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An Assessment of the Performance of Australian Railways, 1990 to 1998

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Preface

This report is a supplement to the Productivity Commission's inquiry report *Progress in Rail Reform* (Report No. 6, 5 August 1999). It is designed to provide technical information about the research undertaken to assess the performance of Australian railways over the period 1990 to 1998. The Commission's Act requires transparency with regard to its research and modelling work. Two technical workshops (December 1998, February 1999) and a public workshop (April 1999) were held to discuss the analysis presented here.

The report was researched and written by Chris Chan, Tendai Gregan, Kim Gusberti, Melvino Mangolini, Soynia Salerian, Alexandra Strzelecki, Steven Wright and Yimin Zhao. The project was led by Patrick Jomini, Deborah Peterson and John Salerian.

The Commission wishes to acknowledge the comments from two independent referees, Dr Joseph Hirschberg of the University of Melbourne and Mr Steve Meyrick of Meyrick and Associates Pty Ltd, and a consultant, Dr Richard Morey of Richard C. Morey Consultants Inc. The referees' reports are reproduced in appendix F. The referees are not responsible for any remaining errors or omissions. Helpful comments and suggestions were also provided by Helen Owens (Presiding Commissioner), Professor Derek Scrafton (Associate Commissioner) and Associate Professor Keith Trace.

This study would not have been possible without the cooperation of participants to the inquiry within the rail industry, both in Australia and other countries. The Commission would like to thank all those who generously provided information.

Introduction

This study supports the Productivity Commission's inquiry into progress in rail reform (PC 1999). Its purpose is to provide an assessment of the economic performance of rail transport in Australia within a broad international context.

The Commission, as part of its inquiry, was required to undertake a stocktake of reforms implemented in the rail industry since 1991. The measurement of performance was conducted with a view to evaluating the outcomes of reform and identifying impediments to achieving best practice performance. Details of the data and analysis underpinning the measurement of performance are provided in this paper.

A broad approach to measuring the performance of Australian railways is adopted, encompassing the measurement of productivity as well as outcomes for stakeholders.

Productivity is measured using the data envelopment analysis technique.[1] In order to obtain robust estimates of productivity levels and growth rates, five models are estimated, each with different coverage in terms of the countries and services included. Comparisons are made at two levels: one comparing the productivity of Australian government-owned railways in providing freight services to that of North American railways; and the other comparing the productivity of national rail systems in providing both freight and passenger services for Australia and other countries.

Outcomes for three groups of stakeholders — consumers, shareholders and labour — are examined to investigate how changes in productivity have been distributed among each group. Outcomes have been measured in terms of prices and service quality for consumers, returns for shareholders and remuneration for labour.

Chapter 1 discusses the analytical framework adopted, while chapter 2 outlines issues relating to data collection and availability. Chapter 3 presents an analysis of the productivity of railways in both Australia and other countries and chapter 4

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[1] The data set used in the data envelopment analysis is available on the Productivity Commission's web site.

presents an analysis of performance outcomes for stakeholders. Chapter 5 presents an overall assessment of performance.

A number of appendices support the analysis provided in the chapters. Appendix A discusses the principles of data envelopment analysis. Appendix B discusses the robustness of the results presented in chapter 3. Appendix C describes railway characteristics. Appendix D compares productivity results from this study with those of other studies. Appendix E presents the complete set of productivity results for this study and appendix F contains the reports of the independent reference panel.

1 The Commission’s approach

The purpose of assessing the performance of Australian railways is to shed light on the impact of rail industry reform on performance and to identify the scope for improvement. The inclusion of international comparisons provides an insight into best practice performance and the extent to which this is attainable in Australia.

However, there are limitations on the extent to which assessments of performance can be used to make judgments about the impact of reform and potential for improvement. The attribution of changes in performance to specific reforms is difficult because there are other factors simultaneously affecting performance. The degree of comparability between railways can affect how differences in performance are interpreted, particularly in international comparisons. Further, the availability and quality of data limit the scope and depth of analysis possible.

For these reasons, performance indicators should be treated as broadly indicative rather than as precise measures of performance. The apparent link between performance and reform should also be interpreted cautiously.

1.1 The framework for analysis

The performance of railways in Australia has been the subject of many studies. Most have focused on productivity (or efficiency) and others have focused on financial performance (appendix D). The framework for analysis adopted in this study differs from most other studies in two key respects:

- it focuses on ‘systemwide’ performance rather than the performance of individual rail operations (such as track provision or train operation); and
- it assesses performance in terms of both productivity and stakeholder outcomes.

Several earlier studies also advocate a broader approach to performance assessment (Freebairn 1986; Salerian 1993; Waters 1998; Waters and Tretheway 1999).

Systemwide performance

From a policy perspective, rail system performance is generally more informative than the performance of individual organisations within a rail system.

A single operation is often only one component of a rail system. Rail systems include both above track and below track operations, and may comprise several independent and competing operators — depending on the structure and coverage of the system.

Policy makers and managers of rail organisations have different interests and require different information. Managers are typically interested in performance at an operational level, seeking to improve the technical efficiency of their operation(s). Policy makers are primarily interested in performance at an aggregate level, seeking to improve the performance of the industry as a whole.

Rail system performance is also more likely to be indicative of the merit of rail reform. Government policy is one of an array of factors that simultaneously affect performance. The commercial success or failure of individual rail operations will vary according to all or many of these factors over time. At any one point in time the best and worst performers coexist within a system. Assessing system performance is a way of netting out some of these variations to reveal the underlying (or average) performance of the rail system as a whole.

The effects of structural change that may occur within the rail industry over time are also internalised within a system. The separation or transfer of rail activities within a system can radically alter the measured performance of individual operations. For example, the mix of freight carried among railways could change, or the below track operations of an integrated railway could be separated from its above track operations. The effects of such changes are automatically captured within a systemwide assessment.

Another advantage of the system approach is that it overcomes the problem of allocating shared inputs between rail organisations. A sharing of inputs such as track can distort measured performance, to the extent that inputs are arbitrarily allocated for performance measurement purposes.

Until recently, all state-based rail systems in Australia consisted of one rail organisation (chapter 2, section 2.1). For this reason, state-based rail systems are referred to in this study as ‘railways’. The term ‘national rail system’ is used to refer to the aggregation of all railways in a country.

Productivity and stakeholder outcomes

The assessment of performance in this study is based on the relationship between two key facets:

- *productivity* which refers to the quantity of inputs required to produce a given quantity (and quality) of outputs. Changes in the ratio of outputs to inputs imply a change in productivity (chapter 3); and
- *stakeholder outcomes* which refers to the prices of rail inputs and outputs, such as freight rates, returns to capital and wage rates. Changes in these prices imply changes in outcomes for stakeholders (chapter 4).

Changes in productivity are distributed among stakeholders through changes in the prices or quality of inputs and outputs. This can be explained with a simple diagram, which links productivity to the prices of inputs and outputs (figure 1.1).

There are three main groups of rail stakeholders[1]:

- consumers — users of freight services, urban and non-urban passengers;
- shareholders — government and private owners of railways; and
- labour — people employed in railways.

Associated with these groups are three price variables and one quality variable[2]:

- prices of rail services paid by consumers;
- quality of rail services purchased by consumers;
- returns earned by shareholders; and
- wages paid to labour.

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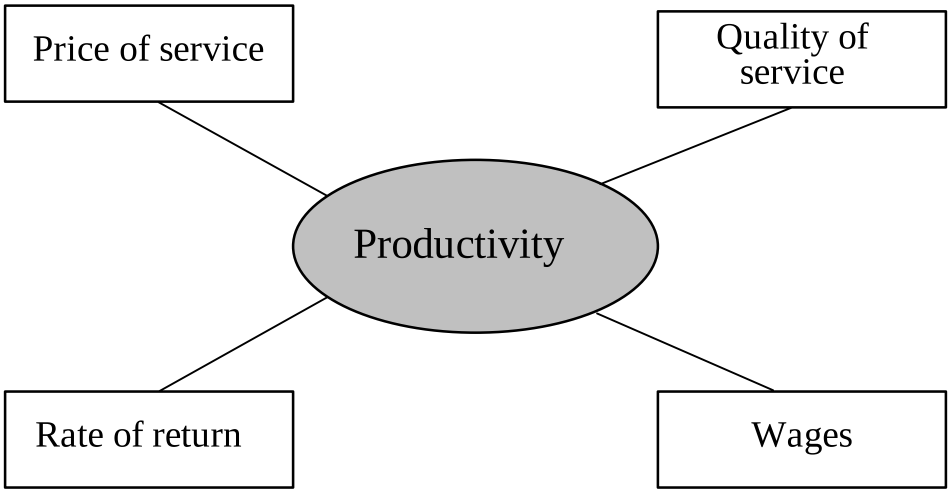
[1] The framework adopted in this study is essentially a partial equilibrium analysis and does not assess the economywide implications of rail industry performance. For this reason stakeholder groups outside the rail industry, (such as the wider community and other transport industries) which may also be affected by the performance of rail, are excluded.

[2] A ‘quality’ variable is also relevant to labour to represent factors such as ‘conditions of employment’ for example. However, in this study quality is incorporated only in relation to consumers.

Figure 1.1 **The relationship between productivity and prices**



Source: Salerian (1993).

A productivity gain (or loss) must be appropriated by one or more of the stakeholder groups, and can be shared any number of ways. Gains (or losses) may flow to consumers through a reduction (increase) in service prices, they may also flow to labour and shareholders through an increase (reduction) in wages and return on capital, or a combination of all. For example, a railway with increasing productivity may reduce freight rates, increase employee wages, and increase its profits and pay its shareholders a larger dividend.

Quality allows for the fact that changes in productivity may also be partially or totally absorbed by a change in the quality of output. For example, a railway may use the freed-up resources arising from an increase in productivity to improve the quality of its freight services — rather than reducing freight rates or increasing employee wages.

This relationship can be examined more formally using a simple unifying identity (box 1.1). This identity brings together the quantities and prices of inputs and outputs. It equates total revenue with total cost (assuming return on capital is the balancing variable). This equivalence enables changes in quantities and prices to be mapped out precisely.

Box 1.1 **The distribution of productivity gains**

Consider a firm which produces a single output with two inputs, where Q represents output, L labour and K capital. P_Q is the output price, P_L the wage rate, and P_K the return on capital.

Since total revenue equals total costs (assuming P_K is the residual balancing item), the identity can be expressed as follows:

$$P_Q \times Q = P_L \times L + P_K \times K$$

This expression can be generalised to accommodate any number of outputs and inputs.

Consider the case where the firm achieves an increase in productivity, that is, increased output for unchanged levels of inputs. In this case, one or more of the price variables must change to re-establish equality. There are several possibilities. The entire productivity gain may flow to a reduction in the output price with input prices remaining unchanged, or higher returns to labour and capital while the price of output remains constant, or a combination of these.

Source: Freebairn (1986).

Non-productivity factors affecting stakeholder outcomes

Changes in productivity are an important source of change in stakeholder outcomes and are the focus of this study. However, changes in input and output prices can occur independently of changes in productivity. In the absence of changes in productivity, changes in price for one group of stakeholders must be offset by changes in the price variable(s) for other groups.

Non-productivity sources of change include market and regulatory factors. Market factors include prices in input markets and prices in other goods markets. For example, a fall in road freight prices may induce railways to reduce the price of rail services, which would amount to a transfer from railway shareholders to rail service consumers (holding all other prices and quantities constant). Regulatory factors include labour market regulation and the regulation of rates of return to government trading enterprises. For example, an increase in the dividend paid to government railway shareholders may be financed through higher rail service prices, amounting to a transfer from consumers to shareholders.

2 Data

The availability of data can limit the assessment of performance. Specifically, the quality and extensiveness of data influences the:

- time period of the assessment;
- techniques used to measure productivity and stakeholder outcomes — such as data envelopment analysis (DEA);
- number (and appropriateness) of comparators used;
- level of disaggregation possible and therefore the 'likeness' of comparisons — such as whether market segments (such as coal) are examined separately; and
- robustness of results — a larger sample tends to produce more robust results.

This chapter discusses the sources of data used in this study (section 2.1), as well as the limitations of analysis arising from data issues (section 2.2). It ends with an analysis of the comparability of rail systems (section 2.3).

2.1 Data sources

Given the broad focus of this study, no single published source satisfied the entire data requirement. Hence, various sources of data were sought to develop a comprehensive database. Some data were available from published sources, and some were collected specifically for this inquiry, from both local and international sources. The sources of data used are described below.

Australian data

The primary source of data on Australian railways was the Steering Committee on the National Performance Monitoring of Government Trading Enterprises (SCNPMGTE) which published *Government Trading Enterprises Performance Indicators* annually (SCNPMGTE various years). This source provided data for the period 1989-90 to 1996-97 for key output and input variables used in the productivity analysis (chapter 3), as well as the financial and quality data used in the stakeholder analysis (chapter 4).

To extend the period of analysis and obtain additional data to that published by the SCNPMGTE, four other data sources were used:

- a survey of government-owned railways conducted by the Commission;
- annual reports of government-owned railways;
- Hensher, Daniels and DeMellow (1992); and
- *Jane's World Railways* (Harris 1998, Allen 1992).

All government-owned Australian railways completed the survey. However, the information provided differed across railways. Some did not provide data disaggregated by service, while others did not provide data on certain variables, such as contracting out expenditure and fuel consumption.

Changes in the structure of Australia's railways further complicated the compilation of data. For most of the period of analysis, Australian railways were made up of a single organisation managing both above and below track operations to provide a combination of freight, urban passenger and non-urban passenger services in its jurisdiction (section 2.2). However, changes in structure and ownership over the period have resulted in three main exceptions.

- In 1993 National Rail Corporation (NRC) commenced a progressive take-up of interstate freight business from Australian National (AN), State Rail Authority of New South Wales (SRA), Public Transport Corporation (PTC), Queensland Rail (QR) and Westrail. This transfer of freight business to NRC caused a discontinuity in the data series of these railways between 1994-95 and 1995-96.
- In 1996-97 SRA was separated into four rail organisations — Rail Access Corporation, FreightCorp, Rail Services Australia and a new SRA. Data for SRA include the operations of these four organisations in 1996-97 and 1997-98.
- In 1996-97 V/Line Freight was separated from PTC, followed by the Victorian Rail Track Access Corporation (VicTrack) in 1997-98. Data for PTC include the operations of these organisations in 1996-97 and 1997-98.

International data

International data were available for major rail systems in the United States, Canada, Japan, South Africa, New Zealand, and 16 European countries. Some of these rail systems are made up of more than one organisation. Some organisations provide a single rail service (that is, only freight services or passenger services) and some manage a single rail function (that is, a below track or above track operation). The national rail systems in this study are the combined major freight and passenger operations in each country (section 2.2).

International data were compiled from a number of sources. The main source of US freight system data was the Association of American Railroads publication *Analysis of Class I Railroads* (AAR various years). Data were not available for Class II freight railways.

The Statistics Canada publication *Rail in Canada* (Statistics Canada various years) was the main source of Canadian data. This provided data on freight (Class I, II and III), as well as non-urban passenger (VIA Rail) railways. Class II and III freight data were only available at the national level (aggregated for all Class II and III railways). Data provided by the World Bank were used for the period before 1990.

A Productivity Commission survey of major rail service providers was the main source of data for New Zealand, South Africa, Japan (passenger) and the US non-urban passenger system (Amtrak). Railways in other countries were surveyed but appropriate data were not provided.

The International Union of Railways (UIC) publications *Chronological Railway Statistics 1979-1996* (UIC 1998a) and *International Railway Statistics 1997* (UIC 1998b) provided data for the 16 European countries included in the study. These publications also supplemented the survey information received from Japan.[1]

Data gaps and inconsistencies

Despite the extensive list of sources used to compile the database, a number of data gaps and inconsistencies remain, limiting the scope of this performance assessment. Ideally, the assessment would include all rail services within Australia and a range of 'like' rail services from a large sample of countries, and include the most recent data for all comparators. Such a comprehensive and up-to-date assessment was not possible. In particular:

- data on prices and costs of some outputs and inputs were not available;
- data on Australia's private railways were not available;
- reliable data for some inputs, such as energy, contracting out, wages and salaries, and locomotive power, were not available for many railways;
- data on Class II and III railways in the United States were not available;
- data were not sufficiently disaggregated by rail service (freight, urban and non-urban passenger) or market segment (classes of freight) for most railways; and
- data on national rail systems were not available beyond 1997.

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[1] In some cases, data gaps and inconsistencies encountered in the data sources listed above were supplemented with information from *Jane's World Railways* (Harris 1998).

2.2 Countries and agencies included in the study

The database includes all government-owned railways in Australia and 21 international rail systems (private and public), providing freight and passenger services.[2] Australian railways are assessed from 1989-90 to 1997-98 and national systems from 1990 to 1997. Tables 2.1, 2.2 and 2.3 below list the countries and railways included in the study.

Table 2.1 **Government-owned Australian railways included in this study, 1989-90 to 1997-98[a]**

Railway	*Jurisdiction*	*Services provided*	*No. of rail organisations[b]*
Australian National Railways Commission & National Rail Corporation (AN–NRC)[c]	Countrywide	Freight Non-urban passenger	2
Public Transport Corporation (PTC)[d]	Victoria	Freight Urban passenger Non-urban passenger	3
Queensland Rail (QR)	Queensland	Freight Urban passenger Non-urban passenger	1
State Rail Authority of New South Wales (SRA)[e]	New South Wales	Freight Urban passenger Non-urban passenger	4
TransAdelaide (TA)	South Australia	Urban passenger	1
Westrail (WR)	Western Australia	Freight Urban passenger Non-urban passenger	1

[a] The Australian railways included were all government-owned during the period of analysis; private railways were not included. [b] The number of rail organisations (below and above track) which comprised the system in 1997-98. [c] AN provided Tasmania and South Australia with intrastate freight rail services until November 1997. NRC was established in 1991 to take over interstate freight business from AN, SRA, PTC, QR and Westrail. By 1997-98 all remaining AN operations had been privatised. [d] In 1996-97, V/Line Freight was separated from the PTC followed by VicTrack the following year. [e] Until July 1997, all rail passenger and freight services were provided by the vertically integrated SRA, after which time SRA was separated into Rail Access Corporation, FreightCorp, Rail Services Australia and a new SRA.

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[2] The smaller railways operating in some countries were not included in the assessment. However the major railways which are included serve over 70 per cent of the total route length in their countries and are representative of the rail sector in these countries (Harris 1998). Urban passenger railways in Canada and the United States are not included.

Table 2.2 International rail systems included in this study, 1990 to 1997[a]

Country	*Railways*	*Services provided* [b]	*No. of rail organisations*[c]
Systems comprised of one organisation			
Austria	Österreichische Bundesbahnen	All	1
Belgium	Société Nationale des Chemins de fer Belges	All	1
Canada	VIA Rail Canada Inc	Non-urban passenger	1
Denmark	Danske Statsbaner	All	1
Finland	VR-Yhtmä Oy	All	1
Germany	Deutsche Bahn AG	All	1
Ireland	Iarnrod Eireann	All	1
Italy	Ferrovie dello Stato	All	1
Luxembourg	Société Nationale des Chemins de fer Luxembourgeois	All	1
Netherlands	NV Nederlandse Spoorwegen	All	1
New Zealand	Tranz Rail	All	1
Norway	Norges Statsbaner BA	All	1
Spain	Red Nacional de los Ferrocarriles Españoles	All	1
United States	Amtrak	Non-urban passenger	1
Systems comprised of more than one organisation			
France	Société Nationale des Chemins de fer Français & Réseau Ferré de France	All	2
Great Britain	British Rail & Railtrack	All	2
Portugal	Rede Ferroviaria Nacional, E.P. & Caminhos de Ferro Portugueses, E.P.	All	2
South Africa	Spoornet & South African Rail Commuter Corporation	All	2
Sweden	Statens Järnvägar & Banverket	All	2
Switzerland	BLS Lötschbergbahn AG & Schweizerische Bundesbahnen	All	2
Japan	JR passenger services (6 orgs) & JR Freight	All	7
United States[d]	Class I freight	Freight	9
Canada[d]	Class I, II, III freight	Freight	36

[a] International rail systems represent the major freight and passenger railways in each country. [b] 'All' means that freight, urban passenger and non-urban passenger services are provided by the system. The distinction between urban and non-urban passenger services in many other countries is not as clear as in Australia. In some countries, some commuter traffic is actually intercity rather than intracity. [c] The number of rail organisations (below and above track) that comprised the system at the end of the sample period: 1997 for all systems (except for Great Britain and Denmark for which data were only available until 1994 and 1995 respectively, and New Zealand and South Africa where data were available until 1998). [d] Table 2.3 provides a list of the North American freight railways included in the performance assessment.

Table 2.3 **North American freight railways included in this study, 1990 to 1997[a]**

Railway	*Jurisdiction*[b]
Burlington Northern Santa Fe Railway Company (BNSF)	United States – western district
Canadian Class II and III[c]	Canada – countrywide
Canadian National (CN)	Canada – countrywide
Canadian Pacific (CP)	Canada – countrywide
Consolidated Rail Corporation (CR)	United States – eastern district
CSX Transportation (CSX)	United States – eastern district
Grand Trunk Western Inc (GTW)	United States – eastern district
Illinois Central Railroad Company (ICR)	United States – eastern district
Kansas City Southern Corporation (KCS)	United States – western district
Norfolk Southern Corporation (NSC)	United States – eastern district
Soo Line Railroad Company (SOO)	United States – western district
Union Pacific Railroad Company (UP)	United States – western district

[a] List of companies at the end of the sample period (1997). [b] The western and eastern district distinction for the United States is based on AAR classifications. Some railways in Canada and the United States also conduct transnational operations. [c] These railways are included as a group, not individually.

2.3 Comparability of railways

The performance of railways is influenced by many factors. Some of these factors are controllable from the perspective of railway managers, such as the mix of inputs used and production process(es) adopted. However many factors, relating to a railway's operating environment are non-controllable.

These factors include demography, geography, resource endowments, income, price of inputs, government policy parameters such as labour market regulation and competition policy, the technical characteristics of rail infrastructure and characteristics of other transport industries.[3] Indicators of some of these characteristics (by country) are provided in table 2.4.

The operating environment can constrain the level of efficiency achievable by railways. For instance, the economies of scale achieved by rail freight operations in North America (by virtue of the size of the markets in which they operate) are simply not attainable in Europe. Aspects of the operating environment that limit the potential performance of railways are discussed below.

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[3] What constitutes a non-controllable factor may vary across railways. For example, for some railways, the quality of track infrastructure is a given and out of the control of railway managers, while for other railways, track infrastructure is another input over which they have control.

Table 2.4 Selected aspects of the operating environment which affect railway performance, by country 1997[a]

Country	*Area* *('000 sq km)*	*Average haul length* *(km)*	*Average trip length* *(km)*	*Population* *(million)*	*Population density* *(inhabitant per sq km)*	*GDP per Inhabitant* *(US$ 1995)*	*Freight output* *(billion ntkm)*	*Freight density* *('000 train km per track km)*	*Passenger output* *(billion pass-km)*	*Passenger density* *('000 train km per track km)*	*Government payments to rail* [b] *(% of revenue)*
Australia	7682.3	281	21	18.3	2.4	20527	66.9	1.8	9.9	2.2	24.4
United States	9372.6	1380	412	267.9	28.6	27471	1984.2	3.2	8.3	0.2	1.1
Canada	9976.1	966	369	30.0	3.0	19370	308.5	1.6	1.5	0.3	4.0
Japan	378.0	509	28	124.1	328.3	42453	24.3	4.1	247.7	34.6	0.0
New Zealand	269.0	304	na	3.7	13.8	16641	3.5	na	0.4	na	3.8
South Africa	1233.0	556	16	39.9	32.4	3456	103.9	na	12.6	1.0	10.5
Austria	83.9	198	44	8.1	96.2	29202	13.8	7.0	8.1	15.2	16.0
Belgium	30.5	127	49	10.2	333.3	27289	7.5	5.1	7.0	21.2	12.0
Denmark	43.1	195	35	5.3	122.5	35583	1.6	3.1	5.0	22.7	na
Finland	338.1	244	68	5.1	15.2	25376	9.9	2.8	3.4	10.9	5.4
France	547.0	398	77	58.6	107.1	26692	52.6	4.9	61.6	4.6	10.9
Germany	357.0	245	44	82.1	229.9	29869	72.4	5.0	59.6	16.8	0.0
Great Britain	244.0	166	40	58.8	240.9	19263	16.9	2.2	34.2	22.3	na
Ireland	70.3	179	47	3.6	51.5	19301	0.5	2.4	1.4	5.8	na
Italy	301.2	306	107	57.5	191.0	19086	22.9	4.3	49.5	16.0	33.7
Luxembourg	2.6	35	26	0.4	161.6	42875	0.7	3.8	0.3	22.2	na
Netherlands	41.5	149	46	15.6	375.7	26458	3.4	3.0	14.4	40.2	34.3
Norway	387.0	459	57	4.4	11.4	35294	3.0	2.4	2.6	6.8	20.4
Portugal	92.1	241	26	9.9	107.7	10877	2.2	3.5	4.6	15.4	9.4
Spain	504.8	439	42	39.3	77.9	14576	11.0	3.3	16.6	10.2	13.7
Sweden	450.0	337	60	8.9	19.7	26488	18.1	3.5	6.3	6.4	19.4
Switzerland	41.3	181	47	7.1	172.2	43438	8.5	8.2	12.8	28.5	11.7

[a] 1996 for Area, Population, Population density and GDP per inhabitant. All other data are for 1994 for Great Britain and 1995 for Denmark. [b] All government payments to passenger and freight operations made in 1997. The definition of total government payments is not consistent across all countries. **na** Not available.

Source: Commission estimates; UIC (1998c); *World Bank World Tables*, dX for Windows, Table T.02, Econdata, 28 July 1999.

Size of the market

Railways operating in larger markets may have an advantage over those in smaller markets. The advantage arises from scale economies[4]. The size of a railway's market is ultimately determined by a country's production capacity and population size.

At the country level, Australia's freight market is large compared to that in most European countries but small compared to that in North America. By contrast, Australia's passenger market is similar in size to the United States and Canada, but small compared to most European countries. Japan has by far the largest passenger market of the countries studied. Within Australia, railways in different jurisdictions operate in different sized freight and passenger markets (appendix C, table C.1).

Composition of traffic

The cost structure of a rail operation is influenced in part by the mix of traffic being transported. Freight and passenger services tend to have inherently different cost structures. This also applies to the mix of traffic within freight and passenger services. The transportation of bulk freight tends to be less costly (per net tonne-kilometre) than the transportation of non-bulk freight. Similarly, commuter travel services tend to be less costly to provide (per passenger-kilometre) than luxury (tourist) travel services. The composition of traffic is influenced by factors such as a country's resource base and the availability of alternative modes of transport.

At the country level Australia's rail traffic is dominated by freight, and within freight, by bulk freight. This is broadly similar to the United States, Canada and South Africa, but vastly different to Japan and most European countries, which carry a greater proportion of passengers and non-bulk freight. Within Australia, traffic mix varies significantly across jurisdictions.

Utilisation of inputs

Railways that use inputs (such as track infrastructure) more intensively may have an advantage over railways that use inputs less intensively. The advantage arises from economies of density[5]. The level of input utilisation is influenced by factors such as population density and the geographic concentration of a country's industries.

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[4] Where average unit costs fall as the size of the railway increases.

[5] Where average unit costs fall as the number of passengers or volume of freight on a particular route or network increases.

At the country level, Australia’s freight density (utilisation of track) is low compared to that in most countries in the study. A notable exception is Canada, which has a similar level of freight density to that in Australia. Australia’s passenger density is higher than that in the United States and Canada, but lower than that in most European countries. Japan has by far the highest passenger density level (of the countries studied). Within Australia, railways in different jurisdictions have different levels of freight and passenger density (appendix C, table C.1).

Average haul/trip length

The average haul/trip length of a rail operation in part influences its cost structure. Evidence suggests that longer hauls are more economical to operate than shorter hauls (BIE 1992, 1995). Fewer resources per kilometre travelled (including time) are required to load and unload freight and passengers. The average haul/trip length of a railway’s operations is influenced by factors such as a country’s urban sprawl, the geographic concentration of its industries and extensiveness of transport infrastructure.

At the country level Australia’s average haul length is comparable with that in some European countries and New Zealand, but significantly lower than that in North America, Japan and South Africa. The comparison is similar for average trip length. Within Australia, average haul/trip length varies significantly across railways in different jurisdictions.

Capacity of infrastructure

The cost structure of a rail operation is influenced in part by the capacity of rail infrastructure used. In particular, track can vary in its capacity to carry rail traffic in terms of both the weight carried and the speed at which trains travel. The gauge, curvature and gradient of track can limit the length of trains used, the axle load per wagon/car and the speed at which trains travel. The design characteristics of track infrastructure are influenced by factors such as geography and terrain, the source and level of investment in track (public or private)[6] and the extensiveness of a country’s transport network.

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[6] To the extent that governments are responsible for the level and type of rail infrastructure investment, railways have no control over ‘track’ as an input into their production process, and may therefore be limited by it. The cost of construction will also influence private owners of infrastructure.

At the country level, Australia's average freight load is low compared to that in North America but high compared to that in most European countries. By contrast Australia's average passenger load is of a similar level to that in the United States and most European countries, but smaller than that in South Africa and Japan (appendix C, table C.2).[7] The capacity of infrastructure varies across railways within Australia.

Level of government intervention

Government intervention can influence the performance of railways directly. This occurs when governments make decisions that affect the type and level of inputs used and the outputs produced by a railway. For example, community service obligations (CSOs) require railways to provide services that would not necessarily be provided in a commercial environment. This may not only affect the financial performance of railways but also may lower measured productivity to the extent that these services are more resource intensive to provide. Government intervention in rail depends on a country's (or jurisdiction's) broad policy environment and the nature and extent of rail industry reform.

The level of direct government intervention tends to be related to the level of government payments made to railways. Government payments, as a proportion of total railway revenue, are relatively high in Australia compared to most other countries studied. Within Australia, government payments vary significantly across services. At the extremes, urban passenger subsidies can be as high as 80 per cent of the cost of the service, while coal freight transportation is unsubsidised. Governments intervene more directly in the provision of urban passenger services, through pricing and service quality provisions (among other things), than they do in the unsubsidised coal freight services (PC 1999).

