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A COMPARATIVE ASSESSMENT OF THE PRODUCTIVITY OF AUSTRALIA'S RAIL SYSTEMS 1971/72 - 1990/91

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ABSTRACT: There is a recognition that Australia's rail systems, as the major recipient of government subsidy, have to improve their performance and become more cost efficient. Any policy designed to reduce costs must consider the implications of resultant actions on the overall productivity of a business. In this paper we propose the use of the total factor productivity index as an appropriate reference benchmark, calculated annually for each rail system. As a reference benchmark, it enables each railway to evaluate the productivity implications of any change to the operating and managerial environment designed in part or in whole as a cost saving strategy. Total factor productivity indices are derived annually from 1971/72 to 1990/91 for the 5 major rail systems and sources of variation are identified.

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Introduction

The Australian rail systems have a recognised historical contribution to the economic and social development of Australia. With the advent of alternative passenger and freight transport opportunities provided by the medium of road systems, the railways suffered a major decline in market share and failed almost nationally to adopt a pro-active marketing strategy to stem the decline. The burden on the State steadily increased with the subsidy reaching a peak in the late eighties. During a large part of the seventies the subsidy was justified as a recognition of the social value of public transport, and became the greatest single item of expenditure by State governments. By the mid-eighties some governments (notably in NSW) commenced a program of major reform in government trading enterprises (GTE's) to find ways of reducing the level of subsidy. The fundamental question to address became the identification of an enterprise's overall cost structure and ways in which this could be changed in order to establish cost efficient practice. In NSW a benchmark approach has been adopted in which international comparisons are used to identify better ways of running a railway of comparable activity. A distinction was created between commercial services and non-commercial services. Governments replaced the concept of subsidy with the idea of a community service obligation (CSO). A "subsidy" would be paid only if an identified non-commercial activity was deemed by the Minister of Transport to have the status of a CSO.

To date governments have tended to treat all non-commercial services as CSO's, tantamount to a "business as usual" scenario. The greatest change however is occurring in the restructuring of GTE's, with efforts to improve the cost efficiency of enterprises. One of the challenges facing GTE's and government monitoring agencies is in establishing suitable measures of improvement. It is clear that one aim is to improve the productivity of the combined set of factor inputs used to produce the output of the enterprise - we need procedures capable of establishing preferred mixes of inputs required to produce a given level of output at minimum cost.

There are three key "indicators" of a business's success: productivity, profitability and the rate of return on assets. A productivity measure such as total factor productivity (TFP) reports how well a transport firm does at turning inputs (labour by type - management, drivers, mechanics etc., fuel, capital etc.) into outputs (e.g. tonne kilometres). Profitability is the result of the relationship between productivity, market power, regulatory controls and the choice of markets to serve. Treasuries increasingly require measures of the real rate of return on invested capital and TFP in their performance portfolio. A railway may be the most productive in a cost efficiency sense, yet may have lower profits than another railway because of the differences in revenue streams attributed to market power. Getting costs down does not guarantee long run profits (and/or minimum subsidy). There is a need to develop demand or market indicators (often called measures of service effectiveness) to identify how effective the supply side level of output (such as train kilometres or train hours in service) is in producing demand side output (such as passenger kilometres, tonne kilometres, or revenue).

This paper argues for the adoption of a performance assessment portfolio (PAP) which uses an index of gross total factor productivity (TFP) as a reference benchmark (and a possible targeting index) and a mechanism for disaggregating the gross measure in such a way that we can identify the sources of composition and hence variation both within a GTE over time and between GTE's at a point in time. The allowance for these sources of variation enables us to derive a residual or net TFP measure. With some governments considering linking changes in prices charged for services to productivity gains, the need for a rigorous measure of performance is clear.

The paper is organised as follows. The next section presents the TFP measure, followed by a description of the approach developed to compile a database suitable for measuring TFP. Data has been collected on an annual basis (1971/72 to 1990/91) for the 5 Australian rail systems. The empirical indices are summarised together with a number of interesting components of the index. This is followed by an investigation of sources of variation in gross TFP, to provide some important insights into the role of scale, density, technology, management and excess capacity. Some important insights are obtained on the role of technology and management in explaining variations in productivity over the last 20 years across all Australia's rail systems.

Gross total factor productivity and performance measurement

The essential elements of performance measurement are:

(i) To set out in a simple way the reasoning behind the need to adopt a particular approach as the preferred way of establishing a reference benchmark for comparisons within a rail business and between it and other GTE's and private businesses. TFP is one such benchmark index.

(ii) To set out the data requirements necessary to obtain meaningful quantitative measures of overall performance at desirable levels of disaggregation (for example, the line, line cluster, depot and division).

(iii) To quantify the overall performance measure within the railway.

(iv) To map the overall index of performance to a large number of partial measures and contextual/operational factors (e.g. network configuration, operating environment, composition of working time - normal and penalty) to establish suitable procedures to assist management in implementing change which is consistent with improving overall productivity.

Total factor productivity is the amount of aggregate output produced by a unit of aggregate input (Diewert 1989). Railways produce more than one type of output (e.g. passenger/freight activity) and use various types of inputs both of an elemental nature within generic classes of inputs (e.g. types of labour - drivers, mechanics, inspectors, managers) and generic categories (e.g. labour, fuel, capital, non-labour maintenance). TFP is an index number which combines multiple outputs and multiple inputs through a weighting procedure which accounts for the contribution of inputs to costs and outputs to revenue.

The base values in the TFP formula can be defined as the values for a particular year and system, say NSW in 1971/72, or alternatively set to the average values, defined over the years and railways in the database. The average values across all observations in the data set were chosen as the base values. This formulation originally developed by Caves et al. (1982) enables comparisons between railways which are independent of the railway or year chosen as the base and gives the index appeal in benchmarking.

$$(1) \qquad \ln\left[\frac{TFP_k}{TFP_b}\right] = \frac{1}{2}\sum_i (R_{ki}+\overline{R_i})(\ln Y_{ki}-\overline{\ln Y_i}) - \frac{1}{2}\sum_i (R_{bi}+\overline{R_i})(\ln Y_{bi}-\overline{\ln Y_i}) - \frac{1}{2}\sum_n (W_{kn}+\overline{W_n})(\ln X_{kn}-\overline{\ln X_n}) + \frac{1}{2}\sum_n (W_{bn}+\overline{W_n})(\ln X_{bn}-\overline{\ln X_n})$$

where

k = each individual observation, k = 1, ..., K
b = base observation (average of all observations)
i = outputs, i = 1, ..., I
n = inputs, n = 1, ..., N

R_i = revenue shares of total outputs; $\overline{R_i}$ = arithmetic mean of revenue share
W_n = cost shares of total inputs; $\overline{W_n}$ = arithmetic mean of cost shares

$\ln Y_i$ = unit measure of output; $\overline{\ln Y_i}$ = geometric mean of unit measure
$\ln X_n$ = unit measure of input; $\overline{\ln X_i}$ = geometric mean of unit measure

Partial measures of performance such as total cost per passenger kilometre (a measure of unit cost) are simple to compute but by their construction fail to recognise the role of each input in the establishment of total cost. Given that each type of input has a different influence on the costs of servicing passenger kilometres, it is desirable to establish a procedure to track (understand) what happens when we change one input in respect of its influence on the need for other inputs and hence the overall change in total cost (Hensher 1991).

