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Australian intercapital freight demand: An econometric analysis

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Abstract

This paper provides estimates of Australian intercapital non-bulk road, rail and sea freight demand, derived using a system of cost-minimising interrelated factor demand equations. Two different functional forms were estimated: (i) using a translog cost function; and (ii) using a linear logit system of expenditure shares and implied cost function. Own-price, cross-price and substitution elasticity estimates are derived for intercapital non-bulk road, rail and sea freight transport. The results imply that road freight is relatively price inelastic, but that rail and coastal shipping are more responsive to price changes. The derived elasticity estimates will be of use to freight transport analysts and help inform Australian freight transport policy development.

1. Introduction

Australian intercapital non-bulk freight has grown more than threefold since the early 1970s—equivalent to average annual growth of 4.2 per cent per annum—and is one of the fastest growing segments of the Australian freight market. Road freight accounts for much of the additional intercapital freight, growing almost sixfold over this period. Road freight sector productivity and efficiency has increased significantly, during this time, as a result of road network improvements under the former National Highway System (NHS) program and latterly through National Land Transport Network (NLTN) expenditure, regulated increases in heavy vehicle size, and continuing technological improvements in vehicle performance. Except on the long-distance eastern State capital cities to Perth corridor, intercapital rail freight has grown far less quickly than road freight. And intercapital non-bulk sea freight, which is generally only significant between the eastern State capital cities and Perth, declined significantly in the early 1980s to almost negligible volumes, as a result of price competition from road and rail, but has carried an increasing share of freight since the late 1990s—coincident with the increase in domestic freight carried by international ships operating under Single Voyage Permits (SVP) and Continuous Voyage Permits (CVP).

By mass (and arguably also value) road freight is the principal transport mode for Australian intercapital non-bulk freight, comprising between 80 and 90 per cent of total freight on the two largest intercapital freight corridors—Sydney–Melbourne and Sydney–Brisbane. Rail carries up to 30 per cent of freight on the Melbourne–Brisbane (1700 kilometre) corridor and is the predominant transport mode for freight between the eastern State capitals and Perth (over 3400 kilometres).

Intercapital freight is one of the few freight markets where there is significant modal competition between road, rail and sea freight transport modes. For much of Australia's freight, there is generally little intermodal competition—one mode or another generally has a clear cost and/or service advantage over all other modes. For example, rail is the preferred mode of transport for land-based bulk commodity movements and sea freight is more

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economic for long-haul movements between coastal regions. Road is generally the only practical alternative for most urban freight and short-distance movements between cities and regional hinterlands. Not surprisingly, aggregate empirical estimates tend to imply low intermodal freight substitutability.

This paper provides empirical estimates of Australian intercapital non-bulk road, rail and sea freight demand, using a system of cost-minimising interrelated factor demands applied to BTRE (2006) intercapital non-bulk freight task and freight rate estimates. Empirical estimates are derived using two different functional forms: (i) a dynamic translog cost function specification; and (ii) a dynamic linear logit-based system of expenditure shares, and associated cost function. The dynamic translog specification provides a second order approximation to the underlying cost function, and restrictions implied by economic theory may be imposed on the system. The aggregate logit-based specification is applicable to any share-based model specification and, with appropriate restrictions, also conforms to economic theory.

The principle outputs of the paper are estimates of the own-price, cross-price and substitution elasticities between road, rail and sea freight transport of non-bulk intercapital freight. The empirical results imply that road freight is relatively price inelastic, but that rail and coastal shipping are relatively responsive to price changes. Separate empirical estimates are also presented for ‘short’-, ‘medium’-and ‘long’-distance inter-capital corridors. The empirical elasticity estimates will be of use in informing freight transport policy analysis.

1.1 Previous estimates of Australian freight transport demand

The paucity of regular, detailed Australian freight activity and freight rate data has tended to constrain modelling of the Australian freight transport sector, particularly with regard to model specification. Previous empirical studies of Australian freight demand have included Fitzpatrick and Taplin (1972), BTE (1979), BTE (1990), NRTC (1997), Booz Allen Hamilton (2001) and PC (2006) (see Table 1).

