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Measuring and Identifying the Causes of the Productivity Performance of the Canadian Class I Railroads

1956 - 1981*

by

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I. Introduction

The objective of this paper is to communicate the results of our measurement and analysis of the Total Factor Productivity[1] (hereafter TFP) of the Canadian National and the Canadian Pacific Railways from 1956 through 1981. This paper is a part of the larger study[2] which we have conducted with a negotiated research grant of the Transportation University Program (TUP). This paper is organized as follows: Section II is a brief description of the data base and the variables. In Section III we discuss the methodology for measuring and comparing (between the two firms and over time) TFP as well as present the empirical results. Section IV investigates the causes of the TFP differentials by utilizing several alternative TFP regression models. These allow us to measure the unexplained TFP levels as a means to evaluate the economic efficiency of the two carriers. In Section V, we summarize and interpret the empirical findings of this paper.

II. The Data

A detailed description of the sources and methods used to develop our data base is contained in Freeman, Oum, Tretheway and Waters (1985). We have relied heavily on the annual reports of the CN and CP filed with the Canadian Transport Commission (CTC). Construction of the data base was aided by access to the Wisconsin group's rail data. The annual reports follow the Uniform System of Accounts instituted in 1956. Accounting procedures and reporting practices before 1956 were significantly different from those instituted in 1956. Thus, our study is limited to the period from 1956 to 1981, the most recent year for which all data was available.

Freight service output is measured as revenue ton-miles and passenger service output is measured in revenue passenger-miles. As of 1978, VIA Rail assumed responsibility for passenger services in Canada. The resulting change in reporting to the CTC shows nearly all non-commuter passenger services being provided by VIA even though the CN and CP produce these services under contract to VIA. We assign VIA output to the appropriate carrier through analysis of passenger train fuel expenditures. For both freight and passenger services, multilateral output indices were formed and rescaled so that the 1956 values of Canadian Pacific were unity. A multilateral aggregate output index was constructed using freight and passenger revenue shares as the weighting components for the respective sub-indices.

On the input side our study identifies five input categories: labour, fuel, way and structures, equipment, and other purchased inputs (which we refer to as materials). The aggregate quantity of labour input is measured as a multilateral index of four component labour sub-indices. Labour price is measured via the dual price index. It is rebased to unity in 1956 for CP. Fuel consumption is measured by converting consumption by fuel types (coal, diesel, crude oil, etc.) to their British Thermal Unit equivalents. The fuel price index is simply the total cost of fuel divided by the aggregate BTU consumption. This is also rebased to unity in 1956 for CP.

Construction of the capital stock and price series required a considerable amount of work. Way and structures investment is essentially total road additions (excluding land) with minor corrections for various plant and machinery accounts. Equipment capital is adjusted to include federal and provincial grain hopper car purchases which are allocated to the two Class I carriers. Both investment series cover the period 1890-1981 and are deflated by the railway industry input price deflators available from Statistics Canada (SC 13-568). Real capital stocks are constructed following the perpetual inventory method. The depreciation rates used for this calculation are 3 percent for way and structures and 6 percent for equipment. These are the figures used in earlier studies. The capital service price of each type of capital is computed following the approach suggested by Christensen and Jorgenson (1969).

Other purchased inputs (or "materials" as we refer to it) includes all inputs not elsewhere classified. Material cost is computed as total carrier expenditures less expenditures on all other identified inputs, less tax accruals, less joint facility and equipment rents. It is deflated by the Canadian Gross National Expenditure price index to yield a real quantity of materials.

Total factor input is calculated as the multilateral index of the five individual input indices. Once again CP 1956 is used as the base. Total factor productivity is the ratio of the multilateral output to multilateral input indices.

A large number of network and technological conditions were considered although only a few were actually used in the final stages. Route miles owned is included to measure scale effects.

III. Total Factor Productivity for Class I Canadian Railroads

A. Methodology

Christensen and Jorgenson (1970) proposed the following index of total factor productivity:

$$\ln (TFP_k/TFP_l) = \sum_i \left(\frac{R_{ik} + R_{il}}{2}\right) \ln \left(Y_{ik}/Y_{il}\right) \qquad (1)$$

$$- \sum_i \left(\frac{S_{ik} + S_{il}}{2}\right) \ln \left(X_{ik}/X_{il}\right),$$

where k and l are adjacent time periods, the Y's are output indexes, the X's are input indexes, the R's are output revenue shares, the S's are input cost shares, and the i subscripts denote the individual outputs or inputs. Diewert (1976) has shown equation 1 to be the exact index procedure that corresponds to a homogeneous translog production or transformation function. Caves, Christensen, and Diewert (1982) have further shown that no restrictions of separability or neutral technological change are implicit in equation 1.

As pointed out by Jorgenson and Nishimizu (1978) [henceforth JN], formulas such as equation 1 can be used to make both time-series and cross-sectional comparisons of TFP. In the case of cross-sectional comparisons, the indexes k and l are interpreted as different firms rather than different time periods. One could follow the approach of JN and choose a base year to carry out a comparison of the levels of CN and CP productivity. The individual growth rates of CN and CP productivity can then be used to extend the level comparison to earlier and later years. This is the approach used by Caves, Christensen, Swanson and Tretheway (1982). Recently, Caves, Christensen and Diewert (1982) [henceforth CCD] have criticized this method as lacking characteristicity, as defined by Dreschler (1973). Thus, in comparing two observations, perhaps CN 1956 and CP 1956, the two points being compared only have 50% of the weight in the comparison; the other 50% is coming from CN and CP in the reference year.

