cost efficiency?

In dealing with these main issues, we also suggest some concepts and develop some methodological principles for studying the effects of railway deregulation using small data sets.

Swedish transport policy has never been static. Gradual changes have been made. However, the new transport policy decision in 1988, coming into force on 1 January 1989, represents a major break in policy. Therefore, operationally, we define the deregulation policy and the deregulation process as being in force from that date. Our aim is to study the impact that the deregulation policy, defined in this way, may have had on cost efficiency.

In general, little is known about the impacts of regulatory reforms on railway efficiency. We are not aware of any paper with focus on the impact of regulatory reforms on cost efficiency in an in depth, single country time series analysis like the one we have done. Existing studies are different in focus and use different methods. A few studies analyse physical efficiency measures based on panel data from European railways. Cantos Sanchez et al. (1999), analysing panel data from 1970 to1995, find that vertical separation and managerial autonomy both seem to have a positive effect on efficiency. Gathon and Pestieau (1995), using panel data from 1961 to1988 (prior to the deregulation period), also find that managerial autonomy impacts efficiency in a positive way. Jorge-Moreno and Garcia-Cebrian (1999), using panel data from 1984 to1995, conclude that the regulatory reform has not influenced technical efficiency in a negative way. Rather, productive efficiency of railway systems may be significantly enhanced by an institutional and regulatory framework that provides a greater freedom for managerial decision-making, according to Oum and Yu (1994). Oum et al. (1999), analysing international productivity measures, find that competition has improved productive efficiency. Covie (1999) finds that privately owned firms in Switzerland have higher technical efficiency than public firms.

2 The Swedish deregulation process

The Swedish de deregulation process was described in Bruzelius et al. (1994) and later by Alexandersson and Hultén (1999). Therefore, the process will only be briefly described here. The Transport Policy Act of 1979 aimed at creating a new institutional structure for local and regional public transport. County Public Transport Authorities (CPTAs) having the formal responsibility for bus traffic and parts of local and regional rail traffic were established in 24 counties. This was a first step towards transferring the cost responsibility from the State to the counties. The aim was also a reallocation of costs between transport modes so that the infrastructure costs would come closer to marginal costs. However, during the 1980s, the financial development of Statens Järnvägar (SJ), i.e. the National State Railway monopoly, was not regarded as satisfactory by the owner, the Swedish state. The railway law of 1985 aimed at improving the financial status of SJ and allowing SJ to act in a more market-like way in at least some respects, e.g. as a borrower in the financial markets. Important elements in the railway law of 1985 were separation of the accounting of infrastructure from that of traffic operations, the increase in total investment appropriation to SJ, and decreased central governing of SJ. However, the financial situation in SJ continued to deteriorate.

In 1988, a new transport policy decision was made. As a consequence, Sweden became the first country in the world to separate the construction and administration of the railway infrastructure organisationally and legally from the operation of trains. The responsibility for the infrastructure was placed in the hands of a new organisation, the Swedish National Rail Administration, Banverket (BV), formally founded on 1 July 1988, but considered to be in effective operation as of 1 January 1989[1]. The responsibility for train operations remained within SJ. Further, the railway network was segmented into main lines and county lines, and an extensive infrastructure investment programme was launched. From 1 July 1990, passenger transportation rights were given

[1] As an example can be mentioned that accounting in BV started on 1 January 1989.

exclusively to SJ on main lines, but on county lines, the CPTAs were given the responsibility. Freight transportation rights were exclusive for SJ on all network parts. However, if SJ or CPTAs ceased their traffic, the new infrastructure authority BV could give the transportation right to a third party.

This made it possible for new actors to enter the market. In 1989, the first competitive tendering for railway passenger transport in Sweden took place, and in 1990, the first new entrant started regional traffic. Encouraged by the success of American short-lines, small entrepreneurial feeder lines started in 1991. In 1992, the first tenders for passenger transport on interregional lines were held. In 1993, the rights of ore transports in Northern Sweden were transferred to the mining company LKAB. On 1 July 1996, BV took over traffic control and allocation of track capacity from SJ. CPTAs were given increased rights for traffic on main lines in their respective counties. In principle, freight train operators have free access to tracks as of 1 July 1996. However, SJ was given grandfather’s right to slot times.

Since then, the number of new entrants has increased, and the organisational change of the railway has been radical. In 2001, SJ was split up in six State owned companies, among them SJ AB (passenger transport) and Green Cargo AB (freight transport).

Summarising, we can distinguish three main elements in the deregulation process:

- Vertical separation of infrastructure service provision from traffic operations.
- Introduction of competitive tendering for passenger transports on some lines.
- Opening of the railway freight transport market.

These three main elements and a cautious introduction step by step constitute the pattern that we will refer to as the Swedish model for railway deregulation.

3 Research design

We have chosen a longitudinal econometric approach in our study, and we analyse the efficiency development between 1970 and 1999 based on annual data. Complete and consistent cost data can only be derived from 1970 to 1999, which determines the length of the period of time that can be analysed. Costs cannot be allocated to various types of output such as passenger services and freight services. Consequently, the analysis will have to be based on total costs. This section develops some methodological aspects.

3.1 Model coverage

There are two sets of train operators in the railway sector for which it seems relevant to analyse efficiency and its development:

- SJ, the main operator and former monopolist
- All operators in the railway sector

Prior to the vertical separation of infrastructure and train operations, SJ was an integrated legal monopolist responsible for both train operation and infrastructure. The effect of the gradual opening up of the market for train operators is illustrated in Table 1.

Table 1. Number of private entrants.

The cost of output from the two sets of train operators can be measured either excluding or including the costs of infrastructure services used for the production of train services. To consider both groupings of costs makes sense, since the costs of the provision of infrastructure services arise within BV. Since BV is a state-owned monopoly, the train operators cannot control these costs, so they should not be included when measuring the efficiency of train operators. Studying the two sets of train operators with and without the cost of infrastructure facilitates comparisons of efficiency between open markets for train operations and integrated sectors where actors are responsible for both train operations and infrastructure. This means that we have four segments of the sector for which cost efficiency will be analysed.

3.2 Output data

Output from the Swedish railway sector is a multiproduct concept, but output statistics are only available for two aggregate product groups: passenger services and freight services. However, statistics for these two output groups are available also before 1970. Output data are taken from the annual official statistics “Sveriges Järnvägar” 1970-1992, “Järnvägar” 1993-1999, and “Bantrafik” 2000-2001, published by SJ, BV, and

SIKA[2] respectively. Figure 1 shows output in passenger-kilometres and Figure 2 output in tonne-kilometres between 1960 and 1999 for SJ and for the sector.

Figure 1. Passenger transport output in passenger-kilometres for SJ and for the sector.

Figure 2. Freight transport output in tonne-kilometres for SJ and for the sector.

3.3 Cost data

Railway cost accounting is designed for other purposes than to satisfy data needs deriving from scientific studies. Therefore, extreme care was taken to explore the statistical data from the accounting systems in order to learn what the key data represent and how they were created. The guiding principle was to find the correct correspondence between output, cost, and year.

Cost data are based on accounting costs from BV, the National Rail Administration, and all train operators of any significance, among others SJ, A-train, BK Tåg, Tågkompaniet, and MTAB. In some cases, the compilation of valid cost data has required special estimation or adjustment of the accounting data (see description below). Information sources for the compilation of cost data are official publications, internal documents from the railway organisations, interviews with key informants within the railway organisation, and also data from the accounting systems.