Many partial measures of performance such as train driver paid hours per 1000 train kilometres and total cost per labour hour have at least two main problems. They consider only a subset of the inputs used by the railway and sometimes only a subset of the outputs. To the extent that a railway may increase productivity with respect to one input at the expense of reducing the productivity of other inputs, then partial measures will inaccurately portray the overall gains/losses in productivity (Talvitie and Obeng 1991). Partial measures also often fail to take into account the nonhomogeneous nature of the inputs and outputs (Windle and Dresner 1991). For example with total cost per labour hour, the total number of employees is used as a measure of labour input despite the fact that the addition of a train driver hour may not have the same impact on productivity as the addition of a station cleaner or mechanic.

The data set

Like any measure requiring quantitative information on inputs and outputs, there are very real challenges in the establishment of meaningful data. Capital, for example, is one of the most difficult inputs to measure correctly, given that the book value rarely coincides with its economic value. Furthermore some capital is arguably not pertinent to the provision of rail services (e.g. the "ownership" of land inherited from the past which is rented out to a non-transport activity) and hence should not be included in financial statements concerned with establishing the sourcing of inputs required to produce transport outputs.

Measuring labour input requires the aggregation of various categories of employees such as drivers, inspectors, mechanics, managers, administration staff etc. which may be complicated by the mix of casual and full time employees. The measurement of output requires the aggregation of various services such as suburban and intercity passenger services, and freight services. The aggregation of the inputs and outputs can be achieved relatively painlessly if the accounting systems are in sufficient detail to enable the retrieval of data from the "bottom up" beginning at the train service level (as distinct from the "top down").

The ideals of a bottom up data approach had to be compromised in this first stage development of a TFP index. Given the aim to compare all railways in Australia, the level of permissible disaggregation was limited. Ongoing research (DeMellow and Hensher, in progress) concentrated on the NSW railways is enabling us to adopt a more detailed disaggregation of all inputs and outputs, and thus test the adequacy of TFP indices derived from more aggregate definitions of inputs and outputs identified from annual reports. The current contribution typifies the quality of data generally available from all rail systems in Australia which has been used in previous studies such as the Industry Commission (1990) and Bureau of Industry Economics (1992). Using archival material, we have expanded the data to include a large number of descriptors of changes in technology and management which may have contributed to explaining variations in gross TFP. The full extent of the data set is documented in Hensher et al. (1992).

The database contains annual data (based on the financial year) for each state's rail system for a twenty year period from 1971/72 to 1990/91. 1971/72 is a significant choice as a base year since financial deficits started to appear in railway accounts in a significant way in the early 1970s. For the study period 1971/72 to 1983/84, the data has been sourced, with variations, from an Australian Railways Research and Development Organisation (ARRDO) Information Paper titled *Rail Transport Performance Indicators* (ARRDO 1986). However compilation and publication of comparative statistics ceased when ARRDO was wound up in 1987. Data for the remaining quarter of the study period (1984/85 to 1990/91) was thus mostly obtained from Annual Reports and their supporting documents. Occasionally where data items were unavailable from other sources, they were estimated by ITS, usually based on physical relationships.

While the organisational structure of service provision has remained the same over the study period in some states (Westrail in Western Australia, and Queensland Railways in Queensland), in others, a number of different organisations have provided services. Thus in the database and analysis, Australia's rail systems are referred to by state, rather than by organisation. Australian National which operates in several states is referred to as South Australia's rail system because it assumed control of SA's nonurban services and is based in Adelaide.

Following ARRDO convention, urban passenger train services in South Australia have been excluded from the statistics. ARRDO's reasoning is that the metropolitan rail network in South Australia, operated by a separate authority, is physically distinct from the remainder of operations in the state. Although urban services in other states are also operated by separate authorities, the networks are not as physically distinct. However it would be possible, given sufficient research, to transplant all relevant data from South Australia's State Transport Authority accounts and graft them onto AN accounts from 1977/78, the year that AN assumed control of SA's nonurban services.

Four inputs were used in the calculation of the input index: labour, energy, materials and capital. Two output indices were calculated: the demand-side measure of output based on urban and nonurban passengers and net tonne kilometres of freight, and the supply-side measure of output defined by train kilometres.

Expenditure on each of the input items (labour, energy, materials and capital) and revenue from each of the output items (urban passengers, nonurban passengers and net tonne kilometres of freight) is necessary to calculate cost and revenue shares used to weight each of the inputs and outputs in the respective indices. Revenue shares are used as a proxy for the cost elasticity of output weights. Ongoing research is identifying the adequacy of this assumption. All revenue and expenditure data used in the calculation of the indices is in 1971/72 dollars. Data items in $current were converted to $constant 1971/72 using the CPI index as a deflator. The data items for each of the indices are explained in the following section.

Inputs

Labour: The unit measure for the labour input is the average number of staff employed during the year. Definitions in available sources range from "total staff employed at end of year," "average staff employed throughout the year", and "full-time equivalent number of staff". Expenditure on labour, used to calculate cost shares for the unit measures of inputs, includes wages and salaries as well as on-costs (such as superannuation, long service leave and recreation leave). However it is often difficult to determine what on-costs, if any, are included in data described as "labour costs per employee" or "total wages, salaries and labour expenses".

Energy: The unit measure for the energy input is joules. The two types of fuel usage, diesel distillate (in litres) and electricity (in kilowatt hours), were converted to the common measure of megajoules. Energy expenditure includes all forms of energy such as motor spirit, kerosene, coal and LPG, however distillate and electricity predominate. Some energy usage and expenditure data was estimated by ITS.