In their article, CCD proposed the following alternative procedure for making such time series cross-section comparisons:

$$\begin{aligned}\ln (TFP_k/TFP_l) = {} & \frac{1}{2} \sum (R_i^k + \bar{R}_i)(\ln Y_i^k - \overline{\ln Y_i}) \\ & - \frac{1}{2} \sum (R_i^l + \bar{R}_i)(\ln Y_i^l - \overline{\ln Y_i}) \\ & - \frac{1}{2} \sum (S_n^k + \bar{S}_n)(\ln X_n^k - \overline{\ln X_n}) \\ & + \frac{1}{2} \sum (S_n^l + \bar{S}_n)(\ln X_n^k - \overline{\ln X_n})\end{aligned} \qquad (2)$$

where $\bar{R}$ is the revenue share for output i averaged over all firms and time periods, $\bar{S}_n$ is the average cost share for input n, $\overline{\ln Y_i}$ is the average of the log of output i, and $\overline{\ln X_n}$ is the average of the log of input n. All bilateral comparisons based on equation 3 are both base-firm and base-year invariant. They are also transitive and have a higher degree of characteristicity than the JN procedure.

Equation (2) can be derived directly from a translog transformation structure by taking the difference between each firm's transformation function and the function resulting from averaging arithmetically the transformation functions across all observations. This procedure, in effect, uses the geometric average level of productivity as the norm.

We use the multilateral TFP index of equation (2) to measure and make comparisons of TFP for the CN and CP railroads for 1956 - 1981.

B. Differences with Wisconsin Studies

In a series of articles Caves, Christensen, Swanson and Tretheway of the University of Wisconsin explored TFP and costs of the Canadian railroads.[3] Their data was used as a starting point for this study. Nevertheless, this study differs from the Wisconsin studies in a number of respects. First, in this study we made several important corrections and refinements of the Wisconsin data. These changes are described in an appendix to our 1985 report. Second, we have updated the numbers to 1981. A third difference of this study from the Wisconsin studies arises from the treatment of outputs in the multilateral TFP index. Caves, Christensen and Swanson (1980) noted that if firms do not engage in marginal cost pricing or if production technology does not exhibit constant returns to scale, then use of revenue shares in (1) or (2) is inappropriate. The proper procedure is to use cost elasticities. Accordingly, they estimate a cost function, using U.S. data, and infer elasticities for each year for CN and CP. By using cost elasticities rather than revenue shares, changes in TFP over time (or among firms) represent shifts in the cost function.[4]

We have adopted a different approach here. We define growth in TFP as the total increase in outputs made possible by an increase in inputs. This will include the pure cost function shift effect of the Wisconsin studies, as well as output increases due to exploitation of economies of scale and from deviation from marginal cost pricing principles. This is the concept of TFP employed by Denny, Fuss and Waverman (1981). The latter authors decompose changes in this concept of TFP into the three components: pure shifts, scale effects and pricing effects. In order to perform such decompositions, one must obtain output cost elasticities, just as the Wisconsin approach did.

In our approach to TFP measurement, we did not want to presuppose cost elasticities. Thus we have measured TFP using revenue shares; i.e. using the Denny, Fuss and Waverman concept of TFP. At a later stage we intend to obtain cost elasticities using a cost function estimated with Canadian data. This would then allow us to decompose total TFP into its components, including pure cost function shifts.

We wish to emphasize that since the TFP concept used in this study differs from that used in the Wisconsin study, the results cannot be compared. The Wisconsin TFP series reflect cost function shifts. Our series additionally includes productivity gains due to exploitation of scale economies and due to changes in deviations from marginal cost pricing. We leave a breakdown of TFP into components, including a cost shift component to a later stage of this research.

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C. Results

In this section we describe the results of our measurement of Total Factor Productivity (TFP) for the CN and CP. We use the multilateral index procedure developed in section A, and apply it to the data described in section C. As described in section B, revenue shares were used to weight the output components.

In Table 1 we show TFP levels and annual growth rates for the CN and CP, 1956 - 1981. The levels are plotted in Figure 1. We normalized our series so that TFP is unity for CP in 1956. We see that CN had a TFP level that was 89.1% of CP's in 1956.[5] This dominance of CP's over CN's TFP level continues throughout the 1956 - 1981 time period. In 1981, CN's level was 81.5% that of CP. Table 2 gives the year to year ratio of CN to CP TFP. Both carriers achieved strong growth rates of TFP over the entire time period; 3.1% per year for CN and 3.5% for CP. The finding that CP's level of TFP is higher than CN's does not imply that CP is more efficient. As described in section B, TFP does not necessarily translate into an efficiency shift of the cost or production functions.

Our methodology for computing TFP does not require the assumption that inputs and outputs are separable or that productivity growth (or firm differences) is neutral. Caves, Christensen and Diewert (1982) have shown that no such restrictions are implicit in equations 1 or 2. However under these assumptions we can interpret the terms on the right hand side of 1 and 2 as indexes of aggregate output and aggregate input. Our measurement of TFP is unchanged.

In Tables 3 and 4 we present these aggregate output and input indices. Again these are scaled so that CP in 1956 has the value of unity. In Table 5 we show the ratio of CN to CP for both output and input. In Figures 2 and 3 we show CP and CN levels of TFP, output and input. Both railroads had strong output growth, an annual rate of 2.8% for CN and 2.4% for CP. At the same time both carriers contracted inputs so that TFP growth for the period exceeded output growth. Figures 4 and 5 show that both TFP and output growth exhibited cyclical behavior. This is true of both carriers.

We can also look at some of the individual outputs and inputs. Table 6 and Figure 6 show freight share in total output. In 1956 CN had a 91% share while CP had an 89% share. CP increased this share to 96% in 1981, while CN decreased it to 87%.

Table 7 gives CN and CP's labour cost shares. The significant decline of labour share, especially for CP can be seen. Tables 8 through 11 give cost shares for the remaining inputs; equipment, way and structures, fuel, and materials, (or other inputs). Fuel costs fell from roughly 8% of costs to 3% in 1964 reflecting dieselization and falling real prices of fuel. In the 1970's fuel share increased to 9% for each carrier.