Cost data for some of the new small operators were not available, e.g. because some of the early entrants went into bankruptcy. However, in some cases, costs were estimated

[2] SIKA (Swedish Institute of Communication Analysis) is a public national institute for transport and communication research and statistics.

on the basis of turnover. If this approximation was impossible, costs and outputs from these operators were excluded. Since they are very small, these approximations can safely be disregarded.

Before 1989, all costs arose within the monopolist, SJ. After 1988, all costs related to infrastructure became the responsibility of BV, and some costs of train operations arose within the new operators. However, the costs of the new operators are small in comparison with those of SJ's. Therefore, we have paid most attention to the compiling of relevant and valid cost data for SJ and BV. In this study, the cost of train operations includes all costs of a train operator except depreciation of rolling stock and infrastructure costs. In functional terms, the cost of train operations includes operating costs, maintenance costs, administration costs, and marketing costs. The cost of infrastructure includes all costs of an infrastructure service provider except costs of new investments and re-investments in railway tracks. This means that operating expenses, maintenance and administration all contribute to the cost of infrastructure as defined here. Table 2 explains the principles for allocating costs to the four segments to be modelled in this paper.

Table 2 Coverage of costs for four segments of the railway sector.

3.4 Data adjustments

There is almost always a need for adjusting railway accounting data before using them in econometric studies. However, the handling of such data problems is seldom reflected in the scientific literature. If data problems are not searched for, they will remain undetected. As a contribution to the knowledge about identification and adjustment of data problems in railway cost research, we summarise those encountered and the solutions chosen in this study:

- Until 1989, infrastructure costs are included in the costs of SJ and shown in the books of Banavdelningen (SJ's former infrastructure department). However, data are missing for the years 1977-1983. For these years, data were created by a statistical interpolation method defined in the Expand Procedure in the SAS library (See SAS/ETS, 1993). This method fits cubic spline curves to the nonmissing values to form continuous-time approximations. These are used to generate approximations to the missing values.
- Until 1981, investments in tracks and real estate were accounted for as operating costs of infrastructure. From 1981, the balance sheet was redefined, and these costs were now included, correctly, as investments not belonging to maintenance or replacement activities. As a correction, careful estimates made by a cost accountant within SJ, who is familiar with the time period, were subtracted from the infrastructure costs for the period 1970-1980 in order to follow our definitions.
- Segment 2 in Table 2 represents the development of SJ including infrastructure. For segment 2, one problem is to allocate the costs of SJ's traffic after the entry of other train operators. We have calculated SJ's relative share of BV's costs as equal to SJ's relative share of total railway traffic.

- SJ altered the date for closing the financial year. By 30 June 1985, the closing of the books was altered to follow the calendar year. Before that, SJ followed a broken financial year ending on 30 June. We have used the formula C(t) = (C(t-) + C(t+))/2 for estimating data for calendar years before 1985. In this formula, C is cost, t is calendar year t, t- is the broken financial year ending on June 30 in year t, and t+ the broken year starting in calendar year t[3].
- SJ Buss and SJ Ferry became subsidiaries of SJ in 1990 and 1991 respectively, and SJ Travel Bureau was sold in 1990. Before that, these organisational units were all parts of SJ and included in the cost accounting of SJ. Their costs should be subtracted from the costs of SJ, since they do not represent any train output. However, data are missing for some years. To solve this problem, data were created for missing years by statistical methods. For SJ Bus, data are missing for 1977- 1980. They were calculated using the SAS Expand Procedure for interpolation described above. For SJ Travel Bureau, data exist for 1966-1976, 1982, and 1985-1988. Missing data were calculated using the same SAS procedure. In the SJ Ferry case, data were predicted using time series regression for 1977-1990 from existing data for 1966-1976.
- From 1996, the ore transport operator MTAB buys the service of 80 locomotive drivers from SJ. This is accounted for as costs in both SJ and MTAB. We have subtracted the costs of this service from the costs of SJ.

[3] For 1984, the cost is calculated as cost of the broken financial year 1983/84 plus the cost of year 1985, both divided by two. The 1985 year cost was given to us from the SJ accounting department.

- From 1992, intermodal transports are produced by SJ, but marketed and sold by Rail Combi. The costs of administration, marketing and sales have been estimated for Rail Combi based on labour costs and added to the costs of SJ.
- From 1995, foreign transports in Sweden are accounted for as gross revenues and costs instead of being measured as contribution to profit. This has been adjusted for.

Figure 3 shows the total costs per year for segments 1-4 between 1970 and 1999.

Figure 3. Costs of segments 1-4 from 1970 to 1999.

Various validity checks were made of the data adjustments and estimations described above. In cases where missing subsets of consecutive yearly data were estimated by means of statistical interpolation or extrapolation, these approximations were checked one at a time using dummy variables in models of method two below. The dummy variables were set equal to 1 for years with approximations and equal to 0 elsewhere. The coefficients of these dummies were highly insignificant and very close to 0. In connection with the vertical organisational separation of infrastructure and traffic after 1988, it is not unreasonable to suspect that "creative accounting" might have been used in order to give the new organisation a good start by taking some costs before instead of after the change. This was checked by defining a dummy variable as equal to 1 for 1988, equal to -1 for

1989, and equal to 0 elsewhere. However, when tried in the models represented by equation (1) below, the coefficient of the variable representing "creative accounting" also turned out to be highly insignificant and very close to 0, which shows that no such "creative" thinking seemed to have taken place. Finally, accounting specialists at SJ have validated the figures and the methods used for compiling data for the four cases. The overall impression from the validation is that the cost data are free from systematic errors.

3.5 Input price index

In Sweden, there is no input price index for the railway sector. Therefore, we have developed an aggregate input price index based on the input categories that dominate the costs, namely labour, capital, and electricity. The aggregate input price index for year t is calculated as $I_t = a_1(LCI)_t + a_2(PPI)_t + a_3(ECI)_t$, where *LCI* is labour price index, *PPI* is producer price index, and *ECI* electricity price index, all normalised to 100 for the year 1999. The weights a_1, a_2, and a_3 are average input cost shares estimated approximately at a_1=0.63, a_2=0.33, and a_3=0.04 for labour, capital, and electricity respectively for the 1970-1999 period.

LCI is based on public wage statistics per month for civil servants existing from 1973 to 2004. This series was linked to a similar series for 1971-72 and extrapolated to the lacking year 1970 (source for these series: SCB[4]). The entire series was normalised to 100 for 1999. The wage rate in this series appears to be relevant for the railway sector. *PPI* is an official producer price index for transport vehicles and transport equipment

[4] www.scb.se SCB Labour statistics.

(source: SCB[5]). We have linked two *PPI* index series to each other, one running from 1970 to 1995 and one from 1990 and onwards. The latter was linked to the former from 1996 and the resulting series normalised to 100 for 1999. *PPI* is assumed to represent the price development of input capital for the railway sector. *ECI*, finally, is an index computed directly from the price of electricity (source: Power supplier E.ON).