Characteristics of other transport industries

The characteristics of other transport industries can affect the performance of rail. To the extent that an integrated transport system improves performance, the performance of rail (as one component) would also improve. Efficient linkages between modes can save resources (including time and duplication of inputs) which would be shared between the service providers of each mode. The level of

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[7] In the absence of data on axle loads, average freight load (tonnes per train) and average passenger load (persons per train) were used as proxies for track capacity. Average load per train is not an ideal indicator because it measures actual loads carried, and not the load carrying capacity of infrastructure.

integration of a transport system is influenced largely by the political and institutional factors governing the transport industries within a country.

Conclusion

Given the diversity of railway operating environments within Australia and between Australia and other countries, the extent to which performance is affected by these factors is likely to vary considerably.

An assessment of the performance of railways requires consideration of these factors, especially when conclusions concerning relative performance are being drawn. A review of productivity measures by the UIC found that variations in railway operating environments confound comparisons of performance (UIC 1998c).

What is possible for one railway in terms of its performance may not be possible for another railway (operating in a different environment) to attain, regardless of the skill and expertise of its managers. Consideration of these factors may also serve to highlight where government policy may be an impediment to improvements in performance or an effective tool for bringing about improvements.

The implications for productivity measurement of some of these factors are discussed in appendix C.

3 Measurement of productivity

The productivity of Australian railways is measured and compared over time (from 1990 to 1998), relative to each other and relative to railways in other countries.

The quantitative techniques used to estimate productivity in this study are data envelopment analysis (DEA) and regression analysis. The term *productivity* (as it is used in this study) is commonly referred to as productive efficiency in the DEA literature.

Section 2.1 discusses concepts of efficiency, section 2.2 describes the use of DEA and its results and section 2.3 describes the use of regression analysis and its results.

3.1 Concepts of efficiency

Efficiency in production refers to the ability of a firm to transform inputs into outputs. A firm is deemed ‘efficient’ if it satisfies two conditions:

- A firm is *technically efficient* if it uses the least amount of inputs to produce a given level and quality of output(s). Technical inefficiency results from excessive use of inputs.
- A firm is *allocatively efficient* if it uses the least cost combinations of inputs to produce a given level and quality of output. Allocative inefficiency results from employing inputs in the wrong proportions.

While ideally it would be desirable to measure overall efficiency (a combination of technical and allocative efficiency) the focus of this study is on technical efficiency. There are two main reasons for this:

- in the long run, changes in technical efficiency tend to dominate changes in allocative efficiency (Oum, Waters and Yu 1999); and
- appropriate price data necessary for measuring allocative efficiency are often not readily available (appendix A, section A.2).[1]

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[1] In particular, appropriate capital rental prices are difficult to estimate.

Productivity and technical efficiency

Productivity is a gross concept that refers to the ratio of outputs to inputs. It is gross in the sense that it captures all sources of differences in the ratio of outputs to inputs, including economies of scale and technical efficiency.

In this study the term *technical efficiency* refers to productivity after accounting for the impact of differences in railway operating environments.[2] DEA is used to estimate the level of technical efficiency by netting out the effects of scale (section 3.2). Regression analysis is used to estimate technical efficiency by netting out the impact on productivity of an array of factors (section 3.3).

3.2 Data envelopment analysis

DEA estimates the productivity of the firm by comparing the ratio of aggregate outputs with aggregated inputs across firms (appendix A).

Many different partial measures of productivity can be used to compare a single output with a single input (such as labour productivity). They can be used to shed light on the possible sources of changes in productivity, revealing the extent to which the use of particular inputs might be driving productivity changes. However, because partial measures can be misleading, a comprehensive measure of productivity was selected (box 3.1).

Modelling approach

The DEA model approximates an unknown production frontier with a piecewise linear production frontier. For each of the railways being compared, a ‘comparable railway’ (or performance target) is created from a linear combination of relatively efficient railways. For instance, the benchmark railway which provides both freight and passenger services may be constructed by taking a weighted average of the best performing freight and passenger railways.

A number of DEA models using different samples are specified in this study. This allows the results of DEA to be validated and provides for a high level of robustness.

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[2] Any measure of technical efficiency will be impure to the extent that it does not account for all differences in railway operating environments (chapter 2, section 2.3).

Box 3.1 **The rationale for using DEA in this study**

DEA has been selected as the preferred technique for estimating productivity on both practical and theoretical grounds.

- It provides a comprehensive measure of productivity, taking into account key inputs and outputs involved in rail operations, in contrast to partial productivity indicators, such as labour productivity.
- It requires only quantity or engineering data on outputs and inputs and does not require price or financial data.
- It does not rely on the assumption of competitive markets and input and output prices to aggregate inputs and outputs, unlike most index number techniques.
- In an environment in which prices are often distorted by subsidies, shadow prices do not need to be calculated, avoiding a potential source of errors.
- It imposes few restrictions on the assumed production technology and uses data to reveal some of the characteristics of this technology, unlike econometric estimation in which a specific production function is assumed.
- It can represent a production process involving more than one output and does not require the construction of an aggregated index measure of output.
- It provides a means by which the effects of scale (and other factors relating to the operating environment) on estimated productivity, can be accounted for.

Source: Appendix A.

Sample stratification

Given the heterogeneity of railway operating environments, the notion of stratified sampling provides an appealing approach to selecting comparators from a sample of railways. In DEA railways tend to be compared to railways which have similar input structures (proportions) and output compositions (appendix C). For example, railways using relatively labour-intensive technology are typically assessed against a different performance target from those using a more capital-intensive technology. In a two-output DEA model, freight-oriented (passenger-oriented) railways tend to be compared to the best performers in the sample in terms of freight (passenger) services.

While the DEA model tends to take into account input structure and output composition, it typically cannot be determined whether the given sample constitutes an appropriate set of comparators for a particular railway. This is because it is unlikely that the DEA model has captured all non-trivial factors relating to the operating environment.[3]

Although sample stratification is a strength of DEA, it is also a potential weakness for small samples and many different inputs and outputs. DEA tends to consider each railway to be unique and assign it the maximum score of one. To overcome this limitation a relatively large sample size is required.

Sample coverage and model specification

DEA has been used to estimate productivity at two levels:

- individual railways for freight services only; and
- national rail systems for combined freight and passenger services.[4]

Sample coverage

Estimation of the productivity for freight services only includes railways providing freight services in Australia, the United States and Canada. The sample includes five government-owned railways operating in Australia, nine private Class I freight railways in the United States and two groups of railways (Class I and Class II & III freight railways) for Canada (chapter 2, section 2.2).

The national rail system analysis includes railways providing freight and passenger services in Australia, the United States, Canada, New Zealand, South Africa, Japan, and 16 European countries. Australia is represented by an aggregation of its five government-owned railways. The United States is represented by an aggregation of Class I freight railways and passenger services provided by Amtrak. Other countries are represented by their major rail service provider (or an aggregation of their rail service providers) (chapter 2, section 2.3).

Model specification

Five DEA models have been specified — two to estimate productivity at the railway level and three to estimate productivity at the national rail system level (table 3.1). Each model is identified in terms of output variables, controllable and non-

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[3] It would only be possible to determine the appropriateness of a railway's comparators for extremely large sample sizes and where data on all significant factors relating to railway operating environments were available.

[4] Passenger services include both urban and non-urban passenger services.

controllable input variables, countries included and the number of observations in the sample.

Table 3.1 **Model specification and data coverage**

	Model 1	*Model 2*	*Model 3*	*Model 4* [a]	*Model 5* [a]
Output variable					
Freight net tonne-kilometres	✓	✓	✓	✓	✓
Passenger-kilometres				✓	✓
Controllable Input variable					
Locomotives (freight)	✓	✓	✓		
Locomotives (freight and passenger)				✓	✓
Wagons	✓	✓	✓	✓	✓
Freight staff	✓	✓	✓		
Total staff				✓	✓
Railway cars and passenger coaches				✓	✓
Non-controllable input variable					
Track	✓	✓	✓	✓	✓
Unit of assessment					
Individual railway	✓	✓			
National rail system			✓	✓	✓
Countries covered					
Australia	✓	✓	✓	✓	✓
United States, Canada		✓	✓	✓	✓
Japan, New Zealand, South Africa, and 16 European countries					✓
Type of DEA model					
Type 1 (productivity)	✓	✓	✓	✓	✓
Type 2 (technical efficiency)	✓	✓	✓	✓	✓
Type 3 (productivity adjusted for locomotive power)	✓	✓			
Type 4 (technical efficiency adjusted for locomotive power)	✓	✓			
Total number of observations	45	141	25	25	174

[a] Includes major urban and non-urban passenger services.

Source: Appendix B.

Accounting for the effects of scale on productivity

DEA (as it is applied in this study) assumes that there are only two sources of productivity: technical efficiency and the effects of scale. In order to isolate the effects of scale, each model was estimated in two ways. The first measures the combined effects of technical efficiency and scale on productivity[5] and the second measures the effect of technical efficiency by netting out the effects of scale.[6]

Track as a fixed input

The DEA models used in this study treat track length as a non-controllable input from the perspective of railway management. This assumes that, unlike other inputs, track is not able to be scaled up or down to facilitate productivity improvements.

Omission of input variables

The DEA models used in this study do not incorporate inputs such as energy and contracted out services due to data limitations (chapter 2, section 2.1). Theoretically, omission of some inputs may over or understate the productivity of railways. For instance, by omitting contracted out services, the model does not account for substitution away from labour towards purchased services and may overstate productivity.

Locomotive power differences

Models 1 and 2 have been adjusted to account for and illustrate the effect of differences in locomotive power. Unadjusted model results use the number of locomotives as the input unit and adjusted model results use total locomotive power as the input unit. The unadjusted model effectively treats all locomotives as if they have the same power rating. This can lead to an error in the measurement of productivity. In this case, an overstatement of measured productivity if increases in locomotive power are not taken into account.

Adjusted results are a more accurate measure of productivity than unadjusted results. Due to data limitations only models 1 and 2 have been adjusted for locomotive power differences over the period (appendix B).

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[5] This method is often referred to as the CCR ratio model or the constant returns to scale model (Charnes, Cooper and Rhodes 1978, Charnes et al. 1994, Fried, Lovell and Schmidt, 1993 and SCRCSSP 1997).

[6] This method is often referred to as the BCC ratio model or the variable returns to scale model (Banker, Charnes and Cooper 1984, Charnes et al. 1994, Fried, Lovell and Schmidt, 1993 and SCRCSSP 1997).

Results

The robustness of results varies across models (and for comparators within models). The relative productivity estimates for some models are likely to be more robust than for others because of sensitivity to sample coverage and model specification (appendix B).[7] For example, the estimation of technical efficiency for small railways is constrained by the limited number of small railways in the sample.

The main results of the following models are discussed in this section:

- model 1 — estimating the relative productivity of Australian government-owned railways in providing freight services;
- model 2 — estimating the relative productivity of Australian government-owned railways and North American railways in providing freight services;
- model 5 — estimating the relative productivity of national rail systems in providing freight and passenger services.

The full results of all models are presented in appendix E.

Model 1

The average growth in productivity suggests that all Australian government-owned railways have experienced substantial productivity gains since 1990. For Australian government-owned railways as a whole, productivity increased by nearly 10 per cent per year over the period. A comparison of the growth in productivity with that of technical efficiency reveals that this model attributes improvement primarily to technical efficiency (and not the effects of scale), which averaged nearly 8 per cent a year over the period (table 3.2).

The results suggest that PTC and SRA are less efficient than the other railways in the sample. After adjusting for the effects of scale the results indicate that PTC is disadvantaged by the relatively small size of its freight operation. Its technical efficiency level is deemed best practice (compared to a productivity level of 36 per cent). After adjusting for the effects of scale, all railways, except SRA, were deemed technically efficient due to the model's low discriminatory power.[8]

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[7] Several procedures have been used to validate the efficiency estimates for Australian railways. First, results from models 1 through to 5 are examined for their sensitivity to sample coverage and model specification (appendix B). Second, the effects of potential data errors and model dimension on results are discussed (appendix A). Finally, the results of models 2 and 5 are compared to a number of other studies of railway productivity which use different data sets and modelling methods (appendix D).

[8] Each railway is deemed unique after adjusting for size and is therefore compared to itself.

Table 3.2 Estimates of relative productivity of Australian railways in providing freight services (model 1), 1989-90 to 1997-98

	Productivity				*Technical efficiency*			
	Level, 1997-98		*Average growth (%) 1989-90 to 1997-98*		*Level, 1997-98*		*Average growth (%) 1989-90 to 1997-98*	
	Locomotive numbers[a]	Locomotive power[b]	Locomotive numbers[a]	Locomotive power[b]	Locomotive numbers[a]	Locomotive power[b]	Locomotive numbers[a]	Locomotive power[b]
AN–NRC	1	1	10.8	5.7	1	1	10.2	5.1
PTC[c]	0.36	0.43	3.7	2.4	1	1	9.4	7.8
QR	1	1	10.9	8.3	1	1	7.5	5.7
SRA[c]	0.73	0.73	4.3	4.3	0.73	0.73	4.4	4.4
WR	1	1	12.8	9.4	1	1	8.9	6.7
Average[d]	*0.93*	*0.93*	*9.7*	*7.4*	*0.95*	*0.95*	*7.7*	*5.8*

a Locomotive inputs are measured as the number of locomotives used regardless of their power rating. **b** Locomotive inputs are measured in terms of their power to take account of differences in locomotive power ratings. **c** A discontinuity in the series of productivity levels occurring between 1994-95 and 1995-96 has lowered the productivity growth rate for SRA and PTC over the period, when a significant part of these railways' long haul general freight was transferred to NRC. **d** National average figures are obtained by weighting individual railways' scores by freight output (ntkm).

Source: Commission estimates.

Adjusting for differences in locomotive power does not alter productivity estimates for 1997-98, in all but one case. The PTC's level of productivity was revised upward from 36 per cent to 43 per cent because its locomotive fleet had the lowest power rating in the sample.[9]

Locomotive power adjusted results suggest that productivity growth rates are overstated when larger locomotives are used to replace smaller locomotives. The average power rating of locomotives used in Australia increased substantially since 1990.[10] In particular, NRC has installed a considerable number of new, state-of-the-art locomotives (NRC 1998). Large increases in the power of NRC's locomotive fleet have overstated measured productivity growth (based on locomotive numbers) by 5 percentage points over the period.

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[9] AN-NRC had the highest average power rating for locomotives in 1998 (estimated at 3500 horsepower), followed by SRA, Westrail (both at 2400), QR (2300), and PTC (2100). By comparison, the average power rating of US locomotives in 1997 was 3100 horsepower (appendix C).

[10] The average power rating of locomotives in Australia increased by over 40 per cent from 1990 to 1998 compared to 15 per cent in the United States from 1990 to 1997.

Model 2

The major freight railways in North America are considered by some to be world's best practice (BIE 1992). Adding North American railways to the sample of Australian government-owned railways is likely to increase the robustness of the results by increasing the discriminatory power of the model (appendix B).

In model 2, Burlington Northern and Santa Fe Railway Company (BNSF) and Canadian National Railway (CN) set the productivity frontier against which all other railways are compared. In this model, unlike model 1, Australian government-owned railways do not form part of the productivity frontier. As a result, productivity estimates are distributed more widely (table 3.3).

Table 3.3 **Estimates of relative productivity of Australian and North American railways in providing freight services (model 2)**[a]

	Productivity				*Technical efficiency*			
	Level, 1997-98		*Average growth (%) 1989-90 to 1997-98*		*Level, 1997-98*		*Average growth (%) 1989-90 to 1997-98*	
	Locomotive numbers[b]	Locomotive power[c]	Locomotive numbers[b]	Locomotive power[c]	Locomotive numbers[b]	Locomotive power[c]	Locomotive numbers[b]	Locomotive power[c]
AN–NRC	0.63	0.63	11.9	4.8	1	1	11.2	5.7
PTC[d]	0.22	0.29	4.4	2.4	1	1	9.5	8.0
QR	0.43	0.52	6.1	4.7	0.50	0.58	5.5	4.4
SRA[d]	0.35	0.35	4.3	0.1	0.57	0.57	4.8	3.4
WR	0.56	0.65	11.6	9.0	1	1	8.9	6.7
Australia[e]	*0.47*	*0.52*	*8.2*	*4.8*	*0.70*	*0.73*	*7.6*	*5.4*
Canada[e]	*0.90*	*na*	*5.5*	*na*	*0.92*	*na*	*5.2*	*na*
US[e]	*0.83*	*0.83*	*4.3*	*3.4*	*0.88*	*0.88*	*4.8*	*3.9*

[a] For the United States and Canada, the level figures refer to the year 1997, the latest year for which data were available. The growth figures refer to the period 1990 to 1997. For Australian railways, the level figures refer to the year 1997-98, the latest year for which data were available. The growth figures refer to the period 1989-90 to 1997-98. [b] Locomotive inputs are measured as the number of locomotives used regardless of their power rating. [c] Locomotive inputs are measured in terms of their power to take account of differences in locomotive power ratings. [d] A discontinuity in the series of productivity levels occurring between 1994-95 and 1995-96 has lowered the productivity growth rate for SRA and PTC over the period, when a significant part of these railways' long haul general freight was transferred to NRC. When accounting for this discontinuity, the growth rate for SRA is 7.5 per cent from 1989-90 to 1994-95 and 17.7 per cent from 1995-96 to 1997-98 (an average of 11.7 per cent for the two periods). The average growth rate for PTC is 16.8 per cent from 1989-90 to 1994-95 and 14.3 per cent from 1995-96 to 1997-98 (an average of 15.8 per cent for the two periods). The discontinuity affects technical efficiency growth rates in the same way. [e] National average figures are obtained by weighting individual railways' scores by freight output (ntkm).

Source: Commission estimates.

Model 2 (like model 1) suggests that all Australian government-owned railways have experienced substantial productivity gains since 1990, which are only partially attributable to the effects of scale (table 3.3).

Average productivity among the Australian railways in 1998 is estimated to be about 45 per cent lower than North American railways. After adjusting for the effects of scale, the technical efficiency gap between Australian and North American railways was around 21 per cent in 1998. The results also indicate that relatively high productivity growth rates for Australian railways, compared to North American railways, has narrowed this gap since 1990.

AN-NRC displayed the highest productivity of the Australian railways in the sample (63 per cent of best practice in 1998). Productivity varied widely from a high of 34 per cent above the Australian industry average (for AN-NRC) to a low of 53 per cent below (for PTC).[11]

A discontinuity in the series of productivity estimates occurring between 1994-95 and 1995-96 has lowered the productivity growth rates for SRA and PTC over the period. In 1995-96 a significant part of these railways' long haul general freight was transferred to NRC. This resulted in a significant drop in their productivity at the point of discontinuity. Adjusting for this discontinuity results in average annual growth rates of about 16 per cent for PTC and 12 per cent for SRA for the entire period. The discontinuity in the data affects estimates of technical efficiency in a similar manner.

As was the case for model 1, the discriminatory power of model 2 decreased after adjusting for scale. Three of the five Australian railways are located on the technical efficiency frontier. This is due mainly to the small size of AN-NRC, PTC and Westrail relative to the largest North American railways.

Adjusting locomotive numbers to account for power differences has a greater effect on results for model 2 than for model 1. The productivity levels of PTC, QR and Westrail are revised upward after the adjustment, moving the measured productivity of these railways significantly closer to best practice. In particular, Westrail's measured productivity increases sufficiently to make it the most efficient government-owned railway in Australia.

As was the case for model 1, locomotive power adjusted results suggest that measured productivity (based on locomotive numbers) is overstated. The reduction in locomotive numbers is partly offset by their larger size.

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[11] Productivity levels of AN-NRC and Westrail are estimated to be higher than for some US Class I railways (appendix E).

Model 5

Model 5 is a two-output DEA model that accounts for the joint production of freight and passenger rail services at a national system level (table 3.4). It has an advantage over models 1 and 2 because it uses a larger sample consisting of rail systems with diverse input and output mixes and sizes (chapter 2, table 2.2).[12]

Table 3.4 **Estimates of relative productivity of national rail systems in selected countries**

	Productivity		*Technical efficiency*	
	Current level	*Average growth (%)*[a]	*Current level*	*Average growth (%)*[a]
Australia (98)	0.64	8.3	0.69	7.9
United States (97)	1	2.0	1	1.8
Canada (97)	0.98	5.5	1	5.5
Japan (97)	1	0.8	1	0.8
New Zealand (98)	0.18	3.9	0.73	3.6
Austria (97)	0.25	1.2	0.27	1.3
Belgium (97)	0.20	0.6	0.24	1.3
Denmark (95)	0.28	-1.4	0.60	3.4
France (97)	0.38	-0.4	0.39	-0.5
Finland (97)	0.35	0.2	0.45	1.1
Germany (97)	0.31	3.5	0.32	3.5
Ireland (97)	0.41	1.0	1	0.5
Italy (97)	0.32	0.3	0.33	0.6
Luxembourg (97)	0.20	1.5	1	0.0
Netherlands (97)	0.52	1.4	0.68	3.6
Norway (97)	0.31	4.5	0.74	7.6
Portugal (97)	0.33	-4.5	0.63	1.6
Spain (97)	0.38	-0.5	0.43	0.7
Sweden (97)	0.38	1.7	0.47	2.9
Switzerland (97)	0.32	3.1	0.38	3.7
Great Britain (94)	0.34	7.1	0.43	12.9
South Africa (98)	0.39	4.5	0.42	4.7

[a] Growth rates are calculated on an average annual basis. The period for Australia's national rail system is 1989-90 to 1997-98. The period for all other national rail systems is 1990 to the year indicated in parentheses.

Source: Commission estimates.

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[12] The adjustment for the effects of scale does not increase with an expansion in the number of national rail systems included in the sample. Because the sample used in the national system comparisons is large and diverse, the results are expected to be robust (appendix B).

Productivity levels

National rail systems in the United States and Japan set the productivity frontier against which all other national rail systems are compared. The other 20 national rail systems in the sample provide a wide range of sizes (measured in terms of ntkm).

Results indicate that Australia's national rail system attained a productivity level of 64 per cent of best practice in 1998. Other countries in the sample attained productivity levels ranging between 52 per cent (the Netherlands) and 18 per cent (New Zealand) of best practice.

The level of technical efficiency attained by Australia's national rail system was 69 per cent of best practice, suggesting that the effects of scale on productivity are relatively small at the national level. The United States and Japan attained the highest level of productivity and technical efficiency.

The gap between productivity and technical efficiency is substantial for some countries, suggesting that the effects of scale are large. In particular, Ireland and Luxembourg attained best practice levels of technical efficiency (compared to 41 per cent and 20 per cent for productivity respectively).

Productivity growth rates

Australia's national rail systems attained the highest average growth in productivity over the period (8 per cent per year). This is 51 per cent higher than the next highest growth rate (Canada).[13] Growth rates for other countries ranged between minus 5 per cent for Portugal and 5 per cent for Norway and South Africa.

Australia's technical efficiency growth rate is only marginally lower than its productivity growth rate over the period (both around 8 per cent per year). For some countries technical efficiency growth rates are substantially higher than productivity growth rates. For example, Norway had growth in technical efficiency of 8 per cent, compared to less than 5 per cent for productivity.

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[13] The growth rate for Great Britain (7.1 per cent), relating only to the 1990 to 1994 period, was higher than for Canada (5.5 per cent).

3.3 Regression analysis

Regression analysis can be used to estimate the impact of various factors on productivity. This includes factors relating to a railway's operating environment and reform initiatives implemented in the rail industry (chapter 2, section 2.3).

There are two possible ways of doing this using DEA — either by comparing railways operating in similar environments (through stratification) or by incorporating various factors as non-controllable (either categorical or continuous) in the analysis (appendix A). Both these methods have been employed to a limited extent in this study. The first is to control for the effects of scale and the second is to hold track as a fixed input (section 3.2).

However, the usefulness of both approaches is limited, particularly if many factors are to be accounted for. The first method is often constrained by the size and diversity of railways in the sample, which in this study is insufficient to provide all railways with 'like' comparators (for example PTC and Westrail have no comparators when measuring technical efficiency using models 1 and 2). The second method often reduces further the power of DEA as it leads to further stratification and reduces the number of comparators for each railway.

Moreover, inferences about technical efficiency made using regression analysis make use of the entire set of sample observations to adjust for the impact of factors relating to railway operating environments. DEA only uses the information contained in a sub-group of observations within the sample, to adjust for the impact of such factors.[14] This is likely to make regression analysis a more reliable means of adjusting measured productivity, rather than incorporating variables directly into DEA models, given the small sample size available.

This section discusses the way in which regression analysis is used to estimate the effects of four operating environment factors on productivity estimates produced by model 2.[15] A set of adjusted productivity estimates from model 2 (assumed to measure technical efficiency) is presented and discussed.

The possibility of adding government policy variables (as explanatory variables) to the regression analysis is discussed and a preliminary analysis presented. This analysis is embryonic in its development and potentially has serious mis-specification problems. It is therefore intended as a starting point for further

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[14] Examples of such regression analyses are given by Tretheway, Waters and Fok (1997), Hensher, Daniels and DeMellow (1995), Gathon and Perelman (1992), Oum and Yu (1994), and Freeman et al. (1987).

[15] Data availability has limited the application of regression analysis to model 2 results only.

analysis, rather than a basis from which to draw conclusions about the impact of rail reforms on productivity.

Modelling approach

Output size, traffic density, average haul length and axle loads are often cited by industry specialists as factors explaining differences in productivity. These four factors were chosen as a starting point for the analysis — although many other factors may also be relevant (chapter 2, section 2.3).

Two-step method

A two-step method has been used to estimate the effect of differences in operating environments on productivity. The first step is to identify the factors that have a significant effect on measured productivity. The second step is to use these factors to generate a set of adjusted productivity levels (which are assumed to be indicative of technical efficiency).

Step 1

Three regression models are used to identify the extent to which four factors might affect productivity (table 3.5). These factors are defined as follows:

- output size — output of the rail operation (ntkm);
- traffic density — intensity of track use (ntkm/track km);
- average haul length — average distance freight is hauled (ntkm/net tonnes carried); and
- average load[16] — average load carried per locomotive (net tonnes carried/number of locomotives).

Output size may be strongly correlated with the other three factors. With a fixed network size, increased output results in increased traffic density. Similarly, for a given level of freight carried, greater output in terms of ntkm is reflected in greater average haul length. For a given number of locomotives, load per locomotive is also related to output size — in the sense that net tonnes carried and ntkm are related (Caves, Christensen and Tretheway 1981, and Freeman et al.1987).

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[16] Industry specialists often use axle load to represent load capacity. However, axle load data are not available for all the railways in the sample.

Table 3.5 **Regression models and the explanatory variables used**

	Definition	Regression 1	Regression 2	Regression 3
Time trend	Year	✓	✓	✓
Output size	Net tonne-kms	✓	✓	×
Traffic density	Net tonne-kms/track kms	×	✓	✓
Average haul length	Net tonne-kms/net tonne carried	×	✓	✓
Average load	Net tonne carried/number of locomotives	×	✓	✓
Country dummy	=1 if Australia; =0 if not Australia	✓	✓	✓

The time trend variable has been included to control for an average rate of ‘technological progress’ which is expected to increase productivity generally for all railways over time. The country dummy variable has been included to control for the effect of unidentified differences in factors between the Australian and North American railways (the comparators used in model 2).

The models use the log of all variables (except the time trend and dummy variables). Tobit regression is used because the log of productivity is right censored at zero.[17] Tobit regression uses a maximum likelihood estimation technique to allow for the discontinuous density function that arises with censored data (Tobin 1958 and Amemiya 1985).[18]

Step 2

The estimated regression equation is used to calculate a factor-adjusted set of productivity estimates. These are obtained by calculating the ratio of the unadjusted productivity estimates to the maximum level of productivity possible — given the factors included in step 1.[19] The maximum level of productivity is represented by the curve that envelops all data points (estimates).

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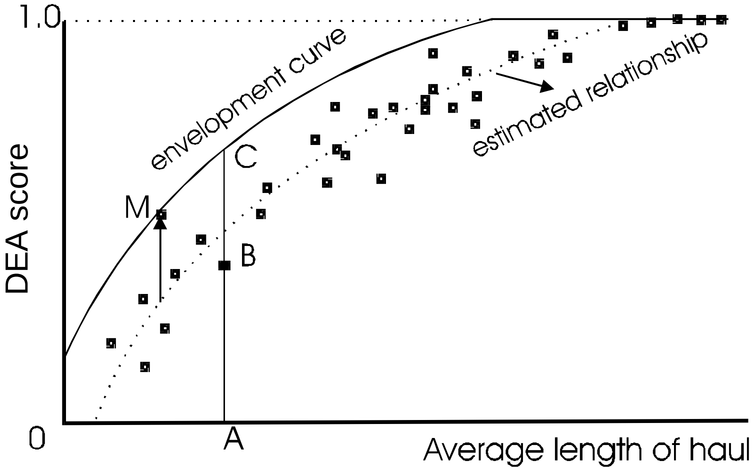
[17] DEA calculates the productivity score of a railway between zero and one (relatively productive railways have a score of one). The log of the dependent variable varies between minus infinity and zero.

[18] In this circumstance, simple ordinary least squares (OLS) estimation would result in biased estimates and incorrect standard errors for the regression coefficients.

[19] The adjusted maximum gives rise to an ‘envelopment curve’ which is calculated as the projected productivity estimate according to the regression obtained from step 1, plus the maximum positive difference between the observations and the estimated relationship.

The principles are illustrated using a single factor (figure 3.1). In this illustration the productivity estimates are plotted against the average haul length. The dotted line is the estimated relationship between average haul length and productivity. In this illustration point M determines the amount by which the estimated curve is shifted to envelop all data points from above, producing an 'envelopment curve'. For instance, the adjusted estimate for observation B is measured by AB/AC.[20]

Figure 3.1 **Illustration of the relationship between DEA scores and average haul length**



Data source: Commission estimates.