Table 1: Australian freight transport demand studies

Author	*Notes*	*Elasticity estimates*
Fitzpatrick and Taplin (1972)	Intercapital road freight, gravity model formulation	Road (own-price): –2.16 Road (rail-price) +2.16
BTE (1979)	Sydney–Melbourne road freight	Long-run Syd–Mel. –0.70
	Four-states intercapital road freight	Long-run four-states –0.90
BTE (1990)	Six intercapital corridors	Syd–Mel: Road (own-price) –0.70 Syd–Mel: Rail (own-price) –0.25 Syd–Mel: Sea (own-price) –0.13 ES–Per: Road (own-price) –3.17 ES–Per: Rail (own-price) –0.92 ES–Per: Sea (own-price) –1.11
NRTC (1997)	Intercapital city pairs	Road (own-price) –0.77
Booz Allen Hamilton (2001)	Intermodal rail freight share	Rail (own-price): –1.1 Rail (transit time): –0.3 to –0.4 Rail (reliability): +0.6
PC (2006)	Modelled aggregate road & rail freight activity	All road (own-price): –0.43 Non-urban road (own-price): –0.25 All rail (own-price): –0.25

Sources: Booz Allen Hamilton (2001), BTE (1979, 1990), Fitzpatrick and Taplin (1972), NRTC (1997) and PC (2006).

Fitzpatrick and Taplin (1972) used a gravity-based formulation to estimate total intercity road freight demand, using a multiplicative relative price ratio for road and rail freight, as the relevant price variable. Fitzpatrick and Taplin estimated the own-price elasticity of road freight demand to be –2.16. By assumption, Fitzpatrick and Taplin's specification restricts the cross-elasticity of road freight with respect to rail freight rates to be equal to the negative own-price elasticity of road, or 2.16. Population and log trend terms were also statistically significant.

BTE (1979) estimated a single equation dynamic partial adjustment model of intercity road freight demand for Sydney–Melbourne origin–destination (OD) freight and combined intercity freight for four capital city pairs—Sydney–Melbourne, Sydney–Brisbane, Sydney–Adelaide and Melbourne–Adelaide. The equations were estimated using quarterly data for the period 1971–72 to 1976–77. BTE estimated a long-run relative price elasticity for road freight demand of –0.70 between Sydney–Melbourne (where the relative price was defined as the price of road freight relative to rail freight) and –0.91 between the four state capitals. BTE's specification placed no theoretical restrictions on the elasticity of substitution between modes.

BTE (1990) estimated separate single equation static models of road, rail, sea and air freight demand, for six Australian intercapital corridors. For each intercapital OD pair and mode, the mode-specific freight task was regressed against freight rates and aggregate economic activity. The mode-specific single equation models did not incorporate cross-modal parameter restrictions implied by economic theory. The empirical results imply that activity is the main driver of road freight demand—freight rates were statistically significant for only two of the six corridors. Rail freight demand was found to be relatively inelastic with respect to rail freight rates and either inelastic with respect to or independent of road freight rates.

The National Road Transport Commission (NRTC) engaged the Melbourne Institute of Applied Economic and Social Research (IAESR) to estimate the impact of increase mass limits for road vehicles on road and rail freight demand (NRTC 1997). The study attempted to replicate BTE (1979) using quarterly data for the period June 1990 to September 1995. NRTC (1997) reported that satisfactory results were only obtained using data for the period December 1985 to March 1993, and restricted to road freight only. The study estimated a long-run own-price elasticity for road freight of –0.77, and a short-run elasticity of –0.19.

Booz Allen Hamilton (2001) used a simple logit model specification to estimate the significance of rail freight rates and service quality on intercapital rail freight demand. The price elasticities used in the study were –1.1 for short-and long-distance intermodal rail freight. Booz Allen Hamilton (2001) assumed rail is relatively unresponsive to changes in service quality, with the elasticity of rail freight demand with respect to each of transit time, reliability and availability between 0.4 and 0.6 in absolute terms.

PC (2006) estimated several dynamic single equation models of aggregate Australian road and rail freight demand. PC (2006) estimates imply both road and rail freight demand are relatively inelastic with respect to own-price, and generally independent of changes in other mode prices, reflecting the fact that there is little intermodal competition for a substantial proportion of the total Australian freight task.