In the models to be developed, the nominal total cost series will be deflated by dividing them with the aggregate input price index I_t. This method is used in transportation research by for instance the U.S. Surface Transportation Board, according to Waters (2000), who gives an overview of productivity measurement. The deflated cost series can be perceived as an aggregate quantity index of the inputs used to produce the outputs or as a general measure of value or buying power in the markets for inputs to the railway sector. Deflated cost series are used in this paper to draw conclusions about the effects of deregulation measures. If these measures can be shown to lead to a decrease in deflated costs for given outputs, this will be interpreted as an efficiency improvement. When used for this purpose, the series of input bundles should have a composition that does not change too much over time. The degree of change is difficult to estimate due to outsourcing of activities, reclassification of costs, and organisational fragmentation. The sensitivity of the method to changing weights a_i depends on the degree of uniform growth over time of the indices in I_t. If $(LCI)_t = (PPI)_t = (ECI)_t$ for all t, then I_t will be completely independent of changing weights. Since *LCI* and *PPI* together represent 96% of the estimated average weights a_i in I_t and since change in cost shares can be assumed to stay within these two categories, we consider it to be sufficient here to restrict a sensitivity analysis to the effect of deviations from unity of the ratio *PPI/LCI*. An error analysis

[5] www.scb.se SCB Prices and Consumption statistics.

shows that if it is assumed (incorrectly) that the weight vector is (a_1=0.63, a_2=0.33, a_3=0.04) and the true vector is (a_1=0.73, a_2=0.23, a_3=0.04), then the maximum error in I_t will be less than 1% if *PPI/LCI*=1.1 and less than 2% if *PPI/LCI*=1.2. Based on 3-year averages, the ratio *PPI/LCI* is equal to 1.008 between 1970 and 1972 and equal to 1.017 between 1997 and 1999. Between these 3-year periods, *LCI* grew by 555% and *PPI* by 560%, both with rather uniform growth. Firstly, since the difference in growth between them is very small and since the change of the cost shares is considered to be moderate, we assume that errors in I_t, if any, are small enough to be neglected. Secondly, I_t does only influence the dependent variables in the models that we develop. The models are specified with time variables and autoregressive parameters or with time differencing. These special properties of our method are assumed to neutralize remaining influences of systematic time related errors in I_t and to allow us to draw valid conclusions about the efficiency effects of deregulation, the main purpose of our study.

3.6 Two methods

For each of the four segments, we analysed the impact of the deregulation measures by means of two different methods[6]. This made a convergent validity evaluation of some aspects of the conclusions possible by comparison (see Churchill (1995, p. 539) or Campbell and Fiske (1959) about "convergent validity"). Our approach is as follows:

[6] In this sense, the term method refers to a problem solving approach consisting of a guiding idea, choice of data, model specification, estimation principle, and related analysis. At lower conceptual levels, the word "method" may be used in other contexts such as estimation method (= estimation principle).

- Method one. We specified models in which costs were explained by outputs, time, and important deregulation measures. We estimated the models on data from 1970 to 1999 using two different estimation principles, and analysed the models regarding the impact of deregulation.
- Method two. We specified and estimated simpler models from data prior to the deregulation, where costs were explained as functions of outputs and time. Using these estimated models, we then predicted the outcomes of costs for the period after the start of the deregulation based on real outputs and time for the years 1989-1999. In this way, we assume that we have described a scenario representing what would have happened without the shift to the deregulation policy, i.e. with the old cost structure remaining. This scenario was then compared with the actual outcomes of costs under the deregulation policy (Method two).

3.7 Instrumental hypotheses

Econometric methods gain in strength if model specification can be based on hypotheses that can help to identify and define explanative variables to be included in the models and to predict the signs of estimated model coefficients. Such hypotheses may be derived from theory, earlier studies, or plausible reasoning (e.g. based on experience). Our model specifications are supported by four instrumental hypotheses. Hypotheses one and two represent our research purpose whereas the aim of hypotheses three and four is to increase the explanative power of cost models for efficient estimation of parameters related to our research purpose.

Hypothesis one: Our first hypothesis is concerned with the impact on cost efficiency from various measures taken by the regulator to increase the competitive pressure on the provision of train services. This impact is taken here to include influence on the quantities of inputs used by train operators in their production activities as well as influence on the prices that operators pay for the inputs. Conceptually, like Jensen (1998), we see the impact of competitive pressure on costs, the cost pressure, as the net result of the gain from cost pressure and the loss of scale advantages. These two effects are both associated with number of competitors in the market. We have found no empirical railway studies giving guidance regarding this impact. However, a hypothesis about negative association between competitive pressure and cost would be in accordance with general economic theory and general opinion in practice. Competitive pressure on incumbent operators originates from their perception of competitive stimuli. Stimuli can be events like market openings or market entry by new operators. Stimuli can also be generated by conditions such as number of competitors in the market or number of potential entrants. Perception can originate from both actual observations of stimuli and from expectations about their occurrence. Therefore, it is clear that there does not necessarily have to be a time lag between competitive stimuli and cost pressure. Since the number of new operators in the market is an important competitive stimulus and also probably strongly associated with other stimuli, we have found it reasonable to assume that the cost pressure in year t from all these competitive stimuli is dependent on a function of the number of new operators in the sector year t. We expect the relationship between number of operators and cost to be negative. The number of new operators can be found in Table 1 (equal to the number of private entrants). The choice of simultaneity is assumed to be reasonable considering the joint effects of incumbents' lead-times associated with possible competitive stimuli. Some experimentation with lagged variables in models of the type represented by equation (1) confirms this assumption.

Hypothesis two: Besides the immediate reorganisation costs due to the vertical separation, three general effects on cost from the vertical separation of infrastructure from traffic can be expected, according to Jensen (1998). The first one is an increase in costs due to vertical sub-optimisation in resource allocation between infrastructure and traffic for creating a desired impact on output. The second effect is the increase in transaction costs caused by the separation. The third effect springs from the fact that the infrastructure, now organisationally within BV as a state monopoly, is cut off from pressure from intermodal competition. The intermodal competitive pressure, which works through the demand for freight and passenger transportation, will now exert an influence only on the train operators. This will gradually lead to an increase in costs of the provision of infrastructure services. The joint impact of these three effects on costs, as described by Jensen (1998), leads us to our second hypothesis: There is a cost driving effect associated with the vertical separation of infrastructure from traffic. Therefore, a variable representing vertical separation will be included in the models.

Hypothesis three: In railway transport, a high share of costs depends on the use of labour, rolling stock, and energy. In passenger transport, the use of these resources year t has traditionally been determined about one year in advance or more and manifested in the form of train plans and time tables (see e.g. Bruzelius et al., 1994, ch. 4). These plans will depend on forecasts of output for year t, which in turn will be based, among other things, on output years t-1, t-2 and perhaps earlier. This type of planning indicates the existence of a lagged relationship between output and costs. The lead time between the observation of need of change of work force and the timing of the effect of such decisions also contributes to the existence of a lagged relationship between output and costs. A working hypothesis, therefore, is that the costs in passenger transport year t will depend on outputs in the years t-1, t-2, and t-3. In freight transport, a substantial share of the output year t will be determined by long or medium range contracts and known with a high degree of certainty. Also, the lead time between resource decisions and their effect on costs is short in most freight services indicating that the relationship between output and costs is simultaneous.

Hypothesis four: Technology, intermodal competition, and politicians can all be assumed to exert pressure on railway costs. This pressure is assumed to be associated with time together with residual systematic impacts.

4 Specification of models

4.1 Method one

In method one, two estimation principles have been used: separate estimation, and time-series and cross-section regression (TSCS).