Regression results

The results indicate a strong relationship between the identified factors and the productivity estimates generated using model 2 (table 3.6).

Regression model 1

Regression model 1 uses output size, time and the country dummy variable as its explanatory variables. It is conceptually similar to the estimation of technical efficiency using the DEA model.

The results suggest that output size is positively related to measured productivity. The coefficient of the country dummy variable is negative and significant, implying that output size alone does not explain a significant portion of the difference in measured productivity across the Australian and North American railways.

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[20] This adjustment method is similar to the Corrected OLS (COLS) used by Perelman and Pestieau (1988) and the Displaced OLS (DOLS) used by Gathon and Pestieau (1995).

Table 3.6 **Regression results**[a]

	Regression 1		*Regression 2*		*Regression 3*	
	Estimated coefficient	*Level of significance*[b]	*Estimated coefficient*	*Level of significance*[b]	*Estimated coefficient*	*Level of significance*[b]
Explanatory *variable:*						
Intercept	**-2.47**	..	**-9.31**	..	**-9.19**	..
Time trend	**0.05**	..	**0.01**	0.07	**0.01**	0.02
Output size	**0.16**	..	**-0.03**	0.06	na	na
Traffic density	na	na	**0.21**	..	**0.17**	..
Average haul length	na	na	**0.76**	..	**0.72**	..
Locomotive load	na	na	**0.81**	..	**0.78**	..
Country dummy[c]	**-0.41**	..	-0.03	0.49	-0.03	0.36
Log likelihood[d]	-10		98		97	

[a] Models based on a total of 140 observations. AN-NRC excluded for 1993-94 because of apparent data inconsistency. [b] These figures are derived using the Chi-square test. They indicate the probability of rejecting the null hypothesis that the explanatory variable is not a significant determinant of the productivity estimate. For instance, a figure of 0.10 suggests that the estimated coefficient is statistically significant at a 90 per cent level of confidence. Thus, the lower figure (probability), the higher the level of significance for the estimated coefficient. Estimated coefficients in bold type are statistically significant at the 90 per cent confidence level. [c] Australia = 1, North America = 0. [d] Log likelihood indicates the 'goodness of fit' of the estimated regression model. It is negatively related to the residual sum of squares and positively related to the sample size. Thus, for a given sample size, a higher log likelihood reflects a better fit. **na** Not applicable; **..** Less than 0.005, that is, greater than 99.5 per cent confidence.

Source: Commission estimates.

The low log likelihood of the regression suggests that the explanatory power of the model is low.

Regression model 2

Regression model 2 uses six explanatory variables.

The results suggest that, other things being equal, high productivity estimates are related to high traffic density, longer haul length, and greater load per locomotive. The coefficient on output size is negative. This may be related to the strong correlation between output size and the other three explanatory variables.[21] This is consistent with observations made by Caves, Christensen and Tretheway (1981).

The log likelihood of regression model 2 has increased dramatically compared to regression model 1, implying that inclusion of the other explanatory variables increases the explanatory power of the regression. Moreover, the coefficient on the country dummy variable is not statistically significant, indicating that the identified

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[21] The correlation coefficient between output size and traffic density is estimated at 0.8, and that between output size and average haul length at 0.7.

factors explain a significant proportion of the difference in productivity between the Australian and North American railways.

Regression model 3

Regression model 3 excludes output size. The coefficients on the other variables are virtually the same as those obtained with regression model 2. The explanatory power is still high and the coefficient of the country dummy variable is still not significant.[22] The coefficient on the time trend — interpreted as a samplewide average rate of technological progress — is estimated at about one per cent per year.

Adjusted productivity estimates

The adjusted productivity estimates are based on the parameters in regression model 3. Not all variables of the regression model are included in the adjustment. Technological progress is excluded because it is regarded as a contributor to technical efficiency (that is, the very component of productivity we are aiming to measure). The country dummy variable is also excluded because it is not statistically different from zero.

Adjusting for the impact of differences in operating environments reduces the gap in railway productivity between Australia and best practice in North America. Before the adjustment, Australian railways had an average productivity of 47 per cent of best practice, compared with an average of 69 per cent after the adjustment (that is, a 22 percentage point reduction in the gap).

Adjusted productivity growth rates still put Australian railways in front of North American railways, but growth rates for both sets of railways were substantially lower after the adjustment. They declined from an average of 8.2 per cent to 3.8 per cent for Australian railways, and from 4.4 per cent to 2.5 per cent for North American railways. This implies that a large proportion of the growth in measured

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[22] The small changes in the coefficients and log likelihood between models 2 and 3 imply that excluding output size does not bias the coefficient estimates of other variables, although the multicollinearity between output size and traffic density (0.8) and output size and average haul length of (0.7) is strong. Multicollinearity may increase the standard errors of estimates. One way to avoid this is to include only one variable to represent a group of related variables. However, this must be done carefully to avoid mis-specification bias of the estimates. For example, excluding output size from model 3 does not change the estimated coefficients on the other variables, indicating that omitting this correlated variable is not a mis-specification. For the purpose of projecting the adjusted estimates using the estimated coefficients, multicollinearity is not a problem provided the relationship between the correlated variables is consistent across the sample (Koutsoyiannis 1977).

productivity is attributable to changes relating to the operating environment over the period.

Among Australian railways, AN-NRC and Westrail have the highest adjusted productivity levels and growth rates. The other Australian railways also have significantly higher adjusted levels of productivity (compared with model 2 results).

Potential impact of government policy on measured productivity

There has been substantial reform of railways in Australia over the period of analysis (PC 1999). Theoretically, the impact of this reform on the productivity of Australian railways could be modelled and accounted for in the same way as differences in operating environments. The preliminary analysis, conducted for this study, provides a starting point for further analysis of the impact of government policy factors on measured productivity.

Regression model 3 was expanded to include the following policy factors as explanatory variables — implementation of third party access regimes and the explicit funding of community service obligations (CSOs) (table 3.7).[23] The expanded version is referred to as regression model 4.

Table 3.7 **Incorporation of policy variables over time**[a,b]

	AN–NRC		PTC		QR		SRA		WR	
	access	*cso*	*access*	*cso*	*access*	*cso*	*access*	*cso*	*access*	*cso*
1989-90	0	0	0	0	0	0	0	0	0	0
1990-91	0	0	0	0	0	0	0	0	0	0
1991-92	0	0	0	0	0	0	0	1	0	0
1992-93	0	0	0	0	0	0	0	1	0	0
1993-94	1	0	0	0	0	1	0	1	0	0
1994-95	1	0	0	0	0	1	0	1	0	0
1995-96	1	0	0	0	0	1	0	1	0	1
1996-97	1	0	0	0	0	1	1	1	1	1
1997-98	1	0	1	0	1	1	1	1	1	1

[a] Access — implementation of third party access regime. CSO — explicit funding of CSOs. [b] A value of one means that the policy is in place in that year, while a value of zero means otherwise.

Source: Commission estimates.

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[23] Vertical separation and privatisation are not analysed because these reforms occurred late in the period of analysis, in which case it is too early to assess their effects. Reform initiatives such as commercialisation and corporatisation are not analysed because of the particular difficulty in identifying the lags in their effects.

The preliminary results suggest a possible positive correlation between the two policy variables used and the measured productivity of Australian railways (table 3.8). However, this is highly speculative given that individual reform initiatives such as access regimes and explicit CSO payments are embedded in a complex matrix of structural reform.

Table 3.8 **Results of regression model 4[a]**

	Estimated coefficient	*Level of significance*[b]
Explanatory variable:		
Intercept	-8.08	..
Time trend	…	0.80
Traffic density	**0.12**	..
Average haul length	**0.61**	..
Locomotive load	**0.69**	..
Third party open access	**0.11**	0.02
Explicitly funded CSOs	**0.08**	0.06
Log likelihood[c]	45	

[a] Regression model based on a total of 45 observations. AN-NRC excluded for 1993-94 because of a data inconsistency. [b] These figures are derived using the Chi-square test. They indicate the probability of rejecting the null hypothesis that the explanatory variable is not a significant determinant of the productivity estimate. For instance, a figure of 0.10 suggests that the estimated coefficient is statistically significant at a 90 per cent level of confidence. Thus, the lower figure (probability), the higher the level of significance for the estimated coefficient. Estimated coefficients in bold type are statistically significant at the 90 per cent confidence level. [c] Log likelihood indicates the 'goodness of fit' of the estimated regression model. It is negatively related to the residual sum of squares and positively related to the sample size. Thus, for a given sample size, a higher log likelihood reflects a better fit. The log likelihood of this regression model has decreased relative to regression model 3 in table 3.7 largely because of a decrease in sample size. The higher the figure, the better the regression equation is fitted with the sample data. **na** Not applicable **..** Less than 0.005, that is, greater than 99.5 per cent confidence. **…** Less than 0.005.

Source: Commission estimates.

Structural reform includes many possible policy variables that are excluded from the specification of this model. For example, the dummy for access is set to one for AN-NRC from 1993-94, which is not long after the establishment of NRC. It is reasonable to expect that what this variable actually captures in this case is more the impact of establishing NRC and associated reforms and structural changes, rather than simply the introduction of an access regime.

These results are at best, indicative of what impact reforms might have had on railway productivity in Australia and therefore should be interpreted with extreme caution.

4 Performance outcomes for stakeholders

Just as government policy can affect the productivity of railways, it can also influence how changes in productivity are shared amongst rail stakeholders — consumers, shareholders and labour.

In this chapter, performance outcomes are discussed in terms of these three stakeholder groups. As with productivity, the outcomes for Australian railways are compared over time (from 1990 to 1998), relative to each other, and (where possible) relative to railways in other countries.

Section 4.1 examines outcomes for consumers, in terms of the prices and quality of rail services. This is followed by an examination of outcomes for shareholders (section 4.2) and labour (section 4.3). For each stakeholder group, the indicators used and limitations are described. Each section begins by comparing Australian railways, followed by international comparisons.

4.1 Consumers

The price and quality of rail services directly affect consumers of rail services. Consumers benefit when prices fall and/or quality improves. Consumers of other goods and services are also affected to the extent that the prices and quality of rail services are reflected in the final prices of other goods and services.

Prices

Prices for rail services are measured as the average revenue from freight, urban passenger and non-urban passenger services. For freight services, this is real revenue earned per net tonne-kilometre. For passenger services, it is real revenue earned per passenger-kilometre travelled.[1]

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[1] To calculate 'real rail service rates' revenue data were deflated by the Australian Consumer Price Index (CPI).

To standardise freight and passenger rates between countries, all international rates have been converted into Australian dollars and adjusted for inflation. Therefore, some of the volatility in rates over the period is the result of exchange rate fluctuations rather than changes in local prices.[2]

Movements in freight and passenger rates measured using average revenue do not necessarily indicate a change in the schedule of rates charged. A change in the composition of freight carried or passenger services can also alter average freight and passenger rates.

Factors affecting prices

Freight and passenger rates are influenced by many factors that may vary substantially across countries and railways (chapter 2, section 2.3). Some of these factors are related to technical efficiency. Others are non-controllable, at least from the perspective of railway managers.

Some factors serve to lower a railway's cost structure or increase its revenue. For example, railways operating in larger markets may have a cost advantage given by scale economies, or railways which receive government subsidies may have an advantage in terms of their revenue base. Because of the variation in these factors, some railways have inherently greater scope to lower the prices they charge their customers.

Australian freight rates

Real national freight rates have declined by 30 per cent over the period (from 5.4 cents per ntkm in 1989-90 to 3.8 cents in 1997-98) (table 4.1). Freight rate declines occurred in all jurisdictions, although the rate varied over time and across jurisdictions.

The relatively sharp rise in freight rates for SRA, PTC and Westrail in the middle of the period reflect (at least partially) the transfer of their interstate freight to NRC. The change in the composition of freight carried by SRA, PTC and Westrail towards intrastate freight, which is characterised by higher priced (high cost of service) short haul freight, is likely to have led to the increase.

Freight rates tend to reflect the different characteristics of railways. For example, AN-NRC had the lowest average freight rates over the period. It also had the

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[2] The average of month end exchange rates was used to convert overseas revenue data into Australian dollars.

longest average haul length, the second largest scale operation and the second highest average freight load factor in 1996-97 (appendix C, table C.1). All these factors suggest that AN-NRC is likely to have an inherently low cost structure compared to other railways in Australia.

Table 4.1 **Real freight rates by jurisdiction (cents per net tonne-kilometre)[a], 1989-90 to 1997-98**

Railway	*1989-90*	*1990-91*	*1991-92*	*1992-93*	*1993-94*	*1994-95*	*1995-96*	*1996-97*	*1997-98*	*Growth (%)*[b]
SRA	5.6	5.5	5.4	5.1	4.8	6.0	5.5	5.3	4.8	-13.4
PTC	5.5	4.9	4.7	4.6	4.1	5.2	5.3	5.2	5.0	-8.0
QR	5.6	5.6	5.2	5.3	5.2	5.0	5.0	4.6	3.8	-33.2
WR	5.6	5.8	5.8	5.5	5.4	5.9	4.9	4.1	3.8	-32.6
AN-NRC[c]	4.2	4.0	3.8	3.6	3.4	3.2	3.0	3.0	2.7	-34.9
Average	*5.4*	*5.3*	*5.1*	*5.0*	*4.9*	*4.9*	*4.7*	*4.4*	*3.8*	*-29.6*

[a] In constant 1996-97 dollars. Real freight rates were constructed using total revenue from freight divided by total ntkm in each year and deflated by the national Consumer Price Index (CPI). [b] Total percentage change in real freight rates over the period. These growth rates may not exactly match those based on the data in the table due to rounding. [c] AN provided intrastate rail services for Tasmania and South Australia until November 1997. These services are included in the AN-NRC figures.

Data sources: SCNPMGTE (various); annual reports (various); PC survey.

International freight rates

Freight rates vary considerably across countries and over time.[3] In 1997 Australia had the fifth lowest freight rate (4.4 cents per ntkm). Luxembourg had the highest (20.3) and Canada the lowest (2.1) (table 4.2).

Differences in technical efficiency only partially explain the differences in freight rates. Differences in operating environments are also likely to be important.

Unlike most European countries, Australia's freight operations are large in scale and dominated by bulk commodities and long haul freight, which tend to decrease the average freight rate. Accordingly, Australia's freight rate was significantly lower than that in most European countries in 1997. On the other hand, the freight operations of the United States, Canada and South Africa have larger scale operations and longer average haul lengths. Australia's freight rate was around double that of these countries in 1997.

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[3] Due to a lack of international data, the period for international comparisons of freight rates ends at 1997.

In terms of growth, most countries experienced a steady decline in freight rates over the period. Growth rates ranged from minus 49 per cent for Italy to 18 per cent for Denmark. The decline in Australia's freight rate was relatively small at 18 per cent, but from a much lower initial rate.

Table 4.2 **Real international freight rates (A$ cents per net tonne-kilometre)[a], 1990 to 1997**

Country	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*Growth (%)*[b]
Australia	5.4	5.3	5.1	5.0	4.9	4.9	4.7	4.4	-18.0
United States	3.0	2.8	2.8	3.0	2.9	2.5	2.3	2.3	-25.9
Canada	3.2	3.0	2.9	2.9	2.7	2.3	2.2	2.1	-32.7
Japan	na	7.8	8.3	9.8	10.8	10.7	8.8	7.4	-4.4
New Zealand	13.2	12.2	11.2	11.5	11.5	11.8	11.5	10.2	-22.6
South Africa	2.5	2.9	3.2	2.6	2.6	2.7	2.8	2.4	-4.3
Austria	12.5	13.4	14.5	12.2	10.8	10.8	10.2	8.5	-32.0
Belgium	8.2	8.5	8.4	9.5	8.3	9.3	8.3	7.3	-10.2
Denmark	14.8	14.5	14.0	16.9	13.3	14.4	15.1	17.4	17.9
Finland	10.2	10.3	8.5	7.0	6.1	na	na	5.4	-47.0
France	9.4	9.6	9.4	10.6	9.3	9.0	8.3	7.0	-25.7
Germany	7.1	12.5	11.5	12.2	10.7	10.8	9.6	7.5	6.8
Great Britain	12.4	13.6	12.1	11.9	10.4	9.0	na	na	-27.9
Ireland	8.4	8.1	7.9	8.0	8.7	7.8	7.4	na	-12.0
Italy	10.5	9.9	8.3	8.7	7.0	6.5	5.9	5.3	-49.4
Luxembourg	na	na	na	na	23.6	25.3	22.2	20.3	-13.7
Netherlands	7.2	7.4	8.1	8.9	8.0	9.7	8.2	6.4	-9.9
Norway	11.2	10.9	11.6	8.8	9.5	10.7	na	8.4	-24.6
Portugal	4.4	5.1	5.5	5.8	4.8	4.9	4.8	4.4	0.0
Spain	7.3	7.9	8.3	8.3	6.2	5.9	5.3	4.5	-38.8
Sweden	5.3	5.3	4.9	4.7	5.1	4.6	3.8	3.3	-37.6
Switzerland	15.3	16.7	16.5	17.6	15.3	13.9	13.4	10.8	-29.5

[a] In constant 1997 dollars. Freight rates are measured as the average selling price of rail services. In order to compare price levels between countries, all rates have been converted into Australian dollars and then deflated by the Australian CPI. Therefore some of the change in rates may be due to exchange rate fluctuations. [b] Total percentage change in real freight rates over the period for which data were available. These growth rates may not exactly match those based on the data in the table due to rounding. **na** Not available.

Data sources: SCNPMGTE (various); annual reports (various); PC survey; UIC (1998a, 1998b); AAR (various); Statistics Canada (various).

Australian urban passenger rates

At the national level, urban passenger rates increased by 9 per cent towards the middle of the period and then decreased, to settle 11 per cent lower than the value for 1989-90 (from 9.2 cents per passenger-kilometre in 1989-90 to 10 cents in

1992-93 and down to 8.2 cents in 1997-98) (table 4.3). Urban passenger rates increased in some jurisdictions and declined in others.

Table 4.3 **Real urban passenger rates by jurisdiction (cents per passenger-kilometre)[a], 1989-90 to 1997-98**

Railway	*1989-90*	*1990-91*	*1991-92*	*1992-93*	*1993-94*	*1994-95*	*1995-96*	*1996-97*	*1997-98*	*Growth (%)*[b]
SRA	10.1	10.6	10.6	11.4	11.2	10.2	9.9	9.4	8.7	-13.9
PTC	7.7	8.1	8.5	8.8	9.1	8.6	8.2	8.1	8.0	3.3
QR	7.1	6.9	7.4	7.4	8.0	8.1	7.6	7.9	8.5	20.7
WR[c]	na	na	na	5.8	5.5	4.6	4.8	4.0	4.2	-28.6
TA[d]	na	na	7.3	6.7	5.5	6.2	na	na	na	-17.8
Average	*9.2*	*9.7*	*9.8*	*10.0*	*9.9*	*9.2*	*8.9*	*8.6*	*8.2*	*-10.9*

a In constant 1996-97 dollars. Real urban passenger rates were constructed using farebox revenue from urban passengers divided by total urban passenger-km in each year and deflated by the national CPI. **b** Total percentage change in real urban passenger rates over the period. These growth rates may not exactly match those based on the data in the table due to rounding. **c** Urban passenger-km data could not be provided by Westrail. Passenger-km were estimated by extrapolating numbers based on boarding statistics in Westrail's annual reports. Data were only available for Westrail from 1992-93. **d** Data for TransAdelaide were only available from 1991-92 to 1994-95. **na** Not available.

Data sources: SCNPMGTE (various); annual reports (various); PC survey.

The general trend of increased urban passenger rates towards the middle of the period may reflect moves by State Governments to introduce more commercial pricing policies to ensure greater cost recovery. In 1993-94 the Victorian Government approved a general fare increase of 10 per cent and the Queensland Government allowed a fare increase and the removal of half price weekend fares.

The decline in passenger rates in some States over the period partly reflects a change in the composition of fares. Governments and pricing regulators in New South Wales, South Australia and Victoria introduced initiatives to curtail declining patronage over the period, resulting in higher patronage from concession holders and greater provision of lower priced off-peak services. Patronage increased towards the end of the period in each of these States, but with a greater proportion of lower priced fares.

International urban passenger rates

Urban passenger rates varied greatly across and within countries over time (table 4.4).[4]

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[4] Due to a lack of international data, the period for international comparisons of urban passenger rates ends at 1997.

In 1997 urban passenger rates for Australia were 8.6 cents per passenger-kilometre, compared to a low of 2 cents for South Africa and a high of 17.2 cents for New Zealand.

Table 4.4 **Real international passenger rates (A$ cents per passenger-kilometre)[a], 1990 to 1997**

Country	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*Growth (%)*[b]
Urban passenger rates									
Australia	9.2	9.7	9.8	10.0	9.9	9.2	8.9	8.6	-10.4
Japan[c]	na	na	12.3	14.7	16.1	16.5	14.0	12.0	-2.4
New Zealand[d]	na	na	na	na	15.7	17.9	17.3	17.2	9.7
South Africa	1.4	1.9	2.0	2.0	2.0	2.2	2.2	2.0	42.7
Non-urban passenger rates									
Australia	10.2	10.4	11.8	12.0	12.8	12.1	12.8	12.4	21.4
United States	15.1	14.1	14.1	15.4	15.0	14.5	15.7	15.9	5.5
Canada	13.9	13.1	13.2	14.7	14.1	12.1	11.4	11.7	-15.4
Japan[c]	na	na	19.2	22.9	25.2	25.7	21.8	18.8	-2.4
New Zealand[d]	na	na	na	na	10.3	11.2	11.3	11.4	10.6
South Africa	4.8	6.0	6.4	6.3	4.1	4.8	4.7	3.6	-24.7
All passenger services									
Japan	na	16.4	17.2	20.5	22.7	23.2	19.9	17.2	4.3
Austria	11.5	12.5	12.0	8.7	8.3	8.3	7.8	9.9	-14.5
Belgium	7.6	8.7	8.9	10.7	9.7	10.4	10.3	9.3	21.7
Denmark	10.7	11.9	12.8	14.2	na	13.5	13.1	15.5	44.9
Finland	14.8	16.4	15.7	13.9	12.3	na	na	10.3	-30.4
France	12.2	13.3	10.7	12.8	11.3	11.9	11.6	10.6	-13.1
Germany	13.5	21.3	15.7	18.9	23.8	24.9	23.7	21.6	60.1
Great Britain	15.8	18.5	17.9	18.9	17.8	18.2	na	na	14.7
Ireland	22.9	23.2	24.7	26.8	23.4	24.7	23.0	na	0.4
Italy	12.1	12.8	10.8	12.5	10.9	10.6	10.3	5.7	-52.9
Luxembourg	na	na	na	na	13.7	15.5	15.1	na	9.7
Netherlands	10.0	8.4	8.7	10.4	10.8	12.8	12.3	11.1	11.1
Norway	15.2	16.0	15.9	17.6	15.7	16.4	na	15.1	-0.3
Portugal	3.2	3.9	4.1	4.6	3.9	4.2	4.3	4.0	24.1
Spain	10.2	11.5	8.7	8.7	7.2	7.5	7.4	6.5	-35.7
Sweden	20.3	21.1	22.4	19.1	17.6	17.0	16.5	14.7	-27.6
Switzerland	12.5	13.1	13.4	15.8	15.6	14.9	14.5	12.2	-2.8

[a] In constant 1997 dollars. Real passenger rates are measured as the average selling price of rail services. In order to compare price levels between countries, all overseas rates have been converted into Australian dollars and then deflated by the Australian CPI. Therefore, some of the change in prices may be due to exchange rate fluctuations. [b] Total percentage change in real passenger rates over the period for which data were available. These growth rates may not exactly match those based on the data in the table due to rounding. [c] The urban and non-urban passenger rates for Japan are for the East Japan Railway Company. [d] The passenger-km data required to calculate rates were only available for New Zealand from 1996. Data for 1994 and 1995 were estimated using boarding statistics. **na** Not available.

Data source: SCNPMGTE (various); annual reports (various); PC survey; UIC (1998a, 1998b); AAR (various); Statistics Canada (various).

A separate analysis of urban and non-urban passengers was not possible for all the countries in the sample. For the European countries, passenger rates in 1997 (urban and non-urban) ranged from a low of 4 cents per passenger-kilometre for Portugal to a high of 21.6 cents for Germany. Growth in passenger rates ranged from minus 53 per cent for Italy to 60 per cent for Germany over the period.

A dominant factor explaining the difference in urban passenger rates across countries is the level of government subsidy provided to rail service providers. The greater the government subsidy, the greater the capacity for rail providers to lower or maintain their rates below full cost recovery levels. Urban passenger systems in South Africa and Australia received substantial government subsidies. All Japanese railways were privatised in the late 1980s and early 1990s, and have not received direct government subsidies since.

The size of the urban population in each country may be driving some of the variation in rates (chapter 2, section 2.3, table 2.4). Scale economies in the production of urban passenger services enable railways in larger markets to provide services at a lower cost than those in smaller markets. In 1997 there were a total of 7297 billion urban passenger-kms travelled in Australia, compared to 10 782 billion in South Africa (1.5 times that of Australia) and 78 298 billion in Japan (nearly 11 times that of Australia).

Urban rates behaved differently over the period in Australia, Japan and South Africa. Rates in South Africa remained fairly constant for most of the period. Rates in Japan rose toward the middle of the period before declining to settle 2.4 per cent lower by the end of the period. This trend in Japan could be due partly to exchange rate effects and changes in the composition of fares over the period.

Australian non-urban passenger rates

Real national non-urban passenger rates increased by 20 per cent over the period (from 10.2 cents per passenger-km in 1989-90 to 12.4 cents in 1996-97, the last year for which complete data are available) (table 4.5). Only non-urban passengers in Western Australia and Victoria experienced a decline in rates.

Competition from other modes has been more relevant in determining non-urban passenger rates than urban passenger rates. However, factors related to government policy (such as the level of government subsidisation of non-urban passenger services) are still likely to influence non-urban passenger rates (chapter 2, section 2.3).

Deregulation of the interstate airline and road coach industries over the period led to intense price cutting and competition for regular travel patronage in these industries. In response, most non-urban passenger service providers have invested heavily in improving the quality of existing regular services and in the creation of new services aimed at the tourist market, rather than cut prices. As a result, towards the end of the period, SRA, QR and AN managed to reverse the initial loss of revenue resulting from the loss of patronage to road and air transport.

Table 4.5 **Real non-urban passenger rates by jurisdiction (cents per passenger-kilometre)[a], 1989-90 to 1997-98**

Railway	*1989-90*	*1990-91*	*1991-92*	*1992-93*	*1993-94*	*1994-95*	*1995-96*	*1996-97*	*1997-98*	*Growth (%)*[b]
SRA[c]	10.6	11.8	13.5	13.5	13.6	12.7	13.2	12.9	na	21.9
PTC[d]	8.9	8.8	9.3	9.3	9.4	9.6	9.3	9.2	8.8	-1.7
QR	7.5	6.7	11.9	12.2	13.7	13.5	13.2	13.9	14.5	93.1
WR[d]	12.6	10.8	9.7	9.0	8.4	7.3	6.8	6.3	5.8	-53.7
AN-NRC[c,f]	13.8	14.2	15.2	16.7	20.7	15.0	20.4	15.6	na	12.8
Average[g]	*10.2*	*10.4*	*11.8*	*12.0*	*12.8*	*12.1*	*12.8*	*12.4*	*11.7*	*-14.7*

[a] In constant 1996-97 dollars. Real non-urban passenger rates were constructed using total revenue from non-urban passengers divided by total non-urban passenger-km in each year and deflated by the national CPI. [b] Total percentage change in real non-urban passenger rates over the period. These growth rates may not exactly match those based on the data in the table due to rounding. [c] Data for SRA and AN were not available for 1997-98. [d] From 1994-95, non-urban passenger-km for PTC were estimated using boarding statistics. [e] For Westrail non-urban rail passenger revenue could only be provided from 1993 -94. From 1989-90 to 1992-93, non-urban rail passenger revenue was estimated by taking the proportion of rail passenger-km to total passenger-km (including buses) and applying the same factor to total revenue. [f] NRC did not provide passenger services. [g] Average for 1997-98 is based on PTC, QR and WR only. **na** Not available.

Data sources: SCNPMGTE (various); annual reports (various); PC survey.

The shift in the composition of non-urban services, towards more tourist services would have the effect of increasing the non-urban passenger rate. This is because tourist services are generally more costly to provide than regular travel services. For example, a tourist who travels overnight requires sleeping and entertainment facilities that a passenger using an intercity or regional service may not.

The sharp decline in AN's rates in 1994-95 was the result of a six week disruption to its Indian Pacific service due to flooding on the Nullarbor Plain, causing a downturn in passenger service revenue. The sharp increase in QR's rates in 1991-92 was due to strong growth in Queensland's tourist industry and the subsequent expansion of its tourist services.

International non-urban passenger rates

Non-urban passenger rates varied greatly across and within countries over time (table 4.4).[5] In 1997 non-urban passenger rates were 12.4 cents per passenger-kilometre for Australia, compared to a low of 3.6 cents for South Africa and a high of 18.8 cents for Japan. By 1997, non-urban rates increased by 21 per cent for Australia and 11 per cent for New Zealand but declined by 25 per cent for South Africa.

The relatively large differences in non-urban passenger rates between Australia, the United States, Canada and Japan are driven by similar factors to those affecting urban passenger rates. In particular, the level of government subsidy to rail providers differs across countries. VIA Rail in Canada relies more heavily on government assistance than Amtrak in the United States. VIA Rail's cost recovery ratio was around half that of Amtrak's over the period (Statistics Canada 1996). Australian non-urban operations also received significant subsidies over the period in contrast to Japanese non-urban operations, which received no government subsidy.

Non-urban rates tended to increase for the United States and decline for Canada and Japan over the period. Rates in Canada fell over the period, due in part to a reduction in operating costs and an increase in passenger-kms in 1994.[6] Costs increased in the United States while passenger-kms declined (Statistics Canada 1996).

Quality

The quality of rail services can be examined through a variety of indicators, the choice of which is more subjective than the choice of price indicators.[7] Quality indicators vary in importance depending on the specific service being provided.

