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# AN EMPIRICAL INVESTIGATION FOR CANADIAN CLASS I RAILWAYS OF BOTH PERFORMANCE AND INDUSTRY COST STRUCTURE[1]

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## Introduction

The objective of the paper is twofold. First it quantifies the recent productivity performance of Canadian National Railways' (CN) and Canadian Pacific Limited's (CP) rail operations. Indirectly, it compares the performance of a publicly owned firm to that of a privately owned one and allows one to see which of the two performed better over the 1956 to 1981 period. Initially, the intent was to simply update an earlier study carried out by Caves and Christensen[2] on the performance of Canadian railways. As it turned out, there was a need to measure the variability of empirical results to specific built-in methodological assumptions. Caves and Christensen assumed that it was appropriate to use cost elasticities, derived from a cost function estimated for U.S. railroads, to weight Canadian railways' output. These U.S. cost elasticities are replaced here by Canadian ones derived from an estimated cost function. The estimated cost function allows one to address the second objective of the paper, i.e., the analysis of the cost structure of Canadian railways.

## Data

The present analysis is limited to CN and CP operations and covers the period 1956 to 1981. While failure to consider all railways prevents generalizing the results to the whole railway transport industry in Canada, the analysis does nevertheless concentrate on the two most important railways in Canada. The last statement can be substantiated by a few key indicators. Looking at statistics for the year 1981, it is possible to note that CN and CP accounted in that year for 83.3% of railways' operating revenues in Canada, 91.6% of freight operating revenues, 82.1% of operating expenses, 90.6% of rail investments, 87.5% of railway employees, and 90.5% of tracks.

TABLE 1. RELATIVE IMPORTANCE OF CN AND CP IN THE CANADIAN RAILWAY SYSTEM, 1981

| | CN and CP | Total All Railways |
|---|---|---|
| Operating Revenues(million of $) | 5,119 | 6,145 |
| Freight Revenues(million of $) | 4,247 | 4,635 |
| Operating Expenses(million of $) | 4,712 | 5,742 |
| Investments-rail(million of $) | 86 | 94 |
| No. of Employees | 12,227 | 14,157 |
| Track(route kilometres) | 83,651 | 92,415 |

Source: Statistics Canada, Catalogue Nos. 52-205, 52-208
52,209, 52-212, 52-214

To study productivity growth, the production process of railway services is viewed as a two output and five input process. On the output side, passenger and freight services are the two types of railway services considered. The basic measure of passenger service used is aggregate passenger-kilometres while aggregate tonne-kilometres is the actual measure of rail freight output. The inputs used to produce the two outputs are: way and structure, equipment, labour, fuel and materials.

Way and structure and equipment constitute what could be called the capital input required to produce railway services. Massive amounts of capital are required by railways. Capital inputs are a significant component of total railway costs. Therefore careful attention must be given to measure accurately their contribution to productivity growth. Unfortunately, the measuring of capital, irrespective of the approach used, remains usually a subject for debate. The study employs physical units of measurement for the two types of capital. For way and structure, total kilometres operated of first main track is the measurement unit. For equipment, a distinction is made between freight and passenger services. On the freight side, nominal capacity of the freight equipment, measured in tonnes, is used, while on the passenger side, the number of passenger equipment as of the end of the year, is used. The two are weighted according to the relative importance of the revenues generated by each type of traffic.

For labour, quantities of hours worked for four classes of labour are used for the computation of translog labour index, wage payments serving as weights. Actual quantities of each type of fuel utilized by railways are converted to their British thermal units (BTU) equivalents and then added. Material is also an input difficult to measure in the sense that numerous types of materials enter in the production of rail services. For these different types of materials, it is not possible to have a common physical unit of measurement. Expenditures on materials become the alternative measurement unit to adopt. Material expenditures are computed as a residual from total expenditures. From total railway expenses, the following are subtracted to arrive at material expenditures: railway tax accruals, joint facility rents, equipment rents, pensions, road property depreciation, other equipment and machinery depreciation, rolling stock and vessels depreciation, cost of fuel and net labour costs. The expenditures are then deflated by the Industry Selling Price Index.