4.1.1 *Separate estimation*

We specified the models according to the function

$$ln\ C_{kt} = \beta_{0k} + \beta_{1k} ln\ X_{k,t-1} + \beta_{2k} ln\ X_{k,t-2} + \beta_{3k} ln\ X_{k,t-3} + \beta_{4k} ln\ W_{kt} + \beta_{5k} ln\ NO_t + \beta_{6k} VS_t +$$

$$+ \beta_{7k}t + e_{kt} \quad (1)$$

separately for segment k, k=1, 2, 3, 4, year t. C_{kt} is total cost, X_{kt} output in passenger kilometres, W_{kt} output in freight tonne kilometres ($X_{1t} = X_{2t}$, $X_{3t} = X_{4t}$, $W_{1t} = W_{2t}$, and $W_{3t} = W_{4t}$). The variable $ln\ NO_t$ is used to represent the cost pressure from competition on $ln\ C_{kt}$. The variable NO_t is equal to one before 1989 (representing SJ) and equal to one plus the number of private entrants according to Table 1 1989 and later. VS_t is a dummy variable equal to 0 until 1988 and equal to 1 from 1989. VS_t=0 represents vertical integration between infrastructure and traffic operations, whereas VS_t=1 represents vertical separation. The variable t is assumed to represent effects on costs from technological development, intermodal competition, political pressure, and residual systematic impacts, such as shifting cost shares of inputs in the deflator I_t , if any. The term e_{kt}, finally, is an error term. We expect the coefficients of $ln\ X_{kt}$, $ln\ W_{kt}$, and VS_t to be positive and those of $ln\ NO_t$, and t to be negative in accordance with the instrumental hypotheses formulated above.

The dependent variable and several of the independent variables are specified in logarithmic forms. An advantage of this specification is that the coefficients β of the logarithms of these independent variables can be interpreted as constant elasticity measures. Another advantage is that taking logarithms of dependent variables that have significant growth or decline normally tends to improve the homoscedasticity of the residual errors. For the variables *VS* and *t*, it seems more realistic to use natural units. The interpretation of their coefficients β is proportionate change in costs from a unit increase in the independent variable. This implies that β_{7k} is the proportionate rate of growth or decline in costs C_{kt} per year, and β_{6k} is the proportionate change in costs C_{kt} from vertical separation. Within the framework of the research purpose, the instrumental hypotheses, and the available data, the choice of the specification (1) is the result of a trial and error process involving the joint evaluation of outcomes in the dimensions of interpretability of parameters, explanative power of independent variables, precision of parameter estimates, and statistical quality.

The impact of deregulation on cost efficiency in terms of our model is the joint effect of vertical separation and competitive pressure. The joint effect of these two forces is represented by ($\beta_{5k} ln\ NO_t + \beta_{6k} VS_t$) in (1). When the dependent variable is $ln\ C_{kt}$ as in model (1), then β_{5k} can be interpreted as the elasticity of competitive pressure, the percentage increase in cost due to a 1 % increase in the number of railway operators. With the same dependent variable, β_{6k} is the proportionate increase in cost from vertical separation of infrastructure from traffic.

Using the SAS software, we have estimated (1) with the maximum likelihood (ML) method. The error term e_{kt} was specified as an autoregressive term $e_{kt} = \rho_k e_{k,t-1} + v_{kt}$ following the standard assumptions for AR(1) processes (e.g. see Pindyck and Rubinfeld (1998, p. 160)).

Autocorrelation is analysed using the Durbin-Watson test statistic (DW), the LM statistic, and the Box-Ljung statistic for measuring autocorrelation up to lag 6. To analyse whether our models are structurally stable over the two regulatory regimes, we divide the data into one subset representing the integrated monopoly period (1970 -1988) and another representing deregulation (1989-1999). We use a Chow test to see if the regression coefficient vector of model (1) is the same in both periods. Homoscedasticity is analysed using Q and LM tests for autoregressive conditional heteroscedasticity (ARCH) as described in Johnston and DiNardo (1997).

Defining $\Delta Y_{kt} = Y_{kt} - Y_{k,t-1}$ for a general variable Y, we also estimated the differenced version

$$\Delta ln\ C_{kt} = \beta_{1k}\Delta ln\ X_{k,t-1} + \beta_{2k}\Delta ln\ X_{k,t-2} + \beta_{3k}\Delta ln\ X_{k,t-3} + \beta_{4k}\Delta ln\ W_{kt} + \beta_{5k}\Delta ln\ NO_{t} + + \beta_{6k}\Delta VS_{t} + \beta_{7k} + \Delta e_{kt} \quad (2)$$

of model (1). Differencing (1) may give more stationary variables and less autocorrelation in the residuals. If so, the gain will be lower risk in general of spurious regression and also more reliable t and F tests, as argued by Granger and Newbold (1974). We estimated the coefficients using both (1) and (2) and compared the estimates from the two models. If the estimates have the same signs and are not too different, the convergent validity of the specifications is supported. Therefore, comparing the coefficients β_{5k} and β_{6k} estimated from (1) with those estimated from (2) is a useful validity check, since these coefficients are focal in the purpose of this paper.

4.1.2 TSCS.

Capitalising on the structure of the problem and the data set, we also considered the four segments as a cross section and estimated the parameters of the four models represented by (1) jointly from the pooled data consisting of 120 observations using the TSCSREG procedure in SAS with an estimation method developed by Parks (1967). The error term $e_{kt} = \rho_k e_{k,\ t-1} + v_{kt}$ is now specified to represent cross-section correlation and cross-section specific first order autocorrelation (v_{kt} is assumed to be uncorrelated across segments). The error term e_{kt} also allows for heteroscedasticity between segments.

This choice is based on the assumption that the same external factors may influence all four segments in more or less the same way leading to cross-correlation among them and also that minor elements in the cost allocation procedures could lead to cross-correlation among segments. The gain from capitalising on the cross-correlation and the increased number of degrees of freedom is more precise estimation. The TSCS model is specified as follows:

$$
\begin{aligned}
ln\ C_{kt} = {} & \beta_{01} + \theta_2 Z_{2t} + \theta_3 Z_{3t} + \theta_{4t} Z_{4t} + \beta_{11} Z_{1t} ln\ X_{1,t-1} + \beta_{12} Z_{2t} ln\ X_{2,t-1} + \beta_{13} Z_{3t} ln\ X_{3,t-1} + \\
& + \beta_{14} Z_{4t} ln\ X_{4,t-1} + \beta_{21} Z_{1t} ln\ X_{1,t-2} + \beta_{22} Z_{2t} ln\ X_{2,t-2} + \beta_{23} Z_{3t} ln\ X_{3,t-2} + \beta_{24} Z_{4t} ln\ X_{4,t-2} \\
& + \beta_{31} Z_{1t} ln\ X_{1,t-3} + \beta_{32} Z_{2t} ln\ X_{2,t-3} + \beta_{33} Z_{3t} ln\ X_{3,t-3} + \beta_{34} Z_{4t} ln\ X_{4,t-3} + \\
& + \beta_{41} Z_{1t} ln\ W_{1t} + \beta_{42} Z_{2t} ln\ W_{2t} + \beta_{43} Z_{3t} ln\ W_{3t} + \beta_{44} Z_{4t} ln\ W_{4t} \\
& + \beta_{51} Z_{1t} ln\ NO_t + \beta_{52} Z_{2t} ln\ NO_t + \beta_{53} Z_{3t} ln\ NO_t + \beta_{54} Z_{4t} ln\ NO_t \\
& + \beta_{61} Z_{1t} VS_t + \beta_{62} Z_{2t} VS_t + \beta_{63} Z_{3t} VS_t + \beta_{64} Z_{4t} VS_t + \\
& + \beta_{71} Z_{1t}\, t + \beta_{72} Z_{2t}\, t + \beta_{73} Z_{3t}\, t + \beta_{74} Z_{4t}\, t + e_{kt} \qquad (3)
\end{aligned}
$$

where k= 1, 2, 3, 4. The dummy variable Z_{kt} is equal to 1 for segment k, and equal to 0 for other segments. The remaining variables are defined as in (1). We also estimated a differenced version $\Delta ln\ C_{kt}$ of (3) using the same estimation method.