Quality of freight services

The Bureau of Transport and Communications Economics (BTCE 1997) identified about forty possible freight service characteristics. The most important of these from the perspective of freight forwarders were:

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[5] Due to a lack of international data, the period for international comparisons of non-urban passenger rates ends at 1997.

[6] Towards the end of the period VIA Rail provided fewer high priced tourist services. Some of these services are now operated by private railways in Canada.

[7] International comparisons of rail service quality are not included due to a lack of data.

- punctuality of trains;
- care of cargo and containers;
- rail terminal efficiency — as measured by truck turn-around times;
- wagon availability — the number of container slots available as a percentage of the number scheduled to be available or the number requested by customers; and
- staff quality.

The focus in this study is on punctuality of freight services as this is the most commonly measured indicator. On time running is one measure of punctuality. Here it is defined as the proportion of trips that arrive within thirty minutes of the scheduled arrival time. Some of the perceived deficiencies of this indicator and potential alternatives are described in box 4.1.

Box 4.1 Problems with on time running as a measure of freight service quality

Participants to this inquiry expressed reservations about using on time running as a measure of freight service quality.

Perceived problem	*Alternative measure to address the problem*
On time running is not equally important for all freight traffics — it is most critical for intermodal and interstate freight.	In bulk freight markets, a measure such as delivery performance (tonnes actually delivered compared to programmed or ordered tonnes) may be more appropriate.
Expected arrival times can be adjusted to allow for (deteriorating) track conditions, thus improving on time running although service (in terms of transit times) may be deteriorating.	Incorporate trends in average transit times for a given distance and compare this to on time running data.
It is more important for ‘internal management control’ than as a measure of customer service — for instance, a train may be scheduled to arrive at 3.00am but the cargo has not been promised to be available to a customer until 6.00am. If the train arrives at 4.30am it is not ‘on time’ but this has not affected service from the customer’s perspective.	Freight availability — which measures the percentage of occasions when customers receive delivery of their freight at the time they were promised by the rail operator. On time and availability statistics can provide different indications of service quality (BTCE 1997). However, these data were not available for all jurisdictions.

Sources: PC (1999); BTCE (1997).

While recognising the limitations of on time running as an indicator of quality, it is the most consistently reported indicator and so it is used to give some indication of the comparative reliability of freight services across jurisdictions.

A number of factors may influence the on time running of freight services. Average haul length may influence the ability of a train to run on time. For instance, shorter trips may make it easier to reach a destination within a scheduled time. However, a late train may also have less opportunity to recover lost time over a short journey.

The value customers attach to on time running may depend on the type of freight transported. As noted in box 4.1, the importance of on time running varies among commodities, and is particularly important for intermodal and interstate freight.

The quality of track affects the speed at which trains can travel. Deteriorating track conditions tend to decrease the maximum allowable speed of trains. To the extent that scheduled arrival times are not changed to adapt to slower speeds, this may result in diminished on time performance.

Track work and maintenance may affect the time taken by trains to travel any given distance. Trains may need to slow down or temporarily stop as they pass affected track, or may need to take alternative (slower) routes. These works are likely to improve transit times and service performance in the longer term by improving track quality. However, the disruptions the works create may result in diminished on time (service) performance in the shorter term.

Traffic congestion on a network also affects the speed at which trains can travel. Increased congestion may result in slower travel times or longer periods where trains must remain stationary on the track, waiting for others to proceed.

The availability of rollingstock (locomotives and wagons) influences the actual departure time of a scheduled freight service. If rollingstock availability is limited relative to what is required, then delays may result. To the extent that the time lost through late departure is not made up during the journey, this will result in diminished on time performance.

All jurisdictions, apart from Victoria, experienced on time running rates below 90 per cent by the end of the period for which data were available (table 4.6). However, freight customers in both New South Wales and Queensland experienced significant improvements over the period, although starting from a relatively low base and mostly remaining well below Victoria. Western Australian customers experienced a decline in on time running, while Victorian and AN-NRC customers experienced fluctuating service over the period.

A number of factors influenced on time running performance. The generally higher on time running for PTC may partly reflect the shorter freight trips in Victoria. The deterioration in QR's service in 1994-95 was predominantly due to the Mainline Upgrade Project, which involved major track and bridge works. However, not only has on time performance improved since then, but transit times have also fallen as a result of these works (QR 1996).

Table 4.6 **On time running for freight services by jurisdiction (per cent)[a], 1989-90 to 1997-98**

Railway	*1989-90*	*1990-91*	*1991-92*	*1992-93*	*1993-94*	*1994-95*	*1995-96*	*1996-97*	*1997-98*
SRA	59.3	79.1	78.4	81.1	85.0	90.0	89.0	86.0	83.0
PTC	89.0	92.0	96.0	87.0	78.0	86.0	91.9	91.0	96.5
QR[b]	na	na	na	na	60.8	45.1	77.3	79.5	82.3
WR[c]	na	na	72.0	83.0	70.0	na	na	51.8	na
AN-NRC[d]	52.9	72.3	81.2	63.2	62.6	67.4	72.3	76.5	na

[a] On time running for freight services measures the proportion of trips arriving within thirty minutes of the scheduled arrival time. [b] Data were only available for QR from 1993-94. QR's service in 1994-95 was affected by the Mainline Upgrade Project that began in 1993. This involved major track and bridge upgrading works that created short term service disruptions. [c] Data were only available for Westrail from 1991-92 to 1993-94 and 1996-97. [d] On time running for AN-NRC relates only to AN between 1989-90 and 1992-93. From 1993-94, AN-NRC on time running is a weighted average of AN and NRC measures (weighted by the share of ntkm). Data for AN-NRC were not available for 1997-98. **na** Not available.

Data sources: SCNPMGTE (various); annual reports (various); PC survey.

Quality of passenger services

As with freight services, there are a number of indicators of the quality of passenger services, including: punctuality; reliability (for instance, the proportion of services which are cancelled); frequency (the number of services scheduled and run); the capacity of services; and non-time factors, such as cleanliness of trains and passenger safety.

On time running is one indicator of the punctuality of services. The factors that influence passenger on time running rates are similar to some of those that affect freight on time running.

Traffic congestion may be a particularly important factor influencing urban passenger on time running performance due to the frequency of urban passenger services. A slight delay for one train may have significant cascading effects on other trains in the network. Timetable changes are sometimes instituted to limit the occurrence of these problems. It is also possible that on time running can be superficially improved by cancelling trains that will run 'too late'.

Therefore, the assessment of the punctuality of urban passenger services should be accompanied by an examination of the reliability of services — the proportion of scheduled train trips that are cancelled (urban passenger cancellations). A major influence on train cancellations is the reliability of rollingstock, which is partly affected by the quality of maintenance programs.

In all jurisdictions, there has been a slight improvement in the on time running of urban passenger trains during the period (table 4.7). Urban passengers in Victoria and Western Australia have consistently experienced the most timely urban passenger services, with on time rates above 90 per cent.

The performance of QR deteriorated significantly in 1994-95 and 1995-96 due to network track upgrading and lower rollingstock availability due to the extension of services to the Gold Coast. Improved timetabling since early 1997 contributed to the dramatic improvement in on time running of urban passenger trains in Queensland (QR 1996, 1997).

Table 4.7 **On time running for urban passenger services (per cent)[a,b], 1989-90 to 1997-98**

Railway	*1989-90*	*1990-91*	*1991-92*	*1992-93*	*1993-94*	*1994-95*	*1995-96*	*1996-97*	*1997-98*
SRA	84.0	86.6	90.3	92.0	92.2	90.8	88.7	86.4	91.4
PTC	93.0	92.0	91.0	91.3	92.3	92.3	93.3	94.8	93.7
QR[c]	na	na	84.2	87.1	85.6	71.6	58.8	86.4	96.0
WR	90.0	92.0	94.0	95.0	93.0	94.0	95.0	96.0	93.0

[a] On time running for urban passenger services measures the proportion of trips arriving within three minutes of the scheduled arrival time. **[b]** TransAdelaide data were not available. **[c]** Data were only available for QR from 1991-92. On time running for QR in 1994-95 and 1995-96 was affected by network track upgrading and lower rollingstock availability due to the extension of rail services to the Gold Coast. **na** Not available.

Data sources: SCNPMGTE (various); annual reports (various); PC survey.

In terms of service cancellations, the performance of railways providing urban passenger services has been more variable than on time running. Urban passengers in Western Australia have tended to experience the lowest number of service cancellations during the period, whereas Victorian passengers have experienced the highest proportion of service cancellations (table 4.8).

Table 4.8 **Urban passenger cancellations (per cent)[a], 1989-90 to 1997-98**

Railway	*1989-90*	*1990-91*	*1991-92*	*1992-93*	*1993-94*	*1994-95*	*1995-96*	*1996-97*	*1997-98*
SRA	1.00	0.70	0.60	0.50	0.70	0.70	0.70	0.60	1.00
PTC	na	1.30	1.00	0.60	0.30	0.50	0.50	0.90	1.40
QR[b]	na	na	0.30	0.20	0.29	0.40	0.90	0.40	0.20
WR[c]	na	na	0.32	0.42	0.37	0.34	0.21	0.11	na

[a] Urban passenger cancellations are measured as the proportion of scheduled services that are cancelled. [b] Data for QR were only available from 1991-92. [c] Data for Westrail were only available from 1990-91 to 1996-97. **na** Not available.

Data sources: SCNPMGTE (various); annual reports (various); PC survey.

Direct comparison of on time running of non-urban passenger services cannot be performed as each jurisdiction defines on time running in different ways. However, trends for each railway can be examined. Overall, consumers of all non-urban passenger services have experienced a general improvement in on time running. Non-urban passengers in Victoria have experienced the most consistent service in Australia (table 4.9).

Table 4.9 **On time running for non-urban passenger services by jurisdiction (per cent)[a], 1989-90 to 1997-98**

Railway	*1989-90*	*1990-91*	*1991-92*	*1992-93*	*1993-94*	*1994-95*	*1995-96*	*1996-97*	*1997-98*
SRA	66.8	76.8	84.8	87.9	84.8	86.3	89.0	87.0	85.0
PTC	89.0	89.0	91.0	92.0	92.4	95.7	96.1	94.5	96.0
QR[b]	na	na	64.1	67.3	63.3	56.0	69.0	72.0	75.0
WR[c]	na	na	76.0	85.0	75.0	na	na	77.7	na
AN-NRC[d]	34.3	66.8	85.0	63.0	76.6	75.7	76.4	84.0	na

[a] Different definitions of on time running for non-urban passenger services apply in different States. For QR, it is the proportion of trips arriving within fifteen minutes of the scheduled arrival time (excluding tourist trains). For PTC it is the proportion of trips arriving within ten minutes of the scheduled arrival time for regional traffic (excluding non-urban peak services). The definitions of other railways are composites of on time rates for their different non-urban services, so no specific timeframe can be defined for them. [b] Data for QR were only available from 1991-92. [c] Data for Westrail were only available from 1991-92 to 1993-94 and 1996-97. [d] Data for AN-NRC were only available until 1996-97. **na** Not available.

Data sources: SCNPMGTE (various); annual reports (various); PC survey.

4.2 Shareholders

Shareholders are generally interested in the financial returns generated by their investments. Where Governments are shareholders, returns of a purely financial nature may not be the only consideration, as social and environmental objectives are also likely to be important. These objectives can have an impact on financial outcomes, but their costs and benefits have not been included due to difficulties in measuring them.

Returns to shareholders

Return on equity (ROE) is the ideal measure of shareholder returns. However, where shares are not publicly traded, equity must be treated as the residual of total assets and liabilities and may be negative. Where equity is negative, ROE cannot be used.

In addition, comparing ROE across time or railways is confounded by the impact of capital structure. An increase in debt, holding other things constant, leads to a rise in the rate of return required by shareholders to compensate for the extra risk incurred. Changes in ROE over time or differences across railways could be due to changes (or differences) in capital structure rather than higher risk-adjusted returns.

To overcome these problems, ROA (measured as earnings before interest and tax divided by total assets) has been used. It would be expected that trends in the ‘underlying’ ROE would broadly follow those of ROA.

However, there are some problems in measuring ROA. Reported returns are sensitive to asset valuation and accounting procedures, both of which have changed in Australian railways during the 1990s. Furthermore, the method of valuing assets differs across railways and countries. In addition, abnormal (accounting) items, such as reductions in unfunded superannuation liabilities, have an impact on the reported performance of railways. These ‘accounting-type’ factors make it difficult to compare ROA, either over time or across countries and railways, and must be considered when making such comparisons.

ROA is affected by a number of other factors that may vary substantially across countries. The type of service provided affects the potential profits a railway can expect to earn. In purely financial terms, passenger services tend to generate lower returns than freight services. Governments tend to impose non-commercial objectives on passenger services to a greater degree than freight operations.

The level of government funding affects the revenue of a railway. Governments often subsidise railways, particularly those providing passenger services, for a variety of social and environmental reasons. The degree to which this funding accurately reflects the non-commercial objectives of Governments may differ among jurisdictions and countries.

Other government policies may influence the broader environment in which rail operates and, hence, the revenue of railways. For example, if transport policy ensures competitive neutrality between road and rail, rail may be able to gain a larger share of the transport market, earning higher returns than would be the case if policy disadvantaged rail relative to road.

The level of (intermodal) competition has an impact on the prices railways can charge for their services and, hence, on their revenue. A greater degree of competition from other modes constrains the degree to which prices can be raised above marginal costs and, hence, the profitability of rail.

The scale and density of operations affect the cost structure of railways. Where economies of scale are present, larger scale operations have lower unit costs. To the extent that the degree of competition allows prices to be maintained at a higher level, larger operations may be more profitable.

Return on assets in Australia

Australian government-owned railways have displayed variable ROA over the period. ROA was positive for QR, Westrail and TransAdelaide, but tended to be negative for SRA and PTC (table 4.10). The returns of PTC, QR and Westrail appear to have displayed an upward trend over the period, while the returns of AN-NRC fluctuated substantially.

Table 4.10 **Return on assets by jurisdiction (per cent)[a], 1989-90 to 1997-98**

Railway	*1989-90*	*1990-91*	*1991-92*	*1992-93*	*1993-94*	*1994-95*	*1995-96*	*1996-97*	*1997-98*
SRA[b]	1.1	-0.5	-3.7	-1.6	-2.3	-3.9	-5.6	-4.3	2.6
PTC[c]	-5.7	-7.9	-4.6	-0.1	8.8	-1.5	-3.7	-0.4	-1.7
QR	na	na	na	2.3	1.9	2.4	9.1	9.5	7.7
WR	2.1	22.5	3.2	4.8	51.0	4.5	12.4	10.3	10.3
AN-NRC[d]	4.0	9.6	-23.0	-0.8	2.5	1.4	-6.7	33.0	-42.2
TA[c]	na	na	5.5	6.5	5.3	7.4	6.7	6.3	3.6

[a] Return on assets is calculated as the ratio of earnings before interest and tax (EBIT) to total assets. Profit includes CSOs and other government payments. Return on assets cannot be calculated on a strictly comparable basis because of revaluations and abnormal items during the period. [b] SRA includes FreightCorp, RSA and RAC for 1996-97 and 1997-98. [c] PTC and TransAdelaide include all operations, including buses and trams, in addition to rail. The results presented here probably overestimate the returns to rail. [d] The large rise in ROA of AN-NRC in 1996-97 and the subsequent fall in 1997-98 are due to large abnormal revenues and expenses for AN in the respective years. **na** Not available.

Data sources: SCNPMGTE (various); annual reports (various); PC survey.

Fluctuations in returns for all railways are largely due to the impact of abnormal items on profits. For instance, the turnaround in PTC's performance in 1993-94 reflected the impact on abnormal revenue of reductions in unfunded superannuation liabilities (which accounted for half of total revenue). If abnormal items were excluded in this instance, ROA falls from 8.8 per cent to minus 4.4 per cent.

Comparisons of financial performance over time and across railways are made difficult by differing government funding policies across jurisdictions. For instance, towards the end of the period, community service obligations (CSOs) for QR and Westrail were explicitly funded. However, Governments often accept lower rates of return as a type of CSO.

Changes in the structure of the NSW rail system make it even more difficult to compare its ROA over time. Asset valuations and the treatment of capital funding differ across the organisations that now form the NSW rail system.

International return on assets

Return on assets was highly variable both across countries and within countries during the period (table 4.11).

Table 4.11 **Return on assets by country disaggregated by type of service (per cent)[a], 1990 to 1997**

Railway	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*
Australia (all services)	-0.7	0.5	-3.3	0.5	5.0	-1.0	-1.1	5.0
US (Class I freight)	7.5	1.2	6.7	8.2	9.4	6.4	8.9	7.2
US (Amtrak)	-17.5	-17.4	-16.1	-16.2	-17.4	-15.9	-13.8	-12.0
Canada (Class I freight)	1.8	-0.5	-10.6	0.5	4.4	-4.6	2.8	8.6
Canada (VIA Rail)	3.0	-4.2	-3.7	-5.6	-4.7	-3.2	-9.6	-6.0
Canada (Class II–III)	-1.1	4.1	3.5	-0.7	0.8	-0.3	-3.3	-0.1
Japan (passenger)[b]	5.8	3.9	3.6	3.4	2.9	3.3	3.5	3.2
South Africa (SARCC)[c]	6.5	-17.2	8.2	5.4	na	na	na	na
South Africa (Spoornet)[d]	2.4	-1.1	-5.8	4.2	4.4	1.8	4.6	4.1
New Zealand (all services)[e]	na	na	12.8	7.2	13.1	21.2	16.1	12.4

[a] Return on assets is calculated as the ratio of earnings before interest and tax (EBIT) to total assets. Profit includes revenue from government subsidies. [b] Japan only includes (urban and non-urban) passenger services. The lower ROA figures after 1990 were caused by an increase in the asset base of JR Central and JR West as the Japanese Government transferred ownership of Shinkansen railway assets. [c] South Africa (SARCC) refers to the South African Rail Commuter Corporation, the provider of urban passenger services. SARCC data were only available from 1990 to 1993. The large fall in ROA in 1991 was due to a large fall in subsidies. [d] South Africa (Spoornet) includes non-urban passenger and freight services. [e] The large rise in ROA of New Zealand in 1995 was due to a large abnormal revenue item. **na** Not available.

Data sources: SCNPMGTE (various); annual reports (various); PC survey; AAR (various); Statistics Canada (various).

Australia's rail system experienced fluctuating but generally negative or low returns for most of the period. This is in contrast to the positive returns earned by US

Class I freight railways and in New Zealand, Japan and South Africa. The non-urban passenger services in the United States and Canada consistently provided negative returns, while the positive returns to South Africa's urban passenger system were highly dependent on government subsidies.

Abnormal items, such as restructuring costs, account for much of the variability within countries over time. For instance, the large fall in ROA for Canadian Class I freight in 1992 was partly attributable to a large rise in operating expenses (due largely to redundancy costs).

There are a number of problems in attempting to compare returns across countries. Due to differences in accounting methods, strict comparisons of ROA cannot be made. Furthermore, in some countries, the rail companies operate businesses other than rail, such as intermodal freight (New Zealand) or retail businesses (Japan), so 'like with like' comparisons cannot be made.

Even if these problems could be overcome, the wide variety of factors which interact to influence returns makes it difficult to distinguish any particular factor as the most significant. For instance, a number of factors may contribute to the relatively high returns of New Zealand's Tranz Rail. Freight dominates its business. It conducts non-rail transport businesses, which may boost its returns. It has been privatised and is now listed on the stock exchange so commercial incentives are strong. The road user charging system in New Zealand may allow a greater degree of competitive neutrality between road and rail than elsewhere. However, which of these factors (if any) is dominant, is speculative.

4.3 Labour

The interests of employees in an industry can be defined in a number of ways including numbers employed, wages and other financial benefits (remuneration), and non-financial considerations such as conditions of employment, job security, training and professional development, and work safety issues. The most readily quantifiable measure is remuneration.

Remuneration

Employee remuneration includes wages and salaries as well as non-wage components such as superannuation. Due to difficulties in obtaining this information, a proxy for remuneration has been used (labour costs, including on-costs).[8] In order to gain an insight into how payments to workers, on average, may have changed, labour costs per employee[9] (average labour costs) are examined.

Changes in average labour costs may not be indicative of the actual changes in the direct remuneration of workers for several reasons.

- Labour costs include payments such as workers' compensation premiums and payroll tax which workers do not directly receive. However, wages and salaries account for a large proportion of labour costs.
- The composition of labour on-costs varies between railways and, in some cases, over time within the same railway. Thus, care must be taken in comparing levels across railways, as well as rates of change.
- Staff composition or the hours worked per worker may change.

Remuneration of Australian employees

Real average labour costs have risen to varying degrees in all jurisdictions (table 4.12). AN-NRC experienced the largest rise in real average labour costs of about 70 per cent over the period. Only SRA and PTC, which have experienced the most volatility in their real average labour costs, have not shown a consistent upward trend.

Part of the increase in real average labour costs is likely to be due to wage and salary rises granted through Enterprise Bargaining Agreements (EBAs) under which Australian government-owned railways operate. The large increases in real average labour costs of QR (in 1992-93 and 1996-97) coincide with new EBAs.

However, information provided by the Rail Tram and Bus Union (RTBU) shows that a rise in average labour costs might overstate pay outcomes for workers under EBAs in some jurisdictions. EBAs for SRA resulted in a total pay increase of 20 per cent between 1992 and 1998 (compared to an increase in real average labour costs of 23 per cent). Real average labour costs for TransAdelaide rose by 41 per cent from 1992 to 1997 but salaries rose only 9 per cent from 1992 to 1998 (PC 1999).

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[8] On-costs include payments such as superannuation, payroll tax, annual leave entitlements, workers' compensation premiums and, sometimes, redundancy payments.

[9] The average number of employees rather than the number of employees at the end of the year has been used to calculate average labour costs. Using end of year figures would tend to overestimate average labour costs when large reductions in staff occur during the year.

Table 4.12 Real average annual labour costs by jurisdiction (dollars)[a], 1989-90 to 1997-98

Railway	*1989-90*	*1990-91*	*1991-92*	*1992-93*	*1993-94*	*1994-95*	*1995-96*	*1996-97*	*1997-98*
SRA	43561	48072	43835	51812	46691	39486	38368	46174	53781
PTC[b]	na	na	40959	46760	58777	48364	41779	45873	na
QR[c]	38321	37524	37983	45004	46980	46906	47691	55124	54690
WR	33950	32165	35775	38449	43912	44810	42545	47623	51570
AN-NRC[d]	32537	31973	33679	35715	39446	45628	56631	67319	67292
TA[e]	na	na	42807	38816	44033	53042	55501	60265	na

[a] In constant 1996-97 dollars. Real average labour costs were calculated by dividing real total labour costs (including on-costs) by average employee numbers. Real labour costs are nominal costs deflated by the national CPI. [b] PTC data were only available from 1991-92 to 1996-97. [c] QR moved from cash to accrual accounting in 1992-93. [d] NRC is only included in the AN-NRC data from 1995-96. AN is only included until 1996-97. The sharp rise in real average labour costs of AN-NRC since 1995-96 can be attributed partially to the different composition of the NRC labour force compared with AN. [e] TransAdelaide data were only available from 1991-92 until 1996-97. **na** Not available.

Data sources: SCNPMGTE (various); annual reports (various); PC survey.

Some railways were able to separate out the wages and salary component of their labour costs (table 4.13). Trends in real average wages and salaries are very similar to those of real average labour costs and, as with real average labour costs, their growth rates tend to exceed EBA growth rates.

Table 4.13 Real average wages and salaries by jurisdiction (dollars)[a], 1989-90 to 1997-98

Railway	*1989-90*	*1990-91*	*1991-92*	*1992-93*	*1993-94*	*1994-95*	*1995-96*	*1996-97*	*1997-98*
SRA[b]	na	na	32748	40090	34133	26612	26383	30261	45805
QR[c]	32794	32277	32485	38004	38924	39455	38503	45556	43720
WR[d]	na	na	na	33417	38592	39424	36766	41808	45488
TA[e]	na	na	42807	38816	39957	49538	50677	53249	na

[a] In constant 1996-97 dollars. Real average wages and salaries were calculated by dividing real total wages and salaries by average employee numbers. Real wages and salaries are nominal wages and salaries deflated by the national CPI. [b] SRA data were only available from 1991-92. [c] QR moved from cash to accrual accounting in 1992-93. [d] Westrail data were only available from 1992-93. [e] TransAdelaide data were only available from 1991-92 until 1996-97. **na** Not available.

Data sources: SCNPMGTE (various); annual reports (various); PC survey.

The apparent divergence between outcomes represented by real average labour costs and EBAs might in part be explained by the effect of changes in the composition of the workforce.[10]

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[10] Given the similar patterns in real average labour costs and real average wages and salaries for those railways that provided both sets of data, the majority of the divergence is unlikely to be

In the case of TransAdelaide, this may be the result of two factors: first, the contracting out of jobs performed by lower paid workers; and second, the reallocation of higher paid workers from the bus to the train business of TransAdelaide. Changes in reporting methods may also have been a factor.

Changes in the composition of the workforce also partially explain the sharp rise in real average labour costs of AN-NRC towards the end of the period. The workforce composition of NRC, which is only included in the AN-NRC labour cost figures from 1995-96, differs significantly from AN. In addition, the introduction of new work practices in NRC, such as single man crewing, led to increased wages for some workers to compensate for the extra responsibilities taken on.

A temporary rise in redundancy payments is likely to explain the increased real average labour costs for PTC toward the middle of the period. During that time, there were large staff reductions that would have led to increased termination payments. Unfortunately, a break down of PTC's labour costs was not available to confirm this.

International remuneration

Real average labour costs in Australia fluctuated during the period studied, as they did to a lesser extent in both Canada and New Zealand (table 4.14).[11] Fluctuations were smaller in Japan and the United States. The overall increase in Australia of 27 per cent (or 4 per cent per year) between 1990 and 1997 was lower than the 36 per cent (10.8 per cent per year) increase experienced in South Africa between 1993 and 1997, but greater than that experienced in the other countries.

Apart from the sharp rise in Canada in 1992 (caused by labour force restructuring), there was a slight rise in real average labour costs of around 12 per cent over the period. The wages component rose by about 12 per cent in real terms between 1991 and 1996. In contrast, real average labour costs in the United States have been fairly constant.

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attributable to changes in the components of labour costs, such as workers' compensation payments or payroll tax.

[11] An index is used to compare trends, rather than levels, across countries. The index is based on real average labour costs valued in the currency of the country concerned. This avoids variations caused by exchange rate fluctuations.

Table 4.14 **Index of real average labour costs by country, index (1993=100)[a], 1990 to 1997**

Railway	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*
Australia[b]	85.5	88.9	86.4	100.0	103.1	94.3	93.3	108.7
United States	105.8	104.8	101.9	100.0	100.6	99.0	97.8	102.9
Canada[c]	95.0	102.2	132.8	100.0	101.3	105.4	104.9	106.5
Japan[d]	87.7	92.2	98.1	100.0	101.2	103.6	106.4	106.7
New Zealand[e]	100.3	112.6	104.8	100.0	101.7	96.2	90.6	92.0
South Africa	na	na	na	100.0	99.2	111.0	132.3	135.9

a Index constructed on the basis of real average labour costs valued in the currency of the country in question. Real average labour costs are calculated by dividing real total labour costs (including on-costs) by average employee numbers. Real labour costs are nominal costs deflated by national CPI (in constant 1996-97 dollars). **b** The Australian total does not include TransAdelaide in 1989-90 or 1990-91 when data were not available. NRC is only included from 1995-96. **c** A large rise in real average labour costs in Canada in 1992 was due to a large rise in payments classified as employee benefits due to labour force restructuring. **d** Japanese real average labour costs include those of two companies for which labour cost data were available: East Japan Railway Co. and Hokkaido Railway Company, which account for 53 per cent of employees hired by the six Japanese passenger rail companies. **e** The results for New Zealand before and after 1993 are not comparable due to changes in accounting policy that occurred in 1993. **na** Not available.

Data sources: SCNPMGTE (various); annual reports (various); PC survey; AAR (various); Statistics Canada (various).

Only in New Zealand have real average labour costs fallen significantly, but mainly towards the end of the period. However, this does not necessarily indicate a decline in the direct remuneration of NZ workers over this period. First, changes in accounting methods occurred in 1993, so that labour costs are not defined consistently over the period. Second, trends in real average labour costs do not always reflect wage outcomes. For instance, while real average labour costs fell in 1996, an across-the-board increase in salaries was granted.

5 Summary of performance

To fulfil the objectives of this study, the performance of Australian railways was measured and compared over time and with railways overseas. Several factors affecting the performance of railways were also analysed. The task of linking reform to performance proved to be difficult and further work in this area is required before conclusions can be drawn.

This chapter brings together the results presented in chapters 3 and 4 and, where possible, draws a number of conclusions.

5.1 Productivity

The productivity of Australian government-owned railways has improved over the period 1989-90 to 1997-98. Australia's railway productivity has been amongst the fastest growing in the world. However, a significant gap in the level of productivity between Australia and other countries remains. Scale of operation and other factors have contributed to some of this gap, although a substantial part is attributable to differences in technical efficiency.

Freight operations at the railway level

On average, the productivity of Australian freight operations improved at greater rates than that of their counterparts in North America, although they remain only half as productive. After accounting for the effects of scale and other aspects of the operating environment, which generally advantage North American railways, the technical efficiency of Australian railways was around two thirds that of the most technically efficient North American railways.

Freight and passenger operations at the national system level

The productivity of Australia's national rail system was fourth highest — above New Zealand, South Africa and the European countries — and around two thirds that of the best practice rail systems in the United States, Japan and Canada. Australia experienced the greatest rate of improvement in productivity of all countries. After accounting for the effects of scale, technical efficiency in Australia remained around two thirds of best practice attained in North America.

5.2 Stakeholder outcomes

Outcomes for stakeholders have varied substantially between 1989-90 and 1997-98 and the directions of change are not always clear, particularly for shareholders and labour.