For the multiproduct cost characterization of railway operations, a production process with two outputs and three inputs is used. The two outputs defined for the productivity assessment serve also in the cost analysis. On the input side, the three inputs used in the cost function are labour, fuel, and capital and material. The average hourly salary deflated by the CPI is the labour price measure. Fuel is measured in terms of constant dollar expenditures on the said input. For capital and material, the net stock of equipment and structure is added to the material expenditures, both being measured in constant dollars.

## Methodology and Concepts: An Outline

Productivity refers to the efficiency with which inputs are transformed within the production process into output. Productivity advancement contributes to economic growth. A measure of productivity identifies changes in the level of production that cannot be explained by changes in usage of the associated inputs and by the characteristics of the original production process.

Total factor productivity (TFP) measures are among the more accurate measures of productivity advancement. TFP measures relate changes in all outputs to changes in all inputs. A production process with several inputs and outputs requires specifying a method of aggregation where the weighting system for the construction of aggregate input and output measures determine the underlying production function. The approach used for measuring the relative growth rates of outputs and inputs is the Divisia index.

The conventional Divisia index is defined as the ratio of aggregate output to aggregate input, aggregate output (input) being an index of disaggregated outputs (inputs). The Divisia indices for aggregate output and input are defined in terms of proportional rates of growth. Because yearly data is used, the Tornqvist approximation to the continuous Divisia index enters into play:

$$\begin{aligned}\ln(TFP_t/TFP_{t-1}) &= \frac{1}{2}\sum_j (r_{jt} + r_{j,t-1}) \ln(Y_{jt}/Y_{j,t-1}) \\ &\quad - \frac{1}{2}\sum_i (s_{it} + s_{i,t-1}) \ln(X_{it}/X_{i,t-1})\end{aligned}$$

where $r_{jt}$ is the revenue share of output $Y_j$ in total revenues of period t, and $s_{it}$ the cost share of input $X_i$ in total costs of period t. Using revenue shares as weights for outputs implies constant returns to scale for the structure of production and output prices proportional to their marginal costs. By assuming constant returns to scale, scale effects are assumed not to contribute to the railways' productivity performance. This explains why these measures are referred to as being "unadjusted" measures of productivity.

It is widely accepted that prices for rail services do not reflect marginal costs of production. Instead of using revenue shares to weight outputs, the alternative is to do what Caves and Christensen did and use estimated output cost elasticities:

$$\ln(TFP_t/TFP_{t-1}) = \sum_j \left[ \left( \frac{1}{2} \; \frac{\partial \ln C}{\partial \ln Y_j} \right)_t + \left( \frac{1}{2} \; \frac{\partial \ln C}{\partial \ln Y_j} \right)_{t-1} \right]$$

$$\ln(Y_{jt}/Y_{j,t-1}) - \frac{1}{2} \sum_i (s_{it} + s_{i,t-1})$$

$$\ln(X_{it}/X_{i,t-1})$$

The elasticity of cost with respect to output can be interpreted as a measure of static or scale economies. It isolates the change in cost that is independent of technical change and changes in input prices. Output cost elasticities, by accounting for scale effects, allows for a more accurate measurement of productivity growth. This explains why this second TFP measure is referred to as the "adjusted" measure.

Caves and Christensen computed their freight and passenger cost elasticities for CN and CP from a multiproduct cost function estimated for U.S. railroads for the years 1955, 1963 and 1974. They justified their approach by saying that "the largest U.S. railroads have cost and output levels similar to the CN and the CP". From their estimated multiproduct cost function, they came to the conclusion that "in the region of freight and passenger output levels produced by the CN and the CP, the hypothesis of constant returns to scale (could not) be rejected". They then normalized the estimated cost elasticities to sum to unity and interpreted them between the years for which the cost function was estimated.