IV. Total Factor Productivity Regressions

A. Analysis of Differences in TFP - Methodology

As described in section B, we use a "total" concept for TFP measurement. That is, our measure of TFP includes the "efficiency" shift in the cost function, as well as components due to economies of scale and density, network differences, and deviations of prices from marginal costs. Denny, Fuss and Waverman have proposed a decomposition of TFP into components due to efficiency, scale and deviations from marginal cost pricing. Their methodology, however, requires prior knowledge of cost elasticities, information which we do not have as yet. In addition, their methodology has not yet been generalized both to the multilateral case, and to include TFP effects for other factors such as density economies and network effects.

Caves, Christensen and Tretheway (1981), adopted a different approach to TFP decomposition. They regressed TFP on a number of factors, including output and network variables to decompose TFP differences into a number of sources. In fact, a Cobb-Douglas TFP function is dual to a Cobb-Douglas neoclassical total cost function. Thus, using TFP regressions they were able to obtain estimates of cost elasticities from a (very) restricted cost function.

Since TFP regressions reveal cost elasticities, one might ask why not proceed directly to cost estimation. The answer is that TFP estimation is less costly to perform. Cost functions are usually estimated jointly with input demand equations. Further, TFP regressions have greater degrees of freedom since input prices do not appear. We have found TFP regressions to be a cost effective method for performing preliminary analysis on the data.

FIGURE 1

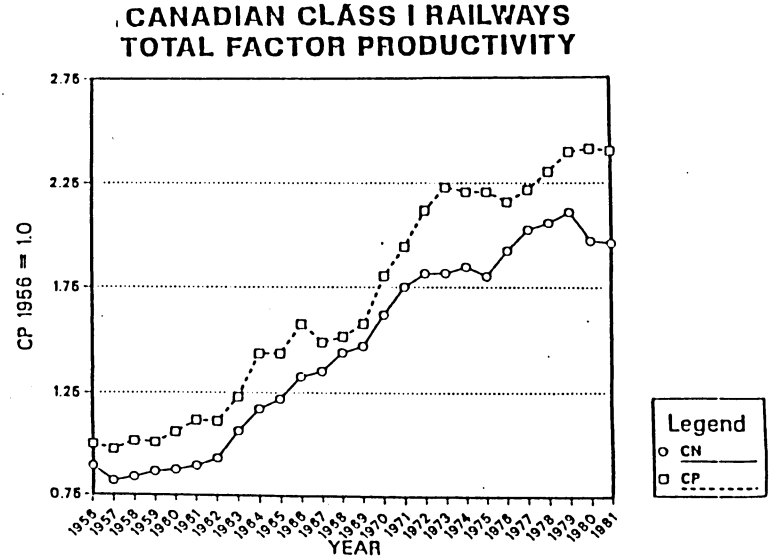

TABLE 1

Total Factor Productivity

(CP(1956)=1)

	Index		Growth	
	CNR	CPR	CNR	CPR
1956	0.892	1.000		
1957	0.819	0.976	-8.544	-2.426
1958	0.838	1.017	2.299	4.073
1959	0.865	1.009	3.168	-0.711
1960	0.873	1.061	0.984	4.979
1961	0.894	1.117	2.333	5.188
1962	0.930	1.112	3.935	-0.486
1963	1.064	1.230	13.485	10.124
1964	1.172	1.435	9.619	15.345
1965	1.219	1.434	3.994	-0.051
1966	1.325	1.574	8.333	9.328
1967	1.351	1.487	1.908	-5.667
1968	1.439	1.516	6.311	1.881
1969	1.470	1.577	2.154	3.945
1970	1.619	1.803	9.648	13.440
1971	1.749	1.943	7.748	7.459
1972	1.814	2.117	3.641	8.573
1973	1.815	2.228	0.047	5.120
1974	1.845	2.205	1.632	-1.056
1975	1.801	2.205	-2.436	0.004
1976	1.921	2.156	6.472	-2.258
1977	2.022	2.216	5.106	2.757
1978	2.054	2.303	1.571	3.845
1979	2.106	2.397	2.524	4.025
1980	1.967	2.412	-6.816	0.630
1981	1.957	2.402	-0.545	-0.421

TABLE 2

Relative TFP

(CN/CP)

	ratio	growth
1956	0.892	
1957	0.839	-6.118
1958	0.824	-1.774
1959	0.857	3.879
1960	0.823	-3.996
1961	0.800	-2.855
1962	0.836	4.422
1963	0.865	3.361
1964	0.817	-5.727
1965	0.850	4.045
1966	0.842	-0.996
1967	0.908	7.575
1968	0.949	4.430
1969	0.933	-1.791
1970	0.898	-3.792
1971	0.900	0.289
1972	0.857	-4.932
1973	0.815	-5.074
1974	0.837	2.688
1975	0.817	-2.439
1976	0.891	8.730
1977	0.912	2.349
1978	0.892	-2.273
1979	0.879	-1.501
1980	0.816	-7.447
1981	0.815	-0.125

TABLE 3

MULTILATERAL OUTPUT

(CP(1956)=1)

	index		growth	
	CNR	CPR	CNR	CPR
1956	1.209	1.000		
1957	1.076	0.909	-11.638	-9.546
1958	1.026	0.882	-4.746	-2.967
1959	1.034	0.850	0.752	-3.779
1960	0.992	0.835	-4.159	-1.730
1961	1.006	0.840	1.348	0.605
1962	1.028	0.830	2.188	-1.235
1963	1.160	0.918	12.140	10.116
1964	1.313	1.072	12.389	15.522
1965	1.363	1.055	3.719	-1.608
1966	1.480	1.144	8.245	8.112
1967	1.505	1.077	1.649	-6.062
1968	1.486	1.041	-1.250	-3.387
1969	1.529	1.086	2.842	4.181
1970	1.653	1.244	7.782	13.619
1971	1.803	1.340	8.687	7.409
1972	1.924	1.434	6.490	6.796
1973	1.876	1.477	-2.524	2.947
1974	2.072	1.533	9.964	3.745
1975	2.031	1.485	-2.001	-3.229
1976	2.107	1.441	3.671	-2.943
1977	2.185	1.529	3.630	5.884
1978	2.282	1.628	4.346	6.271
1979	2.356	1.721	3.181	5.559
1980	2.447	1.712	3.789	-0.490
1981	2.441	1.762	-0.247	2.837