4.2 Method two

Here we estimate separate models of total costs based on data for the period 1970 – 1988 according to the following specification:

$$\ln C_{kt} = \beta_{0k} + \beta_{1k}\ln X_{k,t-1} + \beta_{2k}\ln X_{k,t-2} + \beta_{3k}\ln X_{k,t-3} + \beta_{4k}\ln W_{kt} + \beta_{5k}t + e_{kt} \qquad (4)$$

Each estimated model is then used to predict the cost C_{kt} in (4) for the period 1989 – 1999 by substituting real outcomes on the independent variables for the prediction period into the model. This gives us cost predictions based on the cost structure prevailing prior to the deregulation. In other words, these cost predictions are interpreted as the costs that would have appeared given that the deregulation had never taken place. The predictions can be compared with the actual outcomes. Where applicable, the same diagnostic statistical tests for homoscedasticity were used as for model (1).

5 Estimated models

5.1 Method one

Models according to (1) estimated separately by the maximum likelihood method (ML) for the four segments are presented in Table 3 together with some diagnostic statistics.

Table 3. Estimates, standard errors, t-values, and diagnostic parameters of separate regression models (Dep. Variable: ln C_{kt}) for segments 1-4 (Estimation method: ML).

All the models have good explanative power with coefficients of determination close to 0.97. All coefficients have expected signs and the outcomes of the diagnostic statistics are satisfactory. According to the outcome of the Durbin-Watson statistic (DW), a hypothesis of no positive serial correlation at the 1 % level cannot be rejected for any of the four models. DW falls in the non-conclusive region (but in the upper part). According to the LM statistic (only lag one shown in the table), the hypothesis of no first order autocorrelation can be accepted at the 1% level, and the Box-Ljung statistic (BL) shows that a hypothesis of no serial correlation up to lag 6 can be accepted at the 1% level. Considering these tests together, it is not likely that the separate models suffer from autocorrelation.

The Chow tests do not indicate structural breaks in the coefficient vectors between the two sub periods from 1970 to 1988 and from 1989 to 1999 at the 5% level. Overall, the estimated models seem to be of good statistical quality.

The validity of representing competitive pressure on costs by the variable $ln\ NO_t$ in (1) was analysed by running a slightly different version of (1) for the four segments using the variable $t{*}VS_t$ (the product of time and VS_t) instead of $ln\ NO_t$, everything else being equal. This means that competitive pressure is represented by a brake in the time trend after 1988. Averaging R^2 over the four segments gives a better fit for (1) with $ln\ NO_t$ (0.97 versus 0.96). Another important aspect is that the use of NO_t can be motivated theoretically and from practical experience. Empirical fit together with theoretical foundation support the choice of the variable $ln\ NO_t$ as a proxy for competitive pressure. When more data become available in the future, it may be possible to refine the competition variable to a more detailed representation of a complicated reality.

Table 4. Estimates, standard errors, t-values, and diagnostic parameters of separate regression models of differenced variables (Dep. Variable: $\Delta \ln C_{kt}$) for segments 1-4 (Estimation method: OLS).

The most pronounced difference between Table 3 and Table 4 is the outcomes of the test statistics for autocorrelation. Table 4 has excellent values for DW, B-L, and LM showing no autocorrelation, even if the values of Table 3 can also be considered to be acceptable. However, the coefficient estimates and their standard errors and t-values are very similar for the differenced and the undifferenced models thus showing convergent validity. Our main conclusion from this analysis is that autocorrelation does not represent a problem, and that bias from omitted variables can be neglected. Therefore, we will use estimates from model (1) when estimates from separate models are needed for specific calculations.

Table 5 shows the parameter estimates, their standard errors, and t-values from the TSCS models. The estimates from the differenced and undifferenced TSCS models are practically identical. When comparing Table 5 with the separate estimates described in Tables 3 and 4 above, it is apparent that all estimates are very close and consistent. The standard errors of the key parameters are lower in the TSCS models. Based on the same arguments as above, we will use the estimates from the undifferenced version, model (3), in our analyses when testing the impact of vertical separation and competitive pressure.

Table 5. Estimates, standard errors, t-values and diagnostic parameters of the TSCS models.

Based on the TSCS estimates of the model of ln C_{kt} in Table 5, there are two main conclusions that can be drawn for the four segments. Firstly, the competitive pressure from new entrants represented by the variable NO_t has had a significant impact on the cost efficiency of the sector and on the main operator SJ. Our instrumental hypothesis about competitive pressure is statistically confirmed by one-sided tests ($p \leq 0.005$). The elasticity of competitive pressure is negative and strongly significant. Secondly, the vertical separation has raised the cost level of the sector and SJ. Our instrumental hypothesis, in this respect, is statistically confirmed with $p \leq 0.012$ for one-sided tests for all segments.

In our models, the effect of deregulation is the joint effect of vertical separation and competitive pressure represented by the deregulation component ($\beta_{5k} ln\ NO_t + \beta_{6k} VS_t$). Estimating the separate models defined by (1) with and without this component for each segment and using the residuals from each of these two estimated versions of (1) in an F-test shows that the added explanative power from the deregulation component is statistically significant at the 0.5% level for all four segments. This F-test is described in e.g. Stewart (1991, p. 67). Table 6 shows the deregulation effect represented by ratios for the years 1989-1999[7] defined as real cost of output divided by predicted cost C_{kt}. The predicted costs are computed from (1) that is estimated on data from 1970 to 1999. The predicted costs are calculated from the models with $NO_t = 1$ and $VS_t = 0$ for the prediction period and interpreted as the costs that would have appeared without the deregulation. Ratios less than one are interpreted as improved cost efficiency from deregulation. The F-tests together with the ratios of Table 6 prove the significant positive impact on cost efficiency from the deregulation component ($\beta_{5k} ln\ NO_t + \beta_{6k} VS_t$).

Table 6. Real costs per year divided by predicted costs for the period from 1989 to 1999. Calculations based on estimates from Table 3 (Method one).

5.2 Method two

The four models were estimated separately using OLS. The results are shown in Table 7.

Table 7. Estimates, standard errors, t-values, and diagnostic parameters of separate regression models (Dep. variable: ln C_{kt}) 1970-1988 for segments 1-4 (Method two). Estimates are identical in pairs for segments 1 and 3 and for segments 2 and 4 respectively and shown only for segments 1 and 2 (Estimation method: OLS).

Table 7 shows that model (4) has been efficiently estimated despite the relatively short data series.

Table 8 shows effectiveness ratios from method two defined as real costs per year divided by their predicted counterparts computed from models defined in (4) and presented quite in analogy with those of Table 6. In method 2, the separate models

[7] The set of models defined by (1) were used instead of TSCS models due to the limited calculation capability of TSCS in the SAS system.

specified in (4) are estimated from data for 1970 to 1988. Costs are then “forecasted” ex post by substituting real output data for independent variables in the models for the forecasting period.

Table 8. Real costs per year divided by predicted costs for the period from 1989 to 1999. Calculations based on estimates from Table 7 (Method two).

5.3 Comparing deregulation effectiveness between methods

In the following, method one is regarded as the main method. Method two is used for convergent validation. The efficiency ratios in Tables 6 and 8 are based on two different methods. Corresponding ratios are almost identical between tables, an outcome indicating convergent validity. The ratios are greater than one during the first years after the vertical separation, which means that the deregulation is ineffective at first, thus supporting a hypothesis put forward by Jensen (1998). Then, the ratios drop below one, a development that is interpreted here as an impact from the increasing competitive pressure created by the deregulation.