Output cost elasticities estimates, specific to CN and CP are derived, in this study, from the generalized translog functional form used to represent the cost function:

$$
\begin{aligned}
\ln C = {} & \alpha_0 + \sum_i \alpha_i \ln P_i + \sum_{ij}\sum \ln P_i \ln P_j + \sum_m \alpha_m \left[\frac{Y^{\lambda_m} - 1}{\lambda_m}\right] \\
& + \sum_{mn}\sum \gamma_{mn} \left[\frac{Y_m^{\lambda_m} - 1}{\lambda_m}\right] \left[\frac{Y_n^{\lambda_n} - 1}{\lambda_n}\right] \\
& + \sum_{mi}\sum \gamma_{mi} \left[\frac{Y_m^{\lambda_m} - 1}{\lambda_m}\right] \ln P_i + \theta_T \ln T
\end{aligned}
$$

where the $Y_m$ are outputs and the $P_i$ input prices. The Box-Cox transformation ($\lambda$) is used for the outputs. The minimization of the SSE serves as the criteria to arrive at the appropriate value for $\lambda_s$. The $Y_m$ and $P_i$ are normalized such that their mean values are equal to unity. The mean value of each variable is derived from the pooled series of observations of CN and CP. The cost function is estimated over the period 1956 to 1978 and the period 1956 to 1981 with CN and CP data pooled together. The cost function and the cost share equations of the factor inputs (one of which is deleted to avoid singularity) are treated as a multivariate regression system and the parameters are estimated using the two stage Zellner technique, which produces asymptotically maximum likelihood estimates. The cost function is not used to infer productivity growth but to infer the railways' structure of production.

Railways are viewed as highly integrated vertically. The integration of railway system activities within large companies increases the need for an evaluation of the efficiency of railway market structures, the industry being dominated in Canada by two railways operating in various markets. A conventional concept of structure such as economies of scale comes to mind. But railways are multiproduct firms and economies of scale cannot capture the complexity of market relationships. Besides, the concept for railway operations lead to definitional confusion. It is important to distinguish between economies of traffic density, economies of size and economies of scale. Economies of scale resulting from increased traffic volume when the network configuration is held fixed, is referred to as economies of density. Since route kilometres or track kilometres are not explicitly introduced into the equation, it is not possible to estimate the minimum efficient traffic density from the model. According to Braeutigam, Daughety and Turnqvist[3], economies resulting from an increase in output, when the size of the network can also change to adjust optimally to traffic volume along each arc of the network, should be referred to as economies of size, being a broader notion of economies of scale.

In a multiproduct context, new cost concepts are needed to gain insight into the behaviour of a multiproduct firm and industry. To the old concept of economies of scale, the new concept of economies of scope, which measures cost advantages of having firms providing large numbers of diversified products as against specialization in production, has been introduced. But empirical study of multiproduct firms is in its infancy and the empirical results arrived at are presented in the hope that they will generate further econometric analysis of Canadian railway costs. It is important to emphasize that the empirical evidence is based exclusively on a pooled cross section and time series analysis of CN and CP over the period 1956-1981, a period which saw the creation of VIA Rail, the intercity rail passenger service operator in Canada. The evidence on multiproduct cost concepts is obtained with the generalized translog cost function. The measures of the multiproduct cost concepts are both functions of the data and the estimated parameters. Formal definitions of the concepts follow.[4]

A comparison of the cost of producing passenger and freight rail services separately with the actual joint cost allows one to determine whether it is less costly for a single railway to produce jointly or separately the services:

$$SC = \sum_{j=1}^{2} C_j (Y_j) - C(Y_1, Y_2)$$

When overall economies of scope exists, SC is greater than zero. The translog cost function shows economies of scope when cost complementarity can be observed (i.e., when $\partial^2 C / \partial Y_1 Y_2 < 0$). In a multiproduct context, the identification of the proportion of economies of scale attributable to each output is important. Product specific economies of scale are equivalent to the ratio of the incremental cost for that output over its marginal cost. If economies are achieved in the production of a given output, the measure of economies of scale specific to that output will be greater than one. For a multiproduct production process, the degree of economies of scale, i.e., the evidence on scale effects for the overall production process, accounts for both the economies of scale specific to each output and the economies of scope. The global measure of economies of scale will indicate the presence of economies of scale if the measure is greater than one.