TABLE 4

MULTILATERAL INPUT

(CP(1956)=1)

	index		growth	
	CNR	CPR	CNR	CPR
1956	1.356	1.000		
1957	1.314	0.931	-3.094	-7.119
1958	1.225	0.868	-7.045	-7.041
1959	1.196	0.842	-2.416	-3.068
1960	1.136	0.787	-5.143	-6.709
1961	1.125	0.752	-0.984	-4.583
1962	1.105	0.746	-1.748	-0.749
1963	1.090	0.746	-1.345	-0.008
1964	1.121	0.748	2.770	0.177
1965	1.118	0.736	-0.275	-1.557
1966	1.117	0.727	-0.088	-1.217
1967	1.114	0.724	-0.259	-0.396
1968	1.033	0.687	-7.561	-5.268
1969	1.040	0.689	0.688	0.236
1970	1.021	0.690	-1.867	0.179
1971	1.031	0.690	0.939	-0.050
1972	1.060	0.677	2.849	-1.778
1973	1.033	0.663	-2.571	-2.173
1974	1.123	0.695	8.332	4.801
1975	1.128	0.673	0.435	-3.232
1976	1.097	0.669	-2.801	-0.685
1977	1.081	0.690	-1.476	3.127
1978	1.111	0.707	2.775	2.427
1979	1.119	0.718	0.657	1.534
1980	1.244	0.710	10.606	-1.121
1981	1.247	0.733	0.298	3.257

Table 5

RATIO OF INDICES

(CN/CP)

	Output	Input	TFP	
			index	growth
1956	1.209	1.356	0.892	
1957	1.184	1.411	0.839	-6.118
1958	1.163	1.411	0.824	-1.774
1959	1.217	1.421	0.857	3.879
1960	1.188	1.443	0.823	-3.996
1961	1.197	1.496	0.800	-2.855
1962	1.238	1.481	0.836	4.422
1963	1.264	1.461	0.865	3.361
1964	1.225	1.500	0.817	-5.727
1965	1.292	1.519	0.850	4.045
1966	1.294	1.536	0.842	-0.996
1967	1.397	1.538	0.908	7.575
1968	1.427	1.504	0.949	4.430
1969	1.408	1.510	0.933	-1.791
1970	1.329	1.480	0.898	-3.792
1971	1.346	1.495	0.900	0.289
1972	1.342	1.565	0.857	-4.932
1973	1.270	1.559	0.815	-5.074
1974	1.352	1.615	0.837	2.688
1975	1.368	1.675	0.817	-2.439
1976	1.462	1.640	0.891	8.730
1977	1.429	1.567	0.912	2.349
1978	1.402	1.572	0.892	-2.273
1979	1.369	1.558	0.879	-1.501
1980	1.429	1.752	0.816	-7.447
1981	1.386	1.701	0.815	-0.125