2. Model specification

Two alternative flexible functional forms are used in this paper to estimate Australian intercapital freight transport demand:

i. a generalised translog cost function

ii. an aggregate linear logit expenditure share system

The translog cost function is a second-order logarithmic approximation to the true cost function (Christensen, Jorgenson and Lau 1973), and has been used extensively to estimate factor input demands across a wide range of industries. The translog cost function satisfies the necessary conditions required by economic theory—that costs are positive, monotonic and linearly homogeneous in input prices. It is less restrictive than other popular functional specifications, such as the Cobb-Douglas, constant elasticity of substitution (CES) and Diewert functional forms (Diewert 1971), which restrict the range of substitution possibilities between inputs. However, the translog function has been observed to frequently violate concavity in empirical applications—implying that, across part of the sample period, there is a cheaper combination of factor inputs than the combination actually chosen.

The linear logit model is ideally suited to any problem involving the modelling of demand or product shares, where all shares are positive and sum to one. Binomial, multinomial and related logit-type model specifications are used extensively in discrete choice problems, but have been used less often in aggregate demand modelling. Considine (1990), Considine and Mount (1984), Chavas and Segersen (1986), Jones (1995) and Urga and Walters (2003) have used the flexible linear logit model in aggregate economic applications. Oum (1979a) used a restricted linear logit specification to estimate freight demand in Canada.[2] With appropriate parameter restrictions, the flexible logit model satisfies the necessary conditions implied by economic theory, and, unlike the translog cost function, it (generally) preserves concavity across the sample.

Both the translog and linear logit specifications assume that the market minimises aggregate transport costs for a given freight task—for a cost minimising firm, any positive, differentiable and non-decreasing function, linearly homogeneous and concave in input prices, is sufficient to describe a cost function for a given technology (Varian 1978, p. 65). In both the translog and linear logit specifications, transport mode choice is assumed independent of other, non-transport inputs. In the current context, this assumption is most likely to be violated by storage and warehousing costs—to a certain extent, firms can trade-off higher transport costs for lower storage and warehousing costs, and vice versa. The empirical estimates presented here only account for the impact of changes in line-haul transport costs on intercapital freight demand.

The model specifications estimated in this paper also exclude explicit treatment of service quality factors—such as travel time, reliability and availability—which may also influence freight mode choice. In practice, for some commodities, shippers may trade-off between price and service quality at the margin. Inclusion of explicit service quality effects might have some impact on the estimated price elasticities presented in this paper.

2.1 Dynamic translog cost model

The static translog cost function is:

$$\begin{aligned}\ln C_t^* = \gamma_0 + \sum_i \gamma_i \ln P_{it} + \gamma_{iy} \ln y_t + \gamma_{it} t + 1/2 \sum_i \sum_j \gamma_{ij} \ln P_{it} \ln P_{jt} + \sum_i \gamma_{iy} \ln y_t \ln P_{it} \\ + \sum_i \gamma_{it} t \ln P_{it} + 1/2 \gamma_{yy} \ln y_t^2 + \gamma_{yt} t \ln y_t + 1/2 \gamma_{tt} t^2\end{aligned} \tag{1}$$

where ln C_{t^*} is the total cost at time t; ln P_{it} is the log of the price of factor i at time t; y_t is industry output at time t; and t is a time trend term.

Economic theory requires that the cost function be linearly homogeneous and concave in input prices, and symmetric price substitutability. Linear homogeneity and 'adding up' imply the following restrictions on the parameters in equation (1):

$$\sum_i \gamma_i = 1; \quad \sum_j \gamma_{ij} = 0, \forall\, i = 1,\ldots,N; \quad \sum_i \gamma_{iy} = 0; \quad \sum_i \gamma_{it} = 0.$$

Symmetry is imposed by assuming, $\gamma_{ij} = \gamma_{ji}$.

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[2] Urga and Walters (2003) noted that, contrary to Oum (1979a), the general dynamic logit specification does not unnecessarily restrict the allowable market response.