Consumer prices and quality

On average, Australia’s freight consumers pay among the lowest freight rates in the world. Real freight rates in Australia declined by 30 per cent but freight rate declines were even greater in some other countries.

Indicators of freight service quality suggest that freight rate declines did not come at the cost of deteriorating quality, although on time running remained poor in some jurisdictions. On time running actually improved in New South Wales and Queensland.

Australia’s rail passengers have not benefited significantly in terms of passenger rate reductions. After initial increases, urban passenger rates finished 10 per cent below their 1989-90 levels, while non-urban rates rose 21 per cent. In many countries rate reductions for rail passengers have been less than for freight customers.

Indicators of passenger service quality show that both urban and non-urban passengers experienced improved service quality over the period. On time running improved for all Australian government-owned railways, while urban passengers in all jurisdictions experienced fewer service cancellations.

Shareholder returns

Many government-owned railways in Australia were either making a loss or barely viable and returns to government shareholders were often negative and highly variable. However, there appears to be some improvement in return on assets in most jurisdictions. Returns in other countries also tended to be variable, with freight operations usually earning higher financial returns than passenger operations.

Remuneration to labour

Employee remuneration in government-owned railways in Australia has increased to some extent, although the number of jobs in these railways has declined substantially. Real average labour costs, as a proxy for remuneration, increased by 27 per cent. However, only some of this increase represents wage rises to employees. Some of the increase in real average labour costs was due to a reduction in the proportion of lower paid workers being employed and an increase in redundancy payments. Real average labour costs per employee remained relatively stable in the United States and Canada, increased in Japan and South Africa, and declined in New Zealand.

5.3 Conclusion

The productivity of Australia's government-owned railways has improved substantially since 1990. Freight customers have been the biggest beneficiaries, although labour and shareholders also gained, but to a lesser extent.

Despite productivity improvements, there remains a gap between Australia's performance and best practice. Part of this gap may never be bridged because of factors such as scale that inherently limit railways operating in Australia from attaining best practice productivity. However, a substantial part of this gap is due to differences in technical efficiency, implying that there is still room for improvement.

Improvements in performance thus far have coincided with substantial reform of the Australian rail industry (PC 1999). It is difficult to draw conclusions regarding the link between these reforms and performance improvements because of data limitations. Moreover, the recent nature of many reforms means that their full impact would not yet have been realised. However, it is more than likely that reform has had a positive impact on performance. The extent to which reform and other factors have been driving improvements in performance is unclear and requires further research.

A Principles of data envelopment analysis

Efficiency in production can be measured using a variety of techniques. Partial indicators of labour productivity (such as tonne-kilometres per employee) and capital productivity (such as tonnage carried per locomotive) are commonly used. Although useful for some purposes, these ratios are difficult to interpret because the effects of factor and product substitution are embedded in them.

The limitations of single factor productivity measures highlight the need to use a comprehensive measure of productivity, both over time and across railways. To measure and compare productivity, all key inputs and outputs need to be taken into account.

Section A.1 discusses the ways in which productivity can be measured comprehensively. Section A.2 explains why DEA was the technique chosen for this study. Section A.3 discusses the DEA methodology used in this study. Section A.4 discusses specific modelling issues relevant to DEA.

A.1 Measuring productivity

Productivity and technical efficiency can be estimated using several techniques. These techniques are unlikely to produce exactly the same set of results. Oum, Tretheway and Waters (1992) identify the following techniques for assessing productivity in the transport industry:

- econometric estimation of cost and production functions;
- estimation of total factor productivity (TFP) using index number methods; and
- DEA, which is a mathematical programming approach to estimating a production frontier.

With the econometric approach, a production or cost function is explicitly specified and estimated. Technical change is represented by an estimated shift in the production or cost function and inefficiency is measured as the deviation between the estimated production frontier and the observed level of productivity.

The index number approach typically assumes a specific form of production function (for example, the translog function) and uses price and quantity information to estimate productivity. The assumptions of competitive pricing, a smooth production function and constant returns to scale enable differences in index values to be interpreted as differences in technical efficiency. An example of a TFP index is the Törnqvist index, which is expressed as the ratio of an aggregate output index to an aggregate input index, in which outputs and inputs are aggregated based on revenue and cost shares respectively.

DEA only requires data on input and output quantities. Assuming a piecewise linear production function, differences in the input and output mix are viewed as the result of firms adopting discrete technology and work practices and providing different types of output. This does not rule out the role of prices in affecting the firm’s behaviour, especially in the long term. Rather, the model prescribes that the firm need not adjust its mode of operations on a continuous basis in response to a finite change in relative prices. A given mix of outputs or inputs can be consistent with a range of relative prices.

Appendix D summarises several studies that have applied these techniques to measure productivity in the rail industry.

A.2 Selection of DEA method for this study

DEA has been selected as the preferred technique for estimating railway productivity on both practical and theoretical grounds.

On the practical side, DEA has a relatively small data requirement. It requires physical data without the need for price and financial data. Data on the quantity of inputs and outputs used by a railway can be collected with greater ease and a higher degree of accuracy than data on the monetary values of inputs and outputs.[1] For some inputs and outputs, prices can only be derived through crude methods of index deflation. Cross-section comparisons of financial data are affected by inconsistent accounting procedures. International comparisons of financial data are further complicated by the need to adjust for exchange rates and inflation rates overseas.

On the theoretical side, DEA does not depend on the assumption of competitive pricing. Such an assumption is not likely to hold for government-owned railways. For example, a government-owned railway may charge below market prices due to

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[1] For example, capital costs need to be estimated as annual user charges, which depend on assumptions relating to the patterns of depreciation and economic life, discount rates, and salvage values of assets.

government subsidies. In theory, this could be remedied by estimating shadow prices that reflect the true opportunity cost of resources and true value of outputs. But the estimation of shadow prices itself constitutes a potential source for errors.

Further, DEA imposes little restriction on the assumed production technology. The estimated production frontier can reveal production technology characteristics, such as returns to scale and rates of factor and product substitution. As substitution effects are not imputed on the basis of price differences, DEA is particularly useful for comparing railways of different operational characteristics, since aspects of the operating environment rather than prices may dictate a railway’s mode of operations.

Lastly, DEA can represent a multiple output production process, such as freight and passenger services, without an aggregation of outputs. It is common for a rail system to run both freight and passenger services using shared inputs of track, locomotives and staff.

Although DEA has advantages, it has some inherent weaknesses that should also be considered.

- DEA is a non-parametric technique and does not make allowances for measurement error through stochastic noise (section A.4).
- Comparisons are sensitive to the selection of comparators and the sample size. If the sample includes only a few isolated observations with very different input-input, input-output, and output-output combinations, a large proportion of railways in the sample may be deemed unique and therefore equally efficient.
- Unlike econometric estimation, DEA provides no statistical tests to determine the goodness of fit of an estimated production frontier.

A.3 DEA methodology

DEA assesses the level of productivity for an observation (defined in this study as a railway or system in a given year) relative to the observed best practice.[2] DEA can be used to compare the productivity of a railway over time and to other railways, on a cross-section basis. Box A.1 contains a glossary of the DEA terms used to describe the application of the technique.

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[2] For an introduction to DEA, readers are referred to SCRCSSP (1997), Pearson (1993), Fried, Lovell and Schmidt (1993), Charnes et al. (1994), and Chan and Patton (1989).

Box A.1 **Glossary of DEA terminology used in this study**

Benchmarking — The process of comparing the performance of a railway against the best practice performance of other railways.

Best practice — The set of management and work practices which results in the highest potential level of outputs for a given level of inputs (and given operating environment).

Data Envelopment Analysis (DEA) — A linear programming technique that identifies best practice within a sample and measures productivity based on differences between observed and best practice units.

Input-contraction — One method of applying DEA which calculates productivity and technical efficiency scores as the maximum proportionate reduction in all inputs to produce a given amount of outputs based on the observed best practice.

Mathematical program — A set of mathematical equations in which an objective function is optimised, subject to a number of constraints.

Operating environment — Factors that affect productivity and are beyond the control of railways.

Output-expansion — One method of applying DEA which calculates productivity and technical efficiency scores as the maximum proportionate increase in all outputs using a given amount of inputs based on the observed best practice.

Peers — The group of sample units among which relative productivity is directly compared.

Productivity — A gross concept that refers to the ratio of outputs to inputs. It is gross in the sense that it captures all sources of variation in the ratio of outputs to inputs, including the technical efficiency of the firm.

Returns to scale — Relationship between productivity and size of operation.

Scale effect — The extent to which productivity can be affected by the (dis)advantage of returns to scale as the size of operation changes.

Slack — The extra amounts by which an input (output) can be reduced (increased) to achieve best practice after a maximum uniform reduction in all inputs (increase in all outputs) is taken.

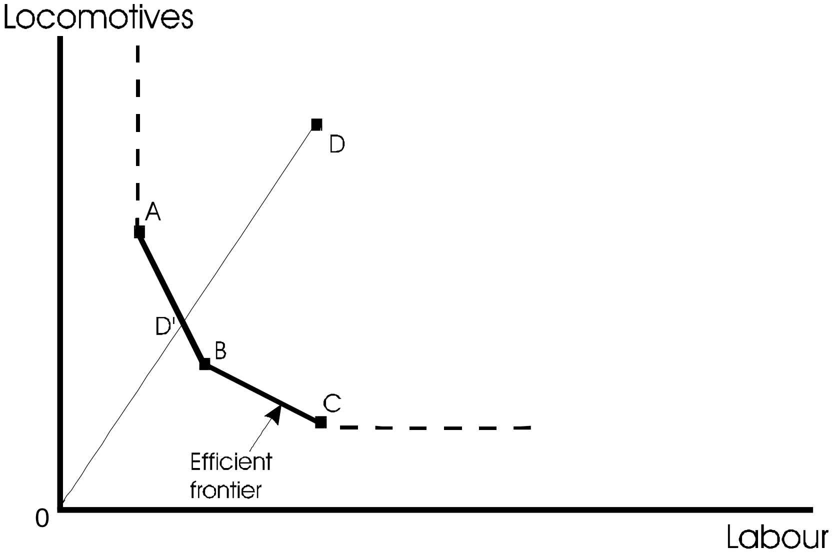
Technical efficiency — The extent to which productivity can be affected by factors not related to the (dis)advantage of returns to scale and other aspects of a railway's operating environment that are accounted for in the model.

Source: SCRCSSP (1997).

DEA calibrates the level of productivity on the basis of an estimated *efficient frontier*. The frontier provides a yardstick against which to measure the relative productivity of all other railways that do not lie on the frontier. The frontier is also called the *envelopment surface*. Railways located on the frontier use the minimum amount of inputs to produce the same amount of outputs as similar railways.[3] Railways using different combinations of inputs to produce different combinations of outputs can coexist on the frontier. These railways are called the *best practice performers* within the sample. They are assessed as relatively efficient and given a score of one, whereas others are deemed relatively inefficient and given a score between zero and one.[4] The DEA score of each railway can be interpreted as the radial distance to the frontier.

Figure A.1 shows the efficient frontier for a sample of four railways (*A* to *D*) that are assumed to produce a given level of output (a standard amount of freight transport, say) using two inputs (labour and locomotives). Railways *A*, *B* and *C* make up the frontier because a linear combination of adjacent pairs generates the shortest distance to the origin. Joining points *A*, *B* and *C* gives rise to the line segments *AB* and *BC*, which represent combinations of the three best practice railways and form part of the efficient frontier.

Figure A.1 **Efficient frontier**



DEA recognises the possibility of using a different combination of resources to achieve the same level of output. The frontier formed by connecting points *A*, *B* and *C* indicates such substitution possibilities. The respective partial productivities of locomotives and labour vary between *A*, *B* and *C*. Labour productivity decreases and locomotive productivity increases from *A* to *B* to *C*.

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[3] 'Similar' railways are identified on the basis of their input mix and output composition.

[4] This discussion is based on the input orientation, which asks how much a railway could reduce its inputs without lowering its output (see section A.4 and the definitions of input-contraction and output-expansion in box A.1).

Railway *D* is inefficient because it uses more labour and locomotives than a linear combination of *A* and *B* to produce the same level of output.

D is compared with a linear combination of railways *A* and *B* (*D*'s peer group), denoted *D'*. The input mix of these three railways (that is the ratio of labour to locomotives) is comparatively similar.[5] Railway *C* is in a separate peer group as its input structure (high labour intensity) differs from *A*, *B* and *D*. As a result, it is not used to evaluate *D*.[6]

For each railway in a peer group, the DEA score is calculated as a relative measure. The productivity score of efficient railways, in this case *A* and *B*, is one. The score for railway *D* is given by the ratio *OD'*/*OD*, taking the measurement along the radial line connecting the railway and origin (around 0.5). That is, the benchmark *D'* uses only *OD'/OD* of the amount of both labour and locomotives used by *D*.[7] A score of, say, 0.5 for railway *D* means that it could produce the same level of output using only half the resources it currently uses according to the best practice demonstrated by railways *A* and *B*.[8]

A.4 DEA modelling issues

There are a number of specific modelling issues to address when applying DEA, ranging from the model orientation to the sensitivity of the technique to data errors.

Input and output orientation

DEA can compare productivity from two points of view — output-expansion and input-contraction. Output-expansion models ask how much more output could be produced with a given amount of inputs. Input-contraction models ask how much

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[5] By grouping railways that have a broadly similar input or output mix, the comparative assessment implicitly takes into account the factors that drive the different choices of input or output mix by the railways. For instance, railways using labour intensive technology in consideration of high capital costs are compared against one another.

[6] The grouping of railways need not be exclusive. This means that railways such as *B* may appear efficient in different groups.

[7] In reality, such a performance target may or may not be practically feasible. It has been created as a modelling assumption.

[8] Zhang and Bartels (1998) interpret the DEA score as a composite function of a single factor productivity measure. Such an interpretation is slightly different to the conventional view prevalent in earlier DEA literature (eg Banker et al. 1989), which expresses the score as a ratio of an aggregate output index to an aggregate input index where outputs and inputs are aggregated based on the model's estimates of implicit (or shadow) prices for the output and input variables.

the railway could reduce its inputs without lowering its output.

This study uses the input-contraction orientation, as it is considered that railways tend to have more control over their inputs than outputs. For instance, railways in Australia may have limited ability to increase their provision of freight and passenger services outside the state border to which they are confined. Further, the output levels of railways are likely to be determined to a large extent by factors beyond their control, such as export markets, activity in other industries, and demographic patterns. Competition from other transport modes also constrains the capacity of railways to expand their output.[9]

Scale effects and technical efficiency

The DEA model can be estimated in two ways, to analyse and decompose productivity into technical efficiency and scale effects.

Productivity includes the combined influence of technical efficiency and scale effects, producing a *productivity frontier*.[10] A railway is compared against the best performing railway(s) in the entire sample. That is, all railways are ranked in terms of their relative productivity, regardless of the potential effect of scale on the productivity score.

The second way identifies the contribution of the scale effect separately from the contribution of technical efficiency, producing a *technical efficiency frontier*.[11] A railway is compared against the best performing railways of a similar scale (in terms of input intensity and output mix). That is, each railway is ranked within a group of similar scaled railways, thereby taking into account the potential effect of scale on the productivity score. This gives a measure of technical efficiency.

The level of technical efficiency is always greater than or equal to productivity. If the two scores are identical, productivity is said to be explained in full by technical efficiency. If technical efficiency is higher than productivity, productivity is partly determined by the effects of scale.

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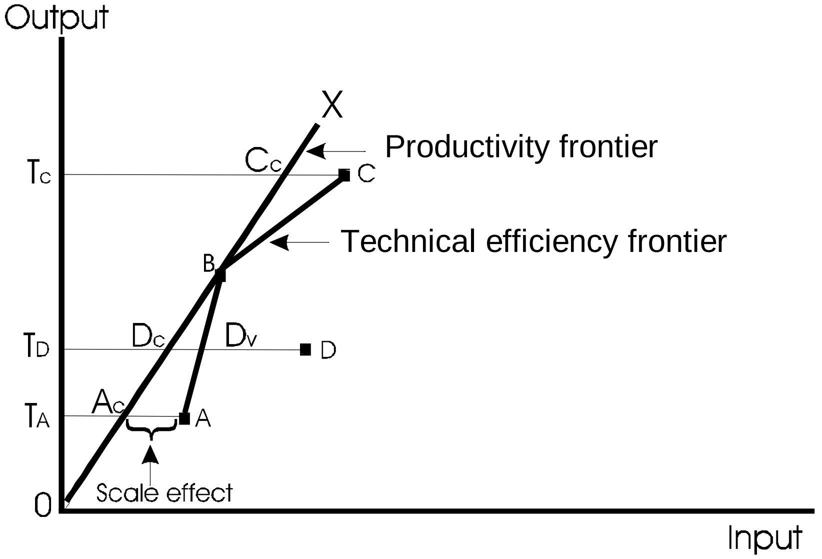
[9] The choice of model orientation is not likely to make a significant difference to the comparative assessment among the sampled railways, although it may change the estimated DEA scores. For a detailed exposition of the two model orientations, see Banker et al. (1989), Charnes et al. (1994), and Ganley and McCubbin (1992).

[10] This method is often referred to as the CCR ratio model or the constant returns to scale model (see Charnes et al. (1994), Fried, Lovell and Schmidt (1993) and SCRCSSP (1997).

[11] This method is often referred to as the BCC ratio model or the variable returns to scale model (see Charnes et al. (1994), Fried, Lovell and Schmidt (1993) and SCRCSSP (1997).

Figure A.2 illustrates the decomposition of productivity into scale effects and technical efficiency for the single input-output case. The productivity score is given by the product of the scale effect and technical efficiency.

Figure A.2 **Technical efficiency and scale effect**



The productivity frontier is represented by the line *OX*. It is determined by rotating a ray from the origin to the railway with the highest level of productivity (ratio of output to input), which in this case is railway *B*. The technical efficiency frontier is the kinked line connecting points *A*, *B*, and *C*. These railways show the highest output to input ratio for linear combinations of paired observations. The contribution of scale effects is captured by the horizontal distance between the two frontiers. Railways that are technically efficient but disadvantaged by size (such as *A* and *C*) are located on the technical efficiency frontier but not on the productivity frontier.[12]

To measure productivity, a railway is compared against the frontier given by the line *OX* in figure A.2. The performance targets for respective railways are points A_C, *B*, C_C and D_C. By input contraction, relative productivity is measured by the horizontal distance from the frontier. The peer group for observation *D* is *B* for productivity and *A* and *B* for technical efficiency. For example, the productivity score of railway *D* is given by the ratio of $T_D D_C / T_D D$. Its technical efficiency score is given by the ratio $T_D D_V / T_D D$ and the scale effect is $T_D D_C / T_D D_V$.

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[12] The technical efficiency frontier is shown to envelop the data points more tightly than the productivity frontier. This means that more railways are likely to be rated as efficient using the technical efficiency frontier.

Assuming the existence of scale diseconomies, the larger railway *C* has a technical efficiency score of one, higher than its productivity score given by the ratio $T_C C_C / T_C C$. The contribution of scale is given by the distance $C_C C$.

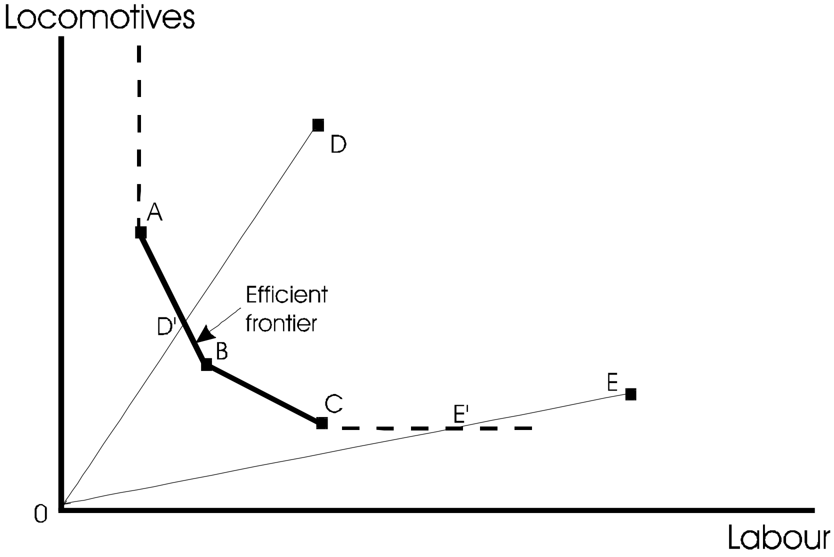
Input slack

The discussion around figure A.1 shows that DEA creates performance targets by scaling in a linear fashion all inputs and outputs (radial contraction).

Slack variables arise when, after radially contracting inputs, it is still possible to reduce one or more of the inputs in isolation. This is likely to occur when the sample size is small or the data have a skewed configuration.

An example of input slack is shown in figure A.3. None of the best practice railways (*A*, *B* and *C*) have the same input mix as railway *E*. Nor is it possible to construct such a performance target for railway *E* by taking a linear combination of the best practice railways. Rather, the efficient frontier is determined as a horizontal line to the right of point *C*.

Figure A.3 **DEA scores and input slack**



A uniform contraction of inputs used by *E* along the radial line *OE* would improve its productivity to the level represented at point E'. The DEA score is thus given by the ratio *OE'*/*OE*. However, such an input contraction does not exhaust all of the potential to reduce resources. The performance target set at point *C* suggests further scope for labour reduction by the amount *CE'* (after the input contraction) without lowering its output level.[13]

There are several possible ways to use slack variables in analysing DEA results. First, a complete assessment of relative productivity may need to take into account both the DEA score and any positive slack variables. Measures that combine the radial score and remaining slack are proposed in DEA literature. However, as Lovell (1993) pointed out, such combination measures have flaws of their own.

Second, the slack variables may indicate differences in factor intensity between a railway and its performance target. Subject to such input mix differences, the DEA score provides a conservative measure of productivity that ignores the possibility of achieving further savings by realigning the railway's input structure with that of the best practice railway.

However, the slack variables may be viewed as a modelling problem arising from either a limited sample or the use of a linear programming technique.

Viewed as an outcome of a limited sample, slack variables may disappear by adding more observations to extend the boundary of production possibilities beyond the one estimated using the existing data. In the context of figure A.3, this means adding some data points below the line segment *CE*, thereby defining a production relationship and a performance target in this area and eliminating the labour slack for railway *E*.[14]

Viewed as a problem associated with model specification, slack variables are specific to DEA as this method uses linear programming to estimate a piecewise linear production function. Other techniques (such as estimating a translog function) do not have this weakness. However, they have other problems, such as restrictive functional forms or inappropriate assumptions.

In summary, the existence of positive slack variables in the model may to some extent qualify the assessment based on DEA scores. But in a practical sense, the results are unlikely to be seriously biased by abstracting from slack variables.

Sensitivity of DEA scores to data errors

Data errors can distort the estimated efficient frontier and affect the accuracy of DEA scores. Since DEA provides relative measures of productivity, the sensitivity

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[13] For a complicated model specification such as that used when trying to estimate technical efficiency with fixed inputs, output slack variables may also arise. But it is difficult to illustrate the concept of output slack using a simple diagram.

[14] Adding such data points will not result in large changes in the score for railway *E*.

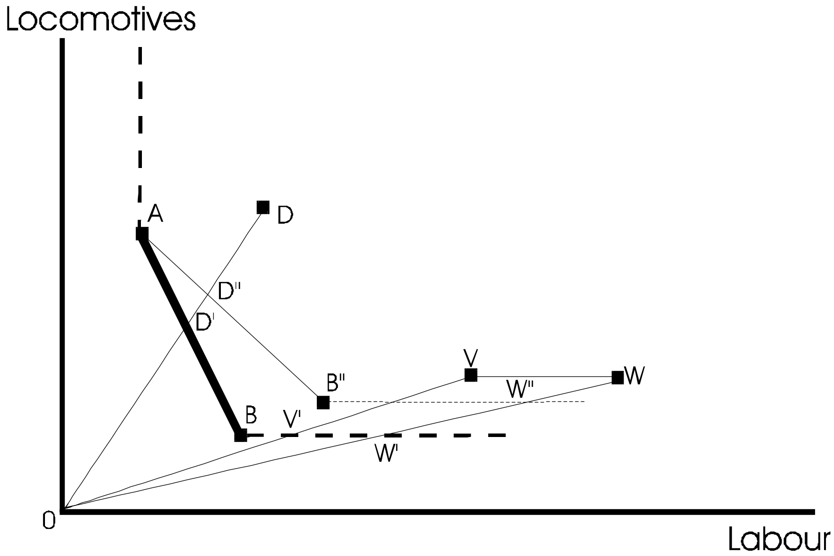
of results to data errors is particularly important for observations that form the frontier as this affects scores of other railways in the sample. For observations that do not form part of the efficient frontier, the sensitivity of a score to data errors in a particular variable depends on whether that variable is estimated with positive slack.

Even data errors in a minor input or output item can have a significant impact on results. This is because, unlike some productivity measures, inputs and outputs in DEA are not aggregated on the basis of their shares in total cost and revenue or functions which are estimated based on deviations from the whole sample.[15]

Using a single-output two-input model, figure A.4 demonstrates some situations in which a DEA score may be affected by errors in the input variables.

A measurement error in input variables for a best practice railway, such as *B*, may shift the estimated frontier, thus affecting the scores of other railways in the sample. In the case illustrated in figure A.4, if the true amount of locomotives and labour is given by *B”*, then the efficient frontier becomes *AB”*. This changes the ‘true’ performance target for *D* from D*’* to *D”*, and for *W* from *W’* to *W”*, improving the DEA scores of both.

Figure A.4 **Sensitivity of DEA scores to data errors**



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[15] The data used in this study have been carefully verified. Thus the possibility of incurring data errors in the sample is reduced, though not eliminated.

For a railway estimated to be relatively inefficient but with no input slack (such as *D*), any data errors in the input variables will be translated into errors of its scores.

Data errors in a slack input variable may affect the slack estimate but not the DEA score, providing that the error size is no greater than the slack estimate. Take railway *V* in figure A.4 as an illustration. An underestimation of its labour input by an amount of *VW* would reduce the slack variable from *BW'* to *BV'*. Meanwhile, the DEA score remains unchanged as *OV'/OV* is equal to *OW'/OW*.[16]

In this study, most Australian railways that are estimated as relatively inefficient have positive slack in the input variables of labour and, to a lesser extent, passenger cars, locomotives and wagons. Assuming the inputs and outputs of the countries forming the frontier (United States and Japan) are measured correctly, this implies that the results for Australia are more likely to be affected by potential data errors in measuring rollingstock than in measuring labour.

Input and output dimensions

In principle, by accounting for all inputs and outputs, productivity and technical efficiency can be compared on a comprehensive basis.

From a practical point of view however, it is neither possible nor desirable to include every input or output in a DEA model. The selection of input and output variables should provide the best modelling outcome in terms of balancing data quality, model dimensions and sample size.

First, the choice of variables is constrained by whether data are recorded on a consistent basis for all railways in a database. This study includes two outputs (freight and total passenger services) and five inputs (labour, wagons, locomotives, passenger cars and track). Consistent data on other non-labour operating and maintenance inputs were not available. This category of inputs includes items such as energy, contracted out services, computer equipment, buildings, and overhead cables for electrified rail systems.

By excluding data of poor quality, model results may actually be more reliable. As discussed above, even data errors in small items can affect the accuracy of DEA scores. Relatively large data errors are more likely to arise in measuring minor rather than major items due to the difficulties in classifying and keeping records of them on a consistent basis. Therefore, it makes sense to exclude a less significant

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[16] The analysis of figure A.4 can be extended to models of higher input or output dimension.

variable if its accuracy is dubious.

Putting the data problem aside, the discriminatory power of the model may be lowered by increasing the input or output dimension. The added input or output variables introduce additional dimensions by which to compare the railways. As a result, the railways may be classified and compared in small peer groups or even against themselves, increasing the chance of modelling railways as efficient by default. This is particularly relevant when estimating technical efficiency.

The omission of some input and output variables does not necessarily distort comparisons in a significant way, provided the partial productivity measures constructed from these variables are correlated.[17]

Instead of using exhaustive data for all relevant variables, modelled variables are assumed to represent the key factors that drive productivity. Specifically, a productivity improvement in using the modelled inputs is assumed to mirror a similar improvement in the use of other inputs omitted from the model.

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[17] As an example, suppose that energy productivity and locomotive productivity change at a similar rate. Then the DEA scores derived as a function of locomotive productivity would be similar to those that are derived from a model covering both input variables.

B Towards robust measures of productivity

Appendix A (section A.4) discussed some of the issues involved in applying a DEA model. Once DEA is chosen as the modelling technique, there are a number of ways to implement it in terms of model design, that is, which inputs, outputs or comparators are used. This appendix outlines the five DEA models used in this study. The five models differ mainly in terms of the railways used to form observations in the database and the specification of outputs. Using a range of model specifications is a way to test the robustness of the estimates and to provide a range of estimates.

Using different models illustrates the sensitivity of results to:

- the level of aggregation — analysis is carried out at the aggregate (national) and disaggregate (railway) levels;
- the outputs specified — single output (freight) and joint output (freight and passenger) services; and
- the observations included — restricted (Australian only) and international (domestic and foreign).[1]

Section B.1 briefly discusses the structure of the models used in the study, and considers which criteria are important in choosing a model. Section B.2 presents and compares the results of each model used.

B.1 Model selection

Two major aspects are relevant to the selection of a DEA model:

- sample size and type of railways; and
- model specification.

Given appropriate sample coverage, model specification can be tested for its ability

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[1] The robustness of model results can also be examined in terms of their sensitivity to data errors and model dimension (that is the number of input and output variables). Appendix A contains a general discussion of these issues.

to generate stable results in terms of levels of productivity and growth rates. Unlike econometric approaches, DEA provides no statistical basis for testing the goodness of fit with sample data. Hence, the extent to which a particular DEA model is applicable to different railways is decided largely on a judgmental basis.