FIGURE 2

CANADIAN PACIFIC RAILWAYS MULTILATERAL TFP, OUTPUT, AND INPUT INDICES

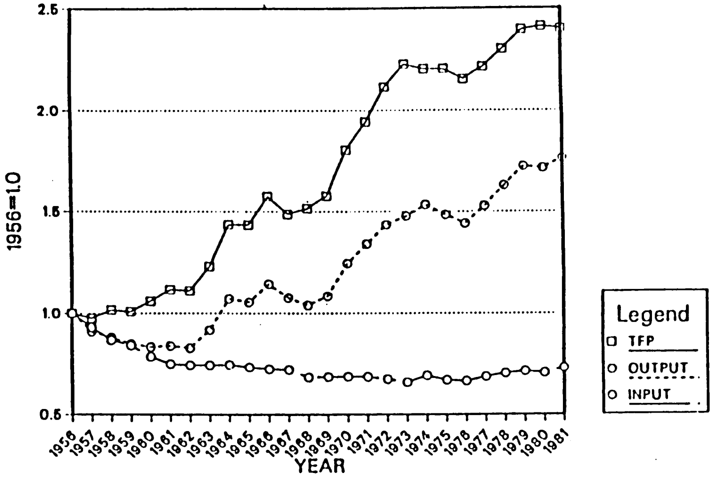

FIGURE 3

CANADIAN NATIONAL RAILWAYS MULTILATERAL TFP, OUTPUT, AND INPUT INDICES

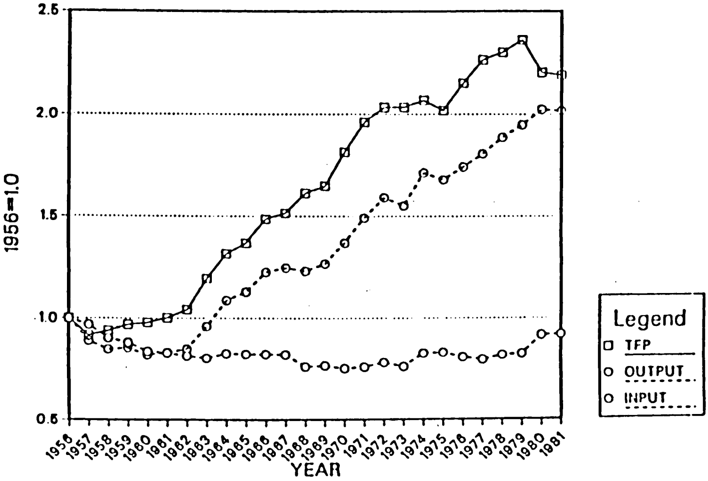

FIGURE 4

CANADIAN PACIFIC RAILWAYS
TFP and OUTPUT
ANNUAL GROWTH RATES

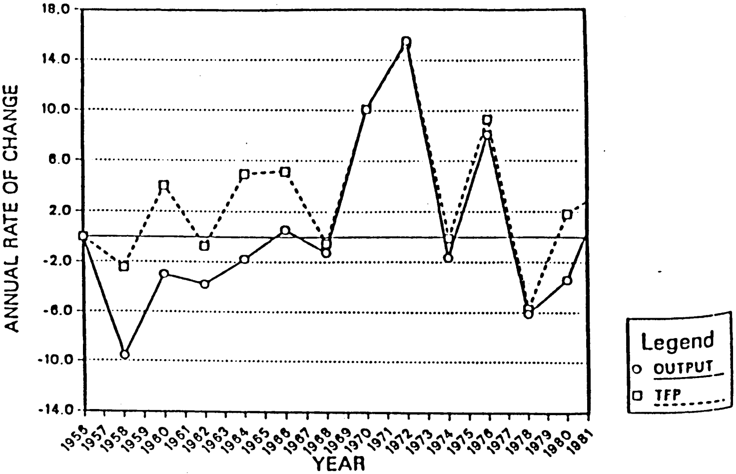

FIGURE 5

CANADIAN NATIONAL RAILWAYS
TFP and OUTPUT
ANNUAL GROWTH RATES

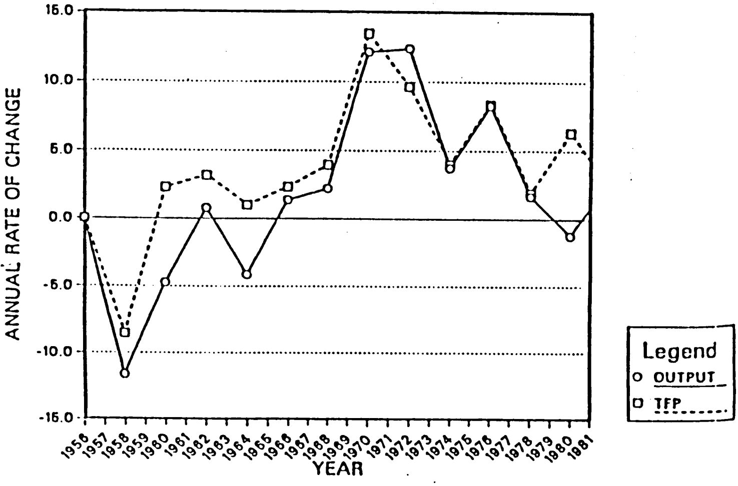

TABLE 6

Freight Revenue Share

	Percent		Growth	
	CNR	CPR	CNR	CPR
1956	91.299	88.978		
1957	90.691	88.503	-0.668	-0.536
1958	91.317	89.033	0.688	0.597
1959	91.809	89.857	0.538	0.921
1960	91.433	90.213	-0.411	0.396
1961	92.505	91.802	1.165	1.746
1962	92.591	91.488	0.094	-0.343
1963	92.776	92.208	0.199	0.784
1964	92.254	92.431	-0.565	0.241
1965	91.637	93.025	-0.671	0.641
1966	91.210	95.707	-0.467	2.843
1967	88.248	94.462	-3.301	-1.310
1968	90.338	95.694	2.340	1.297
1969	91.170	95.862	0.917	0.175
1970	91.845	96.516	0.738	0.680
1971	92.598	96.985	0.817	0.485
1972	92.839	97.266	0.260	0.289
1973	94.416	98.062	1.684	0.815
1974	93.542	97.395	-0.930	-0.683
1975	93.678	97.674	0.146	0.286
1976	94.342	97.921	0.707	0.253
1977	94.380	98.109	0.040	0.191
1978	93.957	97.725	-0.449	-0.392
1979	90.067	95.766	-4.229	-2.025
1980	88.441	95.784	-1.821	0.020
1981	87.479	96.043	-1.094	0.270

TABLE 7

Labour Cost Share

	Percent		Growth	
	CNR	CPR	CNR	CPR
1956	57.962	54.078		
1957	55.765	50.958	-3.863	-5.943
1958	53.781	49.402	-3.623	-3.101
1959	52.712	47.939	-2.007	-3.005
1960	49.837	46.205	-5.609	-3.684
1961	48.868	44.908	-1.965	-2.848
1962	47.810	43.206	-2.188	-3.864
1963	48.092	44.314	0.589	2.533
1964	49.448	45.898	2.779	3.512
1965	51.585	47.103	4.232	2.590
1966	49.922	45.410	-3.278	-3.661
1967	50.963	44.499	2.064	-2.025
1968	50.942	43.011	-0.042	-3.402
1969	51.501	43.370	1.091	0.832
1970	49.891	39.659	-3.175	-8.945
1971	51.342	42.338	2.866	6.536
1972	52.457	43.206	2.148	2.030
1973	53.473	45.793	1.920	5.816
1974	53.876	44.035	0.751	-3.916
1975	55.208	45.323	2.442	2.883
1976	56.966	48.362	3.134	6.490
1977	59.181	51.191	3.815	5.685
1978	57.099	49.842	-3.581	-2.670
1979	53.420	44.405	-6.660	-11.551
1980	46.488	36.847	-13.898	-18.659
1981	41.164	32.384	-12.163	-12.909