Materials: The data item expenditure on materials (excluding fuel which is counted separately) is equivalent operationally to the cost of maintenance (non-labour). It was calculated in different ways for different systems, depending on data availability. Definitions used included total maintenance costs minus expenditure on maintenance labour; operating expenses: stores and materials; and operating expenses: services and supplies minus an estimate for services. In the absence of a unit measure for materials (as for labour and energy), total expenditure was used.

Capital: The definition of capital used in this analysis is capital utilisation. Capital utilisation is the amount by which a system's capital assets amortise from year to year (which is equivalent to annual amortisation value or annualised capital costs). For any year, it is calculated as the amount by which assets existing in 1971 have amortised between one year and the next (assuming an asset life of 12.5 years) plus the amount by which new assets purchased by capital expenditure in the years after 1971 have amortised between one year and the next (assuming an asset life of 25 years). The accounting concept of depreciation was rejected in developing the measure of the performance of capital in favour of the annualised capital costs.

In calculating capital utilisation, several assumptions were made. These are documented fully in Hensher et al. (1992). It was assumed that the asset stock existing at 1 July 1971 had reached its "half-life" of 25 years, that is 12.5 years, while a full asset life of 25 years was assumed for new assets bought in each year after 1971/72. A real interest rate of 7% was used in the calculation of annualised capital costs. Expenditure on assets is assumed to occur evenly throughout the year, thus there is no annualised capital cost in the year of capital expenditure. The cost recovery factor (CRF) is defined as:

$CRF = r / [1- (1+r)^{-n}]$, where r = real rate of interest and n = life of assets.

Outputs

Passengers: Passenger numbers are divided into urban and nonurban, in recognition of the two distinct markets for passenger services. Suburban rail services in South Australia are not included in the database. All other states' urban services are included. Perth's metropolitan rail service is operated by Westrail under contract to Transperth. Trip length data for all systems is either unavailable or too unreliable to convert the number of passengers to passenger kilometres.

Net tonne kilometres (freight): The tonne kilometre, representing the haulage of one tonne over one kilometre, is the most accurate reflection of the freight transport task. Net tonne kilometres refers to the weight of the goods carried.

Train kilometres: Train kilometres is a supply side measure of output. Train kilometres per employee is an universally used partial (simple) productivity measure. However it has an in-built bias toward those systems with substantial passenger services.

Other variables

Route kilometres: Route kilometres is a useful variable to measure the effect of the size of each system's network. Other productivity studies (e.g. Freeman et al. 1987) have found network size is an important determinant of TFP. Another useful measure is track kilometres, but data was not available for all systems.

Managerial change: Major organisational and managerial changes over the 20 year period were identified and are listed in Table 1. The variables are dummy variables, taking the value of 1 for each year that the change is relevant in a particular system while all other years and systems take the value of 0. For instance, Hill as Chief Executive of SRA from July 1981 to November 1986 is recorded as a 1 for the years 1981/2 to 1984/5 in NSW and as a 0 for all other observations.

Table 1 Summary of managerial and organisational change variables

STATE	**MANAGERIAL AND ORGANISATIONAL CHANGES**
New South Wales	Public Transport Commission formed; Shirley era; Reiher era; Granville train disaster; Hill era; traffic branch reorganised; Johnson era; Sayers era
Victoria	Bland report; Victorian Railways Board formed; Gibbs era as Chair of VRB; planning services reformed; traffic branch reorganised; organisation structure investigation; traffic branch permanently split; Gallagher era as GM of VRB; State Transport Authority formed; Fitzmaurice era as MD of STA; Public Transport Corporation formed (Stoney era)
Queensland	Hooper era as Transport Minister; Urban Public Transport Act 1974; Lee era as Commissioner; Goldston era as Commissioner; Tomkins era as Transport Minister; Financial Assistance Act 1979; Mendoza era as Commissioner; management reorganisation; Sheehy era as Commissioner; major management reorganisation; Read era as Commissioner
South Australia	Australian National Railways Commission formed; Smith era as Chair of ANRC; ANRC full control of SA and Tasrail; Williams era as GM of ANRC; Marks era as Chair of ANRC; distinction between commercial and non-comm. services; Williams era as Chair of ANRC; King era as GM of ANRC
Western Australia	Pascoe era as Commissioner; McCullough era; WA Transport Policy (Stage 1); joint venture with Total Western Transport; major top management changes; Gill era; major reorganisation

Technological change: Over 60 technological change variables were identified in several categories including rollingstock, permanent way, electrification, signalling and telecommunications, and office automation. They are listed in Table 2. The technological change variables are also dummy variables. For each innovation, the value 1 is recorded in the year in which it was introduced to each system and for every year afterwards through to 1990/91.

Difficulties in data compilation

A major difficulty in the compilation of data particularly from Annual Reports is the inconsistency of definitions. This includes inconsistency *within* systems over the 20 year period where the reporting term remains the same but its meaning changes or the term changes but it continues to refer to the same item, as well as inconsistency of terms and definitions *between* systems.

This problem is exacerbated by changes in the organisational structure of public transport over time, particularly in Victoria. For instance, in Victoria the Victorian Railways Board operated all rail services until 1983, when services were then divided between the State Transport Authority (V/Line) and the Metropolitan Transit Authority (Met). In 1989 V/Line and the Met were amalgamated to form the Public Transport Corporation (PTC).

Table 2 Summary of technological change variables

TYPE OF CHANGE	INDIVIDUAL CHANGE VARIABLES
Rollingstock	
Main line locomotives	81 class diesel; BL class diesel; DL class diesel; electric
Long distance passenger trains	XPT; N class; refurbished Ghan; Australind
Interurban passenger trains	Double decked; other improved
Double decked suburban trains	First generation; improved; Tangara
Single decked suburban passenger trains	Improved
Freight wagons	Extra long flat wagons and containers; other flat wagons and containers; high capacity bulk; specialised BFW wagon; specialised steel wagon; specialised S pack
Bogies	High speed
Couplers	High strength/high capacity
Maintenance	Wheel profiling; in-situ wheel reconditioning
Locotrol	
Innovations	Tri-bo locos; driver training simulators; on-train diagnostic equipment; low speed control equipment; creep control equipment; adhesion improvement equipment; chopper controls; radio controls
Permanent way	
Track (rail bed)	Paved (Macgregor) track; noise control devices (rubberised beds, cologne eggs); geodetic fabrics for seepage control
Track (sleepers)	Concrete sleepers
Track (fastenings)	Pandrol clips and electric rail fastenings
Track (rail)	Continuous welded rail; glued insulated rail joints; head hardened rail; metricated rail profiles
Related infrastructure	Armco culverts; automated points and turnouts; automated ballast cleaning, sledding, tamping; automated track laying; automated weighbridges; overhead cranes
Other	Integration of stations into high rise developments; rail grinder
Electrification	New electrification; major extensions; AC electrification
Signalling, safety & telecommunications	Centralised Train Control signalling; radio control systems; fibre optics; train order systems; advanced TG and Bi-directional SIGS; passenger information systems; automatic ticketing
Office automation	Mainframe computers; rail CAD, TIMS, RICS, real time RS control