The five DEA models used to measure railway productivity are listed below.[2]

- Model 1 uses a restricted sample of Australian railways to compare productivity and technical efficiency in providing freight services.
- Model 2 expands the sample used in model 1, adding major North American freight railways to the database. This model compares productivity and technical efficiency estimates for railways in Australia to those in the United States and Canada. In this context, large differences in the scale of operation of Australian and some North American railways are an important aspect of the analysis.
- Model 3 is an aggregate version of model 2, using national level data to assess the productivity and technical efficiency of Australian and North American systems in providing freight services.
- Model 4 is a two-output extension of model 3, comparing the joint productivity and technical efficiency of freight and passenger services between Australian and North American systems.
- Model 5 expands the sample used in model 4, by adding other countries.

Model 1 is designed expressly to compare Australian railways. Due to data limitations, such comparisons are only possible for freight services — a major component of services provided by these railways, but still only a partial assessment. Unfortunately, the heterogeneity of the input mix, together with the small number of observations, leads the DEA model to make most railways part of the efficient frontier.

Adding North American railways to the sample (model 2) allows for a better comparison in that the sample now includes a number of railways that are thought by industry analysts to be very good performers on a world scale. However, since model 2 is applied to freight activities only, it suffers from a source of potential error: the possibility of allocating resources that may be used in passenger services. In addition, the fact that the North American railways only provide freight services (and therefore operate in different environments compared to the passenger and freight carrying railways in Australia) may make the comparison less robust than desired.

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[2] Model specifications are described in chapter 3.

These problems are avoided by using national data. This is the case for the two-output models 3, 4 and 5. Models 3 and 4 are designed to provide a link between the freight-only models and the two-output model with the broadest coverage, model 5.

In using national data, and accounting for both activities carried out by a national rail system, model 5 produces relatively robust estimates of productivity and technical efficiency. The estimates and growth rates obtained from this model tend to confirm the assessments made with model 2, thus supporting the results obtained for Australian railways in the freight-only model.

B.2 Comparing model results

Synthesising the model results brings out the strengths and weaknesses of each model. In this section, the following comparisons are performed.

- Between models 1 and 2 — this highlights the significance of using common external benchmark(s) to assess Australian railways.
- Between models 2 and 3 — this demonstrates the degree of consistency that can be expected between the assessments conducted at the railway and industry levels respectively.[3]
- Among models 3 to 5 — this demonstrates the requirement of representative benchmarks for assessing productivity.
- Between models 2 and 5 — this illustrates the importance of using a diverse sample in an effective assessment of technical efficiency.

Systemwide assessment based on models 1 and 2

Table B.1 presents the estimates of relative productivity for the railways analysed in models 1 and 2.

Each Australian railway has a lower productivity estimate in model 2 than model 1. In model 2, the best practice comparators change from the Australian benchmarks used in model 1 to the superior North American benchmarks — CN and BNSF.

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[3] There are some practical advantages to using aggregate data to assess industry performance (chapter 3, box 2.3). However, by making comparisons at the railway level, model 2 can show varying levels of productivity among the railways in a country. Further, model 2 uses specific best practice railway(s), instead of an average of the best practice country, to benchmark the productivity of individual railways.

Table B.1 Estimates of productivity for individual railways in Australia and North America, 1989-90 to 1997-98[a]

	Current level				*Average annual growth, (%) since 1989-90*			
	Model 1		*Model 2*		*Model 1*		*Model 2*	
	Locomotive numbers[b]	Locomotive power[c]	Locomotive numbers[b]	Locomotive power[c]	Locomotive numbers[b]	Locomotive power[c]	Locomotive numbers[b]	Locomotive power[c]
Australia								
AN–NRC	1	1	0.63	0.63	10.8	5.7	11.9	4.8
PTC	0.36	0.43	0.22	0.29	3.7	2.4	4.4	2.4
QR	1	1	0.43	0.52	10.9	8.3	6.1	4.7
SRA	0.73	0.73	0.35	0.35	4.3	4.3	4.3	0.1
WR	1	1	0.56	0.65	12.8	9.4	11.6	9.0
Average[d]	*0.93*	*0.93*	*0.47*	*0.52*	*9.7*	*7.4*	*8.2*	*4.8*
Canada								
CN			1	1			7.3	5.2
CP			0.83	0.73			3.4	na
Class II & III			0.62	na			2.6	na
Average[d]			*0.90*	*na*			*5.5*	*na*
US								
CR			0.54	0.54			4.3	2.4
CSX			0.65	0.62			3.3	1.9
GTW			0.48	0.60			12.1	10.6
ICR			0.80	0.83			4.8	4.5
KCS			0.77	0.77			4.0	3.9
NS			0.67	0.62			3.1	1.3
SOO			0.70	0.77			1.8	1.0
UP			0.88	0.88			6.7	6.1
BNSF			1	1			2.5	1.8
Average[d]			*0.83*	*0.83*			*4.3*	*3.4*

[a] Estimates for Australia are up to 1997-98, and those for the United States and Canada are up to 1997. [b] Locomotive inputs are measured as the number of locomotives used regardless of their power rating. [c] Locomotive inputs are measured in terms of their power to take account of differences in locomotive power ratings. [d] National average obtained by weighting individual railway estimates by freight output (ntkm) **na** Not available.

Source: Commission estimates.

Table B.2 Estimates of technical efficiency for individual railways in Australia and North America, 1989-90 to 1997-98[a]

	Current level				*Average annual growth, (%) since 1989-90*			
	Model 1		*Model 2*		*Model 1*		*Model 2*	
	Locomotive numbers[b]	Locomotive power[c]	Locomotive numbers[b]	Locomotive power[c]	Locomotive numbers[b]	Locomotive power[c]	Locomotive numbers[b]	Locomotive power[c]
Australia								
AN–NRC	1	1	1	1	10.2	5.1	11.2	5.7
PTC	1	1	1	1	9.4	7.8	9.5	8.0
QR	1	1	0.50	0.58	7.5	5.7	5.5	4.4
SRA	0.73	0.73	0.57	0.57	4.4	4.4	4.8	3.4
WSR	1	1	1	1	8.9	6.7	8.9	6.7
Average[d]	*0.95*	*0.95*	*0.70*	*0.73*	*7.7*	*5.8*	*7.6*	*5.4*
Canada								
CN			1	1			7.1	5.1
CP			0.85	0.74			3.4	na
Class II & III			0.72	na			1.9	na
Average[d]			*0.92*	*na*			*5.2*	*na*
US								
CR			0.55	0.56			4.2	2.5
CSX			0.66	0.62			3.4	1.9
GTW			1	1			3.1	3.1
IC			0.96	0.96			4.0	4.0
KCS			0.94	0.94			0.3	0.3
NS			0.68	0.63			3.1	1.4
SOO			0.87	0.90			2.8	1.7
UP			1	1			8.5	7.8
BNSF			1	1			2.5	1.8
Average[d]			*0.88*	*0.88*			*4.8*	*3.9*

[a] Estimates for Australia are up to 1997-98, and those for the United States and Canada are up to 1997. [b] Locomotive inputs are measured as the number of locomotives used regardless of their power rating. [c] Locomotive inputs are measured in terms of their power to take account of differences in locomotive power ratings. [d] National average obtained by weighting individual railway estimates by freight output (ntkm). **na** Not available.

Source: Commission estimates.

This explains the across-the-board scaling down in productivity estimates for the domestic railways. In model 2 AN-NRC, QR and Westrail are no longer compared to themselves but are compared to US railways.

Models 1 and 2 provided similar estimates of growth rates for the Australian railways over the study period. This means that changing the basis for comparison (the benchmark) has altered the level of productivity for each observation pertaining to a particular railway, but has not changed the estimated rate of growth in productivity.

Table B.2 presents estimates of technical efficiency for individual railways in Australia and North America.

Both models credit most Australian railways with the highest possible estimate of one for technical efficiency. These estimates do not, however, mean that Australian railways are technically efficient. Rather, the models (especially model 1) have low discriminatory power as each of the Australian samples is classified in a distinct peer group which contains no railways other than itself.[4] In model 1, all domestic railways except SRA are benchmarked mainly against their own performance in 1997-98. The inclusion of North American railways in model 2 provides an external benchmark (BNSF) against which to assess QR's 1998 level of technical efficiency.

The absence of relatively small railways besides the Australian ones is the main reason the two models attribute differences in productivity to scale rather than technical efficiency for Australia. For the North American railways (except GTW), differences in productivity are attributed to technical efficiency rather than scale.

Adjusting for locomotive power increases estimates of productivity and technical efficiency for Australian railways relative to North American railways. It overcomes the downward bias in the measurement of the locomotive input for US railways ,which have few, but larger, locomotives.

International assessment

Table B.3 presents the estimates of productivity for the railways and national systems analysed in models 2 to 5. The estimates of technical efficiency generated by these models are given in table B.4.

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[4] This is indicated by the weighting factors estimated in the creation of performance targets for the railways in the models. The construction of performance targets is discussed in appendix A. Estimates of the weighting factors can be requested from the authors.

Models 2 and 3

Models 2 and 3 produce broadly consistent estimates of productivity (table B.3). Both models estimate a gap of about 40 per cent on average for Australian railways in providing freight services in 1998 relative to US counterparts in 1997.[5] The estimates of productivity growth over the study period are also similar.

However, the models differ in the contribution of technical efficiency and scale to productivity (table B.4). In terms of the estimates for 1997-98, model 2 rates Canada higher than the United States and Australia, while model 3 assesses the three countries as equally efficient. In model 3, all differences in productivity are attributed to differences in scale. However, the sample coverage in both models is probably inadequate for producing good estimates of technical efficiency.[6]

Just as model 3 attributes a greater role to scale effects in determining productivity than model 2, it also attributes a greater role to scale effects in the growth of productivity. This is reflected in the relatively low growth of technical efficiency associated with this model (table B.4).

Models 3 and 4

Model 4 illustrates the problems associated with increasing the number of dimensions of the analysis (in this model, output includes both freight and passenger services) using a restricted sample. Model 4 has poor discriminatory power; it reveals no differences in productivity among the national systems in Australia, the United States and Canada (table B.3). Estimates of technical efficiency growth differ markedly from those obtained with model 3 (table B.4). Australian railways are benchmarked against themselves, sometimes even for individual years. Therefore this model provides no useful information relating to productivity and its growth rate over time.

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[5] Expressed in percentage terms, model 2's estimate of the productivity gap is calculated using the average estimates of 0.47 for Australia and 0.83 for the United States (table B.3).

[6] Two factors temper the degree of consistency between the results of models 2 and 3. The first is the different bases of comparison used in calibrating productivity estimates. The second is related to the potential for double-counting inputs in constructing railways aggregates. With regard to the first factor, the best practice performances of the US and Canadian systems represent an average performance of the whole system in which the performance of individual best practice railways (BNSF and CN) are diluted in the national aggregates. With regard to the double-counting problem, an input in a national system may be smaller than the arithmetic sum of the input amounts allocated to individual railways.

Table B.3 **Estimates of productivity for national rail systems, since 1989-90**[a]

	Current level				*Average annual growth, (%) since 1989-90*			
	Model 2[b]	*Model 3*	*Model 4*	*Model 5*	*Model 2*[b]	*Model 3*	*Model 4*	*Model 5*
Australia (98)	0.47	0.62	1	0.64	8.2	8.4	2.7	8.3
United States (97)	0.83	1	1	1	4.3	4.4	0.9	2.0
Canada (97)	0.90	1	1	0.98	5.5	5.1	4.6	5.5
Japan (97)				1				0.8
New Zealand (98)				0.18				3.9
Austria (97)				0.25				1.2
Belgium (97)				0.20				0.6
Denmark (95)				0.28				-1.4
France (97)				0.38				-0.4
Finland (97)				0.35				0.2
Germany (97)				0.31				3.5
Ireland (97)				0.41				1.0
Italy (97)				0.32				0.3
Luxembourg (97)				0.20				1.5
Netherlands (97)				0.52				1.4
Norway (97)				0.31				4.5
Portugal (97)				0.33				-4.5
Spain (97)				0.38				-0.5
Sweden (97)				0.38				1.7
Switzerland (97)				0.32				3.1
Great Britain (94)				0.34				7.1
South Africa (98)				0.39				4.5

a The estimates are presented up to the latest year for which data were available. The period for Australia's national rail system is 1989-90 to 1997-98. The period for all other national rail systems is 1990 to the year indicated in parentheses. **b** Locomotive input measured as number of locomotives. National average obtained by weighting individual railway estimates by freight output (ntkm). **na** Not available.

Source: Commission estimates.

Table B.4 Estimates of technical efficiency for national rail systems, since 1989-90[a]

	Current level				Average annual growth, (%) since 1989-90			
	Model 2[b]	*Model 3*	*Model 4*	*Model 5*	*Model 2*[b]	*Model 3*	*Model 4*	*Model 5*
Australia (98)	0.70	1	1	0.69	7.6	3.7	2.6	7.9
United States (97)	0.88	1	1	1	4.8	3.8	0.8	1.8
Canada (97)	0.92	1	1	1	5.2	3.9	1.9	5.5
Japan (97)				1				0.8
New Zealand (98)				0.73				3.6
Austria (97)				0.27				1.3
Belgium (97)				0.24				1.3
Denmark (95)				0.60				3.4
France (97)				0.39				-0.5
Finland (97)				0.45				1.1
Germany (97)				0.32				3.5
Ireland (97)				1				0.5
Italy (97)				0.33				0.6
Luxembourg (97)				1				0.0
Netherlands (97)				0.68				3.6
Norway (97)				0.74				7.6
Portugal (97)				0.63				1.6
Spain (97)				0.43				0.7
Sweden (97)				0.47				2.9
Switzerland (97)				0.38				3.7
Great Britain (94)				0.43				12.9
South Africa (98)				0.42				4.7

[a] The estimates are presented up to the latest year for which data were available. The period for Australia's national rail system is 1989-90 to 1997-98. The period for all other national rail systems is 1990 to the year indicated in parentheses. [b] Locomotive input measured as number of locomotives. National average obtained by weighting individual railway estimates by freight output (ntkm). **na** Not available.

Source: Commission estimates.

Therefore, Australian railways are rated to be as productive as the North American railways, despite the inferior assessment produced by models 2 and 3, which are based on freight services only.

Models 3 and 5

By expanding the sample coverage (especially the inclusion of Japan, a major provider of passenger services), model 5 produces estimates of productivity for Australian, US and Canadian national rail systems which are similar to those produced by the freight-only model 3 (table B.3). Australia’s productivity gap is estimated to be around 40 per cent of the best practice level in North America and Japan. Models 3 and 5 also estimate consistent growth in productivity for Australia, Canada and, to a lesser extent, the United States over the study period. This suggests that the freight-only model may provide a good indication of performance in providing both types of services.

Model 5 is superior to model 3 in its ability to differentiate technical efficiency (table B.4). The inclusion of smaller European rail systems in model 5 contributes to its effective assessment of technical efficiency as Australia is now grouped with some European systems. This contrasts with all the other models where the peer group for Australia contains only Australian observations.

Model 5 suggests that Australia’s productivity gap relative to world best practice results mainly from differences in technical efficiency. This is a robust result in the context of DEA, because the measure of scale effects in DEA does not increase when new observations are added to the sample. Thus, a further expansion of the country coverage in model 5 will not substantially change the results related to Australia (box B.1).

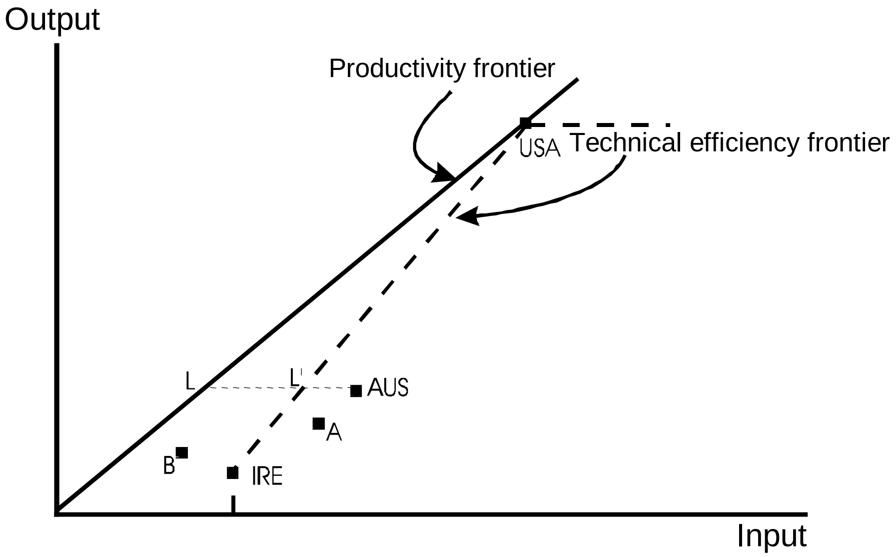
Model 5 suggests that productivity in many countries is relatively low. The contribution of technical efficiency is large for many European countries such as Austria, Belgium and France (tables B.3 and B.4 show only small differences between productivity and technical efficiency). In other countries, scale effects are estimated to contribute significantly to the productivity score, as for New Zealand, France and Ireland (where there is a large difference between the two scores).

Box B.1 **Country coverage and the measure of technical efficiency**

The impact of a change in sample coverage on the measure of technical efficiency is illustrated in the figure below, which is a stylised representation of model 5 results.

In this figure, the input-output relationships for Australia, the United States, and Ireland (which all belong to the same peer group) are denoted by the points labelled AUS, USA, and IRE respectively. The productivity frontier is the line joining the origin and the point USA. The technical efficiency frontier for Australia is the dotted line between USA and IRE. Scale effects are measured as the horizontal distance between the two frontiers. For Australia, scale effects are measured to be LL', the wedge between the estimates for productivity and technical efficiency.

Estimating the scale effect in DEA



Adding a new sample country such as point A does not alter either frontier, hence there is no effect on Australia's estimates. However, a new observation such as point B shifts the technical efficiency frontier towards the productivity frontier. The productivity frontier remains intact as it is determined by the world best practice (USA). With such a shift in the technical efficiency frontier, the model reduces the contribution of scale effects for Australia, and increases the contribution of technical efficiency.

Models 2 and 5

Both models estimate similar levels of productivity for Australia, at about 40 per cent below the United States (table B.3). According to model 2, not accounting for differences in locomotive power may introduce a bias in the order of 10 per cent in estimating Australia’s productivity gap (table B.1).[7] The ranking of the domestic railways changes little after accounting for differences in locomotive power.

Model 5 suggests that scale differences explain less than 10 per cent of the productivity gap between the Australian system and world best practice (table B.4).[8] The limited country coverage of model 2 constrains its ability to produce robust estimates of technical efficiency for individual Australian railways.

Combining results from models 2 and 5 for Australia, the United States and Canada allows for the following inference: since model 5 estimates small scale effects for these national systems, model 2 results in terms of productivity can be used as a reasonable predictor for the individual railways’ technical efficiency.

Model 5’s estimates of small scale effects at the national system level suggest that small scale effects are likely to be estimated at the railway level under similar sample coverage. This proposition is supported by two arguments. First, differences in scale are less pronounced across railways within a country than across countries (see appendix C, tables C.1 and C.2). Second, results for models 2 and 5 suggest a strong degree of consistency between the results at the individual and national levels. This implies that, if model 2 included small productive railways in its sample, estimates of productivity would not be very different from estimates of technical efficiency.

Many caveats are in order. For example, this ignores the impact of factors relating to different operating environments (such as traffic density) may have on each model’s estimates. However, model 5 does in a way help to support results from model 2 and allows some (albeit careful) reinterpretation of model 2 estimates of technical efficiency.

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[7] This is based on the difference between model 2’s estimates of Australia’s productivity of 0.47 (using the unadjusted locomotive data series) and 0.52 (using the power adjusted data series) respectively (table B.1).

[8] This is based on the difference between model 5’s estimates of Australia’s productivity of 0.64 (table B.3) and technical efficiency of 0.69 (table B.4).

C Railway characteristics

This appendix discusses factors relating to the characteristics of railway operating environments. The objective is to understand the link between such factors and relative performance.

Section C.1 presents a profile of the railways, highlighting the similarities and differences in their size and traffic pattern. These factors are discussed in the categories introduced in chapter 2 (section 2.3). Section C.2 describes the railways' input structure, output mix and partial productivity and, using such information, illustrates the major factors that influence the measurement of productivity using DEA.

C.1 Railway profiles

Freight railways in Australia and the United States

The operational characteristics of Australian and US freight railways vary considerably both within and between the countries (table C.1).[1]

Size of the market

There are large differences in the scale of railways included in the sample. The scale of rail operations can be measured using output (net tonne-kilometres) or network size (track kilometres). In terms of freight output in 1997, the largest railways in the United States (namely UP and BNSF) were more than twenty times larger than any in Australia. Domestically, QR has the largest freight output, over ten times greater than the smallest railway (PTC in Victoria) in 1997. In terms of track length, Australian railways are much smaller than those in the United States.

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[1] Data on the traffic pattern of individual Canadian railways are not available.

Table C.1 **Indicators of factors affecting railways in Australia and the United States, 1996-97**

	Freight output *(billion ntkms)*	*Track length* *('000 kms)*	*Freight train density* *('000 train kms per track km)*	*Average freight load* *(tonnes per train)*	*Average haul length* *(kms)*	*Average power rating of locomotives* *(horsepower)*
Australia:						
AN-NRC	17.5	6.0	2.1	1376	815	3235
PTC	2.3	5.7	0.7	551	277	2049
QR	28.8	9.5	3.5	878	274	2331
SRA	12.1	8.6	0.8	1856	167	2333
WR	6.2	6.5	1.2	794	200	2382
US:						
CR	143.4	33.8	1.8	2383	1113	2845
CSX	243.5	49.8	2.2	2215	905	3204
GTW	14.3	2.8	3.0	1712	1447	2057
ICR	32.7	7.1	1.8	2519	834	2323
KCS	28.7	6.5	1.7	2561	1008	2723
NSC	199.0	40.6	2.0	2486	955	3106
SOO	31.6	8.0	1.5	2682	1303	2567
UP	664.7	91.0	2.6	2790	1746	3168
BNSF	626.3	81.9	2.8	2704	1794	3063

Source: Commission estimates.

Utilisation of inputs

Measured in terms of freight train density, the rate of network utilisation seems to have no direct relationship to network size. The relatively small domestic railways (PTC, SRA and Westrail) are associated with low train density. However, QR displays the highest train density despite its modest size compared to US railways. Many lines in Queensland transport large quantities of coal and ore over relatively short distances. In the United States, the smallest Class I railway, GTW, runs more trains per track kilometre than the others, including BNSF and UP.

Average haul length

Freight trains in the United States run longer hauls than those in Australia, partly reflecting the geographical differences between the two countries.

Capacity of infrastructure

Average loads are also different between the two countries. In 1997, most freight railways in the United States carried on average more than 2500 tonnes, while the average loads in Australia varied between 550 and 1900 tonnes.

In 1997 the average power of locomotives for US railways exceeded 2500 horsepower. By comparison, railways in Australia use smaller locomotives. However, NRC has recently increased the size of its locomotives.

National rail systems

The national rail systems analysed in this study represent a diverse sample of railways operating in different environments (table C.2).

In general, there are large variations in the scale and mix of operations. The US Class I railways are the largest in terms of freight output and track length. The Japanese system carries more passenger traffic than any other rail system in the sample.

Size of the market

Australia's network size is similar to that of France, Germany and South Africa. Australia's total freight output in 1997 is comparable to that of France and Germany (though much more heavily weighted towards bulk haulage) but notably lower than that of South Africa. Within this sub-sample, the railways in Australia taken together have the lowest level of total passenger traffic in 1997.

Composition of traffic

The rail systems in Japan and most European countries specialise in passenger services. In Japan, Denmark, the Netherlands and Great Britain, about 90 per cent of train movements in 1997 were passenger services. In contrast, the rail systems in North America are heavily skewed towards freight services, leaving most passenger traffic to other transportation modes.[2] The Australian national rail system shows a mix between passenger and freight traffic.

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[2] The omission of North American urban passenger services from this study may have affected the reported freight/passenger mix.

Table C.2 Indicators of aspects the operating environment affecting selected national rail systems, 1997[a]

	Freight output *(billion ntkms)*	*Passenger output* *(billon passenger kms)*	*Output composition* *(% passenger train kms in total)*	*Track* *('000 kms)*	*Passenger train density* *('000 train kms per track km)*	*Average passenger load* *(persons per train)*	*Average trip length* *(kms)*	*Freight train density* *('000 train kms per track km)*	*Average freight load* *(tonnes per train)*	*Average haul length* *(kms)*
Australia	66.9	9.9	56	36.4	2.2	119	21	1.8	1046	281
United States	1984.2	8.3	6	235.2	0.2	161	412	3.2	2596	1380
Canada	308.5	1.5	16	75.0	0.3	69	369	1.6	2595	966
Japan	24.3	247.7	89	20.2	34.6	355	28	4.1	295	509
New Zealand	3.5	0.4	na	4.1	na	na	na	na	na	304
Austria	13.8	8.1	68	5.7	15.2	94	44	7.0	345	198
Belgium	7.5	7.0	81	3.4	21.2	96	49	5.1	430	127
Denmark	1.6	5.0	88	2.2	22.7	98	35	3.1	231	195
France	52.6	61.6	69	31.7	10.9	178	77	4.9	338	398
Finland	9.9	3.4	62	5.9	4.6	125	68	2.8	592	244
Germany	72.4	59.6	77	38.5	16.8	92	44	5.0	378	245
Ireland	0.5	1.4	73	1.9	5.8	122	47	2.2	125	179
Italy	22.9	49.5	79	16.0	16.0	193	107	4.3	329	306
Luxembourg	0.7	0.3	85	0.3	22.2	48	26	3.8	540	35
Netherlands	3.4	14.4	93	2.8	40.2	128	46	3.0	401	149
Norway	3.0	2.6	74	4.0	6.8	94	57	2.4	312	459
Portugal	2.2	4.6	82	2.6	15.4	115	26	3.5	249	241
Spain	11.0	16.6	76	12.3	10.2	133	42	3.3	273	439
Sweden	18.1	6.3	65	10.2	6.4	96	60	3.5	508	337
Switzerland	8.5	12.8	78	3.2	28.5	141	47	8.2	326	181
Great Britain	16.9	34.2	90	16.7	22.3	92	40	2.4	428	166
South Africa	103.9	12.6	na	33.0	1.0	376	16	na	na	556

[a] Except for Great Britain (up to 1994 only) and Denmark (1995).

Source: Commission estimates.

Utilisation of inputs

The traffic pattern of passenger trains is partly related to the scale of operations and partly driven by such factors as population density and the proximity of locations served by the rail network. For instance, Japan’s population size and density support relatively high levels of network utilisation (passenger train density) and train use (average passenger load) in transporting passengers between relatively close destinations (average trip length). Australian passenger services utilise the total network at a lower rate and carry smaller passenger loads per train.

The rate of network utilisation by Australian freight trains is low compared to that in other countries in the sample. Australia’s average freight load is lower than in North America but higher than in Japan and Europe.

C.2 Input–output relationships

This section examines the input structure, output mix and partial productivity of the railways analysed. This not only describes the railways’ characteristics but also helps to explain how DEA assesses relative productivity.

Freight railways in Australia and North America

Railways providing freight services in Australia (except AN-NRC) and Canada are labour intensive compared to US practice, as indicated by the labour-locomotive ratios given in table C.3.

Further, the domestic rollingstock fleets consist of a smaller proportion of wagons relative to locomotives than those in the United States and Canada. This reflects the use of relatively powerful locomotives, large wagons, and long trains in North America where tracks permit higher axle loads. Tracks on most Australian networks are designed for lower axle loads.

The maximum value for each of the output–input ratios across the sampled railways indicates the best partial productivity achieved. In the DEA technique, railways that achieve the best partial productivities are selected to form the efficient frontier. DEA takes a linear combination of these efficient railways to create a representative best practice railway for each of the other railways in the sample.

Table C.3 Selected measures of input intensity and partial productivity of freight railways in Australia, Canada and the United States, 1997-98[a]

	Labour / Locomotive *(freight staff per locomotive)*	*Wagons / Locomotive* *(wagons per locomotive)*	*Freight / Labour* *(million ntkms per freight staff)*	*Freight / Locomotive* *(million ntkms per locomotive)*	*Freight / Wagon* *(million ntkms per wagon)*	*Freight / Track* *(million ntkms per km track)*
Australia:						
AN-NRC	8.6	27.3	9.0	77.2	2.8	2.7
PTC	22.1	29.4	1.4	30.1	1.0	0.4
QR	18.1	22.6	3.2	94.9	2.6	3.1
SRA	18.2	13.9	1.8	32.3	2.3	1.7
WR	14.4	25.4	5.3	76.9	3.0	1.0
Canada:						
CN	19.8	50.6	7.4	145.8	2.9	4.3
CP	15.9	38.8	7.4	117.5	3.0	4.7
Class II & III	16.5	39.3	5.3	87.6	2.2	2.4
US:						
CR	10.1	23.3	7.2	72.9	3.1	4.2
CSX	10.0	35.1	8.7	87.6	2.5	4.9
GTW	8.4	20.6	7.0	58.5	2.8	5.1
ICR	7.8	42.2	11.5	89.7	2.1	4.6
KCS	6.3	40.1	11.1	69.7	1.7	4.4
NSC	10.6	40.5	8.5	90.6	2.2	4.9
SOO	10.1	33.1	9.4	94.9	2.9	4.0
UP	7.5	16.8	12.7	95.4	5.7	7.3
BNSF	9.2	19.9	14.4	132.2	6.6	7.6

[a] 1997 for the United States and Canada.

Source: Commission estimates.

To illustrate, BNSF in 1997 is shown in table C.3 to be the most efficient in using labour, wagons and track inputs. Meanwhile, CN in 1997 achieves the highest level of productivity in locomotive use. [3] As a consequence, the observations of BNSF

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[3] The attainment of highest partial productivity is a sufficient but not necessary condition for an observation to be rated as relatively efficient in the DEA model. The frontier may include additional observations that show relatively high levels of partial productivity. The frontier also depends on the peer group composition as determined by the model. For instance, the two observations of BNSF in 1995 and 1996 are part of the frontier in model 2 because they show higher levels of labour and wagon productivity than the 1997 observation of CN. The technical efficiency frontier may have additional facets as the sample is divided into an increased number of peer groups and partial productivity measures are compared within groups rather than across the whole sample (appendix A).

and CN in 1997 form the efficient frontier in model 2 and are rated with productivity scores of one.