FIGURE 6

CANADIAN CLASS I RAILWAYS FREIGHT REVENUE SHARE

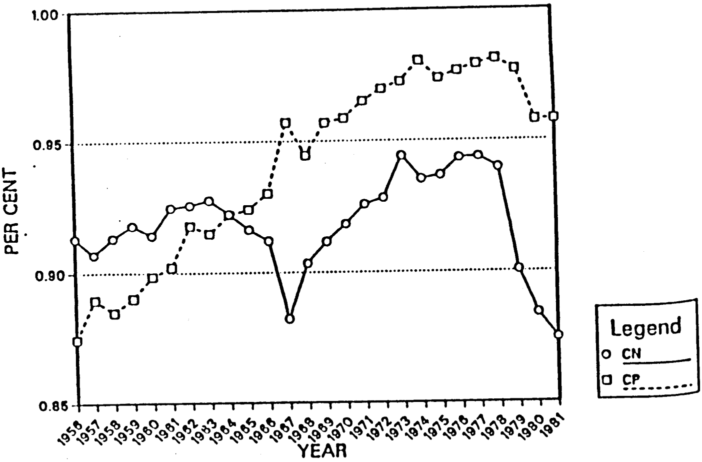

FIGURE 7

CANADIAN CLASS I RAILWAYS RESIDUAL TFP

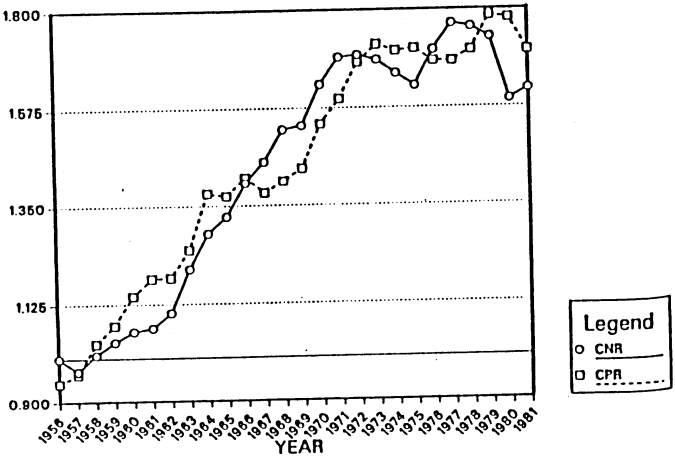

TABLE 8

Equipment Cost Share

	Percent		Growth	
	CNR	CPR	CNR	CPR
1956	9.012	13.190		
1957	8.088	13.284	-10.819	0.706
1958	8.978	14.675	10.441	9.963
1959	10.462	15.640	15.303	6.364
1960	11.565	16.694	10.021	6.524
1961	11.653	17.033	0.752	2.009
1962	12.151	17.975	4.185	5.384
1963	12.242	17.441	0.749	-3.016
1964	11.140	15.843	-9.430	-9.608
1965	10.795	14.810	-3.151	-6.747
1966	11.523	16.550	6.526	11.112
1967	12.165	17.976	5.425	8.264
1968	13.289	19.939	8.838	10.366
1969	13.126	19.280	-1.235	-3.362
1970	13.447	19.993	2.414	3.633
1971	13.005	18.507	-3.343	-7.724
1972	13.394	16.420	2.949	-11.965
1973	12.346	14.676	-8.151	-11.227
1974	10.246	14.118	-18.641	-3.878
1975	9.612	13.134	-6.382	-7.227
1976	8.809	11.548	-8.726	-12.864
1977	6.151	7.329	-35.913	-45.464
1978	3.952	4.699	-44.245	-44.453
1979	6.972	7.985	56.761	53.020
1980	11.128	12.265	46.761	42.914
1981	9.506	11.092	-15.758	-10.048

TABLE 9

Structures Cost Share

	Percent		Growth	
	CNR	CPR	CNR	CPR
1956	7.704	10.293		
1957	11.056	14.914	36.119	37.089
1958	13.004	17.614	16.228	16.635
1959	15.175	18.677	15.437	5.859
1960	17.305	20.489	13.137	9.261
1961	19.874	22.693	13.843	10.218
1962	20.699	23.153	4.065	2.005
1963	19.929	21.601	-3.787	-6.938
1964	19.725	21.309	-1.033	-1.362
1965	18.546	20.049	-6.164	-6.094
1966	17.777	20.127	-4.234	0.390
1967	17.113	20.077	-3.805	-0.251
1968	17.952	21.328	4.785	6.046
1969	16.700	20.562	-7.228	-3.660
1970	20.402	23.977	20.024	15.366
1971	17.878	20.952	-13.206	-13.486
1972	16.262	19.322	-9.473	-8.097
1973	15.391	17.012	-5.511	-12.736
1974	13.457	19.097	-13.426	11.563
1975	10.264	16.957	-27.083	-11.885
1976	7.729	14.024	-28.365	-18.989
1977	5.536	9.849	-33.382	-35.339
1978	7.825	13.253	34.615	29.683
1979	11.139	17.614	35.306	28.443
1980	15.992	24.373	36.166	32.478
1981	20.295	27.860	23.831	13.372

TABLE 10

Fuel Cost Share

	Percent		Growth	
	CNR	CPR	CNR	CPR
1956	8.761	7.823		
1957	6.986	5.966	-22.643	-27.105
1958	5.183	4.613	-29.847	-25.723
1959	4.415	4.012	-16.045	-13.950
1960	3.875	3.409	-13.040	-16.288
1961	3.629	3.157	-6.550	-7.676
1962	3.610	3.069	-0.530	-2.824
1963	3.736	3.281	3.436	6.678
1964	3.839	3.621	2.708	9.859
1965	3.871	3.762	0.838	3.822
1966	3.731	3.636	-3.681	-3.403
1967	3.618	3.412	-3.079	-6.357
1968	3.524	3.263	-2.641	-4.466
1969	3.416	3.239	-3.097	-0.764
1970	3.217	3.129	-6.028	-3.433
1971	3.479	3.530	7.846	12.056
1972	3.686	4.271	5.790	19.043
1973	3.884	4.720	5.230	9.993
1974	5.552	5.859	35.711	21.631
1975	5.877	6.315	5.691	7.494
1976	6.539	6.567	10.683	3.911
1977	7.553	7.759	14.408	16.671
1978	8.079	8.211	6.732	5.672
1979	7.733	7.927	-4.378	-3.520
1980	7.901	7.953	2.158	0.325
1981	9.013	9.484	13.164	17.606