A related problem is lack of information on the definition of terms - e.g. what is included in "labour costs", does it include on-costs or not ? Annual reports are summary documents for public consumption and often do not contain detailed descriptions or explanations of terms used in the report. The ARRDO information paper (ARRDO 1986) is also unclear on the exact definition of a number of its data items.

Productivity results: gross total factor productivity and its components

Best performers on gross TFP

Interpretation of a state's performance varies according to whether the demand side or supply side based TFP index is analysed. The gross TFP indices are shown in Figures 1a and 1b. Based on the demand side measure, South Australia has the highest TFP throughout the 20 year period while Victoria has the lowest TFP. Of all the systems, SA uses its inputs best to carry passengers and freight. SA is able to use a fixed amount of the input set to supply a service which attracts higher patronage (passenger and freight) than do other systems. One reason for SA's good performance is the absence of urban passenger provision. Western Australia, however, is best at using its inputs to produce train kilometres, as it had the highest TFP based on the supply side measure of output. WA is able to supply more train kilometres for a given amount of inputs than any other operator. If SA is excluded due to the absence of the urban passenger task and the systems servicing all three markets (urban and nonurban passengers, and freight) are examined, then Queensland is the best performer in respect of moving more people and freight for a given amount of inputs. However, Queensland does poorly in producing train kilometres from its inputs.

Worst performers on gross TFP

NSW has been the worst performer on gross TFP in respect of the use of inputs to perform a train kilometre task, but Victoria has been the worst performer in respect of using its inputs to move passengers and freight.

Overall change in productivity

South Australia's demand side measure of TFP has almost trebled between 1971/72 and 1990/91, while the two poorest performers, NSW and Victoria doubled productivity. Overall increases in supply side productivity were much lower. The best performer, WA, almost doubled its TFPs value while NSW and Victoria increased TFPs by a half and SA by a third. Queensland had only a marginal increase in supply side productivity between the beginning and end of the study period.

Constancy of performance

It is interesting to note the constancy of the 5 systems' rankings in productivity over the twenty year period. Since 1976/77, the rankings of the systems on TFP (demand side based) have remained the same: South Australia 1 (most productive), Queensland 2, Western Australia 3, New South Wales 4, and Victoria 5 (least productive). Similarly, the rankings based on the supply side based TFP index have also remained the same since 1976/77: Western Australia 1, South Australia 2, Victoria 3, Queensland 4, and New South Wales 5. In 1990/91 only, NSW had a marginally higher level of TFPs than Queensland.

Despite the constancy of rankings, there is variation in the relative levels of TFP, as evident in Figures 1a and 1b. For instance, the difference in TFPd between NSW (4th ranked) and Victoria (5th ranked) was constant during the seventies but has increased since 1984/85. In contrast Queensland had a higher level of TFPs than NSW in 1971/72 through to 1982/83, but the difference between the two states has been decreasing since then. NSW's TFPs has increased over time while Queensland's has remained fairly constant: by 1990/91 NSW even had a marginally higher level of TFPs than Queensland.

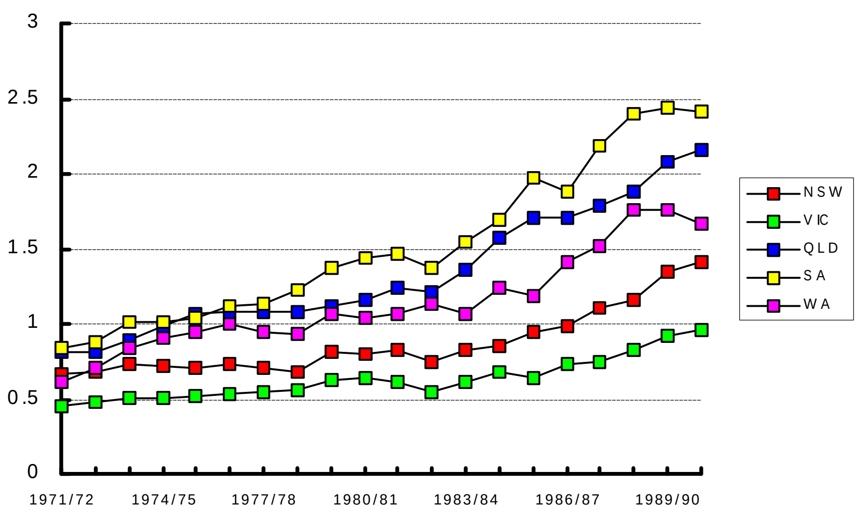

Figure 1a Gross TFP based on demand side measure of output

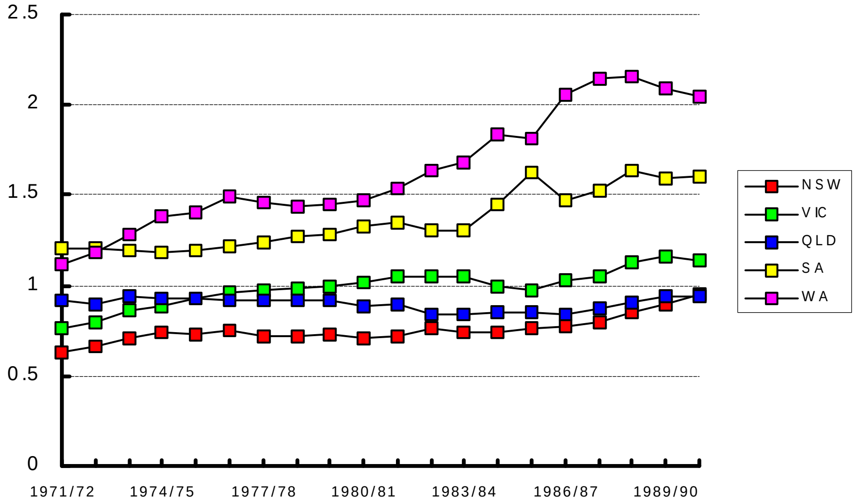

Figure 1b   Gross TFP based on supply side measure of output

Components of TFP

Analysis of the input and output indices can explain the pattern of productivity changes evident in Figure 1. The components of TFPd and TFPs, the output and input indices, are shown for each state in Figures 2 to 6. Indices of the individual components of the input and output indices (such as labour, megajoules or urban passengers carried) would be necessary to determine in more detail why TFP has changed.