Differentiating the logarithm of total cost (ln C_t) with respect to the logarithm of the price of freight mode i gives the expenditure share equation for input factor i:

$$S_{it}^{*} = \gamma_i + \sum_j \gamma_{ij} \ln P_{jt} + \gamma_{iy} \ln y_t + \gamma_{it} t, \quad i = 1,\ldots,N. \tag{2}$$

The Allen-Uzawa partial elasticity of substitution (σ_{ij}) and the own-price and cross-price elasticities of demand (η_{ij}) may be computed from the parameters of the cost function.

$$\sigma_{ii} = \frac{\gamma_{ii} + S_i^2 - S_i}{S_i^2}, \quad \eta_{ii} = \sigma_{ii} S_i; \quad \text{and} \quad \sigma_{ij} = \frac{\gamma_{ij} + S_i S_j}{S_i S_j}, \quad \eta_{ij} = \sigma_{ij} S_j \tag{3}$$

The elasticities of substitution and the own-price and cross-price elasticities may be derived by simply estimating the system of expenditure share equations. Because the expenditure shares must sum to one, it is necessary to drop one of the equations for estimation. Estimating the cost function jointly with the expenditure share equations, however, yields more efficient parameter estimates, since more information is used in estimation. The translog cost function does not place any restrictions on the values of the partial elasticities of substitution, and it is usual to test concavity of the empirical cost function.

2.1.1 Dynamic specification

Dynamic response is modelled using a *generalised error correction mechanism (ECM)* specification. Anderson and Blundell (1982) posited the following generalised ECM model for the expenditure share equations:

$$\Delta S_t = \Gamma \Delta S_t^{*} + \mathrm{K}\left(S_{t-1}^{*} - S_{t-1}\right) + \varepsilon_t \tag{4}$$

where S_t is the vector of observed expenditure shares at time t; $S_t{}^{*}$ is the vector of predicted expenditure shares at time t and ε_t is random error term.

Following Urga and Walters (2003) and Allen and Urga (1999) we adopt the following short-run cost function, which includes both equilibrium and disequilibrium terms, consistent with the generalised ECM share terms of equation 4:

$$\ln C_t = \lambda \ln C_t^{*} + (1-\lambda)\ln C_{t-1}^{*} + (1-\lambda)\left(\sum_i S_{i,t-1} \ln P_{it} - \sum_i S_{i,t-1}^{*} \ln P_{i,t-1}\right) + \sum_i \sum_j b_{ij}\left(S_{j,t-1}^{*} - S_{j,t-1}\right)\ln P_{it} \tag{5}$$

where ln C_t is the observed total cost at time t and ln $C_t{}^{*}$ is the predicted total cost at time t.

The short-run dynamic expenditure share function for input i has the form:

$$S_{it} = \lambda S_{it}^{*} + (1-\lambda) S_{i,t-1} + \sum_j b_{ij}\left(S_{j,t-1}^{*} - S_{j,t-1}\right) \tag{6}$$

The partial generalised error correction model (PGECM) includes several other dynamic specifications as special cases, including the simple ECM and Partial Adjustment (PA) specifications. The most parsimonious statistically significant dynamic structure may be established by a series of nested likelihood ratio tests. Table 2 lists the various nested dynamic specifications and associated parameter restrictions.

Table 2: Nested dynamic specifications – PGECM

Dynamic specification	*Restrictions*
Symmetric PGECM	λ, $B = B'$
Diagonal PGECM	λ, $B = b_{ii}$ I
Simple ECM	λ, $B = b$ I
Partial adjustment	λ, $B = 0$
Static	$\lambda = 1$, $B = 0$

Sources: Anderson & Blundell (1982, 1983 and 1984).

The long-run substitution, own-price and cross-price elasticities are identical to that of the static translog cost function (equation 3). The short-run substitution, own-price and cross-price elasticities are:

$$\sigma_{ii}^{sr}=\frac{\lambda\gamma_{ii}+S_i^2-S_i}{S_I^2},\quad \eta_{ii}^{sr}=\sigma_{ii}^{sr}S_i;\quad \text{and}\quad \sigma_{ij}^{sr}=\frac{\lambda\gamma_{ij}+S_iS_j}{S_iS_j},\quad \eta_{ij}^{sr}=\sigma_{ij}^{sr}S_j \tag{7}$$