DEA scores for railways that are assessed to be less efficient relative to the best practice, are a function of the partial productivity gaps. For instance, the 1998 productivity score for AN-NRC in model 2 (that is 0.63) is produced by the smallest gap between its partial productivity and best practice within the whole sample, which is the labour productivity gap relative to BNSF in 1997.[4] The 1998 productivity score for PTC in model 2 can be similarly obtained by comparing its 1998 level of locomotive productivity against the best practice of CN in 1997. The corresponding estimate for SRA is given by the comparison of its wagon productivity against the best practice of BNSF in 1997. The derivation of productivity estimates for QR and Westrail is less straightforward as it involves taking linear combinations of the various partial productivity gaps.

The partial productivity measures provide clues about the impact of selecting different comparators on the assessment of Australian railways. For instance, by using a restricted sample of domestic railways (as in model 1), three domestic railways providing freight services in 1998 are assessed to be equally efficient. These railways are AN-NRC (highest labour productivity within the domestic sample), QR (highest locomotive productivity domestically) and Westrail (highest wagon productivity domestically). As a result, the assessment based on the restricted sample does not provide a useful ranking. In contrast, extending the sample to include North American railways provides the external benchmarks required to yield a meaningful ranking which is based on the high scores recorded for BNSF and CN.

National rail systems

Table C.4 presents various input-input ratios and output-input ratios to describe the factor intensity and partial productivity of the national rail systems.

In the context of joint production, a simple ratio used in isolation may not be a useful indicator of railway characteristics. Such a ratio is often not robust enough to represent the rail system in a comparative study. As an example, although the rail systems in Europe have a similar traffic mix (table C.2), the comparison of their

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[4] The estimate can be obtained by dividing AN-NRC's level of labour productivity (9.0) by that of BNSF (14.4).

Table C.4 Selected measures of input intensity and partial productivity of the national rail systems, 1998[a]

	Labour / Locomotive *(staff per locomotive)*	*Labour / Passenger car* *(staff per passenger car)*	*Wagons / Locomotive* *(wagons per locomotive)*	*Freight / Labour* *(million ntkms per staff)*	*Freight / Locomotive* *(million ntkms per locomotive)*	*Freight / Wagon* *(million ntkms per wagon)*	*Passenger / Labour* *(billion pass-kms per staff)*	*Passenger / Locomotive* *(billion pass-kms per locomotive)*	*Passenger / Car* *(billion pass- kms per passenger car)*
Australia	29.3	10.7	20.0	1.72	50.25	2.51	0.25	7.30	2.66
United States	9.9	147.3	24.2	9.85	97.64	4.04	0.04	0.41	6.08
Canada	14.8	109.1	34.5	6.63	98.14	2.86	0.03	0.48	3.56
Japan	122.3	7.1	13.5	0.13	16.4	1.21	1.36	166.55	9.74
New Zealand	15.7	21.4	16.5	0.76	11.82	0.72	0.09	1.34	1.82
Austria	45.7	17.1	21.8	0.25	11.43	0.52	0.15	6.75	2.52
Belgium	41.9	11.9	19.7	0.19	7.78	0.40	0.17	7.28	2.07
Denmark	56.8	9.3	14.9	0.11	6.38	0.43	0.30	17.27	2.83
France	35.1	11.1	21.2	0.30	10.54	0.50	0.35	12.33	3.92
Finland	22.4	15.2	20.2	0.68	15.28	0.76	0.23	5.23	3.54
Germany	26.6	12.6	25.5	0.31	8.23	0.32	0.26	6.78	3.21
Ireland	97.0	32.1	14.8	0.05	4.75	0.32	0.13	12.61	4.18
Italy	38.9	7.9	24.5	0.19	7.33	0.30	0.41	15.84	3.22
Luxembourg	47.5	21.1	35.1	0.18	8.71	0.25	0.10	4.54	2.02
Netherlands	52.4	9.6	9.6	0.13	6.88	0.72	0.56	29.14	5.36
Norway	50.8	13.5	17.0	0.28	14.10	0.83	0.24	11.97	3.19
Portugal	44.8	9.7	14.3	0.17	7.59	0.53	0.34	15.42	3.34
Spain	37.2	8.5	29.1	0.30	11.20	0.38	0.46	16.95	3.89
Sweden	31.1	12.1	29.2	0.93	28.99	0.99	0.32	10.06	3.92
Switzerland	24.2	8.3	14.1	0.26	6.19	0.44	0.38	9.33	3.21
Great Britain	62.8	10.9	7.6	0.11	6.91	0.91	0.24	15.23	2.66
South Africa	15.3	16.8	35.1	0.19	29.28	0.83	0.24	3.62	3.95

[a] The estimates are presented up to the latest year for which data are available. This is 1998 for Australia, New Zealand and South Africa, and 1997 for most other countries. Exceptions are Great Britain (up to 1994 only) and Denmark (1995).

Source: Commission estimates.

overall labour intensity depends on the type of capital goods — locomotives or passenger cars — used for calculating the labour-capital ratio.

DEA integrates the various partial productivity measures into a composite indicator of productivity. Among the sample countries, the United States was the most efficient freight system. Japan was the most efficient in passenger services, according to various partial passenger productivity measures. These observations of the United States and Japan are thus assessed as relatively efficient in the DEA model covering the whole sample of national rail systems (model 5). Therefore, best practice is a composite of the United States and Japan.

Australia's DEA scores are determined mainly by comparing its partial measures of freight productivity to US best practice. For instance, the 1998 productivity score for Australia in model 5 (0.64) is approximately equal to its wagon productivity gap relative to the US 1997 observation.[5]

Figure C.1 compares the levels of various partial productivity measures and DEA scores estimated by model 5 for the Australian rail system over the period 1990 to 1998.[6]

The partial productivity measures point to differing trends of productivity improvement in the usage of various inputs in domestic rail operations. For instance, increases in freight-labour ratios indicate rapid improvement in labour productivity as a combined result of expansion in freight output and reductions in the railway workforce. Generally speaking, the productivity of freight services appears to have improved at a faster rate than that of passenger services.

The varying trends in productivity gains imply that the industry's output mix and input structure have shifted over time along with technological advances and changes in work practices which have driven the improvement in railway productivity since 1990. Taking into account such structural changes in the input-output relationships, the DEA estimates provide a robust assessment of productivity that is consistent with the indications of the partial productivity measures.

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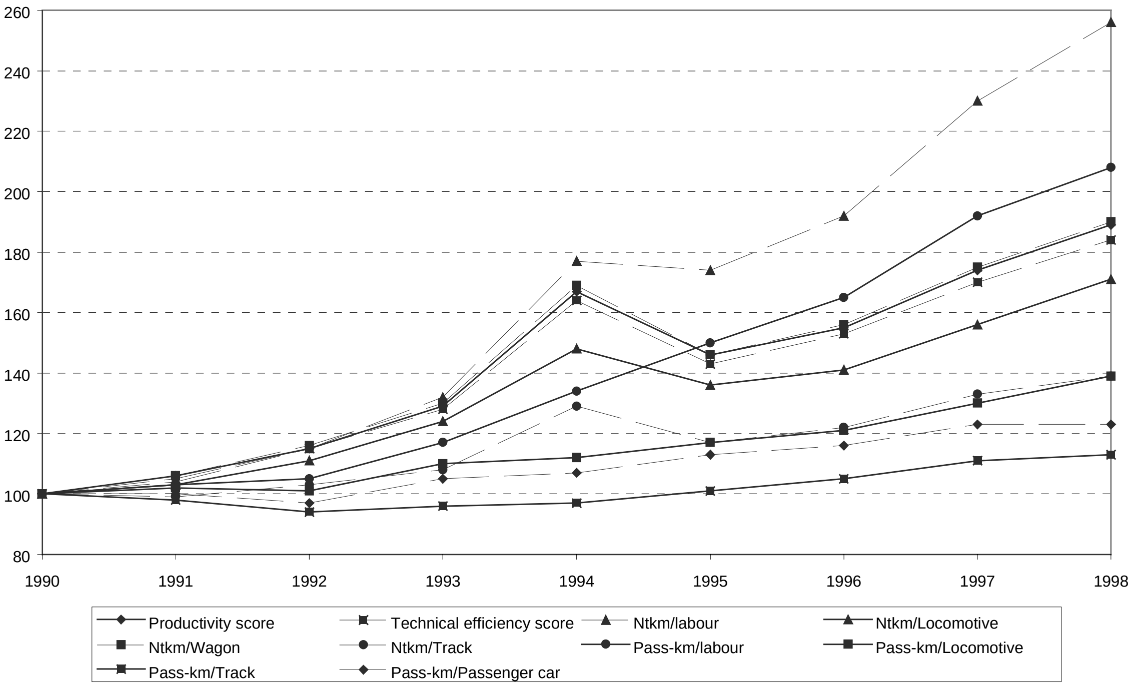
[5] Exact estimates of Australia's productivity scores also depend on its productivity gaps for passenger services relative to Japan, although the weighting factors applied to the latter are relatively small.

[6] Estimates for 1993-94 are affected by the transfer of freight business from the state-based railways to AN-NRC (chapter 2, section 2.1). The transfer possibly contributed to faster productivity growth at the industry level. As another possibility, data errors may arise as the reallocation of outputs and inputs among the railways may not be consistently recorded.

Figure C.1 **Productivity and technical efficiency estimates and partial productivity measures for Australia's rail industry**[a]**, 1989-90 to 1997-98**



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[a] Productivity scores and Ntkm/Wagon ratios virtually overlap.

Data source: Commission estimates.

D Studies of railway performance

As discussed in chapter 1, there are two aspects to measuring the performance of railways — productivity and stakeholder outcomes. A number of studies have examined the performance of railways, both in Australia and internationally. Most have concentrated on measuring productivity, rather than stakeholder outcomes. This appendix briefly discusses some of these studies.

Section D.1 discusses studies of railway productivity. Section D.2 compares the results of the present study to some of these. Section D.3 presents details of other studies that have examined stakeholder outcomes (financial performance).

D.1 Studies of railway productivity

The general perception of Australia's railways during the 1980s was that of an industry in decline — inefficient, costly and inconvenient. Participants to the Industry Commission's (IC) 1991 inquiry into rail transport (IC 1991) made numerous criticisms of the productivity, pricing and service quality of Australia's railways.

Studies of Australia's rail industry prior to the 1990s generally supported the anecdotal view of an inefficient industry. However, they also highlighted improvements in the productivity of Australia's government-owned railways, although the extent of these improvements varied across jurisdictions.

Most studies undertaken to measure the productivity of the rail industry have focused on measuring total factor productivity (TFP). There are several methods of measuring TFP including index number methods, DEA and econometric techniques.

This section examines previous studies undertaken in each of these categories, outlining the approaches and results. Appendix A, section A.1 summarises the theory underlying each method.

Index numbers

Most TFP studies of Australian railways use the index number method. Examples include Hensher, Daniels and DeMellow (1995), IC (1994), IC (1991), IAC (1989) and BTCE (1991). Other studies using index number methods include Waters and Street (1998) and Waters and Tretheway (1999).

IC (1991) used multilateral TFP to compare the levels and growth rates for the five Australian railways over the period 1980-81 to 1989-90. Output categories were freight and passenger services and inputs were labour, capital and ‘others’ (fuel, materials, and purchased services). The study found that Queensland Rail (QR), Australian National (AN) and Westrail achieved relatively high levels of productivity. Their productivity growth rates ranged from 5 to 6 per cent a year. In contrast, the State Rail Authority of New South Wales (SRA) had a slower rate of productivity growth (2.9 per cent a year). Also, the Public Transport Corporation (PTC) in Victoria was found to have a relatively low level of productivity.

The same IC (1991) report decomposed TFP levels using regression techniques and found that scale was significantly and positively related to TFP. This finding suggests the presence of scale economies in some Australian railways. Further, TFP was found to be strongly influenced by output composition (ratio of freight to passenger service outputs), suggesting that freight-oriented railways have higher TFP than passenger-oriented railways, other things being equal. After the adjustments made for the effects of scale and output composition, the analysis revealed that QR, PTC and SRA made little productivity gains over the period.

BTCE (1991) estimated the annual rate of TFP growth for Australian National between 1979-80 and 1987-88 to range between 5 and 6 per cent. This growth was attributed to reductions in surplus staff, a more commercially determined mix of outputs, and changes to management techniques.

IC (1994) and Hensher, Daniels and DeMellow (1995) represented railway outputs by the alternative demand- and supply-side measures. Demand-side output measures included passenger-kilometres for passenger services, and net tonne-kilometres for freight services. Supply-side output measures referred to train kilometres and seat kilometres.

IC (1994) evaluated productivity performance of three urban railways from 1986-87 to 1992-93. The three urban railways analysed were PTC, Transperth, and the State Transport Authority (STA) of South Australia. The study found that Transperth was the most efficient based on the supply-side output measure and STA was the most efficient railway based on the demand-side output measure. For both STA and Transperth, buses were found to be more efficient than rail in providing public transport. As Transperth increased rail services relative to bus services over the years, its productivity was noted to have fallen below that of STA.

Hensher, Daniels and DeMellow (1995) used the Törnqvist index formula to compare the productivity of the five railways in Australia, providing freight and passenger services, over the period 1971-72 to 1991-92. Like IC (1994), they used both demand- and supply-side output measures to calculate the TFP index. SRA and PTC were noted to have the lowest relative levels of productivity. QR recorded the best performance. The demand-side TFP measures for SRA and PTC were estimated to have doubled over the period, while the corresponding measure for QR tripled. The rates of TFP growth estimated using the supply-side output measure were generally less than those based on the demand-side output measure, except for QR. Using different output measures to calculate the TFP index can lead to some variations in estimated relative productivity levels.

In their paper, Hensher, Daniels and DeMellow attempted to explain the causes of productivity growth by decomposing the TFP measure into components representing the effects of technological changes, management practices, traffic density, scale economies, output composition, network size, and other railway-specific factors. After making adjustments for these factors, the authors found that there were still significant differences in TFP between the five railways. The authors ascribed such remaining differences to technical efficiency.

DEA studies

DEA has been used extensively in Australia and overseas for various benchmarking purposes.[1] However, the Commission is unaware of any studies applying DEA to measure the productivity of Australian railways.

Oum and Yu (1994) used DEA to measure the technical efficiency of 19 OECD rail systems that derive a high proportion of business from passenger services. Australian railways were not included in the study. The period covered was 1978 to 1989. The authors noted that their choice of DEA was particularly influenced by the lack of adequate data for constructing price indices on a consistent basis across countries.

Two alternative sets of output measures were used to estimate productivity scores using DEA: (i) revenue output (demand-side) measures (passenger-kilometres and freight tonne-kilometres); and (ii) available output (supply-side) measures. Seven inputs were used: labour, energy consumption, ways and structures, materials, the

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[1] For example, DEA has been applied in Australia to measure the productivity of electricity generation (Zeitsch and Lawrence 1996), telecommunications (BIE 1992), and government services (SCRCSSP 1997).

number of passenger cars, the number of freight wagons and the number of locomotives.

Oum and Yu found that the demand and supply side output measures produced quite different productivity estimates. However, the estimates had a fairly consistent pattern in the relative performance of national rail systems. In particular, railways in Great Britain, Sweden, Japan, Ireland, the Netherlands and Finland all improved their performance over the period to be close to the efficient frontier in 1989. The greatest improvement in railway performance occurred in Denmark and Finland. Railways in Luxembourg and Norway were estimated to have had declines in their productivity.

Oum and Yu used econometric techniques to adjust productivity to take into account the differences in operating environments. Factors taken into account included traffic density, traffic mix, electrification, subsidies and managerial autonomy. The adjusted productivity estimates produced a change in the rankings and relative performance of railways.

Econometric analysis

There is an extensive literature that uses econometrics to estimate cost functions, including Wilson (1997), MacDonald and Cavalluzzo (1996), Freidlander et al. (1993), Caves, Christensen and Tretheway (1981), Freidlander and Spady (1981) and Caves, Christensen and Swanson (1980). All are studies of US railroads. Either a total cost function or the variable cost function is estimated using the translog functional form. Three studies that used econometric techniques for non-US railways are those by Lubulwa and Oczkowski (1987), Perelman and Pestieau (1988) and Coelli and Perelman (1998).

Using a variable cost function, Caves, Christensen and Tretheway (1981) derived implied estimates of productivity growth for US Class I railroads for the period 1955 to 1974. The four outputs were ton-miles of freight, average haul length, passenger-miles, and average passenger trip. The three variable inputs were labour, fuel and equipment (and materials).

They estimated three productivity measures (table D.1). The first measure was defined according to constant output levels (input-saving measure) and the remaining two measures according to constant input levels (output-augmenting measures) but with different estimates of scale economies.

Table D.1 **Annual productivity growth, US Class I railroads, 1955 to 1974**

Measure		*1955 to 1974*	*1955 to 1963*	*1963 to 1974*
		%	%	%
Outputs fixed		1.8	3.4	0.6
Inputs fixed	scale estimate 1	2.0	4.2	0.7
	scale estimate 2	1.8	3.5	0.6

Source: Caves, Christensen and Tretheway (1981).

The three measures indicate that there was rapid productivity growth from 1955 to 1963 in the order of 3.5 per cent to 4.0 per cent a year. The rate slowed to less than 1 per cent a year from 1963 to 1974. Productivity growth averaged about 2 per cent annually over the entire period.

Wilson (1997) used US Class I freight data from 1978 to 1989 to estimate a translog cost function. Using this model, productivity gains and cost savings through time and regulatory regimes were identified. Revenue ton-miles was the output measure. The model included prices for the inputs of labour, fuel, equipment and materials and supplies. No capital prices or expenditures were used in the model. Instead, the railways' track speed rating was used as a proxy for differences in capital across railways. The model included a time trend and a dummy variable to capture the effect of the Staggers Act, which partially deregulated railways in 1980. Three technological variables were included — average haul length, the percentage of unit train traffic (trains carrying one commodity from one origin to a single destination) and the percentage of interlined traffic (freight carried by more than one railway).

Wilson had two major findings.

- Deregulation resulted in a dramatic downward shift in the average variable cost function.
- Annual productivity gains were low in the period prior to deregulation (costs falling 1 to 2 per cent per year), but rose significantly in the period immediately after deregulation (6 to 7 per cent year), before falling back to their pre-Staggers levels. In 1989 costs were estimated to be around 40 per cent lower under partial deregulation than they would have been if the Staggers Act were not passed.

Lubulwa and Oczkowski (1987) adopted an econometric approach to analyse technical changes in Australian freight railways over the period 1952-53 to 1982-83. They estimated a Cobb Douglas production function based on both demand- and supply-side output measures, and two inputs (labour and rollingstock). The estimated rates of technical progress varied significantly depending on the output measure used. For instance, the average rate of technical progress was estimated at 2 per cent a year based on the supply-side measure of output (train kilometres). This compared with an estimate of 6 per cent based on the alternative output measure of net tonne-kilometres. Also, the results of comparative performance across railways changed considerably.

Perelman and Pestieau (1988) adopted an econometric approach to estimate a translog production frontier for European rail systems. Freight and passenger services were aggregated as a single output variable. The input variables included labour, energy, rollingstock, and fixed equipment. The study covered the years from 1970 to 1983.

Coelli and Perelman (1998) used an econometric distance function to represent the production frontier of rail systems in Europe. Outputs were measured in terms of passenger-kilometres and freight tonne-kilometres, while inputs were labour, rollingstock, and total length of lines. The study period spanned 1988 to 1993.

Detailed results of the last three models are presented in section D.2, comparing their results to those of the present study.

D.2 Comparing results

In this section, the DEA estimates of productivity obtained from the present study are compared with those from selected external studies sampling a similar set of rail systems.

The main purpose of such a comparison is to test the robustness of the present modelling results with respect to both the benchmarking technique and the model specification chosen. This is a way of validating the model, which contributes to the reliability of the results. Differences between study results can shed light on certain features of the model that may be responsible for differences in performance assessment.

To calculate productivity scores for the same time intervals as the previous studies, the DEA models are estimated using rail data back to the 1970s.

Compared to the productivity scores obtained for the post-1990 period (chapter 3 and appendix B), the scores calculated in this study for earlier years may be less accurate. This is because earlier data are of lower quality than recent data. The historical data sets available for this study contain gaps and lack uniformity. Parts of the data series required for this exercise were imputed using information collated from different channels, including secondary data sources (chapter 2).

When judging the degree of consistency between the different studies, a few factors should be borne in mind.

- Different studies may use different data series to represent the same model variable, and use revised figures for the same data series.
- Underlying the productivity measures are different modelling assumptions adopted by respective studies, which prescribe different ways to interpret the scores.
- Only estimates for productivity are examined here. Some studies use DEA and regression to obtain estimates of technical efficiency, which are not compared in this exercise.

Study results compared

Two types of railway studies are selected for validating the assessment results of this study:

- the assessment of individual railways in Australia; and
- the assessment of the rail systems in a large sample of countries.

The results of these studies are presented in this section to compare them with the current study. The detail of each study is presented in section D.1.

Australian comparisons

As noted in section D.1, previous studies of productivity for Australian railways have been conducted either by means of the total factor productivity index (TFP) or using the regression technique. The two studies examined to compare results with the present study are Hensher, Daniels and DeMellow (1992) (TFP index) and Lubulwa and Oczkowski (1987) (regression). As these two studies cover different periods, they are compared separately to models 1 and 2 used in this study.

Table D.2 compares the productivity scores of the Hensher, Daniels and DeMellow study with those of the present study for the year 1992. For ease of comparison, these estimates are all re-based taking the 1992 average level as one. For example, productivity estimates derived from the DEA model are converted to index numbers that are no longer bound between zero and one. In this table, a reading of the productivity level at, say, 0.95 for AN-NRC means that the railway is estimated to be five per cent less efficient than the industry average.

Also included in table D.2 are the average annual rates of productivity growth from 1982 to 1992. Long term growth rates can smooth year-to-year fluctuations in measuring productivity.

Table D.2 **Comparison of TFP and DEA estimates of productivity for Australian railways[a], 1981-82 to 1991-92**

	Relative level, 1991-92			*Average annual growth rate, 1981-82 to 1991-92 (%)*		
	Hensher et al.	*Model 1*	*Model 2*	*Hensher et al.*	*Model 1*	*Model 2*
AN-NRC	1.03	0.95	1.01	4.2	7.6	7.8
PTC	0.53	0.50	0.50	3.8	3.1	3.1
QR	1.33	1.05	1.12	6.1	6.6	6.9
SRA	0.76	1.11	0.94	4.6	5.7	5.7
WSR	0.96	0.85	0.91	4.9	6.0	6.6
Average	*1.00*	*1.00*	*1.00*	*5.7*	*6.4*	*6.8*

[a] All estimates presented in this table are re-based taking the 1991-92 average level as one.

Sources: Hensher, Daniels and DeMellow (1992); Commission estimates.

The studies compared in table D.2 produce broadly consistent estimates of the 1992 productivity level, notwithstanding their use of different benchmarking techniques and the selection of different input variables. In particular, model 2 results on freight productivity closely resemble Hensher, Daniels and DeMellow's results on the combined productivity of freight and passenger services.

On the other hand, models 1 and 2 tend to estimate faster rates of productivity growth over the ten years to 1992 than Hensher, Daniels and DeMellow. This may be due to the fact that the TFP measures of Hensher, Daniels and DeMellow's study include inputs that have not been used in the present study. The difference may also be related to the use of revised and imputed historical data in the present study.

Estimates of productivity from the Lubulwa and Oczkowski (1987) study are shown in table D.3, along with the corresponding figures obtained from this study, for the year 1983.[2] These estimates are all expressed as indices with the 1983 average level equated to one. Between the studies, the relative ranking of the railways is roughly comparable. For instance, the estimated productivity levels for PTC are consistently lower than other railways.

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[2] Long term productivity growth rates are not compared since no data prior to 1980 are available for this exercise.

Table D.3 **Comparison of regression and DEA estimates of productivity for Australian railways[a], 1982-83**

	Lubulwa and Oczkowski	*Model 1*	*Model 2*
AN-NRC	0.92	0.87	0.93
PTC	0.36	0.55	0.57
QR	1.03	1.07	1.13
SRA	1.05	1.11	0.95
WSR	1.27	1.00	1.04
Average	*1.00*	*1.00*	*1.00*

[a] All estimates presented in this table are re-based taking the 1982-83 average level as one.

Sources: Lubulwa and Oczkowski (1987); Commission estimates.

International comparisons

Three studies — Perelman and Pestieau (1988), Oum and Yu (1994), and Coelli and Perelman (1998) — provide alternative estimates of productivity for a panel of national rail systems in Europe. These studies all use International Union of Railways (UIC) data. Their results are compared to the results of model 5 used in this study.[3]

Table D.4 compares the productivity scores obtained by the above studies for different years to the corresponding results of model 5. In this table, Ireland is arbitrarily chosen as a common base for re-scaling all scores.

In general, the external studies suggest smaller intercountry differences in rail system productivity than the present study. This may be explained in part by the absence of some sample countries in the external studies and the different estimation methods adopted.

The omission of the United States in the external studies (and Japan in Coelli and Perelman's study) results in low discriminatory power of the models. This happens because sample data representing relatively inefficient rail systems will be enveloped more tightly by the frontier if efficient performers such as Japan and the United States are not present in the sample. For example, in Oum and Yu's study, the estimated level of productivity for Japan in 1989 is equal to that for Finland, Ireland, Portugal, Sweden and Great Britain.

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[3] Unlike model 5, the external studies do not include Australia, the United States, Canada, New Zealand, nor South Africa in the sample. Such differences in sample coverage are partially responsible for variations in productivity estimates in these studies.

Table D.4 Comparison of estimates of productivity for selected national rail systems[a]

	Perelman and Pestieau		Oum and Yu[b]		Coelli and Perelman	
		1981–83		1989		1988–93
Japan	0.92	(2.67)	1	(2.58)	na	(na)
Austria	0.71	(0.65)	0.62	(0.66)	1.32	(0.61)
Belgium	0.54	(0.67)	0.71	(0.55)	1.30	(0.52)
Denmark	1.02	(0.97)	0.75	(0.82)	1.26	(0.75)
France	0.81	(1.30)	0.84	(1.19)	1.36	(1.04)
Finland	0.79	(1.10)	1	(0.97)	1.34	(0.85)
Germany	0.69	(0.92)	0.65	(0.75)	1.32	(0.65)
Ireland	1	(1)	1	(1)	1	(1)
Italy	0.51	(1.02)	0.82	(0.91)	1.20	(0.85)
Luxembourg	0.67	(0.85)	0.70	(0.58)	1.31	(0.48)
Netherlands	1.41	(1.58)	0.94	(1.31)	1.49	(1.43)
Norway	0.93	(0.92)	0.67	(0.68)	1.34	(0.59)
Portugal	0.78	(1.65)	1	(1.62)	1.22	(1.20)
Spain	0.71	(1.36)	0.77	(1.11)	1.29	(1.02)
Sweden	0.85	(1.17)	1	(0.94)	1.27	(0.87)
Switzerland	0.89	(0.79)	0.73	(0.76)	1.36	(0.71)
Great Britain	0.72	(0.69)	1	(0.75)	1.32	(0.73)

[a] Figures in parentheses are the corresponding scores obtained from model 5. All scores presented in this table are re-based taking the estimated productivity level for Ireland as one. [b] As discussed in section D.1, Oum and Yu used two alternative sets of output measures to compute the DEA scores. For the comparison purposes, the revenue-output based DEA estimates are quoted. **na** Not available.

Sources: Perelman and Pestieau (1988); Oum and Yu (1994); Coelli and Perelman (1998); Commission estimates.

In Perelman and Pestieau's study, Japan has a lower rating of combined productivity than in model 5. This is related to the different ways in which freight and passenger outputs are represented. In Perelman and Pestieau's model, freight and passenger services are aggregated on the basis of their revenue shares and represented by a single output variable. This assumes that a railway's performance in different service areas is essentially compensatory. Such an assumption differs from the treatment of a two-output DEA model, which assesses the railway on separate counts of freight and passenger productivity. For instance, model 5 assesses Japan as relatively efficient on account of its superior performance in passenger services.

Further, the similar productivity estimates obtained across the sample countries in Coelli and Perelman's study are related to the use of a flexible functional form (translog function) for formulating the production frontier. Composed of a large number of unknown parameters, such a function can be fitted closely with sample data. This implies that the railways are mostly evaluated close to the estimated frontier, resulting in a small variance of the productivity estimates on average.

Table D.5 shows the productivity growth rates over different time periods as estimated by the external studies. Some notable differences between these figures and model 5 results are observed. For some sample countries (such as Ireland, Austria, Italy, Switzerland and Great Britain), however, the estimated trends of productivity gains are similar across studies.

Table D.5 **Comparison of estimated rates of change in productivity for selected national railways (per cent per year)[a]**

	Perelman and Pestieau		*Oum and Yu*		*Coelli and Perelman*	
		1970 to 1983		*1978 to 1989*		*1988–93*
Japan	0.9	(0.4)	0.0	(1.7)	na	(2.8)
Austria	0.9	(0.9)	0.3	(2.3)	2.9	(2.6)
Belgium	0.4	(-4.2)	1.4	(-0.4)	2.9	(0.6)
Denmark	3.1	(0.5)	3.0	(8.7)	3.3	(2.2)
France	0.0	(2.6)	0.8	(2.4)	2.5	(1.4)
Finland	0.0	(2.9)	2.2	(2.1)	3.1	(1.0)
Germany	0.1	(-1.1)	0.3	(0.1)	2.4	(-0.2)
Ireland	6.1	(6.5)	NA	(1.1)	3.0	(2.9)
Italy	-0.1	(-1.0)	0.0	(0.7)	2.4	(1.3)
Luxembourg	-0.2	(0.0)	-2.6	(-1.6)	2.5	(-2.6)
Netherlands	2.3	(-0.1)	0.6	(0.4)	0.8	(2.2)
Norway	1.5	(2.5)	-0.9	(0.3)	2.3	(-1.2)
Portugal	3.6	(3.1)	1.1	(1.4)	2.4	(-0.4)
Spain	1.4	(0.3)	0.1	(-1.3)	3.0	(0.2)
Sweden	0.9	(3.9)	1.0	(0.7)	2.5	(0.4)
Switzerland	0.1	(0.2)	0.5	(2.4)	2.8	(2.2)
Great Britain	2.8	(1.7)	1.1	(3.5)	2.8	(4.1)

[a] Figures in parentheses are the corresponding figures of model 5. **na** Not available.