## Empirical Results

Average annual changes in outputs, inputs and productivity are reported in Table 2. Over the 1956 to 1975 period, the two Canadian railways were increasing their outputs but reducing their utilization of inputs. On average, CN's productivity improved over that period at an annual rate of 3.9% while a rate of 4.0% was attained by CP. From 1975 to 1981, the situation changed somewhat. CN's output was growing at a slower rate than the one observed over the 1956 to 1975 period, while CP was achieving a higher rate of growth for its output. On the input side, CN and CP were unable to maintain between 1975 and 1981, a declining rate of input utilization, CP having the worst record. As a result, a decline in productivity growth is observed. For the period 1956 to 1981 as a whole, CN seems to have attained a slightly higher level of efficiency, its average yearly productivity growth reaching 3.25% compared to 3.1% for CP.

## TABLE 2. AVERAGE ANNUAL CHANGES IN PRODUCTIVITY UNADJUSTED MEASURE

| | CN | CP |
|---|---|---|
| | **Aggregate Output** | |
| 1956-1975 | 2.03 | 1.73 |
| 1975-1981 | 1.83 | 2.51 |
| 1956-1981 | 1.98 | 1.91 |
| | **Aggregate Input** | |
| 1956-1975 | -1.86 | -2.27 |
| 1975-1981 | 0.60 | 2.28 |
| 1956-1981 | -1.27 | -1.18 |
| | **Productivity** | |
| 1956-1975 | 3.89 | 3.99 |
| 1975-1981 | 1.23 | 0.23 |
| 1956-1981 | 3.25 | 3.09 |

Caves and Christensen's productivity measures indicated also that CN had achieved better results over the 1956 to 1975 period. For various reasons such as outputs' weights, measurement unit for some of the inputs, Caves and Christensen's measures of productivity changes differed from ours. The approach used in this study shows a more important reduction in input utilization by the two railways, especially for CN, than the one measured by Caves and Christensen.

### TABLE 3. AVERAGE ANNUAL CHANGE IN PRODUCTIVITY(%), ADJUSTED MEASURE

| | CN | CP |
|---|---|---|
| | **Aggregate Output** | |
| 1956-1975 | 6.08 | 1.63 |
| 1956-1975* | 2.30 | 0.80 |
| 1956-1981 | 8.54 | 2.60 |
| | **Aggregate Input** | |
| 1956-1975 | -1.86 | -2.27 |
| 1956-1975* | -0.80 | -1.80 |
| 1956-1981 | -1.27 | -1.18 |
| | **Productivity** | |
| 1956-1975 | 7.94 | 3.90 |
| 1956-1975* | 3.10 | 2.70 |
| 1956-1981 | 9.81 | 3.77 |

*Caves & Christensen estimates.

When Canadian cost elasticities are introduced to weight the outputs, the calculated productivity indicators give quite a different picture than the one obtained when adjustments for scale effects are neglected (Tables 2 and 3). Prior to making such an adjustment, productivity measurements indicated an average annual growth rate of respectively 3.25% and 3.1% for CN and CP between 1956 and 1981. After adjusting for scale effects, their productivity growth are respectively 9.8% and 3.8%.

This, normally, would imply that the two railways are facing diseconomies of scale, diseconomies which are more important in CN's operations than in CP's. But before jumping to such a conclusion, it is important to emphasize that the output cost elasticities are derived from the estimated cost function, that the function is estimated with pooled data of CN and CP from 1956 to 1981, and that the specification of the function did not allow for differences among the years in the structure of production. The integer measure of time (T) used here does not really allow for the accounting of the yearly differences in the production structure. It is also important to note that regularity conditions (e.g., negative semidefinite Hessian matrix) from the theory of cost and production are not satisfied over the entire period for the two railroads.