The input index for each state has generally shown a downward trend over the 20 year study period. Victoria, SA and WA have shown a steady reduction in the use of inputs, while Queensland's use has remained fairly constant. The output index (demand side) has generally been increasing, although the index in NSW and Victoria has fluctuated. The output index (supply side) in most states has been very constant/steady, with little change, although Victoria and WA have experienced slight downward trends. This explains why levels of productivity have increased over time, and why overall growth in TFPs is lower than TFPd growth. Train kilometres have remained constant, passengers and freight carried has been increasing, while the level of inputs has decreased.

An increase in gross TFP can be due to change in either the input or output index, or to change in both indices. For instance, NSW's increase in TFPd from 1982/83 is attributable partly to an increase in output (demand side) and partly to a sharp decrease in inputs from 1986/87 onwards. However Queensland's large increase in TFP (demand side) from the early 1980s is related primarily to the output index which almost doubled in value from 1982/83 to 1990/91.

South Australia's consistently high levels of TFPd are attributable to on-going increases in output and declines in the input index from the beginning of the period through to the last year. Western Australia's large increase in TFPd from 1985/86 was due to a decline in inputs and an increase in the output index.

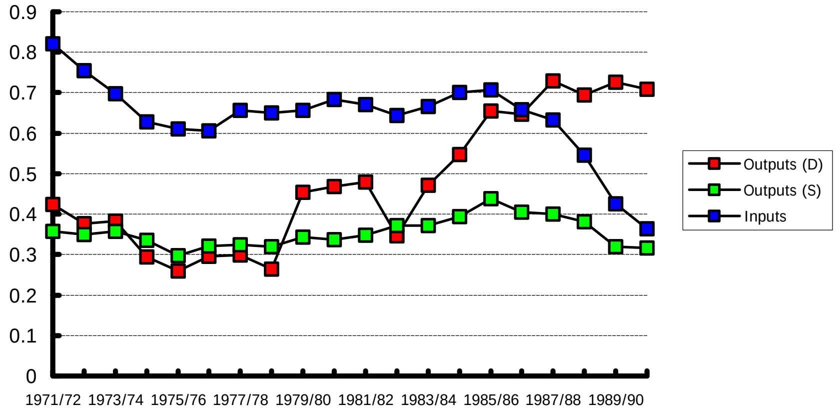

Figure 2 Input and output indices for NSW

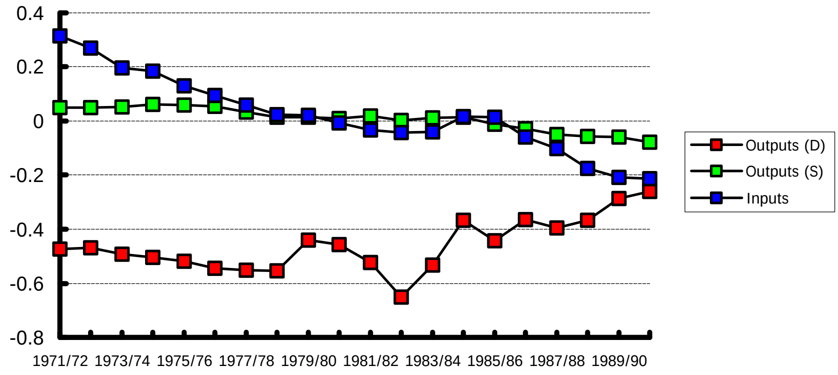

Figure 3 Input and output indices for Victoria

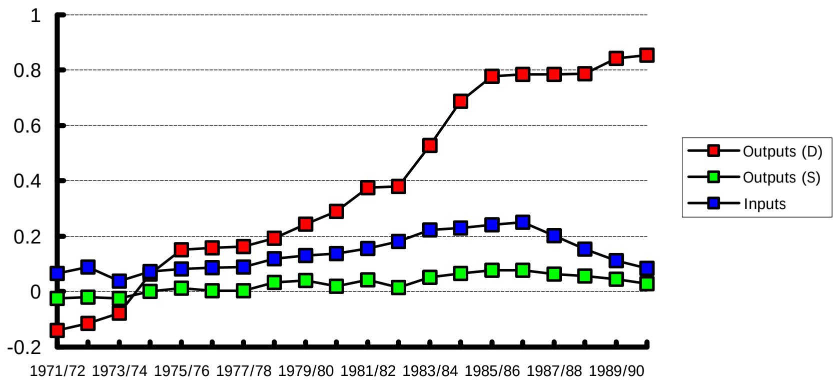

Figure 4 Input and output indices for Queensland

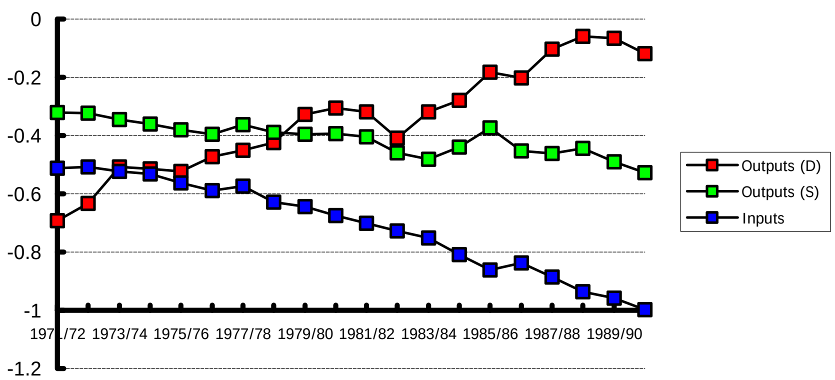

Figure 5 Input and output indices for South Australia

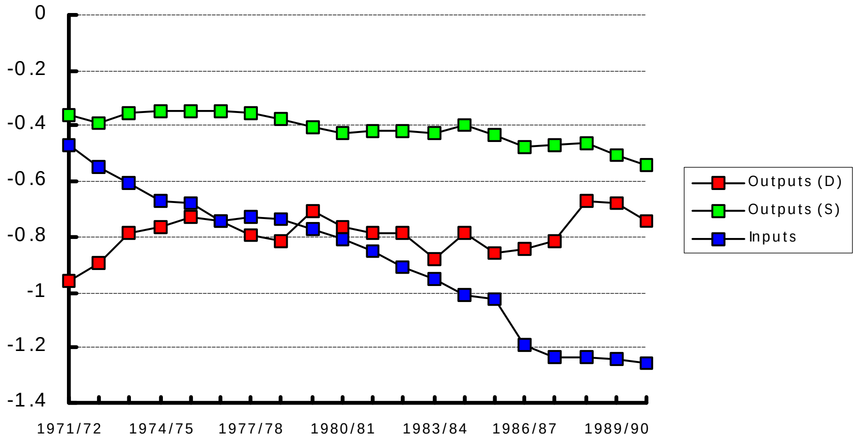

Figure 6 Input and output indices for Western Australia

Analysis of variations in total factor productivity

Possible sources of variation

Although the gross measures of TFP are useful indicators of the overall annual performance of each railway, a comparative assessment across time and railways must take into account the different operating environments. The differences between systems in TFP may be purely related to economies of scale and density, quality of management, suitable technologies, or composition of services.

Some of these sources of variation are under the control of the rail enterprise, while others may be under the control of government or simple dictates of market forces. Although some factors may be outside the enterprise's control, it is likely that enterprises can do much more to improve the input set required to service the two interpretations of output. The strength of competing modes can influence the drawing power of the railways, a factor which is clearly not directly related to inefficient use of inputs. However the railways, through union power and other factors, may have failed to adjust their input set in response to their market position. Future research needs to develop TFP in the context of a market equilibrium model or even a market disequilibrium model, possibly using switching regression (Greene 1990).

The residual component of gross TFP remaining after accounting for operating environment differences can be compared directly. If as we will see in our empirical work, the unexplained component is very small, we are in a good position to understand what features of the operating environment are explaining significant variations in gross TFP, and the extent to which deviations from national "best practice" can be reduced by appropriate action. It is within this performance assessment portfolio (PAP) framework that TFP is most valuable as an operational tool for the railways, in contrast to its role as a monitoring and bargaining tool of regulators.

Modelling sources of variation