2.2 The Dynamic Linear Logit Model

In the dynamic linear logit model, the expenditure shares (S_{it}) are assumed to have a logistic functional form. Considine (1990) provides the following logistic approximation to a set of N non-homothetic cost shares with non-neutral technical change:

$$S_{it}=\frac{\exp(f_{it})}{\sum_j \exp(f_{jt})},\qquad \text{where } f_{it}=\beta_i+\sum_j \beta_{ij}\ln P_{jt}+\beta_{iy}\ln y_t+\beta_{it}t+\lambda\ln X_{i,t-1}+\varepsilon_{it} \tag{8}$$

and P_{jt} denotes the price of input j, y_t output, t is the trend term capturing factor-biased technical change, and $X_{i,t-1}$ is lagged freight task of mode i.

Linear homogeneity may be imposed by setting $\sum_j \beta_{ij}=d$ where d is an arbitrary constant (usually 0). Following Urga and Walters (2003) symmetry may be imposed either locally or globally. Local symmetry is specified for a given set of expenditure shares, usually the sample means. Global symmetry is obtained if the expenditure shares are provided for each year of the sample. Restating the price coefficients as $\beta_{ij}^{*}=\beta_{ij}/\tilde{S}_{jt}$, assuming $\tilde{S}_{jt}=\bar{S}_{jt}$, the time invariant sample mean, gives local symmetry, and assuming $\tilde{S}_{jt}=\hat{S}_{jt}$, the predicted shares for each observation, gives global symmetry. Symmetry is imposed by restricting $\beta_{ij}^{*}=\beta_{ji}^{*}$ for all $i = j$.

Estimation of the model is expedited by linearising equation (8). The adding up restrictions β_N = β_{Ny} = β_{Nt} = 0 are required to ensure identification of the model. Hence the share equations to be estimated are:

$$\ln\left(\frac{S_{it}}{S_{Nt}}\right)=\beta_i+\sum_j^{N-1}\left(\beta_{ij}-\beta_{Nj}\right)\ln P_{jt}+\beta_{iy}\ln y_t+\beta_{it}t+\lambda\left(\ln X_{i,t-1}-\ln X_{N,t-1}\right)+\left(\varepsilon_{it}-\varepsilon_{Nt}\right) \tag{9}$$

Assuming that the error term $\varepsilon_{it}-\varepsilon_{Nt}$ is distributed normally, we may estimate the system using a parametric estimation method.

The cost function is then estimated as a single equation using the predicted shares ($\hat{S}_j$) from the system of expenditure shares:

$$\ln C_t=\beta_o+\sum_j \hat{S}_{jt}\ln P_{jt}+\beta_y\ln y_t+\beta_t t+1/2\,\beta_{yy}\ln y_t^2+\beta_{yt}t\ln y_t+\beta_{tt}t^2 \tag{10}$$

The short-run own- and cross-price elasticities are: $\eta_{ii}=\beta_{ii}+S_i-1=\left(\beta_{ii}^{*}+1\right)S_i-1$ and $\eta_{ij}=\beta_{ij}+S_j=\left(\beta_{ij}^{*}+1\right)S_j$, and the partial elasticity of substitution between factor inputs is given by $\sigma_{ij}=\eta_{ij}/\hat{S}_j$, which, in the linear logit model, is constant over the sample (Urga and Walters 2003). The long-run own-and cross-price elasticities, and activity elasticities are equal to their short-run equivalent divided by 1 – λ.

3. Data

3.1 Data sources

The data used for estimating intercapital freight demand is sourced from BTRE (2006) and covers the period 1972 to 2001. BTRE (2006) contains separate estimates of non-bulk road, rail and sea freight movements for seven intercapital corridors:

- Sydney–Melbourne
- Sydney–Brisbane
- Sydney–Adelaide
- Sydney–Canberra
- Melbourne–Brisbane
- Melbourne–Adelaide
- Eastern state capitals–Perth

There is no single time series collection of intercity freight movements and freight rates in Australia. Unlike the US and Canada, Australia does not undertake regular surveys of interregional freight movements nor require road and rail industry operators to provide annual returns on activity, revenues and costs. The BTRE (2006) intercapital freight movement estimates are a compilation of non-bulk intercapital freight movement estimates from various sources, including:

- Australian Bureau of Statistics (ABS) *Interstate Freight Movement* surveys (ABS 1995, and earlier issues)
- ABS *Freight Movements Survey* (FMS) (ABS 2002)
- ABS *Year Book* (ABS 1997, and earlier issues)
- FDF P/L *FreightInfo* database of national freight flows
- ABS *Survey of Motor Vehicle Use* (SMVU) (ABS 1996, and earlier issues) for road freight
- National Rail Corporation (NRC) and state rail authorities for rail freight
- Bureau of Infrastructure, Transport and Regional Economics (BITRE) coastal shipping database and, prior to 1990, DoT (1995) and DoTC (1989, and earlier issues) for coastal shipping freight movements.

The BTRE (2006) intercapital freight task data is the best available time series of freight movements between Australian capital cities.

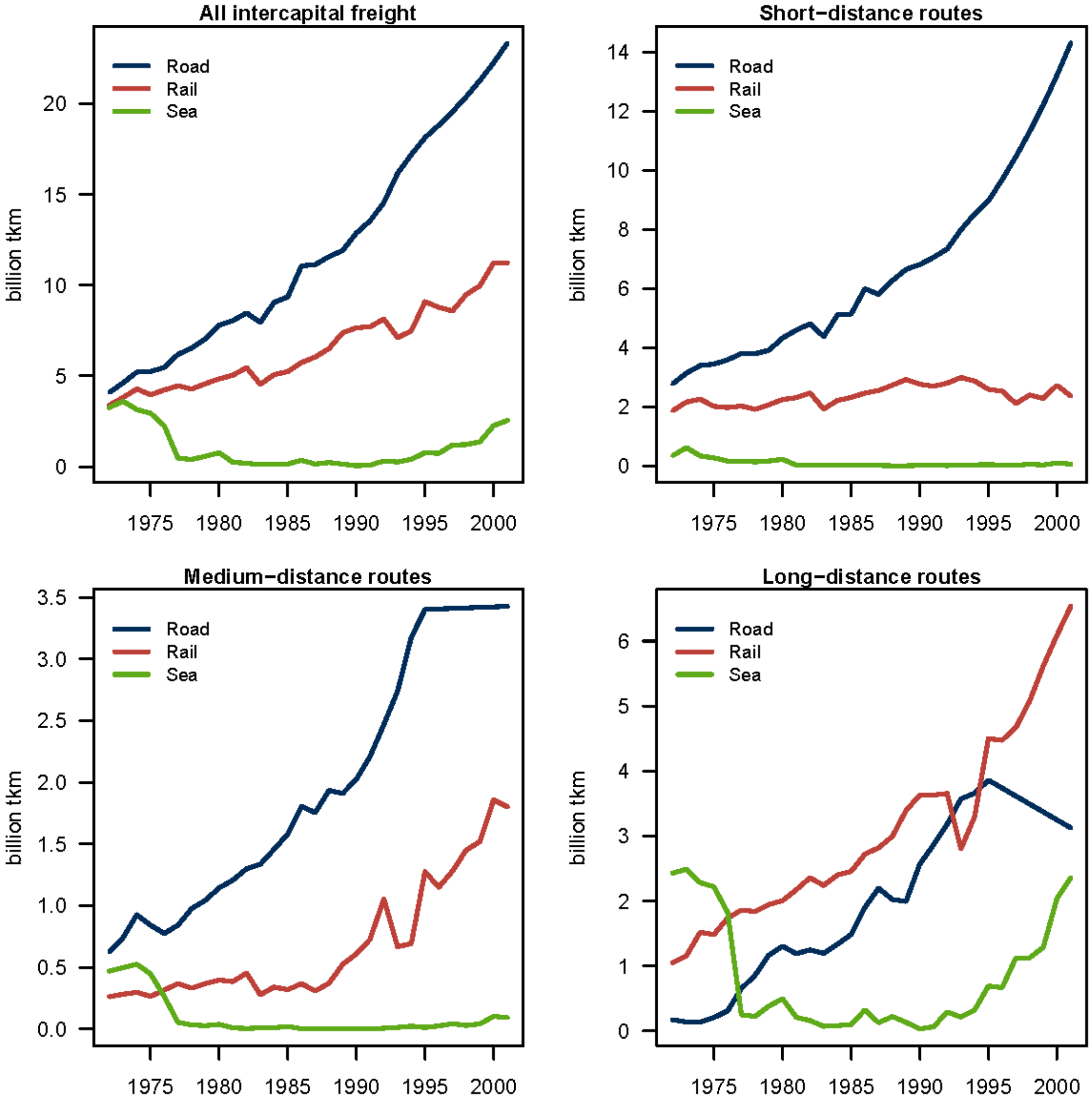
The road, rail and coastal shipping freight rate series are based on the non-bulk freight rate estimates published in BTRE (2006), which, in turn, are based on a combination of published freight rates and transport cost estimates (for road), average revenue of public rail authorities and coastal shipping freight services from several different sources. Road freight rates are based on Sydney–Melbourne road freight rates (BTE 1990) supplemented by information from TransEco (2001, and earlier issues). Rail freight rates are based on Sydney–Melbourne rail freight rates (BTE 1990) supplemented by average freight revenue earned by the State Rail authorities. Coastal shipping freight rates are from BTE (1990). BTRE (2006, Appendix VIII, pp. 283-335) provides a detailed description of the methods used to derive consistent time series of Australian interstate non-bulk freight rates.

