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Separability and Subadditivity in Australian Railways

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Abstract

From the mid 1990s, Australian public railways were required to provide access to their track infrastructure to third parties seeking to operate trains, and some railways were split into their below-rail (track and signalling infrastructure) and above-rail (rolling stock and locomotives) components to facilitate access. Driving the reform was the notion that it would allow competition to develop in above-rail operations. This paper assesses the policy decision, using a unique dataset for Australian railways to ascertain their separability and the subadditivity of the above-rail task.

Keywords: Australian railways, subadditivity, separability, competition.
JEL Codes: L11, L52, L92

I. Introduction

In the mid 1990s, Australian governments turned the focus of economic reform to railway infrastructure, and to the notion that separation of the natural monopoly below-rail component from the potentially competitive above rail component might yield efficiency gains. In this, policymakers were following the example of the European Union, particularly Britain and Sweden, which had undertaken such reforms over the previous decade.

In Australia, a rationale for the policy shift was provided by a cost-benefit analysis (Travers-Morgan 1995) of various reform options, but the modelling in the analysis was rudimentary with little sensitivity analysis of results, and many of the assumptions underpinning the results were arbitrary. The justification for the shift in policy was largely theoretical: the primary barriers to entry lie in the below-rail infrastructure and hence providing a framework by which the above-rail sector is accessible to entrants should allow competition to occur in that sector and hence produce efficiency gains for the industry as a whole. A similar rationale had already been used to justify similar reforms in Australia's electricity and gas industries. However, the peculiarities of the economics of the railways were not considered and, more importantly, the data pertaining to the cost structures of railways in Australia did not inform the expectations of the reform process. This paper seeks to assess the appropriateness of the policy shift, using data from the Australian railway industry, on two fronts:

- It examines whether railways are econometrically separable into their above and below-rail parts and hence whether efficiency losses might result from vertical separation.
- It examines whether the above-rail task is sub-additive; whether the cost of providing the above rail service for two or more firms are greater or less than the costs of a single firm providing the service. If the above-rail task is subadditive, then the scope for sustainable competition envisaged by policymakers is limited.

Section Two of the paper provides some background to Australian rail reform and to the regulatory regimes it has engendered. Section Three describes the data and the modelling procedures used in the separability and subadditivity assessments. Section Four presents the separability results and Section Five the subadditivity results. Section Six concludes.

II. Background to Australian Rail Reform

The reform of Australia's railways began in the 1980s, after six decades of slow decline following the loss of rail's monopoly over land transport, concurrent with the rise of the trucking industry from the 1920s onwards. The immediate catalyst for reform was the large and growing debt of the railways, which peaked at around $3.7 billion (BTCE 1995) in

1984/85.[1] Australian National Railways Corporation (AN), Queensland Rail (QR) and Westrail led reform, improving labour productivity, divesting themselves of non-performing assets and focusing on niche market applications where rail is competitive, such as bulk freight, rather than endeavouring to provide an holistic service. All railways also benefited from the removal of common carrier obligations and the repeal (during the 1980s and early 1990s) of legislation from the 1930s which reserved the carriage of certain commodities to rail. NSW and Victoria lagged behind Queensland, WA and the Commonwealth in the reform process, but by the early 1990s, internal reform was well underway in railways across the country. The Industry Commission (IC, 1991) referred to these internal reforms as "Phase One Reforms". They were relatively simple as they did not involve any structural changes to the railways. To unlock further productivity gains, the railways needed to undertake "Phase Two", involving substantial structural reform.

There were two key elements to structural reform; ownership and unpacking the businesses within each railway. Traditionally, ownership of the railways was vested in the State governments, a situation dating back prior to Federation when railways were a key driver of colonial (later state) economic development. Although AN was Commonwealth-owned, it too was effectively imprisoned in a State-based structure inherited from the railways acquired by the Commonwealth in 1975.[2] Fragmented ownership, exacerbated by breaks of gauge at some State borders, hindered the development of a nation-wide network similar to that which had existed for a century in North America. Consideration of new ownership structures began with the formation of National Rail (NR) in 1991 through agreement between the Commonwealth and the mainland States. As reform progressed, governments took the view that, as in other infrastructure industries, some assets could be operated more productively as private companies, adopting the risk profile, economies of scope and industrial relations practices of the private sector. The creation of Pacific National (PN) through the merger of NR and FreightCorp (the corporatised freight business of the NSW State Rail Authority, created in 1996) in 2002 and its sale to the private sector was the largest example of this. The sale and lease of Victoria and Tasmania's above and below-rail (above sold and below leased) rail assets to Freight Australia in 1998 (later bought by PN) and a similar process with the rail assets of WA in 2000, sold to a consortium of Wesfarmers and Genesee & Wyoming (later sold to a consortium of QR and Babcock and Brown Infrastructure in 2006) were two further examples, and the sale of AN's Indian Pacific, Ghan and Overlander passenger services to Great Southern Railways in 1997 was a third. For other assets, notably below-rail assets, government ownership was maintained, but government became a shareholder, rather than a manager of these assets. The creation of the Australian Rail Track Corporation (ARTC) in 1998 from the below-rail assets of AN is the prime example of this, as was the leasing rather than sale of below rail assets in Victoria, Tasmania and WA. In Queensland, both the above and below rail assets were corporatised in 1996 and remain under government ownership.

The second element of structural reform, occurring concurrent with the first, was to unpack the businesses within the vertically integrated railways, with a particular focus on those which might become profitable as stand-alone businesses compared to those which would not. It was obvious even before the process began that passenger services, with the exception of some tourism services, would continue to require government support. However, freight, particularly bulk freight, held the potential for profitable commercial operation. In many cases, the separation of businesses occurred first within the organisations, and later through the corporatisation and sale process outlined above. For example, the freight business of the NSW State Rail Authority was first separated from remaining businesses in the accounts of

[1] In real 2005 dollars. The nominal figure in dollars of the day was $1.6 billion. These figures are annual deficits, not the cumulative railway debt. The BTCE defines the deficit as annual revenues minus the sum of annual operating expenses, depreciation charges, interest costs and government subsidies for non-commercial services.

[2] AN was the legacy of Prime Minister Whitlam's partially successful bid for rail reform by taking all of the States' railways into Commonwealth ownership; in 1975 the unviable railways of South Australia and Tasmania were combined with the Commonwealth Railways to form AN.

the organisation in 1989 and eventually corporatised (as FreightCorp) in 1996, before being merged with NR and sold to the private sector in the form of PN in 2002.

AN became a model used by the Commonwealth Government to demonstrate what could be achieved by unpacking rail businesses. Beginning in 1993 AN's interstate freight business, potentially the most profitable, and that of the other State-owned railways, was transferred to newly formed National Rail Corporation Limited (NR). NR was mandated to eliminate the persistent deficits from these interstate rail businesses (estimated at more than $300 million per annum); the Commonwealth, NSW and Victorian Governments contributed around $400 million in equity, as well as assets, to NR to achieve that aim (Affleck, 2002). Profitability was achieved just before the formation of PN in 2002.

The creation of NR had created a new issue in Australian railways, as NR had to negotiate access to the track of other railways in order to carry out its business. In North America railways had negotiated 'running rights' over infrastructure owned by others for more than a century. In Australia however, no such system of mutual running rights had developed. Even the operation of trains carrying interstate freight and passengers was transferred from one state-based railway to another (locomotives, crews and train control) when they cross from one State to another. Initially, cross-border operations by NR were facilitated by negotiated access; prices generally combined 'flagfall' and variable tonne-kilometre charges. These ad-hoc access regimes became the blueprint for the regimes governing the industry today, and the fact that NR was able to operate as a vertically separated entity gave an impetus for similar structural reform amongst other railways, most notably NSW.