The deregulation seems to have been effective for all segments, but the development has not been completely uniform between segments. The deregulation has been more effective in improving the cost efficiency of SJ than that of the entire sector when costs are defined to cover train operations and infrastructure services. For the entire railway sector, the deregulation has also been more effective in improving the cost efficiency of train operations than that of train operations and infrastructure services. Average ratios for the years 1989 to 1999 for segments 1-4 are 0.91; 0.94; 0.89; 0.95 when calculated from Table 6, and 0.88; 0.93; 0.88; 0.93 when calculated from Table 8. The corresponding average ratios for the period 1993-1999 are 0.86; 0.90; 0.83; 0.90 (from Table 6) and 0.82; 0.89; 0.82; 0.88 (from Table 8). The ratios from the latter period show that the trend is positive. The two different methods lead to the same conclusions about deregulation effectiveness.

6 Conclusions

In this final section, we summarise the conclusions and contributions from our study.

6.1 On the effectiveness of the deregulation policy

The methodology used in this study makes it possible to predict costs of output under the assumption that the old policy had continued after 1988 and thus to compare predicted costs with real costs for the same period. In the analysis that follows, the resulting numbers are based on Tables 6 and 8 and the average ratios from section 5.3.

The deregulation policy seems to have been effective over the period 1989-1999 in both the main train operator SJ and in the entire sector and for costs of train operations as well as for the costs of the entire vertical production process consisting of train operations plus the provision of infrastructure services. The cost reduction in the operation of trains is 11 % for the sector (segment 3) and 9 % for SJ (segment 1). The cost reduction in the whole vertical production process is 5 % for the sector (segment 4) and 6 % for SJ (segment 2). Making the same kind of comparison over the period 1993-1999 reveals that the efficiency improvement has a positive trend. The cost reduction in the operation of trains is now 17 % for the sector and 14 % for SJ, and the cost reduction in the whole vertical production process including train operations and infrastructure service activities is 10 % both for the sector and for SJ. The fact that the trend is more positive for the operation of trains only than for operation of trains plus infrastructure service provision is quite logical and consistent with our hypotheses, since only operation of trains is under competitive pressure.

6.2 On vertical separation and competition-enhancing measures

In Swedish railway policy, vertical separation of infrastructure and train operations is regarded as a necessary prerequisite for the introduction of competition in the sector. The separation as such seems to have contributed to a statistically significant immediate increase in costs (approximately 5%) that may be due to both temporary costs of re-structuring the sector and to a more permanent change of cost level. The new monopoly role of the infrastructure provider reducing the exposure to external competition, together with the separated vertical organisation of the sector increasing the costs of vertical suboptimisation and transactions, may represent a new cost driver (see Jensen, 1998).

However, the introduction of various competition elements in the railway sector, which was made possible by the vertical separation of infrastructure from the operations of trains, seems to have had a statistically significant positive impact on cost efficiency in the production of train services. The impact, expressed as a cost elasticity of competitive pressure on the whole vertical production process of the sector, was estimated to be approximately -0.06. The reduced cost efficiency from the vertical separation is more than compensated for by the increased cost efficiency of operators' production of train services due to increased competitive pressure, and the latter impact seems to have a positive trend as explained in section 6.1.

6.3 On the causes of cost reduction. Deregulation or other factors?

In the public discussion, there is a tendency to attribute the reduction in costs since 1988 to the deregulation policy. It is not understood that part of the cost reduction most probably would have occurred anyway due to other factors such as technology, intermodal competition, and general political pressure. Comparing the total real cost of train operations and infrastructure service provision of the sector between 1978 and 1988 with the total real cost between 1989 and 1999 shows a cost reduction of 16% in fixed monetary value (adjusted for output differences). However, only 9% seems to be attributable to the deregulation. The rest would have occurred anyway. If only the costs of train operations are compared between the periods, the total cost reduction is 19%, but only 10% can be explained by the deregulation. For SJ, the corresponding reductions are 17 % and 21%, but only 10 % and 12 % respectively seem to be assignable to the deregulation policy. The remaining 7% and 9% would probably have occurred also under the old policy.

Comparing 1982-1988 with 1993-1999 in the same way for the sector shows a cost reduction for train operation and infrastructure service provision of 23% with only 13% being explained by deregulation. For train operation only, the corresponding figures are 27% and 14% respectively. For SJ, the cost of train operation and infrastructure service provision declined by 25% with 14% being explained by deregulation. In the case of train operation only, the corresponding figures are 28% and 16% respectively.

These comparisons show that only between 50 and 60% of the cost reductions can be explained by deregulation. The rest would have occurred anyway.

6.4 On the relationship between output and costs

Although not a main focus in this paper, the observed lag between output and costs in passenger traffic deserves mentioning. This result represents important knowledge for railway cost research in railways or railway units with mixed passenger and freight traffic or with passenger traffic only. Using cross section data of output of passenger and freight services (e.g. in passenger-kilometres and tonne-kilometres) and costs only, without a time perspective in the analysis of relationships between output and costs, may lead to biased or indeterminate results. In our study, we found a significant relationship between passenger-kilometres years t-1, t-2, and t-3, on one hand and costs year t on the other, but no such relationship between output and costs for year t. On the freight side, we found a strong relationship between tonne-kilometres and costs for year t, but no lagged such relationships. We think these results are valid in a general sense for other railways even if the shapes of the lag distributions may be contextual.

6.5 Evaluating the Swedish deregulation model in general terms

The Swedish model for railway deregulation can be said to have followed an evolutionary gradual development between 1988 and 1999, the period studied in this longitudinal study. The deregulation model contains the following main elements:

vertical organisational separation of infrastructure from traffic (from 1989); continued public ownership of the infrastructure and of the main train operator; competition for the market for local, regional, and unprofitable interregional passenger lines; and an open market for freight services. A more complete description of the details of the deregulation can be found in section 2 of this paper. Our main conclusions are the following:

- The Swedish model for railway deregulation seems to have been overall cost effective both in terms of reducing the costs of the entire vertical production process including the provision of infrastructure services and in terms of reducing the costs of the production of train services.
- The competitive pressure on train operators seems to have reduced costs, an effect which we perceive as a net result of the gain from the cost pressure of competition minus the loss (minor) from somewhat reduced scale advantages.
- The vertical separation of infrastructure service provisions from traffic operations seems to be a driver for the sum of some deregulation related cost concepts such as the costs of restructuring, transactions, vertical suboptimisation, and reduced exposure for the infrastructure provider to intermodal competition, but this cost increase is more than compensated for by the net effect of competitive pressure on train operators.
- The observed improvement of costs in the sector's production of railway services compared between the periods 1970-1988 and 1989-1999 can only partly be explained by deregulation. Technology, intermodal competition, and general political pressure seem to explain almost half of the improvement.

6.6 On methodology

Studies of the impact on cost efficiency of railway deregulation will have to be based mainly on national longitudinal data for several years ahead. Deregulation measures and internal and external railway conditions are too different in different countries for econometric studies to be based on international cross-sectional data without a considerable time history. This restricts research to national case studies based on relatively small longitudinal data sets. The research design we have developed is used here for drawing conclusions from a data set consisting of cost data from a 30 year period. The design includes:

- Some aspects of the identification and handling of problems with accounting data for use in econometric cost studies.
- Use of two different econometric approaches for drawing conclusions about the impact of deregulation on costs. One by modelling the cost structure before and after the regulatory reform in the same causal model, and one where a model of the cost structure before the reform is used for predicting costs of the real outputs observed after the change but under the conditions of the old policy.
- Where possible, use of dual regression model specifications for estimating the same regression parameters, one with variables at natural levels and one with time differenced variables.
- Careful analysis of regression residuals to assure the statistical quality of the models.

The use of different econometric approaches for drawing conclusions about the same research problems and different model specifications for estimating the same parameters gives convergent validity to the methodology provided that the main conclusions are the same and the parameter estimates are close. This is the case in this study, which supports the validity of the conclusions.