3.2 Intercapital freight movements and freight rate trends

Figure 1 shows trends in total intercapital freight, by mode, between 1972 and 2001, aggregated across all intercapital corridors and short-, medium- and long-distance corridors. Short-distance intercapital corridors include those intercapital OD pairs less than 1200 and kilometres apart: Sydney–Melbourne, Sydney–Brisbane and Melbourne–Adelaide. Medium-distance corridors are those intercapital OD pairs between 1200 and 1800 kilometres apart: in this case Sydney–Adelaide and Melbourne–Brisbane, and long-distance corridors comprise OD pairs more than 1800 kilometres apart: Eastern state capitals–Perth. The Sydney–Canberra corridor was excluded from the analysis as it is effectively only road.

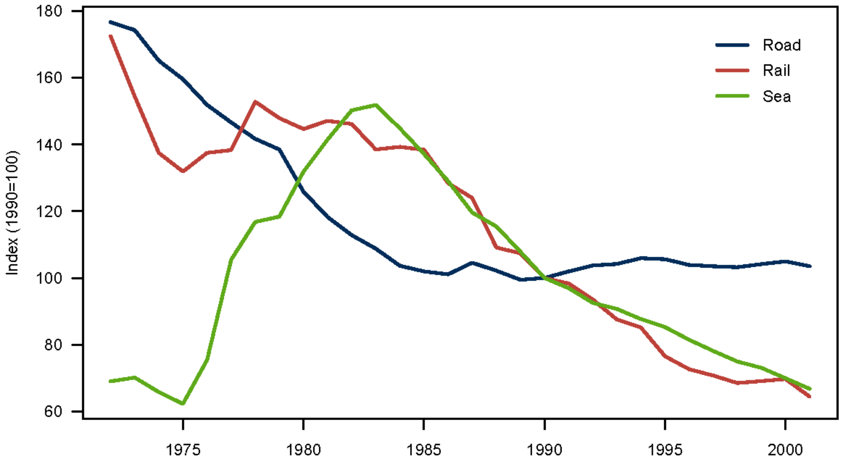
Clearly apparent in Figure 1 is the strong growth in road freight across all corridors between 1971 and 1995. Between 1995 and 2001, road freight continued to grow strongly on short-distance routes, remained more or less constant between Melbourne and Brisbane (the medium-distance corridor) and declined on long-distance corridors. Rail and sea freight grew very little on short-distance routes between 1971 and 2001—sea carries only a small amount of non-bulk freight between short-distance capital city pairs. Rail freight traffic grew quite strongly on the long-distance corridor over the entire period, and especially since 1995—coincident with the commencement of operations by NRC. On the medium-distance corridor, rail freight traffic grew between the late 1980s and 2001. Also apparent is the drop in domestic sea freight on medium- and long-distance corridors in the late 1970s, and the growth in sea freight between the mid-1990s and 2001.