With the advent of vertical separation and of third party access rights came a need for economic regulation of the railway industry. The original intent was for all railways to be regulated, if not by the same regulator, then under a similar set of principles. The fact that the different States were reforming their industries at different speeds made this difficult. WA, NSW and Queensland put forward their proposed access arrangements to be deemed 'effective' by the NCC in the late 1990s. However, that did not eventuate. Although the ACCC model was to be the standard, at the time the States put forward their proposed regimes, it was not yet complete and the states were not prepared to sign up to a standard which they could not yet see. Whilst the NSW regime was temporarily made 'effective' from 1999-2000, this has since lapsed and now none of the states have this status. This has meant that State-based rail access regimes have developed in all States and remain in force, despite the best efforts of both governments and industry lobby groups to achieve greater consistency. The various access regimes are shown in Table One.[3]

Table 1
Australian Rail Access Regulators

Regulator	**Jurisdiction**
ACCC	National track and NSW non-urban track
Queensland Competition Authority	Queensland
WA Economic Regulation Authority	WA south west (WestNet Rail and PTA track), with possibility of regulating Pilbara railways
Independent Pricing and Regulatory Tribunal (IPART)	NSW (metropolitan area and some grain lines)
Victorian Essential Services Commission	Victoria
South Australian Essential Services Commission	South Australian track and Tarcoola-Darwin railway

[3] This does not include the NCC, which retains responsibility for declaration of assets.

In general the regulators operate in much the same way. Each may determine 'floor' and 'ceiling' revenue levels for the infrastructure under its jurisdiction, and these are based on some form of a cost-based 'building-block' approach which takes into account the incremental costs of service for the floor and full economic costs for the ceiling. The most important difference is the way in which asset values are calculated; all adopt the DORC methodology, except the WA ERA which uses the GRV method. All have adopted a 'negotiate-arbitrate' regulatory model, though each has its own process to trigger regulatory intervention, with some acting prior to an access request, and some acting ex-post, only when access negotiations have failed. Some railways (the ARTC and QRA) have included reference tariffs to guide negotiations in their access arrangements, and these have been accepted by regulators. To date, only Victoria has required reference tariffs, which must be calculated by a methodology determined by the regulator.

III. Data and Model Characteristics

This section details the model and data used. Both the separability and subadditivity analyses are undertaken using the transcendental or translog cost function of Christensen, Jorgenson & Lau (1973), which gives the following cost functions:

$$\ln C(y,w,t) = \alpha_0 + \sum_{i=1}^{n}\alpha_i \ln w_i + \sum_{j=1}^{3}\beta_j y_j + \varphi \ln t + \sum_{k=1}^{5}\delta_k D_k + \frac{1}{2}\sum_{i=1}^{n}\sum_{l=1}^{n}\lambda_{il}\ln w_i \ln w_l + \sum_{i=1}^{n}\sum_{j=1}^{3}\gamma_{ij}\ln w_i \ln y_j + \sum_{i=1}^{n}\theta_i \ln w_i \ln t + \frac{1}{2}\sum_{j=1}^{3}\sum_{p=1}^{3}\rho_{jp}\ln y_j \ln y_p + \sum_{j=1}^{3}\sigma_j \ln y_j \ln t + \frac{1}{2}\psi(\ln t)^2 \quad (1)$$

The application of Shephard's Lemma to the cost equations gives *n* factor share equations of the form:

$$S_i = \alpha_i + \sum_{l=1}^{n}\lambda_{il}\ln w_i + \sum_{j=1}^{3}\gamma_{ij}\ln y_j + \theta_i \ln t \quad (2)$$

In both equations, *w* denotes the inputs, *y* the outputs and *t* the technical variables. These are further described in Table Two. The separability analysis uses a total cost function, meaning that the *lnC* term is the log of total cost, and contains four inputs (see below). Thus $n=4$ in both the cost and share equations of the separability analysis. The subadditivity analysis occurs using only the above-rail cost data, meaning that the *lnC* term is the log of above-rail costs only, and contains three inputs (see below). Thus $n=3$ in both equations of the subadditivity analysis and the technical variable incorporates an element describing infrastructure quality.

Estimating the translog functional form as a system of one cost equation and *n* factor share equations results in a singular covariance matrix, since the factor shares must add to one and hence have zero errors. For this reason, following usual practice, the systems were estimated with one factor share equation dropped. There is no a-priori reason to favour one share equation over another, and the results reported below represent the most robust of a number of model specifications. Price homogeneity implies that the α_i terms sum to one, and this further implies that:

$$\sum_{l=1}^{n}\lambda_{il} = 0 \text{ and } \sum_{j=1}^{3}\gamma_{ij} = 0 \quad (3)$$

Also, symmetry implies that $\lambda_{ij} = \lambda_{ji}$. Price homogeneity and symmetry were imposed on the systems to add degrees of freedom to the regression analysis, and the missing parameters were retrieved manually.

The estimation of both separability and subadditivity follow the approach taken in earlier work examining the same issues in US railways, undertaken by Bitzhan (2000,2003) and Ivaldi & McCullough (2001,2006). These authors build on an established literature using translog cost functions to analyse railways, beginning with Brown, Caves and Christensen (1979)[4]. Like Ivaldi & McCullough, but unlike Bitzhan, indexes rather than prices are used. Each of the indexed variables were indexed using Laspeyres, Paasche and average price indices. In general, the average price indices performed best. I also test for unit roots in the underlying data and, finding it, estimate the equations in first differences. Table Two summarises the data used. Where a given variable is used only in the separability or subadditivity analysis, this is indicated.

Table 2
Description of Data

Variable	Description
TC	Total cost (above and below rail) for each railway (used in separability analysis).
TVC	Total above-rail costs (used in subadditivity analysis)
w_{PARL}	The (indexed) cost of above rail labour, being the total cost (wages and on-costs) of above rail labour divided by the number of above-rail workers
w_{PARM}	The (indexed) cost per gross tonne kilometre of materials other than labour and fuel used in the above-rail task.
w_{PF}	The (indexed) cost per megajoule of fuel used in train operations
w_{PWS}	The (indexed) cost per gross tonne kilometre of below rail capital and maintenance expenditure, including labour costs. (used in separability analysis)
y_{GRNTK}	The total net tonne kilometres of grain and other agricultural produce hauled per annum.
y_{MINTK}	The total net tonne kilometres of minerals hauled per annum.
y_{GENTK}	The total net tonne kilometres of general and intermodal freight hauled per annum.
t_{TECHTC}	A technical variable used in the separability analysis comprising of an average of indices of passenger train kilometres, route kilometres and the average haul-length for freight.
t_{TECHVC}	A technical variable used in the subadditivity analysis comprising the same three variables as TECHTC, but with the addition of an indexed variable for track quality.
D_k	A dummy variable for each of the five railways (AN, NSWSRA, QR, Victoria and Westrail) to allow for firm fixed effects and test for the homogeneity of the panel.

Most of the variables follow the previous literature, with the exception that the different freight task in Australia is reflected in the output split above, and the availability of different data on below rail costs necessitated a different variable for w_{PWS}. The components of technical variables mirror closely similar variables in the literature. They are combined here because doing so meant 44 fewer variables needed to be estimated in the relevant cost functions, greatly improving the robustness of the results without sacrificing much that is of interest in the separability or subadditivity analyses.