TABLE 11

Materials Cost Share

	Percent		Growth	
	CNR	CPR	CNR	CPR
1956	16.561	14.616		
1957	18.105	14.878	8.914	1.781
1958	19.054	13.697	5.107	-8.275
1959	17.236	13.732	-10.028	0.261
1960	17.418	13.203	1.050	-3.932
1961	15.976	12.209	-8.638	-7.827
1962	15.731	12.597	-1.550	3.131
1963	16.000	13.363	1.696	5.899
1964	15.848	13.329	-0.950	-0.255
1965	15.203	14.277	-4.158	6.871
1966	17.047	14.277	11.449	0.000
1967	16.140	14.036	-5.465	-1.703
1968	14.293	12.458	-12.154	-11.922
1969	15.257	13.549	6.524	8.396
1970	13.043	13.241	-15.676	-2.300
1971	14.296	14.673	9.171	10.266
1972	14.200	16.780	-0.670	13.422
1973	14.906	17.799	4.850	5.892
1974	16.869	16.891	12.372	-5.237
1975	19.038	18.271	12.097	7.856
1976	19.957	19.498	4.709	6.499
1977	21.580	23.872	7.820	20.237
1978	23.045	23.994	6.571	0.511
1979	20.738	22.069	-10.551	-8.363
1980	18.491	18.563	-11.468	-17.299
1981	20.022	19.180	7.955	3.268

B. Analysis of Differences in TFP - Results

In Table 12 we present results of several simple TFP regressions using aggregate output. If constant returns to scale prevailed then one would expect the coefficient on aggregate output to be zero; i.e., productivity is unaffected by the level of output. In column 1 we find that output has a significantly positive coefficient; productivity rises when output rises. This suggests some kind of returns to scale.

Since output growth may be correlated with a constant rate of technical change, we include a time trend in the regression in column 2. Here we find a smaller but negative coefficient on output, suggesting some diseconomies of scale. The time coefficient indicates productivity not explained by output growth rising at a rate of 5.3% per year, on average.

To distinguish between economies of density and economies of scale we add route miles to the regression in column 3. The output coefficient now reflects economies of density, as network size (measured by route miles) is held constant. Significant returns to density are indicated. Returns to scale are obtained by adding the output and route miles coefficients together. This sum indicates very mild diseconomies of scale.

In Table 13 we investigate the effect of disaggregating output into freight and passenger components. The freight coefficient in column one has almost the same value as that on aggregate output in column one of Table 3.1. Passenger output has a negative sign in Table 3.2. There is no exact duality between TFP regression coefficients and cost function coefficients when we disaggregate outputs. We believe, however, that the results suggest a negative product complimentarity between freight and passenger output. That is, increases in passenger output cause costs to rise for existing freight output, resulting in an overall fall in system productivity.

In Column 2 we add a time trend. The freight coefficient is insignificantly different from zero, while passenger is again negative. We believe these results suggest constant or mild diseconomies of scale with negative interproduct complimentarity. Route miles is added in Column 3. Again negative product complimentarity, significant returns to density and roughly constant returns to scale.

From these regressions, we conclude the following: (a) inclusion of a time trend is critical, (b) inclusion of route miles indicates roughly constant returns to scale with significant economies of density, and (c) there may be negative interproduct complimentarity between freight and passenger outputs.

Table 12
TFP Regressions

Aggregate Output as Regressor
(Standard Errors in Parenthesis)

	(1)	(2)	(3)
Constant	.15 (.05)	-.22 (.03)	3.13 (.51)
Output	.82 (.10)	-.29 (.10)	.30 (.11)
Time Trend		.053 (.004)	.032 (.004)
Route Miles			-.34 (.05)
R-Squared	.55	.91	.95
Durbin Watson	.02	.69	.32

Table 13
TFP Regressions

Freight and Passenger as Separate Outputs
(Standard Errors in Parenthesis)

	(1)	(2)	(3)
Constant	-13.73 (1.36)	.44 (2.61)	2.82 (0.53)
Freight	.80 (.05)	.09 (.13)	.40 (.12)
Passenger	-.27 (.03)	-.13 (.03)	-.04 (.03)
Time Trend		.036 (.006)	.025 (.005)
Route Miles			-.30 (.05)
R-Squared	.88	.93	.95
Durbin Watson	.20	.51	.28

Utilizing the TFP regression model (3) in Table 13, we computed the unexplained TFP levels for both CN and CP. The unexplained TFP levels include the shift in production function over time (time effect) and the TFP residual.[6] The unexplained TFPs are plotted in Figure 7. From these we conclude that, after controlling for output levels and route-mileage, productivity performances have improved dramatically over the period. From 1957 to 1966 CP's unexplained TFP growth exceeds that of the CN. The reverse holds true for 1967 to 1972 and no clear pattern emerges for the 1973-1981 sub-period. However, in all instances the differences are not significant.

Durbin Watson statistics for the TFP regression models reported in Tables 12 and 13 are very low, indicating the existence of auto-correlation within the time-series data for a given firm. Although the parameter estimates are still unbiased, standard errors of the parameter estimates are biased. This may have obscured our conclusions concerning the statistical significance of various parameters. We intend to conduct a further investigation on the TFP regressions by correcting for the autocorrelations.

V. Summary of the Empirical Results

The empirical results of this paper may be summarized as follows:

(1) Because of the inability of the railways to adjust input levels to reflect changing traffic conditions (i.e., economic condition of the largely resource-based economy), at least in the short run, the yearly growth rates of TFP for both railways have been almost perfectly correlated with the growth rates of their outputs. This is particularly true since 1968. The implied rigidity of input use cannot be explained by fixed capital costs; the capital cost for ways and structures has been only about 14% and 19% of the total cost for CNR and CPR, respectively. Other inputs are also rigid. Whatever the cause, an increased ability to manage inputs more flexibly would improve efficiency of railway operations.