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Tables

Table 1. Number of private entrants.

Year	Number of private train operators in passenger transports	Number of private train operators in freight transports
1990	1	0
1991	1	0
1992	1	0
1993	4	5
1994	2	8
1995	3	10
1996	4	11
1997	4	13
1998	4	13
1999	5	12

Source: SIKA *Järnvägar 1993-1999*.

Table 2. Coverage of costs for four segments of the railway sector.

Vertical coverage	Train operators	
	SJ, the main operator	All operators
Train operations	Segment 1. Costs of SJ excluding infrastructure costs for the time period 1970-1988.	Segment 3. Costs of all train operators excluding costs of infrastructure for the time period 1970-1988.
Infrastructure provision and train operations	Segment 2. Costs of SJ plus SJ's share of the costs of BV.	Segment 4. Costs of all train operators plus the cost of BV.

Table 3. Estimates, standard errors, t-values, and diagnostic parameters of separate regression models (Dep. Variable: ln C_{kt}) for segments 1-4 (Estimation method: ML).

Parameter	Segment 1 (SJ , excluding infrastructure)			Segment 2 (SJ, including infrastructure)		
	Estimate	St. error	t-value	Estimate	St. error	t-value
β_{0k}	2.0125	2.0180	1.00	2.5566	2.0003	1.28
β_{1k}	0.2864	0.0989	2.90	0.2560	0.0944	2.71
β_{2k}	0.1632	0.1204	1.36	0.1737	0.1043	1.67
β_{3k}	0.1413	0.0974	1.45	0.1316	0.0903	1.46
β_{4k}	0.2578	0.0933	2.76	0.2458	0.0878	2.80
β_{5k}	-0.0687	0.0189	-3.64	-0.0592	0.0186	-3.18
β_{6k}	0.0316	0.0306	1.03	0.0493	0.0298	1.65
β_{7k}	-0.0136	0.004539	-3.00	-0.0134	0.004432	-3.02
ρ	-0.2232	0.2524	-0.88	-0.4129	0.2281	-1.81
R^2	0.9693			0.9652		
DW	1.6982	Pr < DW: 0.0546		1.6227	Pr< DW: 0.0442	
B-J	8.23	Pr > B-J: 0.2217		11.31	Pr> B-L: 0.0793	
Chow	1.98	Pr > Chow: 0.1257		2.70	Pr> Chow: 0.0501	
LM	0.1474	Pr > LM: 0.7011		1.8469	Pr> LM: 0.1741	
	Segment 3 (All operators, excluding infrastructure)			Segment 4 (All operators, including infrastructure)		
β_{0k}	3.4822	2.0096	1.73	2.2572	1.9769	1.14
β_{1k}	0.2490	0.0930	2.68	0.2588	0.0884	2.93
β_{2k}	0.1430	0.1179	1.21	0.1923	0.0995	1.93
β_{3k}	0.1212	0.0942	1.29	0.1394	0.0897	1.55
β_{4k}	0.1724	0.1025	1.68	0.2513	0.0968	2.60
β_{5k}	-0.0820	0.0130	-6.32	-0.0597	0.0140	-4.27
β_{6k}	0.0293	0.0279	1.05	0.0543	0.0285	1.91
β_{7k}	-0.0111	0.004338	-2.55	-0.0140	0.004302	-3.25
ρ	-0.1053	0.2257	-0.47	-0.3652	0.2191	-1.67
R^2	0.9678			0.9571		
DW	1.8894	Pr< DW: 0.1298		1.7503	Pr< DW: 0.0864	
B-L	7.86	Pr> B-L: 0.2483		7.19	Pr> B-L: 0.3034	
Chow	1.90	Pr> Chow: 0.1397		2.10	Pr> Chow: 0.1070	
LM	1.3986	Pr> LM: 0.2370		1.1216	Pr> LM: 0.2896	

Table 4. Estimates, standard errors, t-values, and diagnostic parameters of separate regression models of differenced variables (Dep. Variable: Δ ln C_{kt}) for segments 1-4 (Estimation method: OLS).

Parameter	Segment 1 (SJ , excluding infrastructure)			Segment 2 (SJ, including infrastructure)		
	Estimate	St. error	t-value	Estimate	St. error	t-value
β_{1k}	0.3052	0.1063	2.87	0.2920	0.0939	3.11
β_{2k}	0.1888	0.1118	1.69	0.1910	0.0987	1.94
β_{3k}	0.1760	0.1134	1.55	0.1367	0.1001	1.37
β_{4k}	0.2576	0.1019	2.53	0.2322	0.0900	2.58
β_{5k}	-0.0549	0.0222	-2.47	-0.0575	0.0196	-2.94
β_{6k}	0.0424	0.0358	1.19	0.0483	0.0316	1.53
β_{7k}	-0.0177	0.007713	-2.29	-0.0156	0.006809	-2.29
R^2	0.5701			0.6291		
DW	2.2349	Pr< DW: 0.7261		1.9986	Pr< DW: 0.4890	
B-J	2.34	Pr> B-J: 0.8854		5.33	Pr> B-L: 0.5025	
Chow	0.54	Pr> Chow: 0.7899		1.17	Pr> Chow: 0.3752	
LM	3.0594	Pr> LM: 0.0803		1.9247	Pr> LM: 0.1653	
	Segment 3 (All operators, excluding infrastructure)			Segment 4 (All operators, including infrastructure)		
β_{1k}	0.3061	0.1090	2.81	0.3017	0.0941	3.21
β_{2k}	0.1953	0.1120	1.74	0.2082	0.0967	2.15
β_{3k}	0.1727	0.1159	1.49	0.1540	0.1001	1.54
β_{4k}	0.2367	0.1127	2.10	0.2367	0.0973	2.43
β_{5k}	-0.0588	0.0216	-2.72	-0.0594	0.0186	-3.19
β_{6k}	0.0423	0.0357	1.18	0.0547	0.0308	1.77
β_{7k}	-0.0171	0.008101	-2.11	-0.0153	0.006994	-2.19
R^2	0.5640			0.6438		
DW	2.4576	Pr< DW: 0.8868		2.1578	Pr< DW: 0.6563	
B-L	3.50	Pr> B-L: 0.7439		4.52	Pr> B-L: 0.6070	
Chow	0.69	Pr> Chow: 0.6809		1.27	Pr> Chow: 0.3269	
LM	2.0973	Pr> LM: 0.1476		2.4304	Pr> LM: 0.1190	

Table 5. Estimates, standard errors, t-values and diagnostic parameters of the TSCS models.