The data form an unbalanced panel. This is due to a lack of data in later years from some railways and to the fact that reform did not occur contemporaneously across jurisdictions. For each railway, the dataset begins in 1970/71. The data for AN continue to 1993/94 (24 observations) after which time some of AN's freight task was given to NR, which sourced some of its locomotives, rolling stock and infrastructure from the NSW State Rail Authority, making the construction of a continuous dataset after 1993/94 all but impossible. NSW data is available from 1970/71 to 1995/96 (26 observations), after which the State Rail Authority was split into different companies, with separate accounts. QR data is available to the present

[4] In the later paper, Ivaldi & McCullough eschew the translog functional form for a Generalised McFadden cost function.

day, but concerns about the comparability of QR today with the other railways a decade ago lead to a decision to include data only to 2000/01 (31 observations). Victorian railways annual reports were available only until 1992/93 (23 observations), and Westrail annual reports after 1995/96 (26 observations) lacked key data necessary for the analysis, and thus the datasets ended in these years. Further issues with the data and a discussion of data sources, is provided below. The issue of the homogeneity of the panels is addressed in the discussions on separability and subadditivity.

As noted above, the data exhibit non-stationarity. Table Three summarises the results of a Phillips-Peron test for unit roots where the data are in log form and indexed by average indices.[5] The results presented are the Z-tests, with a trend and the critical value is -18.2, measured at the ten percent level of significance due to the short time-series.

Table 3
Unit Root Test Results

Variable	Stationarity, I(0)	Stationarity, I(1)	Variable	Stationarity, I(0)	Stationarity, I(1)
TC	AN= -6.3329	AN= -28.583	y_{GRNTK}	AN= -5.8084	AN= -17.155[7]
	NSW= 2.2399	NSW= -20.737		NSW= -20.115	NSW= -32.623
	QR= -4.4513	QR= -21.332		QR= -29.158	QR= -42.028
	Vic= -12.671	Vic= -22.742		Vic= -17.139	Vic= -27.347
	WA= -6.5182	WA= -17.225[6]		WA= -30.491	WA= -37.098
TVC	AN= -6.4579	AN= -28.873	y_{MINTK}	AN= -12.461	AN= -25.772
	NSW= -3.6919	NSW= -30.964		NSW= -13.148	NSW= -34.379
	QR=-3.7589	QR= -27.458		QR= -8.4026	QR= -18.946
	Vic= -6.0746	Vic= -21.352		Vic= -17.601	Vic= -28.395
	WA= -4.9414	WA=-18.025[8]		WA= -12.678	WA= -29.148
w_{PARL}	AN= -9.5815	AN= -24.833	y_{GENTK}	AN= -5.2672	AN= -28.781
	NSW= -20.720	NSW= -37.501		NSW= -11.610	NSW= -25.795
	QR= -9.2415	QR= -26.097		QR= -7.9154	QR= -36.272
	Vic= -4.9103	Vic= -23.684		Vic= -7.5257	Vic= -27.515
	WA= -12.267	WA= -22.055		WA= -13.517	WA= -30.457
w_{PARM}	AN= -17.626	AN= -30.003	t_{TECHTC}	AN= -5.8231	AN= -25.946
	NSW= -16.113	NSW= -32.202		NSW= 2.9855	NSW= -24.219
	QR= -5.4705	QR= -24.296		QR= -28.273	QR= -41.318
	Vic= -8.6369	Vic= -23.401		Vic= -22.392	Vic= -37.996
	WA= -6.6850	WA= -23.115		WA= -5.5384	WA= -33.059
w_{PF}	AN= -5.8665	AN= -17.217[9]	t_{TECHVC}	AN= -5.5262	AN= -26.083
	NSW= -0.7773	NSW= -23.428		NSW= 1.2765	NSW= -24.134
	QR= 0.32551	QR= -19.080		QR= -25.035	QR= -39.455
	Vic= -5.0822	Vic= -25.709		Vic= -12.134	Vic= -40.769
	WA= -5.3442	WA= -24.572		WA= -4.4999	WA= -27.144
w_{PWS}	AN= -7.2162	AN= -23.659			
	NSW= -21.135	NSW= -29.754			
	QR= -13.006	QR= -27.605			
	Vic= -14.326	Vic= -26.181			
	WA= -10.409	WA= -24.527			

[5] The Phillips-Peron test was used over the Dickie-Fuller test as it has higher power when the dataset contains heteroscedasticity and serial correlation, both of which were present in the railway data. Paasche and Laspeyres indices results are broadly similar.

[6] The t test result with trend was -3.4295 (-3.13), the Z-test result without a trend was - -17.071 (-11.2) and the t-test result without a trend was -3.3478 (-2.57). On balance, this suggests an I(1) variable.

[7] The t test result with trend was -3.6918(-3.13), the Z-test result without a trend was - -16.964(-11.2) and the t-test result without a trend was -3.6654(-2.57). On balance, this suggests an I(1) variable.

[8] The t test result with trend was -3.6763 (-3.13), the Z-test result without a trend was -16.335 (-11.2) and the t-test result without a trend was -3.2640 (-2.57). On balance, this suggests an I(1) variable.

[9] The t test result with trend was -3.8214 (-3.13), the Z-test result without a trend was - -17.094 (-11.2) and the t-test result without a trend was -3.8095 (-2.57). On balance, this suggests an I(1) variable.

Whilst some variables are stationary for some railways, no variable is stationary for all, and hence estimation of the models was undertaken in first differences. The presence of non-stationarity also led to an examination of a cointegrating relationship in the error terms. In the case of the total cost function, used in the separability analysis, no cointegrating relationship was found, but one was found for the variable cost function. Although data quality precludes making many inferences from this difference, it perhaps suggests that the above-rail task was tending towards a long-run equilibrium during the period of analysis, but the railways as a whole were not. Intuitively, this is not surprising; railways are subject to path dependency, particularly in their below-rail infrastructure, and many below-rail investment decisions in rail in Australia were made on political, rather than economic efficiency grounds. Neither Bitzan (2000, 2003) not Ivaldi & McCullough (2001, 2006) report results for stationarity, so it is not clear whether the Australian data are unique in this respect.

The total cost and variable cost systems were initially estimated using Zellner's (1962) Seemingly Unrelated Regression (SURE) with OLS regressions for each equation in the system. However, diagnostics from the estimated systems suggest issues with both serial correlation and heteroscedasticity. Modelling was undertaken using the SHAZAM (Standard Edition) software.[10]

Data Sources and Issues

Data from US Class One railways are reported annually to regulators, and these data are summarised in a consistent format in the annual *Analysis of Class One Railways* and quarterly *Railroad Cost Indices* published by the Association of American Railroads. Analysts of US railways thus have access to a wide range of consistent data, and a time-series which goes back for decades. The same is not true of Australia. Under the current regulatory regimes, railways must provide data on key performance indicators, some of which are useful for economic analysis, and the regular regulatory determinations also provide further data on such key variables as asset values. Reporting requirements are not consistent across jurisdictions, however, and the data (at best) covers only the last five to ten years.

The Australian Bureau of Statistics (ABS) publishes an annual *Yearbook Australia* (ABS Cat no 1301.0) which provides a consistent set of data on aspects of the operating costs of Australian railways from 1901 to 1985, and further detail is provided from 1970 to 1985 in the publications *Rail Bus and Air Transport Australia* (1970-1979, ABS Cat no 9201.0) and *Rail Transport Australia* (1979-1986, ABS Cat no 9213.0). However, the ABS data contain almost no data on asset values or depreciation and data on capital expenditure are seldom disaggregated into above and below-rail components.

For the remaining data only three sources remain; a study of Australian railway productivity from 1971/72 (Daniels, DeMellow and Hensher, 1992 & 1994), a study of freight movements in Australia by the BTRE (BTRE, 2006) and the railways themselves, mostly through their annual reports.[11] The latter is an especially difficult source, as there is no consistency amongst the railways on the meanings of terms, nor even consistency in the meanings of terms within a given railway through time. This is especially the case for financial data. Over the period analysed, the railways were coming to terms with a more commercial environment. This meant that depreciation and asset valuation (among other financial data) were evolving concepts, as the railways sought the best way to reflect these figures in their

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[10] SHAZAM does not allow for a generalised least squares regression approach within its linear systems command. It does, however, allow a non-linear regression with an option (called ACROSS, see SHAZAM, 2004, p249) which estimates a SURE model with vector autoregressive errors, admitting autocorrelation across and within equations. This allows for maximum likelihood estimation of the regression parameters, provided the model converges, and provides efficient and consistent estimates of the coefficients. The model estimated is a linear model, but due to the nature of SHAZAM and the nature of the errors in the data, it was estimated using a non-linear approach. For this reason, diagnostic results normally associated with linear models are not available.