The set of TFP measures have been derived from a time-series-cross-section database. Data in this configuration have some specific characteristics which can if not handled properly cause misleading inference. In particular the data set is long enough in time to produce the possibility of different stochastic processes applying to different cross-section units (i.e. heteroscedasticity or unequal variances associated with the unobserved influences). The small number of cross-section units is not a serious concern. The application of ordinary least squares (OLS) regression is not typically valid. OLS treats the data as if it were a pooled set of independent observations with the classical statistical properties for the error variance-covariance matrix of constant variance and zero covariance between all pairs of observations (i.e. homoscedasticity).

In the assessment of sources of differences in gross TFP we evaluated a number of specifications for the error variance-covariance matrix. Commencing with (i) the OLS assumption of homoscedasticity, we then allow for (ii) the variances to vary across the railways (i.e. cross-sectional or railway-specific heteroscedasticity). Then (iii) we relax the entire error matrix set and allow for free correlation between the railways at a point in time together with the railway-specific heteroscedasticity. The only assumption imposed in (i)-(iii) is that (iv) the observations are uncorrelated over time. By allowing for one-lag autocorrelation which is either (v) invariant with each railway or (vi) allowed to vary across railways, we are able to evaluate important sources of model misspecification. The final set of models reported in Tables 3a and 3b are the outcome of evaluating nine combinations of error variance-covariance and autocorrelation. A log-linear specification of the TFP function is estimated, which is dual to a log-linear neo-classical total cost function (Freemand et al. 1987). The Lagrange multiplier (LM) test, asymptotically equivalent to the likelihood ratio test, is used to test the null hypothesis of homoscedasticity, using a chi-square critical value of 5 percent. Heteroscedastic models use a feasible generalised least squares estimator (Greene 1990).

Explanation of models

A number of final models are reported. It is not possible to include all the statistically significant variables associated with each generic source of variation in gross TFP in a single equation due to both degrees of freedom and high partial correlation. Given the sensitivity of the TFP index to the definition of output and the debate as to whether a supply side (TFPs) or demand side (TFPd) measure of output should be used (Applebaum and Berechman 1991, Hensher 1992), we report the findings using both measures.

The first TFPd model evaluates a number of management and technological effects. The hypothesis of homoscedasticity was rejected at 95% confidence on the LM test. Railway-specific autocorrelation, varying from 0.190 for Victorian rail to 0.76 for SA rail, has been accounted for. Ten technologies and eight management effects have a statistically significant influence in explaining the variation in gross TFP. The first TFPs model also found that the homoscedasticity hypothesis was rejected at 95% confidence; with the railway-specific autocorrelation varying from 0.74 for WA rail to 0.98 for Queensland rail.

Table 3a Explaining productivity variation

(Estimated parameters, with t-statistics in brackets)

Explanatory Variables	**TFPd (S2,R2)**	**TFPs (S2,R2)**
Constant	-0.2374	-0.0696
	(-8.70)	(-3.61)
Technology:		
Diesel main line locos (other than 81 class)	0.1325	
	(3.77)	
BL class diesel main line locos	0.1015	
	(1.65)	
Extra long flat freight wagons and containers	-0.0887	
	(-1.97)	
Other flat freight wagons and containers	0.1656	0.1979
	(4.93)	(5.62)
Permanent way: automated points and turnouts	0.1496	
	(4.41)	
Major extensions of electrification	0.0617	
	(1.33)	
Centralised Train Control signalling		0.0856
		(2.71)
Fibre optics		0.2024
		(5.25)
First generation double decked suburban trains		-0.2473
		(-8.82)
New electrification		0.0623
		(3.25)
Management:		
VIC: Planning services reformed as a Branch	-0.4567	
	(-8.35)	
QLD: Era of RG Read as Commissioner of Q' land Railways	0.1088	
	(1.39)	
QLD: Financial Assistance Act 1979	0.1875	
	(3.59)	
SA: ANRC full control over SA (nonurban) and Tasrail	0.1349	0.2148
	(3.07)	(4.58)
SA: Era of LE Marks as Chairman of ANRC	0.0949	
	(1.92)	
SA: Era of RM King as Managing Director of ANRC	0.1530	
	(2.47)	
WA: Era of WI McCullough as Commissioner of Westrail		0.3741
		(5.62)
WA: Era of Dr JI Gill as Commissioner of Westrail		0.5586
		(5.59)
Goodness of fit statistics:		
Lagrange Multiplier (S0, R.)	16.18	15.65
Critical value (.95)	12.59	12.59
Log-likelihood	57.26	75.86
OLS R-squared	0.92	0.85