Seg-ment	Para-meter	Model: ln C_{kt} (R^2= 0.982)			Model: Δln C_{kt} (R^2=0.647)		
		Estimate	Standard error	t-value	Estimate	Standard error	t-value
1	β_{01}	3.8087					
	β_{11}	0.2223	0.0739	3.01	0.2030	0.0817	2.48
	β_{21}	0.1377	0.0930	1.48	0.1365	0.0899	1.52
	β_{31}	0.1130	0.0710	1.59	0.1064	0.0738	1.44
	β_{41}	0.1740	0.0339	5.14	0.1348	0.0435	3.10
	β_{51}	-0.0840	0.0107	-7.87	-0.0736	0.0155	-4.76
	β_{61}	0.0307	0.0227	1.35	0.0322	0.0258	1.25
	β_{71}	-0.0105	0.0027	-3.85	-0.0129		
	ρ_1	0.2094			-0.1767		
2	β_{02}	2.9700					
	β_{12}	0.2232	0.0665	3.36	0.2335	0.0718	3.25
	β_{22}	0.1839	0.0800	2.30	0.1811	0.0780	2.32
	β_{32}	0.1071	0.0637	1.68	0.1212	0.0628	1.93
	β_{42}	0.2442	0.0255	9.59	0.2113	0.0304	6.94
	β_{52}	-0.0635	0.0103	-6.16	-0.0650	0.0132	-4.92
	β_{62}	0.0453	0.0220	2.06	0.0430	0.0227	1.90
	β_{72}	-0.0124	0.0026	-4.81	-0.0140		
	ρ_2	0.3927			-0.0067		
3	β_{03}	3.3490					
	β_{13}	0.2404	0.0703	3.42	0.2277	0.0818	2.79
	β_{23}	0.1617	0.0918	1.76	0.1670	0.0906	1.84
	β_{33}	0.1067	0.0680	1.57	0.1152	0.0762	1.51
	β_{43}	0.1904	0.0386	4.93	0.1624	0.0492	3.30
	β_{53}	-0.0846	0.0084	-10.0	-0.0743	0.0153	-4.87
	β_{63}	0.0328	0.0207	1.59	0.0333	0.0260	1.28
	β_{73}	-0.0112	0.0025	-4.47	-0.0130		
	ρ_3	0.1003			-0.2348		
4	β_{04}	2.445					
	β_{14}	0.2382	0.0647	3.68	0.2511	0.0708	3.54
	β_{24}	0.2084	0.0779	2.67	0.2126	0.0768	2.77
	β_{34}	0.1089	0.0623	1.75	0.1359	0.0627	2.17
	β_{44}	0.2626	0.0296	8.88	0.2405	0.0328	7.33
	β_{54}	-0.0633	0.0990	-7.02	-0.0660	0.0129	-5.10
	β_{64}	0.0516	0.0209	2.47	0.0502	0.0225	2.23
	β_{74}	-0.0134	0.0025	-5.38	-0.0140		
	ρ_4	0.3328			-0.0882		

Table 6. Real costs per year divided by predicted costs for the period from 1989 to 1999. Calculations based on estimates from Table 3 (Method one).

Year	Segment 1 SJ, excluding infrastructure	Segment 2 SJ, including infrastructure	Segment 3 All operators, excluding infra-structure	Segment 4 All operators, including infra-structure
1989	1,04	1,06	1,04	1,07
1990	1,00	1,03	1,00	1,03
1991	0,98	1,00	0,97	1,00
1992	0,95	0,98	0,93	0,98
1993	0,86	0,89	0,84	0,89
1994	0,88	0,92	0,85	0,92
1995	0,90	0,94	0,87	0,94
1996	0,89	0,92	0,85	0,92
1997	0,85	0,89	0,79	0,89
1998	0,84	0,86	0,80	0,87
1999	0,80	0,86	0,79	0,89

Table 7. Estimates, standard errors, t-values, and diagnostic parameters of separate regression models (Dep. variable: ln C_{kt}) 1970-1988 for segments 1-4 (Method two). Estimates are identical in pairs for segments 1 and 3 and for segments 2 and 4 respectively and shown only for segments 1 and 2 (Estimation method: OLS).

Parameter	Segment 1 (SJ , excl. infrastructure)			Segment 2 (SJ, incl. infrastructure)		
	Estimate	St. error	t-value	Estimate	St. error	t-value
β_{0k}	3.9581	1.6120	2.46	3.0803	1.5433	2.00
β_{1k}	0.1869	0.0799	2.34	0.1560	0.0765	2.04
β_{2k}	0.1594	0.1062	1.50	0.1777	0.1017	1.75
β_{3k}	0.1403	0.0794	1.77	0.1874	0.0761	2.46
β_{4k}	0.1459	0.0822	1.77	0.2262	0.0787	2.87
β_{5k}	-0.009973	0.003433	-2.90	-0.0121	0.003287	-3.69
R^2	0.7451			0.7276		
DW	2.8396	Pr< DW: 0.896		2.1046	Pr< DW: 0.331	
LM	0.9952	Pr> LM: 0.3185		1.5693	Pr> LM: 0.2103	

Table 8. Real costs per year divided by predicted costs for the period from 1989 to 1999. Calculations based on estimates from Table 7 (Method two).

Year	<u>Segment 1</u> SJ, excluding infrastructure	<u>Segment 2</u> SJ, including infrastructure	<u>Segment 3</u> All operators, excluding infrastructure	<u>Segment 4</u> All operators, including infrastructure
1989	1.04	1.06	1.04	1.07
1990	1.00	1.03	1.00	1.03
1991	0.97	1.00	0.97	1.00
1992	0.92	0.96	0.92	0.96
1993	0.82	0.85	0.82	0.85
1994	0.85	0.89	0.84	0.89
1995	0.87	0.93	0.86	0.92
1996	0.86	0.93	0.85	0.91
1997	0.80	0.89	0.79	0.88
1998	0.79	0.86	0.79	0.86
1999	0.76	0.85	0.79	0.88

Figures

Figure 1. Passenger transport output in passenger-kilometres for SJ and for the sector.

Figure 2. Freight transport output in tonne-kilometres for SJ and for the sector.

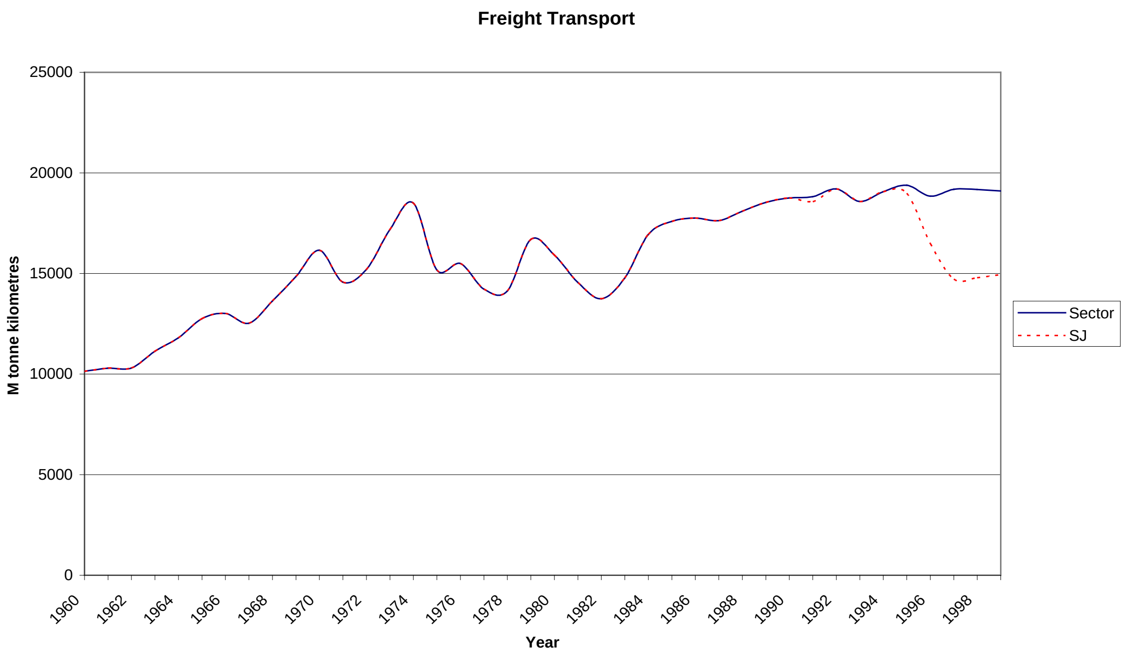

Figure 3. Costs of segments 1-4 from 1970 to 1999.