[11] The author would like to acknowledge the assistance of industry personnel in compiling data.

accounts. Some railways, notably QR, had no asset value information at all for much of the period of analysis, and the information of other railways was not particularly reliable.[12] Moreover, as the railways became more commercially oriented during the early 1990s, the amount of economic information contained within the annual reports decreased markedly.

In collating data from a number of sources, the primary issue is the consistency of the data. For this reason, wherever possible, a single source was used as a base and the remaining data were fitted to it. For example, in the case of operating or working expenses, ABS data provided a suitable breakdown for examining above and below rail aspects, but the series continued only to 1985. During the period, the proportions of expenditure in the various classes were roughly constant, and hence these proportions were applied to data on total operating expenditure (or, more often, some aspect of operating expenditure, such as maintenance) for years after this date.

ABS data formed the basis for operating expenditure data, and was extended past 1985 with data from Daniels et al (1992, 1994) and annual report data. It also formed the basis for net tonne kilometre (ntk) data on freight output and was extended with BTRE (2006) data on freight tonnages. Daniels et al (1992,1994) form the basis for total asset valuation, depreciation, capital expenditure and fuel expenditure, with annual reports being used to break the first three of these into above and below rail components and to check the consistency of aggregate figures.

IV. Separability

There are a number of different ways in which one can address the issue of separability. Ivaldi & McCullough (2006) examine the issue from the perspective of subadditivity, comparing vertically integrated production with vertically separated production and examining which is the more costly to produce for a range of different outputs.[13] As they note, this does not address the heart of the separability issue; the transactions costs associated with a vertically integrated versus a vertically separated firm. Affuso & Newberry (2002) and Yvrande-Billon (2003) assess UK rail reform from within the context of Williamson's (1979) Transactions Costs Economics (TCE), explicitly focussing on these transactions costs effects. Unlike North American railways, British railways were vertically separated, allowing a TCE comparison to occur. Affuso & Newberry (2002) focus on how contracts between the government and the railway franchise operators have influenced investment, and Yrande-Billon (2003) examines whether the governance arrangements in the reformed UK railway environment match those TCE suggest would be appropriate given the assets involved and the consequences on profit where they are not. Potentially, both of these papers provide a useful approach for examining contracts between above and below-rail service providers. However, data on contracts are poor. In Australia, even anecdotal data on contracts is scarce, and in the UK, Yvrande-Billon notes that contracts between above and below-rail entities were not assessed due to a lack of data.

The analysis in this paper is simpler than either that of Ivaldi & McCullough (2006) or that of the two papers examining UK rail reform. It examines the cross-price elasticities between the below rail and the above-rail inputs of Australian railways to ascertain whether they are statistically significantly different from zero. Statistically insignificant coefficients suggest separation is unlikely to cause inefficiency as they imply no relationship between the above and below-rail parameters in the cost function. The intent of this simple model is not to provide the whole answer on vertical separation, but rather to form a first step, serving to

[12] For example, using published figures on asset values and depreciation to infer capital expenditure often lead to instances of negative capital expenditure due to asset revaluation exercises.
[13] This requires specifying infrastructure as an output, rather than as an input. This alters only the presentation of the model, not the mathematics.

open an empirical avenue to a debate which has hitherto only been made at a theoretical level by Australian policymakers.

Table Four summarise the results from the separability analysis, focussing on the λ_{ij} results which indicate the own and cross-price elasticities between the various above and below-rail input variables. The results in Table Four are for the model where the share equation for w_{PARL} was omitted and average indices were used. Other model specifications, including those omitting different railways from the panel, gave different coefficient estimates but reach the same broad conclusions.

Table 4
Separability in Australian Railways

Coefficient	Value	t-ratio
λ_{11} (w_{PARL}, w_{PARL})	- 0.0464	- 2.1063
λ_{22} (w_{PARM}, w_{PARM})	0.0032	0.0900
λ_{33} (w_{PF}, w_{PF})	0.0234	3.1019
λ_{44} (w_{PWS}, w_{PWS})	- 0.0766	- 2.9187
λ_{12} (w_{PARL}, w_{PARM})	- 0.0074	- 0.3321
λ_{13} (w_{PARL}, w_{PF})	- 0.0171	- 0.6463
λ_{14} (w_{PARL}, w_{PWS})	0.0709	3.8854
λ_{23} (w_{PARM}, w_{PF})	- 0.0039	- 0.3891
λ_{24} (w_{PARM}, w_{PWS})	0.0081	0.3383
λ_{34} (w_{PF}, w_{PWS})	- 0.0024	- 0.2471

Diagnostics Results

Durbin Watson (Total Cost Function)	2.0568
R-Squared Between Observed & Predicted (Total Cost Function)	0.7497
$G'(H^{-1})G$ (system)	1.59E-14
Wald Chi Squared Statistic (system - 4 degrees of freedom)	9.256465

The $G'(H^{-1})G$ result indicates the product of the gradient vector and the Hessian matrix of second derivatives of the regression equations and shows how close the estimates are from their true optima. Here, they are very close to zero, indicating model convergence. The Durbin Watson results suggest that the use of the ACROSS command has adequately accounted for serial correlation and heteroscedasticity in the data. The Wald Chi Squared statistic was used to test the null hypothesis that the dummy variables were jointly zero. The null was not rejected, which suggests that the railways have the same fixed cost structure. It is not possible to do a complete test for panel homogeneity incorporating variable costs as well, as each panel is too short to provide sufficient degree of freedom for adequate model closure and thus to compare coefficients across the panels. However, fixed costs comprise roughly half of the costs of Australian railways and hence, where the results of an individual railway differ from the averages in Table Four, it seems likely that the differences will not be too great.

The results of Table Four suggest little evidence of non-separability. Some of the cross-price elasticities between the above and below rail components (λ_{14}, λ_{24} and λ_{34}) are negative and some are positive, which suggests that the railways are separable over some levels of output and not over others. However, only one is statistically significant. The results of Table Four are consistent with those from other model specifications, although the patterns of which coefficients were negative and which statistically significant differ across model specifications. Perhaps more troubling are the coefficients for own-price elasticity. Although it is possible to obtain positive, significant coefficients for all of these using different model specifications, there is no model specification in which all are positive and significant. This suggests caution in interpreting results, but the consistent evidence on cross-price elasticities from Table Four and other model specifications seems point towards separability in

Australian railways. This suggests that separation did not adversely affect efficiency when it occurred.

The results of Table Four differ, but not substantially, from those in the literature. Ivaldi & McCullough (2006) find efficiency losses of between 20 and 40 percent for vertical separation from their subadditivity analysis. However, this is for the average firm across their divisions in outputs and is thus difficult to compare with the simpler model in this paper. When one examines the coefficients in their cost function (a generalised McFadden cost function), the coefficients indicating interaction between the above and below rail terms are similar to that of Table Four; some are positive and some are negative, with none being statistically significant. The sizes of the effects are roughly an order of magnitude larger than in Table Four. In their earlier paper, Ivaldi & McCullough (2001) use a translog cost function and do not use a subadditivity analysis to test separation. A similar pattern on the sign and significance of coefficient parameters emerges, and the magnitudes of the relevant coefficients are roughly comparable to Table Four.