Note: the LM test statistic is the value from the S0 model associated with the R-model selected above.
S2,R2: S2 = groupwise heteroscedastic and correlated; R2 = railway-specific autocorrelation

Table 3b Explaining productivity variation

(Estimated parameters, with t-statistics in brackets)

Explanatory Variables	**TFPd (S0,R2)**	**TFPs (S0,R2)**	**TFPd (S2,R2)**	**TFPs (S2,R1)**
Constant	-0.9588	-0.5211	-0.4790	-0.2278
	(-5.16)	(-2.78)	(-4.21)	(-1.38)
Output index	0.7272	0.0068		
	(6.44)	(0.03)		
Freight revenue share	0.4963	0.3656		
	(1.88)	(1.52)		
Net tonne km per route km	-0.2183	-0.2396		
	(-2.59)	(-4.62)		
Year dummy variables:				
1972/73	0.0529	0.0284	0.1485	0.0343
	(1.99)	(1.20)	(1.54)	(0.25)
1973/74	0.1304	0.0948	0.3044	0.1036
	(3.22)	(2.69)	(2.23)	(0.61)
1974/75	0.1555	0.1148	0.3646	0.1222
	(3.83)	(3.27)	(2.64)	(0.71)
1975/76	0.1865	0.1323	0.4131	0.1624
	(4.60)	(3.69)	(3.02)	(0.95)
1976/77	0.2168	0.1579	0.4443	0.1868
	(5.33)	(4.36)	(3.23)	(1.09)
1977/78	0.2139	0.1592	0.4195	0.1943
	(5.29)	(4.38)	(3.07)	(1.14)
1978/79	0.2278	0.1680	0.4114	0.2087
	(5.62)	(4.54)	(2.99)	(1.22)
1979/80	0.2863	0.2027	0.5330	0.2106
	(6.82)	(5.18)	(3.89)	(1.23)
1980/81	0.3024	0.2098	0.5284	0.2277
	(7.24)	(5.20)	(3.84)	(1.33)
1981/82	0.3344	0.2415	0.5702	0.2558
	(7.94)	(6.01)	(4.16)	(1.50)
1982/83	0.3255	0.2355	0.5543	0.2489
	(7.72)	(5.67)	(4.03)	(1.44)
1983/84	0.3693	0.2564	0.6019	0.2499
	(8.63)	(5.96)	(4.39)	(1.46)
1984/85	0.4170	0.3208	0.7153	0.2136
	(9.39)	(7.26)	(5.21)	(1.25)
1985/86	0.4627	0.3622	0.7532	0.2035
	(10.02)	(8.06)	(5.49)	(1.19)
1986/87	0.5214	0.3889	0.8287	0.2435
	(11.06)	(7.73)	(6.03)	(1.42)
1987/88	0.5966	0.4314	0.9191	0.2679
	(12.07)	(7.98)	(6.70)	(1.57)
1988/89	0.6783	0.5157	1.009	0.3295
	(12.90)	(8.59)	(7.35)	(1.93)
1989/90	0.7522	0.5478	1.0682	0.3579
	(13.65)	(8.06)	(7.78)	(2.09)
1990/91	0.7708	0.5505	1.0527	0.3513
	(13.95)	(7.77)	(7.67)	(2.05)

Continued ...

Explanatory	**TFPd**	**TFPs**	**TFPd**	**TFPs**

Variables	(S0,R2)	(S0,R2)	(S2,R2)	(S2,R1)
Railway firm-specific dummy variables:				
Victoria	0.2898	0.1679		
	(3.83)	(2.36)		
Queensland	0.4168	0.1468		
	(6.20)	(1.58)		
Western Australia	0.9901	0.5736		
	(7.76)	(3.61)		
South Australia	0.9480	0.4286		
	(10.91)	(2.71)		
Goodness of fit statistics:				
Lagrange Multiplier (S0, R.)	7.76	6.29	25.03	25.92
Critical value (.95)	12.59	12.59	12.59	12.59
Log-likelihood	116.94	121.98	63.38	-201.57
OLS R-squared	0.97	0.96	0.30	0.091

Note: the LM test statistic is the value from the S0 model associated with the R-model selected above.
S2,R2: S2 = groupwise heteroscedastic and correlated; R2 = railway-specific autocorrelation
S0,R2: S0 = homoscedastic; R2 = railway-specific autocorrelation
S2,R1: S2 = groupwise heteroscedastic and correlated; R1 = common autocorrelation

Managerial change: The managerial variables identify some of the key players in the last 20 years whose involvement has had a statistically significant impact on the variations in gross TFP. This confirms the importance of good management practices: in particular, the major changes in Queensland following the appointment of R. Read as Commissioner in 1988/89; and a succession of initiatives with Australian National commencing with the formation of the Australian National Railways Commission in 1975/76 followed by their takeover of the South Australian Railways and Tasmanian Railways in 1978/79, and culminating with the appointment of L. Marks as Chairman in April 1981. A succession of initiatives with Westrail commenced with the appointment of W. McCullough with his mission to commercialise Westrail, which continued until his retirement in June 1988 and the succession by Dr J. Gill. McCullough's era as Commissioner of Westrail included a period of major top management changes between 1984/85 and 1987/88.

The management effect in SA has impacted primarily on the way inputs are used to “produce” market power, in contrast to the impact on efficient train kilometres in WA. AN and Westrail are seen as being leaders in better management practice associated primarily with good strategic and corporate planning, generally good relations with government and the unions, successful computerisation, a strong commercial orientation and sound cost practices. The attempts to improve performance by reform of planning services in Victoria in 1975/76 appears to have contributed in a negative way to TFPd.