Because Caves and Christensen believed that there were not enough Canadian railroads to provide data for the estimation of a multiproduct cost function, they used a cross section of U.S. railroads to infer Canadian cost elasticities. The variation in costs and output levels of CN and CP result from changes in their production structure which have occurred between 1956 and 1981. Not being able to account properly for such variations, the cost elasticities obtained are not only reflecting scale effects but also an evolving production process of rail services. Therefore, the derived cost elasticities cannot pretend to adjust the productivity measurement for scale effects. The adjusted productivity measures reported in Table 3, to the exception of those quoted from Caves and Christensen's study, are biased by an adjustment which mixes together scale effects and changes in production structure.

The cost function can nevertheless be used to analyze, at the observed level of output and factor prices, (i.e., the normalization point), the production structure of CN and CP rail services. Already, a reference to decreasing returns to scale has been made. But such a reference has to be placed in a multiproduct context. Looking at Table 4, it is possible to note that product specific diseconomies of scale are observed. But these diseconomies are compensated for by important economies of scope which outweigh the product specific diseconomies and indicate marginal overall increasing returns to scale for rail operations of CN and CP. But, basically, the assumption of constant returns to scale behind the Divisia approach cannot be rejected by the evidence gathered from the estimated cost function.

**TABLE 4. ESTIMATES OF MULTIPRODUCT COST CONCEPTS**

| Concepts | 1956-1978 | 1956-1981 |
|---|---|---|
| Economies of Scale | | |
| - passenger specific | 0.26 | -61.50 |
| - freight specific | 0.17 | -6.08 |
| - total economies of scale | 1.17 | 3.35 |
| Cost Complementarity | -0.34 | -0.63 |
| Overall Economies of Scope | 0.86 | 4.36 |

Coming back to CN and CP production structure of rail services, the evidence indicates that the two railways averaged over the 1956 to 1981 period, cost advantages in the joint supply of passenger and freight services. Such a finding implies that the joint production of the two outputs generate cost savings which, to some extent, questions the decision to create VIA Rail. Outputs are measured unequivocally at a fairly aggregate level, a level too aggregated to let the estimated cost function reflect all the characteristics of rail service production. For instance, looking at the freight side of railway operations, one has to recognize that railroads provide service for a wide range of commodities. Having found that the separation of passenger and freight services increase the cost of rail operations, it is then of interest to inquire into the presence of economies of scope between the various rail commodity movements. The aggregate unit of output measurement used prevents the analyzing of such an important aspect of rail operations and therefore to assess whether commodity rates are or are not compensatory.

## Conclusion

CN and CP have faced a decline in their productivity gains since 1975. Most sectors of the economy, though, have been experiencing lagging productivity growth. Productivity differences between the two railways are not significant and such differences cannot be confidently attributed to differences in the type of ownership. The study has allowed one to question the appropriateness of using Canadian railway cost elasticities to weight the outputs. The evidence indicates that a measure of productivity assuming constant returns to scale is an appropriate measure of railway productivity experience.

The scope of rail operations affects the overall level of railroad's costs more than the actual scale of the operations. The level of aggregation at which the study is carried out, does not allow one to achieve complete evidence on the natural monopoly issue behind any market structure analysis. Due to data limitations imposed by the highly concentrated nature of rail operations in Canada, only a simple cost model can be used which does not allow one to measure at which density of traffic, increasing returns are achieved. The evidence presented suggests that economies of scope are likely to play an important role in the market behaviour of the railroad industry.

## FOOTNOTES

1. The opinions and interpretations expressed are the authors' and do not necessarily reflect those of the Canadian Transport Commission.

2. Caves, D.W. and Christensen, Productivity in Canadian Railroads, 1956-1975, CTC, Report No. 10-78-16.

3. Braeutigam, R.R., Daughety, A.F. and Turnquist, M.A., A firm specific analysis of economies of density in the U.S. Railroad industry, The Journal of Industrial Economics, Vol. XXXIII, No. 1, Sept. 1984, p. 3-20.

4. The algebra behind the said definitions and further details on the cost concepts playing a crucial role in the analysis of multiproduct industries can be found in: Baumol, W.J., Panzar, J.C. and Willig, R.D., Contestable Markets and the Theory of Industry Structure, Harcourt, New York, 1982.