Bitzan (2000) examines a long run cost function similar to that underpinning Table Four, whereby the price of way and structures is an input. In his later paper, Bitzan (2003) examines a short run cost function, and the variable for way and structures becomes a technical variable rather than a price. In both cases, the interaction terms between the above and below-rail components are negative and (apart from one exception) statistically significant. This stands in contrast to Table Four. However, the coefficients are all less than 0.1, suggesting perhaps that efficiency losses might not be very large.

In part the differences between Table Four and Bitzan's results could be poor data; the coefficients on the own price elasticity do not accord with theory, and this suggests caution in interpreting the results of Table Four. An alternative explanation lies in the relationships between above and below rail within a vertically integrated railway in Australia. It may well be the case, in a ceteris paribus sense, that vertical integration is more efficient than vertical separation, and that separating a railway which has very good integration between its above and below rail components would result in significant efficiency losses. However, it need not necessarily be the case that a given railway has particularly good integration between its above and below rail parts. Discussions with industry participants undertaken during this research indicate that in many Australian railways, the above and below rail parts of the company were not particularly well integrated and that the civil and mechanical engineers did not communicate well with each other. Moreover, as Epp & Mutton (2002) note, understanding about how to optimise the wheel-rail interface has advanced considerably over the past 15 years. Finally, the Australian datasets end only a few years after much of the internal reforms, dubbed "Phase One Reforms" by the Industry Commission (1991) had ended, leaving little time for the organisations to re-optimise their internal structure to take advantage of efficiency gains and to make for better communication between above and below-rail. By contrast, the dataset used by Bitzan (2000, 2003) contains more than a decade and a half of data following the *Staggers Act* reforms of 1980, so it is unsurprising that US railways had responded more completely to reform, and would hence suffer more from separation.

Thus, it may be the case that the policy of separation applied to Australian railways did not necessarily cause substantial efficiency losses because when it was applied, many of the railways were not at the leading edge of efficiency in terms of their integration between above and below rail. It does not follow, however, that vertically separating the remaining integrated railways now would be a wise policy, as a decade of productivity improvements have occurred since the last policy shift. Nor does it necessarily follow that re-integrating the railways would be costless, as industry consultation suggests the separated railways have become familiar with addressing the wheel-rail interface via contract and re-integration might initially lead to efficiency losses, rather than gains.

There is, however, an opportunity to undertake a natural experiment; not only are there vertically separated and vertically integrated railways in Australia which can be benchmarked against each other, but some railways are vertically integrated in some jurisdictions and vertically separated in others. QR, for example is vertically integrated in Queensland, but vertically separated in WA, whilst PN is vertically integrated in Victoria,[14] and vertically separated in other states. Moreover, some very similar rail haulage tasks, such as coal haulage, are undertaken by vertically integrated railways in one jurisdiction and by vertically separated railways in another. Provided sufficient data are available, this provides a unique opportunity to empirically assess the issue of whether the wheel rail interface can be managed better by contract or by vertical integration.

V. Subadditivity

Subadditivity in cost equations occurs when output can be produced at lower cost by one firm than many. Baumol (1977) defines subadditivity mathematically as follows:

$C(\sum q_i) < \sum C(q_i)$ where *C* is the cost function and *q* represents output (4)

If the above-rail task is subadditive, competition above-rail will not necessarily be sustainable. Four papers examine subadditivity in US railway networks. Bitzan (2000) examines three different types of subadditivity, focussing on the desirability of parallel railway mergers, end-to-end railway mergers and third party access to railway networks. Bitzan (2003) focuses just on the latter case, finding rail cost subadditivity in 70 percent of cases. Ivaldi and McCullough (2006) using a different model, find subadditivity above rail in 93 to 97 percent of cases. In their earlier paper, Ivaldi & McCullough (2001) do not examine subadditivity per se but find above-rail economics of density of 1.65, implying that a 100 percent increase in above-rail outputs would increase single firm costs by only 65 percent. This supports the conclusion from the subadditivity analysis that, at least in the context of US railways, competition above rail via a third party access regime seems unlikely to be sustainable.

Whilst the literature on subadditivity in railways is relatively new, there is a body of literature from other industries. Telecommunications and the AT&T break-up has been perhaps the most intensively examined industry, with work by Evans & Heckman (1984), Shin & Ying (1992), Wilson & Zhou (2001), Gasmei, Laffont & Sharkey (1997), McKenzie & Small (1997) and Maher (1999) amongst others. Serafice (1998) and Bloch, Cobel-Neal, Madden & Savage (2001) have examined the Philippine and Australian telecommunications markets respectively. Tsirchart (1995) has examined natural monopoly in US energy markets, and Gordon, Ginsch & Pauluk (2003) have examined energy markets in Canada.

The econometric models of each author exhibit some subtle differences, often due to difficulties in the estimation of translog cost functions which play a large role in the literature. Despite these differences, the broad approach is the same; the authors estimate the cost function of the relevant industry using the translog functional form and then apply a test for subadditivity to the resultant model. In the case of a firm with a single output, cost subadditivity can be ascertained by examining economics of scale and scope. In a multi-product setting, the lack of a suitable denominator for calculating average costs complicates matters, requiring the use of ray average costs and some composite good (Baumol, Panzar & Willig, 1988). Even here, economies of scale do not imply cost subadditivity and hence natural monopoly (Sharkey, 1982). Nor do economies of scope (ibid). Only strong cost complementarities imply cost subadditivity, and very few empirical examples of strong cost complementarities exist (Bitzan, 2000). Gordon et al (2003) examine one such empirical

[14] Although it is currently in negotiations with the Victorian government to sell back the infrastructure.

example in Canadian gas pipelines, examining the pairwise transray convexity of the cost function. They also perform a direct subadditivity test and compare the results.

A preferred approach in the literature is to test directly whether two firms can produce the output of a single firm at a greater or lower price. The specification of the translog cost function in terms of prices for inputs assists this endeavour. The direct approach might best be summarised as it is in Shin & Ying (1992) for a three-output firm as follows:

$$C(q^M) < C(q^A) + C(q^B)$$

Where $q^A = (\kappa q_1^M, \lambda q_2^M, \gamma q_3^M), q^B = ((1-\kappa)q_1^M, (1-\lambda)q_2^M, (1-\gamma)q_3^M)$

and $\kappa, \lambda, \gamma =$ (0.1, 0.2, … , 0.8, 0.9). (5)

Evans & Heckman (1984) introduced an earlier version of the test which is similar but, as it was performed on only one firm (compared with 58 firms by Shin & Ying), the authors imposed restrictions on the feasible outputs of the hypothetical two-firm industry such that these outputs were not too far removed from the actual outputs achieved by the monopoly. Shin and Ying (1992), with a much larger dataset, impose no such restrictions, nor do Bitzan (2000, 2003) or Ivaldi & McCullough (2001, 2006). In essence, the subadditivity test involves examining every combination possible in the set $\kappa, \lambda, \gamma =$ (0.1, 0.2, … , 0.8, 0.9), applying the cost function with most components held constant and only the outputs and relevant technical variables altered, and comparing the sum of the two-firm costs with the costs of the relevant monopolist. Evans & Heckman (1984) devise an index of subadditivity degree and test its statistically significant difference from zero in each year, whilst others (including Bitzan) examine the proportion of cases where subadditivity holds.

In this paper, the proportion of cases where subadditivity holds is examined. As discussed above, unit roots in the variables mean that the models of this paper have been constructed in first differences. In the case of the models for subadditivity, a cointegrating relationship was found, and hence an error-correction term was added to the cost function and each of the factor share equations in the system. Whilst usefully providing a model with convergence to a long run equilibrium, estimating a model in first differences makes it difficult to estimate the effects of splitting a level of output as per Shin & Ying (1992). To do this, a starting point in levels is required.