Technological change: The impact of technological change comes through strongest in major developments in signalling, electrification, the introduction of automation to various track related activities, fibre optic development, and the incremental technological improvements in rail wagon and carriage design. The positive sign for the impact of electrification associated with TFPd accords with the view that it has had a “sparks effect” on patronage and freight. Major electrification occurred in extensions of metropolitan systems: from Sutherland to Waterfall in NSW in 1979/80; from Dandenong to Packenam in Victoria in 1974/75, and from Gladstone to Blackwater in Queensland in 1986/87. Complete lines were introduced such as the Eastern Suburbs railway in Sydney (1978/79), the Melbourne Underground Loop (1980/81) and the first section of the Brisbane suburban system (1979/80). Further discussion of the role of technology is given in Hensher et al. (1992).

Average growth rates: The last two columns of Table 3b are the results with only a constant and time-specific dummy variables (with 1972 set to zero). For TFPs the selected model is S2R1 in contrast to the majority of models being S2R2. The assumption of common autocorrelation between the five railways is valid in this instance, with all correlations in the range 0.948 to 0.999. The year-specific dummy variable estimates represent the deviations of the natural logarithm of TFP, averaged over all railways, from the 1971/72 logarithm of TFP. The average annual rate of growth during the 20 year period is 4.758% for TFPd and 1.668% for TFPs. After accounting for the level of output, the composition of output (approximated by revenue shares), the average rate of growth of TFP during the time period 1971/72-1990/91 changed from 4.758% to 3.778% for TFPd and from 1.668% to 2.74% for TFPs. This increase for TFPs is counter-intuitive and arises because of the different treatment of autocorrelation. If we compare the (S0,R2) models for TFPs we find that the average annual rate of growth decreases from 1.66% to 1.47%. Thus one has to be careful in comparisons where there is evidence of differences in autocorrelation between model specifications.

The inclusion of the output scale, composition and network effects for TFPs affects the profile of autocorrelation such that the railway-specific correlation changes from approximately constant (S2,R1) to a variation from 0.79 to 0.98 (S2,R2). This variation is attributable to Westrail; the other operators have autocorrelations varying from 0.959 to 0.981. The 3.778% figure can be compared to the 2.4% figure for Canadian National and Canadian Pacific (Freeman et al. 1987, 193). The average based on the annual changes calculated from the TFP index data as distinct from the models in Tables 3a and 3b are 5.1% for TFPd and 1.92% for TFPs. There is however substantial variation in the annual growth rates.

Density effects: The first set of models in Table 3b include the time-period dummy variable, firm-specific effects and the scale, composition and network effects. Net tonne kilometres of freight per route kilometre is used as our best proxy for the density of traffic over the network, provided we assume that the average train weight has increased imperceptibly over time. Full details justifying this measure are set out in Hensher et al. (1992). A useful distinction is made between economies of scale and economies of density. The latter occurs if unit costs fall when output growth is within a network, in contrast scale economies occurs when output growth is due to expansion of the network. Under the demand-side definition of output, we have evidence of economies of density of 3.67, in contrast to zero economies of density (=1.0067) for the TFPs specification. The negative and significant sign for net tonne kilometres per route km suggests that TFP is lower when the same level of output is served in a larger network. There are strong overall scale economies (= 2.04) for TFPd and diseconomies of scale (=.8112) for TFPs. The latter tells us that the railways on average have been securing additional train kilometres at the expense of proportionally higher input costs. In contrast additional passenger and freight traffic has on average been obtained for a smaller proportional increase in input costs. This highlights the importance of the definition of output and the problems in comparing studies with alternative definitions of output.

Firm specific effects: The firm-specific effects are revealing. Relative to the State Rail Authority of NSW (with TFP set equal to 1), for TFPd, Victoria = 1.34, Queensland = 1.52, West Australia = 2.69 and South Australia = 2.59. These results, based on a model which excludes the management and technology effects identified in the two models reported in Table 3a, confirm the important contribution of management in the relative success of Westrail and Australian National in particular. The five TFP firm-specific residuals represent a purer measure of economic efficiency after netting out the effects of scale, composition of output, and network characteristic. We further investigated the impact of disequilibrium in the capital stock, and found evidence of excess capital. The high partial correlation between capital stock and output d (r = .76), output s (r = .92) and net tonne kms per route km (r = .83) prevented inclusion of a capital stock variable in the models in Tables 3a and 3b. In the absence of these three effects, the capital stock variable is statistically significant and negative, suggesting over-capitalisation.

Conclusions

The empirical assessment of the productivity of all Australian rail systems has highlighted the usefulness of a single composite index for establishing a benchmark of "best national practice". Furthermore, by isolating the sources of variation in the gross measure of total factor productivity, we have been able to identify the extent of difference remaining in the residual or "pure" measure of productive efficiency. Allowance for differences in scale, density, output composition and excess capital still produces discernible differences in the relative productivity of different railways; however a significant amount of the remaining difference can be explained by particular innovations in technology and management practices. Most notably, there is strong evidence that Australian National in particular and to a lesser extent Westrail and Queensland Rail have benefited substantially by good management direction, giving these railways a productive edge over the other rail systems. AN however has the luxury of no urban passenger services. All the other systems service both urban and non-urban passenger markets in addition to the freight sector.

In the last two years however NSW State Rail has started showing signs of exemplary gross TFP annual growth rates, albeit from a relatively poor productivity base. At the same time however gross TFP annual growth rates for Westrail and AN, the best performers in the last 20 years, have deteriorated. For example, in 1990/91, State Rail had growth rates of 4.67% for TFPd and 6.26% for TFPs, in contrast to AN of -1.33% and 0.16% respectively, and for Westrail of -5.54% and -2.13% respectively. After allowing for the relativities with respect to management, technology, scale and composition, this places NSW in an encouraging position in respect of net TFP growth. The "Ross Sayers" effect, shorthand for the NSW government's appointment of Ross

Sayers as Chief Executive and the reformation of State Rail, may just be starting to have a positive impact.

The continuing research program is developing a more disaggregated set of inputs and outputs as well as evaluating alternative ways of measuring the rail network to incorporate both its size and shape. In addition, we are developing an empirical capability for estimating a total cost function in order to derive alternative weights for output (notably replacing the revenue share weights with a cost elasticity with respect to output weight), and to include deviations from marginal cost pricing, shadow pricing of inputs (Brunker 1992), and regulatory constraints on fare setting. Given the growing importance of productivity measurement for both improved decision-making within the rail enterprises and for ongoing monitoring of performance by regulators, the importance of the topic is only now beginning to be appreciated fully.

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