(2) The average annual growth rates of TFP during the entire study period (1956-81) were 3.1% and 3.5% respectively for CN and CP. CN had higher growth rates than CP during the 1960s. This situation was reversed in the 1970s. Both railroads had higher growth rates in the 1960s than the 1970s due to "diezilization" and other technological improvements.

(3) Comparison of the gross TFP levels indicates that the CN's productivity levels are about 15% lower than those of CP for all subperiods. This does not necessarily mean that CN is less efficient than CP. The gross TFP measures do not take into account the effects on productivity of changes in network, attributes of outputs or government-imposed regulations and restrictions.

(4) It is reasonably clear that the volume of passenger transportation impacts negatively on railway efficiency. There is no cost complementarity between freight and passenger services on a system-wide basis.

(5) The significant negative coefficient for route-miles in the TFP regressions indicates that there are significant efficiency losses due to maintaining light-density branch lines.

(6) We found significant economies of traffic density and constant returns to scale (changes in both output levels and network size).

(7) After controlling for the effects of changes in outputs and route-miles, the average annual growth rate of TFP during the study period (1956-81) became about 2.5% for both railways.

(8) Analysis of residual TFP indicates a dramatic increase in time-adjusted residual TFP from 1956 to 1981. Despite differing rates of increase in the various sub-periods under study, there appears to be no significant variation in residual TFP growth rates for the two railroads.

NOTES

[1] Total Factor Productivity is the number of units of aggregate output produced from one unit of aggregate input. It represents overall efficiency of the firm far better than partial factor productivities such as labour and fuel productivities. Partial factor productivities are not able to control for the effects of other input levels on the productivity of an input.

[2] See Freeman, Oum, Tretheway and Waters II (1985) for details.

[3] Caves and Christensen (1978) (1980); Caves, Christensen and Swanson (1981a); and Caves, Christensen, Swanson and Tretheway (1982).

[4] Note that TFP shifts using cost elasticities to weight outputs correspond to cost function rather than production function shifts. The two are related through returns to scale: Production function shift equals cost function shift times returns to scale. See Caves, Christensen and Swanson (1981b), and Ohta (1974).

[5] This finding of CP TFP level above that of CN differs from the Wisconsin results where the opposite was found. There are two reasons for this difference. First, the Wisconsin study used a cost-shift concept of TFP while our study used a "total" TFP concept. Using the cost elasticities from the Wisconsin study we found CN TFP to still be below that of CP. The second reason is correction of errors in the Wisconsin data. Of particular importance was an understatement of CN electricity usage by a factor of 1000.

[6] Unexplained TFP is computed by $\exp(.025 \times \mathrm{TIME}_t + V_{it})$ where V_{it} is the residual of the log-linear TFP regression.

References

Caves, D.W., Christensen, L.R., and Diewert, W.E., "Multilateral Comparisons of Output, Input and Productivity Using Superlative Index Numbers", Economic Journal (March 1982).

Caves, D.W., Christensen, L.R., and Swanson, J.A., "Productivity in U.S. Railroads, 1951-1974", Bell Journal of Economics, Vol. 11 (Spring 1980), pp. 166-181.

Caves, D.W., Christensen, L.R., and Swanson, J.A., "Productivity Growth Scale Economies, and Capacity Utilization in U.S. Railroads, 1955-1974", American Economic Review, Vol. 71 (December 1981), pp. 994-1002.

Caves, D.W., Christensen, L.R., Swanson, J.A., and Tretheway, M.W., "Economic Performance of U.S. and Canadian Railroads: The Significance of Ownership and the Regulatory Environment", in W.T. Stanbury and F. Thompson, editors, Managing Public Enterprises, Praeger Publishers, 1982.

Caves, D.W., Christensen, L.R., and Tretheway, M.W., "U.S. Trunk Air Carriers, 1972-1977: A Multilateral Comparison of Total Factor Productivity", in T.G. Cowing and R.E. Stevenson, eds., Productivity Measurement in Regulated Industries, Academic Press, 1981.

Caves, D.W., Christensen, L.R., Tretheway, M.W., and Windle, R.J., "Network Effects and the Measurement of Returns to Scale and Density for U.S. Railroads", forthcoming in A.F. Daughely, ed., Analytical Studies in Transport Economics, 1985, Cambridge University Press.

Denny, M., Fuss, M., and Waverman, L., "The Measurement and Interpretation of Total Factor Productivity in Regulated Industries with an Application to Canadian Telecommunications", in T.G. Cowing and R.E. Stevenson, eds., Productivity Measurement in Regulated Industries, Academic Press, 1981.

Dreshsler, L., "Weighting of Index Numbers in Multilateral International Comparisons", Review of Income and Wealth, Vol. 19, (March 1973), pp. 17-34.

Freeman, K.D., Oum, T.O., Tretheway, M.W. and Waters II, W.G, "Cost Structure and Economic Performance of the Canadian Class I Railroads", Working Paper No. 1087, Faculty of Commerce and Business Administration, University of British Columbia, 1985.

Friedlaender, A.F., and Spady, R.H., Freight Transport Regulation: Equity,Effficiency, and Competition in the Rail and Trucking Industry, Cambridge, Mass.: MIT Press, 1981.

Harris, R.G., "Economies of Traffic Density in the Rail Freight Industry", Bell Journal of Economics, Vol. 8 (Autumn 1977), pp. 556-564.

Hasenkamp, G., "A Study of Multiple Output Production Functions: Klein's Railroad Study Revisited", Journal of Econometrics, 1976.

Keeler, T.E., Railroads, Freight, and Public Policy, Washington, D.C.: The Brookings Institution, 1983.

Ohta, M., "A Note on Duality Between Production and Cost Functions: Rate of Returns to Scale and Rate of Technical Progress", Economic Studies Quarterly, 25 (1974), pp. 63-65.

Waters II, W.G. and A.D. Woodland, Econometric Analysis and Railway Costing, (North Oxford Academic, Oxford, England; Centre for Transportation Studies, University of British Columbia, 1984).