The starting point was estimated via OLS estimation. The three outputs (grain, minerals and general freight) were then split into proportions (0.1:0.9, 0.2:0.8 etc) providing 216 starting points for each railway. The first difference model was then applied to each of these starting points, to measure how splitting the output in a given way would influence the costs of a two-railway firm compared to a monopolist over time. For each railway in the sample, there were between 22 and 30 observations for each of the 216 starting points. Four railways were included (see below), giving 25,600 cases for analysis.

Under an assumption of ergodicity, the initial values should not affect results in any significant way. Unfortunately, it is not possible to test for ergodicity empirically, and hence the starting point approach is based on an assumption that it holds. Moreover, diagnostic test results from OLS estimation of the system suggest significant issues with both heteroscedasticity and serial correlation. Clearly, using OLS regressions to obtain starting points raises issues of the validity of those starting points. However, a starting point is needed to undertake the analysis at all. For this reason, OLS was used to construct the base, subject to a set of ad-hoc tests below.

With three factor share equations (for w_{PARL}, w_{PARM} and w_{PF}) and three different indices of inputs and technical variables (average, Laspeyres and Paasche), there are nine possible combinations of models which might be used.[15] The nature of the data, and the short timeframes in each panel window meant that it was not possible to simply choose one of these nine at random and obtain results which are roughly comparable. Indeed quite some effort was required in order to obtain a suitable starting point. A series of three ad-hoc tests were devised, and each combination was assessed against these. The tests were as follows:

- Whether OLS predicted within sample to a high degree of accuracy.
- Whether OLS gave a lower cost for zero output than for positive output.[16]
- Whether the first differences model with the same characteristics as its OLS counterpart also predicted within the sample to a high degree of accuracy.

The tests are far from rigorous, but form a very basic benchmark for acceptability of results. Three model specifications were chosen from amongst the set which passed all three tests as a rather ad-hoc way of ensuring that the results obtained were unlikely to be outliers. Within the set of models containing all data, none passed all three tests. However, upon removing one railway from the dataset, several passed. The two best of these were those based on an average index with the Westrail data removed and with the price of labour share equation and the price of fuel share equation removed. In the first case, the linear model predicted within sample to an average accuracy of 0.1 percent and the first difference equation to an average accuracy of 4.4 percent. In the second case, the accuracies were 0.0001 percent and 2.5 percent respectively. In both cases, the OLS models predicted zero output having a lower cost than positive output for all outputs in the sample. These two cases thus formed the basis for the subadditivity analysis. In order to provide results which incorporate Westrail, a third case was chosen, with the price of labour (w_{PARL}) share equation and NSW data removed, based on a Paasche index. The accuracies of this model were three percent for the linear and 0.1 percent for the first-differences model, and the model also passed the second test for the whole sample.

Table Five summarises the characteristics of the first difference equations used in these models.[17] Here *Y2* refers to the share equation for w_{PARM} in the Models One and Three and w_{PARL} in Model Two, whilst *Y3* refers to w_{PF} and w_{PARM} respectively. In all three models, the Wald statistic suggests that the fixed costs of the relevant railways is the same which, as discussed in the context of Table Four, suggests that the cost functions of the individual railways in each panel are unlikely to be too far from the average results of the three models above. The Durbin Watson statistic suggests that the modelling procedure has accounted for heteroscedasticity and serial correlation, and the product of the gradient and Hessian matrices suggests convergence.

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[15] There are also five different options depending upon which dummy is omitted, but these generally do not change model results substantially.

[16] Issues with heteroscedasticity and serial correlation in the OLS models meant that the signs on many variables did not accord with theory in many cases. One example of this was negative coefficients on output variables, implying increasing output reduced costs.

[17] Again, these were implemented using SHAZAM's non-linear model specification and the ACROSS command to account for serial correlation and heteroscedasticity.

Table 5
Subadditivity Model Results

	Model One		**Model Two**		**Model Three**	
	Coefficient	*t-ratio*	*Coefficient*	*t-ratio*	*Coefficient*	*t-ratio*
α_0 (constant)	0.0272	0.4274	-0.0372	-0.6721	-0.5664	-1.0799
α_1 (w_{PARL})			-0.0085	-3.4344		
α_2 (w_{PARM})	0.0072	3.0954	0.0074	3.0192	0.4785	3.2804
α_3 (w_{PF})	0.0009	1.2474			-0.0352	-0.9296
β_1 (y_{GRNTK})	0.0855	2.1353	0.0148	0.2599	0.0866	1.8982
β_2 (y_{MINTK})	-0.2551	-1.5914	0.1706	0.7488	0.1151	0.4933
β_3 (y_{GENTK})	-0.1676	-1.0451	0.1757	0.7664	0.1052	0.4749
φ (t_{TECHVC})	0.6083	1.0146	-0.1486	-0.1761	0.4477	0.8863
δ_2 (D_2)					-0.0345	-0.5370
δ_3 (D_3)	0.0892	0.9367	0.0419	0.5007	0.0260	0.4326
δ_4 (D_4)	-0.1725	-1.8113	-0.1215	-1.6192		
δ_5 (D_5)	-0.1635	-1.6428	-0.0677	-0.8333	-0.0443	-0.6067
$Y1$(ECM - Cost function)	1.3810	9.0059	0.4532	3.5312	0.7732	6.7034
λ_{11} (w_{PARL} w_{PARL})			0.1780	11.4990		
λ_{12} ($w_{PARL,}w_{PARM}$)			0.1383	13.0520		
λ_{13} ($w_{PARL}w_{PF}$)			-0.1339	-1.9120		
λ_{22} ($w_{PARM,}w_{PARM}$)	0.1275	12.3730			0.1291	11.3840
λ_{33} ($w_{PF,}w_{PF}$)	0.0448	9.9254			0.0278	5.5460
λ_{23} ($w_{PARM.}w_{PF}$)	-0.0113	-2.8515			-0.0092	-2.0871
γ_{11} (w_{PARL} y_{GRNTK})			-0.0012	-0.4700		
γ_{21} ($w_{PARM}y_{GRNT,}$)	0.0015	0.7572	0.0036	1.6555	0.0025	1.6155
γ_{31} ($w_{PF}y_{GRNTK,}$)	-0.0006	-0.6974			-0.0008	-0.8692
γ_{12} (w_{PARL})			0.0052	0.2637		
γ_{22} ($w_{PARM,}y_{MINTK}$)	-0.0000	-0.0010	-0.0067	-0.3930	-0.0179	-1.2803
γ_{32} ($w_{PF,}y_{MINTK}$)	-0.0054	-0.9108			-0.0079	-1.0868
γ_{13} (w_{PARL} y_{GENTK})			-0.0345	-2.3841		
γ_{23} ($w_{PARM,}y_{GENTK}$)	0.0318	2.5582	0.0405	3.0497	0.0277	2.3872
γ_{33} ($w_{PF,}y_{GENTK}$)	0.0003	0.0678			0.0003	0.0536
θ_1 ($w_{PARL}t_{TECHVC}$)			0.1306	3.5628		
θ_2 (w_{PARM} t_{TECHVC})	-0.0600	-1.9621	-0.0826	-2.5526	-0.0708	-3.4824
θ_3 (w_{PF} $t_{TECHVC,}$)	-0.0442	-3.6664			-0.0316	-3.1298
ρ_{11} ($y_{GRNTK,}y_{GRNTK}$)	-0.0116	-0.9375	-0.0149	-1.0452	-0.0065	-0.5421
ρ_{12} (y_{GRNTK} y_{MINTK})	-0.6659	-1.0497	-0.0261	-0.0300	-0.7830	-1.1660
ρ_{13} ($y_{GRNTK,}y_{GENTK}$)	0.0236	0.0408	-0.5566	-0.7728	-1.4352	-1.8187
ρ_{22} (y_{MINTK} y_{MINTK})	1.0599	0.8407	-0.4883	-0.3238	-0.4563	-0.3664
ρ_{23} ($y_{MINTK,}y_{GENTK}$)	1.4892	1.1450	-0.0680	-0.0388	3.0532	1.4044
ρ_{33} ($y_{GENTK,}y_{GENTK}$)	1.4639	1.3805	0.8911	0.6281	0.7416	0.5385
σ_1 ($y_{GRNTK,}t_{TECHVC}$)	2.0746	1.9984	1.8877	1.2128	2.1763	1.6621
σ_2 ($y_{MINTK,}t_{TECHVC}$)	-2.2942	-0.5703	-0.8355	-0.1338	-1.7575	-0.3749
σ_3 ($y_{GENTK,}$ t_{TECHVC})	-1.4168	-0.7558	-0.9402	-0.3258	-1.3198	-0.6788
ψ ($t_{TECHVC,}t_{TECHVC}$)	0.0463	0.0268	0.0517	0.0226	-0.6096	-0.3856
$Y2$ (ECM - Share equation)	0.1083	3.3016	0.0217	1.0811	0.2926	5.1784
$Y3$ (ECM - Share equation)	0.1066	3.4619	-0.1303	-2.8947	0.0857	1.6826