Sources: Perelman and Pestieau (1988); Oum and Yu (1994); Coelli and Perelman (1998); Commission estimates.

D.3 Other studies of stakeholder outcomes

The focus of most studies examining the financial performance of railways, particularly prior to the 1990s, has been on profitability and deficits. Looked at in this way, the financial performance of Australian government-owned railways tended to reflect their productivity performance. According to IC (1991), all railways experienced deficits (apart from Queensland freight) but these were particularly large in New South Wales and Victoria. Passenger services tended to have larger deficits than freight services.[4]

Few studies have looked at stakeholder outcomes in the way done in this study and BTCE (1997) is one of the few examples of a study focussing on service quality.[5]

Two sets of publications in Australia have provided data on some aspects of stakeholder outcomes:

- one produced by the Steering Committee on National Performance Monitoring of Government Trading Enterprises (SCNPMGTE); and
- freight benchmarking studies produced by the Bureau of Industry Economics (BIE).

Steering Committee on National Performance Monitoring of Government Trading Enterprises

In July 1991, the SCNPMGTE was established to develop a framework for national performance monitoring of government trading enterprises (GTEs), including rail enterprises. The Industry Commission (acting as Secretariat to the Steering Committee) produced six reports from 1993 to 1998 (one for each year). The monitoring exercise deployed a range of indicators including economic, financial and non-financial measures to monitor the performance of GTEs, including those from the rail sector.

PC (1998), the last of the six reports, included a review of performance outcomes for the various rail sector stakeholders from 1991-92 to 1996-97. Rail stakeholders included consumers (prices and service quality), shareholders (rates of return and earnings), employees (wages, employment levels and safety) and the community (community service obligations). Major conclusions from the study were:

- consumers benefited from lower real prices for rail services, particularly for freight, and improvements in service quality from 1991-92 to 1996-97;
- return on equity was generally negative over the period, due to operating losses;
- employment fell significantly over the period; and
- explicitly funded CSO payments increased significantly over the period.

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[4] BTCE (1995) is another example of an analysis of rail deficits.

[5] UIC (1999) provides an international perspective on rail freight service quality. However, this discusses how service quality measurement and benchmarking could be approached and does not perform any comparisons of actual service levels.

Bureau of Industry Economics benchmarking studies

In March 1991 the Prime Minister announced that the BIE would undertake a project to develop international performance benchmarks for Australia's infrastructure service industries. The study's focus was on benchmarking the performance of Australian railways against overseas railways, with a view to identifying best practice performance and Australia's position relative to this performance. The performance benchmarks developed included productivity indicators and financial indicators.

In relation to its analysis of prices, BIE (1995) concluded that Australian freight prices were considerably higher than world best practice rates in 1993-94 but the gap had closed for general freight rates in 1994-95.

E A complete set of productivity results

This appendix provides a complete set of the DEA results used in this study.

Table E.1 **Estimates of productivity and technical efficiency for Australian railways, 1978 to 1998 (model 1)**

Year	*Productivity*					*Technical efficiency*				
	SRA	*PTC*	*QR*	*WR*	*AN-NRC*	*SRA*	*PTC*	*QR*	*WR*	*AN-NRC*
1978	0.23	0.16	0.25	0.25	0.17	0.24	0.31	0.26	0.37	0.24
1979	0.22	0.16	0.26	0.23	0.18	0.23	0.31	0.26	0.35	0.24
1980	0.27	0.20	0.26	0.26	0.21	0.28	0.32	0.27	0.36	0.25
1981	0.28	0.20	0.27	0.25	0.22	0.29	0.33	0.27	0.36	0.26
1982	0.33	0.19	0.28	0.24	0.23	0.33	0.33	0.29	0.35	0.28
1983	0.28	0.14	0.27	0.25	0.22	0.29	0.33	0.28	0.37	0.28
1984	0.36	0.18	0.30	0.23	0.24	0.36	0.34	0.30	0.37	0.29
1985	0.41	0.24	0.36	0.27	0.26	0.42	0.38	0.42	0.40	0.30
1986	0.48	0.18	0.40	0.27	0.32	0.48	0.32	0.49	0.43	0.34
1987	0.45	0.19	0.40	0.29	0.32	0.46	0.33	0.49	0.46	0.35
1988	0.48	0.18	0.40	0.32	0.36	0.48	0.34	0.49	0.49	0.38
1989	0.49	0.25	0.42	0.38	0.43	0.49	0.54	0.52	0.52	0.45
1990	0.52	0.27	0.44	0.38	0.44	0.52	0.49	0.56	0.51	0.46
1991	0.54	0.28	0.46	0.39	0.43	0.54	0.51	0.59	0.54	0.47
1992	0.57	0.25	0.54	0.44	0.49	0.57	0.52	0.72	0.59	0.52
1993	0.64	0.34	0.56	0.48	0.57	0.64	0.64	0.75	0.64	0.64
1994	0.69	0.60	0.65	0.59	1.00	0.71	1.00	0.80	0.74	1.00
1995	0.45	0.26	0.74	0.71	0.92	0.46	0.92	0.88	0.95	0.93
1996	0.51	0.30	0.78	0.71	1.00	0.53	0.95	0.87	0.92	1.00
1997	0.69	0.36	0.94	0.94	1.00	0.70	1.00	0.95	1.00	1.00
1998	0.73	0.36	1.00	1.00	1.00	0.73	1.00	1.00	1.00	1.00

Source: Commission estimates.

Table E.2 Estimates of productivity for individual railways in Australia and North America, 1978 to 1998 (model 2)

	Australia					*North America*											
Year	*AN-NRC*	*WR*	*QR*	*SRA*	*PTC*	*BNSF*	*CN*	*UP*	*CP*	*ICR*	*KCS*	*SOO*	*NSC*	*CSX*	*Can II-III*	*CR*	*GTW*
1978	0.10	0.14	0.15	0.14	0.09	...	...	...	...	...	...	...	...	...	...	...	...
1979	0.11	0.13	0.15	0.13	0.09	...	...	...	...	...	...	...	...	...	...	...	...
1980	0.12	0.15	0.15	0.15	0.12	...	...	...	...	...	...	...	...	...	...	...	...
1981	0.13	0.15	0.16	0.15	0.11	...	...	...	...	...	...	...	...	...	...	...	...
1982	0.14	0.14	0.17	0.16	0.11	...	...	...	...	...	...	...	...	...	...	...	...
1983	0.13	0.15	0.16	0.14	0.08	...	...	...	...	...	...	...	...	...	...	...	...
1984	0.15	0.13	0.18	0.17	0.10	...	...	...	...	...	...	...	...	...	...	...	...
1985	0.16	0.16	0.21	0.20	0.14	...	...	...	...	...	...	...	...	...	...	...	...
1986	0.19	0.16	0.24	0.23	0.10	...	...	...	...	...	...	...	...	...	...	...	...
1987	0.19	0.18	0.24	0.22	0.11	...	...	...	...	...	...	...	...	...	...	...	...
1988	0.22	0.19	0.24	0.23	0.11	...	...	...	...	...	...	...	...	...	...	...	...
1989	0.23	0.23	0.26	0.24	0.12	...	...	...	...	...	...	...	...	...	...	...	...
1990	0.26	0.23	0.27	0.25	0.16	0.84	0.61	0.56	0.66	0.58	0.59	0.62	0.54	0.51	0.52	0.40	0.22
1991	0.27	0.24	0.28	0.26	0.16	0.84	0.67	0.58	0.70	0.65	0.61	0.65	0.54	0.50	0.54	0.45	0.21
1992	0.30	0.27	0.33	0.28	0.15	0.88	0.69	0.63	0.65	0.66	0.69	0.65	0.56	0.54	0.51	0.45	0.22
1993	0.35	0.30	0.35	0.31	0.21	0.89	0.73	0.68	0.74	0.73	0.71	0.66	0.58	0.56	0.49	0.43	0.27
1994	0.62	0.36	0.37	0.34	0.29	0.95	0.78	0.78	0.87	0.76	0.61	0.59	0.64	0.60	0.58	0.47	0.29
1995	0.41	0.43	0.40	0.22	0.15	1.00	0.75	0.87	0.84	0.89	0.71	0.72	0.67	0.62	0.63	0.49	0.29
1996	0.43	0.44	0.39	0.25	0.17	1.00	0.79	0.93	0.66	0.81	0.70	0.74	0.65	0.61	0.59	0.51	0.43
1997	0.45	0.54	0.41	0.34	0.20	1.00	1.00	0.88	0.83	0.80	0.77	0.70	0.67	0.65	0.62	0.54	0.48
1998	0.63	0.56	0.43	0.35	0.22	...	...	...	...	...	...	...	...	...	...	...	...

... Not available.

Source: Commission estimates.

Table E.3 Estimates of technical efficiency for individual railways in Australia and North America, 1978 to 1998 (model 2)

	Australia					*North America*											
Year	*AN-NRC*	*WR*	*QR*	*SRA*	*PTC*	*BNSF*	*CN*	*UP*	*CP*	*ICR*	*KCS*	*SOO*	*NSC*	*CSX*	*Can II-III*	*CR*	*GTW*
1978	0.24	0.37	0.22	0.21	0.31	...	...	...	...	...	...	...	...	...	...	...	...
1979	0.24	0.35	0.23	0.21	0.31	...	...	...	...	...	...	...	...	...	...	...	...
1980	0.25	0.36	0.23	0.23	0.32	...	...	...	...	...	...	...	...	...	...	...	...
1981	0.26	0.36	0.23	0.24	0.33	...	...	...	...	...	...	...	...	...	...	...	...
1982	0.28	0.35	0.24	0.28	0.33	...	...	...	...	...	...	...	...	...	...	...	...
1983	0.28	0.37	0.23	0.26	0.33	...	...	...	...	...	...	...	...	...	...	...	...
1984	0.29	0.37	0.24	0.30	0.34	...	...	...	...	...	...	...	...	...	...	...	...
1985	0.30	0.40	0.27	0.33	0.38	...	...	...	...	...	...	...	...	...	...	...	...
1986	0.34	0.43	0.29	0.36	0.32	...	...	...	...	...	...	...	...	...	...	...	...
1987	0.34	0.46	0.30	0.35	0.33	...	...	...	...	...	...	...	...	...	...	...	...
1988	0.37	0.49	0.30	0.36	0.34	...	...	...	...	...	...	...	...	...	...	...	...
1989	0.41	0.52	0.32	0.37	0.50	...	...	...	...	...	...	...	...	...	...	...	...
1990	0.42	0.51	0.33	0.39	0.49	0.84	0.62	0.56	0.68	0.73	0.92	0.72	0.55	0.52	0.63	0.42	0.81
1991	0.45	0.54	0.34	0.40	0.51	0.85	0.67	0.59	0.72	0.80	0.94	0.75	0.55	0.51	0.66	0.46	0.78
1992	0.50	0.59	0.40	0.43	0.51	0.88	0.69	0.63	0.67	0.81	1.00	0.75	0.57	0.55	0.63	0.46	0.77
1993	0.60	0.64	0.42	0.47	0.61	0.89	0.73	0.68	0.76	0.87	1.00	0.76	0.59	0.57	0.61	0.44	0.83
1994	0.92	0.74	0.44	0.50	0.99	0.95	0.78	0.78	0.89	0.90	0.81	0.70	0.65	0.60	0.71	0.49	0.85
1995	0.62	0.95	0.47	0.41	0.92	1.00	0.76	0.90	0.86	1.00	0.88	0.82	0.68	0.62	0.76	0.51	0.86
1996	0.65	0.92	0.47	0.44	0.95	1.00	0.79	1.00	0.68	0.95	0.87	0.85	0.66	0.62	0.70	0.53	0.92
1997	0.69	1.00	0.49	0.55	1.00	1.00	1.00	0.99	0.85	0.96	0.94	0.87	0.68	0.66	0.72	0.55	1.00
1998	0.99	1.00	0.50	0.57	1.00	...	...	...	...	...	...	...	...	...	...	...	...

... Not available.

Source: Commission estimates.

Table E.4 Estimates of productivity and technical efficiency for national rail systems in Australia, Canada and United States, 1978 to 1998 (model 3)

	Productivity			*Technical efficiency*		
Year	*Australia*	*United States*	*Canada*	*Australia*	*United States*	*Canada*
1978	0.15	0.37	...	0.73	0.45	...
1979	0.15	0.40	...	0.72	0.47	...
1980	0.17	0.41	...	0.71	0.48	...
1981	0.17	0.41	...	0.71	0.47	...
1982	0.18	0.38	...	0.71	0.42	...
1983	0.16	0.43	...	0.70	0.46	...
1984	0.19	0.50	...	0.68	0.54	...
1985	0.21	0.51	...	0.67	0.55	...
1986	0.24	0.55	...	0.67	0.59	...
1987	0.25	0.63	...	0.67	0.68	...
1988	0.26	0.69	...	0.68	0.73	...
1989	0.30	0.71	...	0.70	0.75	...
1990	0.33	0.74	0.71	0.75	0.77	0.76
1991	0.35	0.77	0.76	0.78	0.79	0.81
1992	0.38	0.81	0.74	0.82	0.83	0.80
1993	0.43	0.84	0.80	0.89	0.86	0.87
1994	0.55	0.90	0.90	0.92	0.92	0.92
1995	0.48	0.98	0.88	0.90	0.99	0.91
1996	0.51	1.00	0.89	0.91	1.00	0.92
1997	0.57	1.00	1.00	0.94	1.00	1.00
1998	0.62	...	...	1.00	...	...

... Not available.

Source: Commission estimates.

Table E.5 Estimates of productivity and technical efficiency for national rail systems in Australia, Canada and United States, 1980 to 1998 (model 4)

	Productivity			*Technical efficiency*		
Year	*Australia*	*United States*	*Canada*	*Australia*	*United States*	*Canada*
1980	**...**	0.61	**...**	**...**	0.63	**...**
1981	**...**	0.63	**...**	**...**	0.66	**...**
1982	**...**	0.59	0.63	**...**	0.63	0.74
1983	**...**	0.64	0.69	**...**	0.68	0.82
1984	**...**	0.69	0.77	**...**	0.72	0.78
1985	**...**	0.74	0.71	**...**	0.77	0.81
1986	**...**	0.78	0.69	**...**	0.81	0.75
1987	**...**	0.81	0.66	**...**	0.83	0.77
1988	**...**	0.86	0.72	**...**	0.87	0.85
1989	**...**	0.91	0.82	**...**	0.92	0.97
1990	0.81	0.94	0.72	0.81	0.94	0.88
1991	0.81	0.99	0.76	0.83	1.00	0.88
1992	0.79	0.98	0.74	0.86	0.98	0.89
1993	0.85	1.00	0.79	0.92	1.00	0.94
1994	0.87	0.99	0.87	0.96	1.00	0.93
1995	0.92	1.00	0.85	0.96	1.00	0.96
1996	0.94	1.00	0.87	0.97	1.00	0.98
1997	1.00	1.00	0.99	1.00	1.00	1.00
1998	1.00	**...**	**...**	1.00	**...**	**...**

... Not available.

Source: Commission estimates.

Table E.6 Estimates of productivity for national rail systems, 1970 to 1998 (model 5)

	1970	*1971*	*1975*	*1976*	*1979*	*1980*	*1981*	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*
US	...	...	0.57	0.53	0.52	0.59	0.60	0.56	0.61	0.66	0.70	0.73	0.76	0.80	0.85	0.87	0.89	0.89	0.94	0.93	0.99	1.00	1.00	...
JPN	0.71	0.71	0.77	0.73	0.75	0.69	0.68	0.72	0.75	0.79	0.81	0.82	0.88	0.88	0.95	0.98	1.00	1.00	0.96	0.99	1.00	1.00	...	...
CAN	...	...	...	...	...	...	...	0.53	0.59	0.75	0.64	0.67	0.63	0.65	0.65	0.67	0.75	0.73	0.78	0.87	0.85	0.86	0.98	...
AUS	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0.34	0.36	0.39	0.44	0.57	0.50	0.53	0.59	0.64
NET	0.41	0.41	0.42	0.40	0.43	0.44	0.44	0.43	0.40	0.41	0.41	0.40	0.42	0.43	0.45	0.47	0.63	0.62	0.60	0.56	0.54	0.51	0.52	...
IRE	0.12	0.13	0.21	0.19	0.31	0.29	0.28	0.26	0.26	0.29	0.31	0.33	0.37	0.36	0.34	0.38	0.40	0.37	0.39	0.39	0.40	0.39	0.41	...
RSA	...	...	...	...	...	...	...	...	...	...	...	...	0.22	0.25	0.42	0.28	0.27	0.26	0.27	0.30	0.32	0.35	0.39	0.39
SWE	0.19	0.18	0.24	0.23	0.30	0.33	0.33	0.31	0.31	0.31	0.31	0.30	0.29	0.31	0.32	0.34	0.32	0.31	0.36	0.36	0.37	0.38	0.38	...
FRA	0.26	0.26	0.32	0.32	0.32	0.33	0.34	0.35	0.36	0.37	0.38	0.37	0.37	0.40	0.41	0.39	0.38	0.39	0.37	0.37	0.34	0.37	0.38	...
ESP	0.35	0.34	0.46	0.44	0.43	0.35	0.37	0.36	0.36	0.37	0.39	0.38	0.37	0.39	0.38	0.39	0.37	0.40	0.36	0.35	0.35	0.35	0.38	...
FIN	0.21	0.22	0.29	0.27	0.27	0.29	0.29	0.29	0.30	0.30	0.30	0.24	0.29	0.30	0.33	0.34	0.33	0.31	0.30	0.31	0.32	0.34	0.35	...
GB	0.16	0.16	0.17	0.16	0.18	0.18	0.19	0.17	0.20	0.24	0.21	0.21	0.25	0.26	0.26	0.26	0.30	0.30	0.27	0.34	...	...	...	...
POR	0.28	0.27	0.38	0.41	0.48	0.52	0.48	0.44	0.42	0.44	0.46	0.46	0.52	0.48	0.55	0.45	0.44	0.35	0.42	0.37	0.35	0.31	0.33	...
ITA	0.29	0.29	0.28	0.30	0.29	0.29	0.29	0.28	0.25	0.26	0.20	0.27	0.28	0.30	0.31	0.32	0.32	0.33	0.33	0.35	0.36	0.37	0.32	...
SWI	0.21	0.21	0.20	0.20	0.20	0.22	0.22	0.21	0.21	0.21	0.21	0.22	0.25	0.25	0.26	0.26	0.28	0.27	0.27	0.27	0.27	0.28	0.32	...
GER	0.28	0.25	0.22	0.23	0.25	0.26	0.25	0.24	0.24	0.26	0.27	0.24	0.24	0.25	0.26	0.25	0.23	0.24	0.24	0.31	0.31	0.32	0.31	...
NOR	0.17	0.14	0.22	0.19	0.24	0.26	0.26	0.24	0.23	0.23	0.23	0.24	0.23	0.23	0.23	0.23	0.19	0.20	0.24	0.25	0.26	0.29	0.31	...
DEN	0.25	0.21	0.23	0.17	0.12	0.23	0.25	0.26	0.27	0.27	0.27	0.28	0.29	0.28	0.28	0.30	0.29	0.27	0.28	0.29	0.28	...	...	...
AUT	0.16	0.16	0.19	0.17	0.18	0.18	0.17	0.18	0.18	0.18	0.24	0.19	0.19	0.20	0.22	0.23	0.23	0.24	0.24	0.24	0.25	0.30	0.25	...
BEL	0.30	0.24	0.23	0.22	0.20	0.19	0.19	0.18	0.17	0.17	0.18	0.17	0.18	0.18	0.19	0.19	0.20	0.21	0.21	0.21	0.21	0.21	0.20	...
LUX	0.22	0.18	0.26	0.21	0.23	0.24	0.23	0.23	0.22	0.21	0.21	0.20	0.19	0.20	0.20	0.18	0.15	0.17	0.17	0.19	0.19	0.19	0.20	...
NZ	...	...	...	...	...	0.07	0.06	0.06	0.06	0.07	0.10	0.11	0.10	0.11	0.11	0.14	0.15	0.16	0.17	0.15	0.16	0.17	0.18	0.18

... Not available.

Source: Commission estimates.

Table E.7 Estimates of technical efficiency for national rail systems, 1970 to 1998 (model 5)

	1970	*1971*	*1975*	*1976*	*1979*	*1980*	*1981*	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*
US	...	...	0.59	0.55	0.53	0.60	0.62	0.58	0.63	0.68	0.71	0.74	0.78	0.82	0.86	0.88	0.90	0.90	0.95	0.93	0.99	1.00	1.00	...
JPN	0.71	0.71	0.77	0.74	0.75	0.69	0.68	0.72	0.75	0.79	0.82	0.82	0.88	0.88	0.95	0.98	1.00	1.00	0.96	0.99	1.00	1.00	...	...
CAN	...	...	...	...	...	...	...	0.54	0.60	0.76	0.66	0.68	0.64	0.66	0.66	0.69	0.77	0.74	0.80	0.88	0.86	0.88	1.00	...
AUS	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0.38	0.40	0.43	0.48	0.61	0.54	0.57	0.64	0.69
NET	0.45	0.44	0.46	0.44	0.47	0.48	0.48	0.46	0.44	0.45	0.45	0.44	0.46	0.47	0.51	0.53	0.67	0.66	0.64	0.61	0.94	0.59	0.68	...
IRE	0.32	0.32	0.40	0.41	0.56	0.57	0.62	0.63	0.65	0.67	0.92	0.91	0.98	0.98	0.92	0.96	0.97	0.95	0.97	0.96	0.97	0.98	1.00	...
RSA	...	...	...	...	...	...	...	...	...	...	...	...	0.23	0.27	0.44	0.29	0.29	0.28	0.29	0.33	0.35	0.37	0.41	0.42
SWE	0.25	0.24	0.28	0.28	0.34	0.37	0.37	0.34	0.35	0.35	0.35	0.34	0.33	0.35	0.36	0.38	0.36	0.36	0.42	0.42	0.43	0.44	0.47	...
FRA	0.26	0.26	0.32	0.32	0.33	0.33	0.35	0.35	0.36	0.37	0.39	0.38	0.38	0.40	0.41	0.40	0.39	0.39	0.37	0.37	0.35	0.37	0.39	...
ESP	0.37	0.35	0.48	0.46	0.45	0.37	0.39	0.38	0.38	0.39	0.41	0.39	0.39	0.41	0.40	0.41	0.39	0.42	0.38	0.37	0.39	0.40	0.43	...
FIN	0.28	0.29	0.36	0.34	0.34	0.36	0.36	0.36	0.37	0.37	0.37	0.30	0.36	0.37	0.41	0.42	0.40	0.38	0.38	0.39	0.42	0.44	0.45	...
GB	0.16	0.16	0.17	0.17	0.19	0.19	0.19	0.17	0.20	0.25	0.21	0.22	0.25	0.26	0.26	0.27	0.31	0.33	0.28	0.43	...	...	...	...
POR	0.36	0.35	0.46	0.49	0.56	0.59	0.55	0.52	0.51	0.53	0.55	0.54	0.60	0.56	0.63	0.57	0.57	0.55	0.59	0.61	0.67	0.62	0.63	...
ITA	0.29	0.29	0.29	0.30	0.29	0.29	0.29	0.29	0.26	0.26	0.21	0.27	0.28	0.30	0.31	0.32	0.33	0.34	0.33	0.35	0.36	0.37	0.33	...
SWI	0.23	0.23	0.23	0.23	0.24	0.26	0.25	0.25	0.25	0.25	0.27	0.27	0.29	0.29	0.30	0.30	0.32	0.31	0.31	0.34	0.35	0.36	0.38	...
GER	0.28	0.25	0.23	0.24	0.26	0.26	0.26	0.25	0.25	0.27	0.28	0.24	0.24	0.26	0.26	0.25	0.23	0.24	0.25	0.31	0.31	0.33	0.32	...
NOR	0.34	0.36	0.38	0.38	0.39	0.39	0.39	0.36	0.36	0.37	0.39	0.41	0.40	0.41	0.43	0.44	0.47	0.49	0.54	0.56	0.62	0.68	0.74	...
DEN	0.31	0.29	0.31	0.30	0.30	0.36	0.36	0.38	0.43	0.41	0.42	0.44	0.51	0.53	0.53	0.51	0.53	0.51	0.52	0.56	0.60	...	...	...
AUT	0.18	0.17	0.21	0.19	0.20	0.20	0.19	0.20	0.20	0.20	0.26	0.21	0.21	0.22	0.24	0.25	0.25	0.26	0.26	0.26	0.27	0.32	0.27	...
BEL	0.33	0.26	0.26	0.24	0.22	0.21	0.21	0.20	0.19	0.19	0.20	0.19	0.20	0.20	0.21	0.22	0.23	0.23	0.23	0.24	0.24	0.23	0.24	...
LUX	1.00	0.99	0.97	0.95	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.93	0.96	1.00	0.98	0.99	1.00	...
NZ	...	...	...	...	...	0.33	0.34	0.31	0.33	0.35	0.37	0.40	0.41	0.45	0.49	0.56	0.62	0.64	0.66	0.68	0.72	0.71	0.74	0.73

... Not available.

Source: Commission estimates.

F Independent reference panel reports

Dr Joseph Hirschberg, Senior Lecturer, Department of Economics, University of Melbourne

The analysis performed by the Commission is in keeping with the state of the art in the use of Data Envelopment Analysis (DEA) for the determination of relative productive efficiency. The development of the comparative database used in this analysis is unique and can serve as a basis for any future comparisons of railways at this level of detail. The analysis proceeds from the specific aspects of the data to important conclusions concerning the nature of recent policy and the other determinants of railway efficiency.

A weakness of DEA that is shared with all other non-parametric analysis, is the total dependence of the quality of results on the availability of like entities for comparison. In this case all the results are subject to the caveat that the data used are representative of other railways which operate in a similar environment to those in Australia. A salient feature of this study is the great effort that has gone into identifying the degree to which these results are the product of this aspect of DEA. Although it is necessary to collect data from as many railways in the world to establish the most appropriate sample possible, only a handful are directly comparable to the Australian railways. In this study comparisons are made at both the state railway level as well as the national level over a number of years. Thus not only is the entire Australian railway system compared to national rail systems in 21 other countries, but the individual state railways within Australia can be compared with major railways in Canada and the US. This allows comparisons to be made between railways that are as alike as possible.

The interpretation of the DEA results is further enhanced by a series of post-DEA regression analyses which account for a number of factors that may influence the relative efficiency measures that are not directly part of the production process. In this case it was found that the indicators of greater demand for rail services (as measured by higher traffic density, average haul lengths, and the locomotive loads) have a significantly positive impact on efficiency. This would indicate that the greater the demand for rail services the higher the relative efficiency. This may be an obvious conclusion but it is possible with this analysis to quantify the degree to which these factors can enhance the relative efficiency. In another post-DEA regression the impact of recent deregulation was modelled. Using this method for the quantification of policy outcomes is an important step in the evaluation of the existing competition policy and it demonstrates the application of a technique that has wide potential in the study of other sectors of the economy.

Mr Stephen J Meyrick, Managing Director, Meyrick & Associates Pty Ltd.

Making valid assessments of the relative efficiency of Australian enterprises, and the extent to which performance has responded to policy change, is a task that is fraught with theoretical and practical difficulties. It is also one that is vital to the process of microeconomic reform.

The modelling work that has been undertaken by the Productivity Commission in connection with its *Performance of Australian Railways* report makes a very valuable contribution to this vexing but important task. Refreshingly, the authors show themselves to be fully aware of the imprecisions, imperfections and uncertainties that inevitably attend any attempt to compare rail systems operating in different physical, economic, financial and political environments. The choice of method made by the authors — Data Envelopment Analysis (DEA) — is at least in part guided by a desire to bypass some of the more intractable of the data problems associated with comparative performance analysis. This choice seems to me a fortunate one.

In the context of the research task, the approach is innovative. To the best of my knowledge there has been no previous attempt to use DEA in evaluating rail performance in Australia, though the approach is becomingly increasingly popular elsewhere. One result of the difficulties alluded to previously is that the results of any individual attempt to assess comparative performance — no matter how well performed — do not attract a high degree of confidence. It is the accumulation of research evidence that provides the level of certainty required for intelligent and constructive action. The contribution that an individual piece of research makes to this cumulative endeavour is greater if it increases not only number of studies but also their methodological diversity. In this respect the Productivity Commission's work will be of great assistance to researchers, advisers and policy-makers. The value of the contribution is further enhanced by the authors' comparison (in Appendixes to the report) of the findings of their own study with those of previous DEA research, and the presentation of partial productivity indicators for many of the rail systems studied.

I am somewhat less persuaded by the outcomes from the variable returns to scale (VRS) analysis than I am by the constant returns to scale (CRS) analysis. While it is easy to believe that scale — or, perhaps more accurately, scale-related parameters such as traffic density — is a very important determinant of achievable performance, it is less clear that the VRS adaptation of the model is an ideal way of accounting for this. This is partly because, as the authors point out, the VRS model loses significant discriminatory power, particular when the sample of railways is small. But it is also partly because of the assumptions of the form of scale effects that are implicit in the VRS approach.

Partly for this reason, I find the regression analysis undertaken by the authors on the ‘raw’ efficiency scores a particularly useful component of the research. This provides an alternative, more flexible, and in my view preferable means of exploring the form and nature of scale effects on the research results, and yields some interesting insights. Especially intriguing is the finding that both the country variable and the pure scale effects become insignificant when three important scale-related factors (traffic density, haul length and locomotive load) are included in the analysis.

Overall, the work undertaken by the Commission is a very useful and timely addition to the corpus of work on this important issue.

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