Diagnostic Results

	Model One	Model Two	Model Three
Durbin Watson Statistic (Cost Function)	1.9359	1.9469	2.0865
R-Square between Obs. & Predicted (Cost Function)	0.6176	0.4234	0.6443
$G'(H^{-1})G$ (system)	1.83E-13	3.07E-13	2.40E-11
Wald Chi Squared Statistic (system , 3 deg. freedom)	7.4049	4.2041	1.3349

Turning to the subadditivity analysis, in the case of Model One, with the share equation for w_{PARL} removed, superadditivity was exhibited in 7004 of 25600 cases, or just over a quarter. In Model Two, with the price of fuel share equation removed, it was exhibited in 1827 cases, or just over seven percent. In Model Three, with NSW data removed superadditivity was observed in 5,064 cases or around 20 percent of the total. For grains and minerals traffic the largest portion of cases in each model were those where the market share of the smallest firm was either zero or ten percent. These results are roughly comparable to those found by Bitzan (2003) but are higher than those of Ivaldi & McCullough (2006). General freight exhibited similar tendencies for Model Three, but for Models One and Two, the largest concentration of cases for general freight superadditivity occurs where the freight task is evenly split between the two hypothetical firms. Cases of superadditivity in grain and in minerals traffic tend to coincide, whilst general freight follows its own distribution. For this reason, cases where all freight tasks fall into a give category are very low. Table Six provides detailed results.

Table 6
Market Shares for Firm A in Cases of Superadditivity

		<11%	**20%**	**30%**	**40%**	**50%**	**Total**
Model One	*Grain*	3283	922	943	931	925	7004
	Minerals	3283	922	943	931	925	7004
	General	1567	936	1051	859	2426	6839
	All	549	158	176	177	177	1237
		<11%	20%	30%	40%	50%	Total
Model Two	*Grain*	1213	126	156	177	155	1827
	Minerals	1213	126	156	177	155	1827
	General	391	156	116	68	1090	1821
	All	89	24	21	20	12	166
		<11%	20%	30%	40%	50%	Total
Model Three	*Grain*	1360	839	934	966	965	5064
	Minerals	1360	839	934	966	965	5064
	General	2056	1018	870	577	450	4971
	All	740	175	167	158	150	1390

The further out of sample one predicts, the less robust the predictions, and hence the results are likely to be weakest for cases where the share of one firm is ten percent. Although this cut-off is rather arbitrary, it seems prudent to at least look with suspicion at results in this category, as they are the least likely to be correctly predicted by the model. Excluding this lowest category from the results means that, overall, 15 percent of minerals and grain traffic cases in Models One and Three are superadditive, whilst the proportions of general traffic are 21 and 11 percent respectively. Model Two has far fewer cases; only 2.5 percent in the case of grain and minerals and 5.5 percent in the case of general freight. Examining the most category closest to the sample data (where each firm has half the freight task), only four percent of cases for grain and minerals fall into this category for Models One and Three, with less than one percent for Model Two. The figures for general freight are ten percent, four percent and two percent respectively. In a general sense, therefore, the case for superadditivity in the above rail task, and hence for an expectation of sustainable competition is weak.

Currently, third party access is granted to a railway, regardless of the freight carried on different lines. The Productivity Commission (2006) has suggested a more case-by-case approach might be appropriate to avoid capturing too many lines. The results of Table Six support this view; whilst grain and minerals freight cases exhibiting superadditivity occur together, the distribution of general freight cases is different, and hence the number of cases where all three railways achieve the same result is very small. Moreover, most of these occur in cases when the market share of the smallest firm is less than eleven percent, which comprise the least robust set of predictions. It thus seems inappropriate to apply access regimes to railways in a blanket fashion, and rather more appropriate to apply them selectively. Since a given line might carry many different types of freight, this can be difficult. However, from the results of Table Six, one might best expect competition to occur in the haulage of general freight, although even then the expectation should not be great. This suggests a policy of access to lines with a large portion of general freight traffic is most likely to result in some above-rail competition, whilst access to minerals and grain networks is likely to result in comparatively little competition. Thus, whilst one might expect some competition to develop on the East West link, where the share of intermodal freight is high, and on the mainline between Brisbane, Sydney and Melbourne (provided some of the issues on that line can be addressed – see ARA, 2005), it seems unlikely that sustainable competition will develop elsewhere on the network.

It now remains to examine the situation for each railway. In the population of cases for each model (25,600), AN occurred 23 percent of the time, NSW 25 percent, QR 30 percent, Victoria 23 percent and WA 25 percent.[18] In the set of superadditive results, AN appears less often than in the population for Models One and Two (13 percent and 2 percent respectively) and more often in Model Three (26 percent). QR accounts for roughly the same proportion of superadditive cases as it does cases overall (34 percent in Model One, 31 percent in Model Two and 29 percent in Model Three), as does WA (22 percent in Model Three). Victoria has a disproportionately larger share of superadditive observations in Models One and Two (33 percent and 37 percent respectively) but contains roughly its population share in Model Three (23 percent. NSW contains marginally fewer observations than in the population in Model One (20 percent) and marginally more in Model Two (31 percent). It is difficult to perceive any clear pattern from these results, other than to say that it does not appear that any one railway has a disproportionate share of superadditivity, nor that one railway appears to be inherently more superadditive than any other.

Tables Seven and Eight provide further detail on cases by freight task.

Table 7
Freight Task Cases by Railway

		Grain	Minerals	General	All
Model One	*AN*	943	943	925	186
	NSW	1399	1399	1369	234
	QR	2360	2360	2298	385
	Vic	2302	2302	2247	432
Model Two	*AN*	33	33	33	1
	NSW	559	559	559	30
	QR	566	566	566	0
	Vic	669	669	663	135
Model Three	*AN*	1302	1302	1279	350
	QR	1487	1487	1459	401
	Vic	1122	1122	1103	319
	WA	1122	1122	1103	319

The results of Tables Seven and Eight may come from the fact that the models are averages of the Australian railways, and hence ameliorate distinctive characteristics of individual railways. However, as noted previously, the results of the Wald Chi-Squared tests indicate that the fixed costs of the railways (above rail) are the same, and hence it seems unlikely that the total costs would be substantially different.

[18] Models One and Two contain NSW but not WA, and Model Three contains WA but not NSW.

Table8
Freight Task Cases by Railway and Share of the Smallest Firm

		Grain					Minerals					General					All				
		<11%	*20%*	*30%*	*40%*	*50%*	*<11%*	*20%*	*30%*	*40%*	*50%*	*<11%*	*20%*	*30%*	*40%*	*50%*	*<11%*	*20%*	*30%*	*40%*	*50%*
Model One	*AN*	391	125	137	142	148	391	125	137	142	148	251	143	141	111	279	83	24	25	26	28
	NSW	704	159	177	180	179	704	159	177	180	179	315	179	211	137	527	107	30	32	32	33
	QR	1146	314	311	298	291	1146	314	311	298	291	387	297	375	335	904	144	50	65	65	61
	Vic	1042	324	318	311	307	1042	324	318	311	307	614	317	324	276	716	215	54	54	54	55
	WA																				
Model Two	*AN*	2	3	6	9	13	2	3	6	9	13	21	6	3	0	3	0	0	0	0	1
	NSW	419	24	29	38	49	419	24	29	38	49	96	32	19	10	402	15	5	4	4	2
	QR	476	13	27	27	23	476	13	27	27	23	57	20	12	1	476	0	0	0	0	0
	Vic	316	86	94	103	70	316	86	94	103	70	217	98	82	57	209	74	19	17	16	9
	WA																				
Model Three	*AN*	340	216	238	249	259	340	216	238	249	259	543	258	218	146	114	187	44	42	39	38
	NSW																				
	QR	388	248	275	288	288	388	248	275	288	288	606	300	255	170	128	209	52	50	47	43
	Vic	295	189	211	215	212	295	189	211	215	212	453	233	200	126	91	169	41	39	36	34
	WA	295	189	211	215	212	295	189	211	215	212	453	233	200	126	91	169	41	39	36	34

Again, there are no great differences between railways, either in terms of the overall concentration of cases in a certain freight task or in terms of concentration in freight tasks and market share of the smallest firm. There are some differences between the three models, with the spread of cases in Table Eight being more even across categories of the share of the smaller firm than in Table Six. The results of Model One and Two might be used to suggest that QR's general freight task could support more competition than the general freight of other railways. Indeed, some general freight in North Queensland formerly hauled by QR has been taken over by a new entrant to that market, PN. However, this was under some considerable controversy as the terms of the contract appeared to favour the customer who was also a part-owner of PN (Toll) and was one of the factors leading to friction between Toll and Patrick, the owners of PN, and the eventual takeover of PN by Toll. As such, whether this entry is sustainable remains to be seen.

Overall, the conclusion from the subadditivity analysis appear to be that policymakers should have expected limited scope for competition to emerge on Australia's railways following the introduction of third party access. It is useful, therefore, to examine how much competition has actually eventuated in the decade since access regimes began. The historical record is still relatively short, but is thus far not particularly bright. Immediately following the introduction of open access, SCT, Toll and Patrick Rail entered the above rail industry, with Toll and SCT taking up to a quarter of the market on the East West freight rail link. Toll and Patrick Rail subsequently formed Pacific National, and SCT now has a market share on the East West link of less than five percent. Other new entrants include:

- South Spur Rail, in WA, which has a small fleet of locomotives and undertakes hook and pull services for other rail companies.
- CRT, in Victoria and NSW which owns wagons, some terminals and has brought Sprinter trains into Australia. CRT has subsequently been taken over by QR
- Lachlan Valley, which owns wagons and moves container freight in NSW.
- Chicago Freight Car Leasing, which leases wagons and locomotives in Australia, filling a key role for new market entrants.

The market share of these new entrants is negligible. Most of the competition in Australia comes from four of the rail companies formed during the reform process or given concessions as part of it (ARTC, PN, ARG, and QR), as well as the company formed with the completion of the Tarcoola-Darwin railway (Freightlink). These companies are beginning to compete in each other's markets. For example:

- PN has secured freight haulage contracts in north Queensland.
- QR has secured coal haulage contracts in NSW and has recently purchased CRT in Victoria (with its associated terminal) and the above-rail interests of ARG in WA. It also plans to turn its Acacia Ridge terminal into an open access terminal.
- Freightlink has begun offering services between Adelaide and Melbourne.

There is also evidence of consolidation, such as the QR takeover of CRT and part of ARG, the PN takeover of Freight Australia in Victoria and ATN in Tasmania and the takeover of Patrick by its PN partner Toll, which will have major ramifications for the industry.

Limited entry is not unique to Australia. The EU moved earlier than Australia in vertical separation, establishing a framework which mandates vertical separation and provides openings for competitors to establish themselves in each market under the aegis of EC Directives 91 and 92. Moreover, Europe has much larger freight markets than Australia. Apart from incumbents in each country obtaining access to neighbouring markets on a reciprocal basis, the best results have been in the UK, where British Rail was completely dissolved and thus all of the current market players are new entrants, Sweden, where half the freight market and a third of the passenger market has been taken by new entrants and Germany, where more than a hundred new rail firms have been created, albeit taking only ten percent of the market (IBM, 2004). In the other EU countries, new entrants have captured less than five percent of the market, and in many cases, none at all (ibid).

Is such marginal competition worthwhile? In the sense that it provides some degree of customer choice, it is. Sustainability is more difficult to assess. The implicit assumption underlying the subadditivity test is that the new entrants will have a comparable cost structure to the incumbent. However, smaller railways do not commonly have the same cost structure; they have non-unionised workforces and rely on older rolling-stock. Therefore, the conclusions from the above analysis might not apply to smaller railways. Unfortunately, the viability of smaller railways is impossible to assess using the same analytical techniques as those used above, as there are insufficient data to do so.

One final point should also be made in regards to subadditivity. Although there is limited scope for more than one railway to be sustainable in any given Australian railway market, the single viable railway in a given market need not be the incumbent. One important element of third party access is that of contestability; provided it can gain access to the track infrastructure, a new entrant can capture the entire above rail minerals, grain or general freight task from the incumbent. In the renegotiation of large minerals haulage contracts in recent years, mining operators have sought tenders from railways around Australia for their bulk-freight tasks and, although the incumbent has usually won each tender, discussions with industry suggest that this victory has come at a lower haulage price than has been the case in the past. Thus, although third party access might not deliver competition, it may well be delivering contestability, and this may be sufficient to further the aims of competition policy.

VI. Conclusions

The twin analyses of this paper were undertaken with the intent of examining whether the two main tenets of competition policy reform in railways were valid; that reform would bring competition and that separation would not adverse affect the efficiency of the railways.

On the latter point, although data quality make conclusions tentative, the paper finds little evidence to criticise the policy decisions which led to vertical separation. The data from the railways at the time provide little support to the argument that the above and below-rail tasks are joint in the production function sense. One reason why this might have been the case is that some Australian railways at the time were not well integrated in their above and below-rail operations, and hence their losses were not as great as others have found in the more efficient US railways. It does not follow from this that re-integrating the currently separated railways, or splitting those that remain vertically integrated would be wise today, as significant changes have occurred in the industry in the intervening decade: the vertically integrated railways have become more adept at managing the wheel-rail interface in-house and the vertically separated railways at managing it via contract. It does, however, provide scope for a unique natural experiment in assessing the efficiency of each approach, as similar freight is carried by both vertically integrated and vertically separated railways.

The paper finds little evidence that policymakers should have expected substantial competition to emerge as a result of third party access. Indeed, there may well be a risk of double-marginalisation, as one monopoly is replaced by two. In this respect, the consultants' report (Travers Morgan, 1995) which underpinned reform, at least at the Federal level, seems to have been overly optimistic in its assessment of competitive benefits. However, the findings of this paper cannot be extended to small railways, with different cost structures than the incumbents, whose small market share may be sufficient to provide sustainable competition at the fringe. Moreover, third party access opens the potential for contestability of freight tasks, particularly for major minerals freight tasks, and this also may be sufficient to drive efficiency gains, as some anecdotal evidence from industry suggests is occurring, at least in the short-term.

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