Figure 1: Intercapital non-bulk freight, 1972 to 2001



Source: BTRE (2006).

Figure 2: Intercapital non-bulk real freight rate indices, 1972 to 2001



Source: BTRE (2006).

Figure 2 shows the trend in real intercapital freight rates, by mode, between 1972 and 2001. Road freight rates declined significantly, in real terms, up until 1990, and have since remained more or less at 1990 real rates. Rail freight rates have declined significantly since the mid-1980s, coincident with major reform of state rail authorities. Real domestic sea freight rates increased significantly between 1975 and 1985, but have since declined.

4 Empirical results

4.1 Estimation method

All empirical results were estimated used data for the period 1973 to 2001. All estimation was undertaken using R (Ihaka & Gentleman 1996). For all but the dynamic translog specification estimates were derived using both iterative seemingly unrelated regression (ISUR) estimation and full information maximum likelihood (FIML).[3] The dynamic translog function was only estimated using FIML. Both the model parameters and covariance terms were estimated simultaneously using FIML estimation. All estimates reported in this paper are based on the FIML estimation results.

Separate estimates were derived for aggregate (all corridors) intercapital non-bulk freight and short-, medium- and long-distance intercapital corridors. Only the aggregate intercapital non-bulk freight demand parameter estimates are listed in this section.

4.2 Static versus dynamic specifications

For both the translog and linear logit models, the dynamic specification was statistically superior to the static specification, indicating differing short-and long-term responses to changes in freight rates and activity. The hypothesis of no statistical difference between the dynamic and static linear logit models (i.e. $\lambda = 0$) is strongly rejected at the 5 per cent level of significance.[4] For the translog model, a likelihood ratio test of the hypothesis of no significant difference between the PA and static models (i.e. $\lambda = 1$, $B = 0$) implies that the PA specification is statistically superior to the static translog specification at the 1 per cent level of significance.[5] The residuals of the static linear logit expenditure share equations exhibit

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[3] The static ISUR parameter estimates were used as initial values for dynamic FIML estimation.

[4] $t_* = 4.77$ and $t_{0.975}$ (42) = 2.01.

[5] $LR_* = 20.19$ and $\chi^2_{0.952}$ (1) = 3.84.

first and second order autocorrelation, but no autocorrelation is observed in the dynamic specification residuals. The linear logit cost function specification exhibits autocorrelation in both the static and dynamic formulations. In the case of the translog specification, the residuals of the cost function are autocorrelated in the static specification but not in the dynamic specification.

Table 3 shows the likelihood ratio test results of the various dynamic specifications under the generalised ECM translog cost function. The results suggest that none of the less restrictive dynamic specifications are statistically superior to the simple PA specification.

Table 3: Nested LR test results: Dynamic translog cost model

Restriction	*LR value*	*DF*	*P-value (* $\chi^2(df)$*)*
λ, $B = B'$	0	3	0.99
λ, $B = b_{ii}\,I$	4.96	2	0.175
λ, $B = b\,I$	3.49	3	0.175
λ, $B = 0$	2.36	1	0.124
$\lambda = 1$, $B = 0$	20.99	1	0.0

4.3 Parameter estimates

Table 4 presents the translog model parameter estimates for aggregate intercapital non-bulk freight demand for both the static and dynamic FIML specifications. In both the dynamic and static translog specifications, all price term parameters, except γ_{23} are statistically significant. The output and time trend parameters from the road expenditure share equation are statistically significant, but the corresponding terms are not significant for the rail expenditure share equation. In the dynamic specification, the partial adjustment parameter estimate equals 0.738, is statistically significant and implies that approximately 25 per cent of the total (long-run) adjustment occurs in the first year.[6] The dynamic specification residuals exhibit no autocorrelation and are approximately normally distributed. In the static specification, the rail equation residuals exhibit first order autocorrelation and the cost equation residuals exhibit both first and second order autocorrelation.

Table 5 presents the aggregate logit model parameter estimates for aggregate inter-capital non-bulk freight demand for the dynamic and static FIML specifications, under both global and local symmetry conditions. In the dynamic, globally symmetric specification all price parameters are statistically significant. The activity variables in the road and rail expenditure share equations are both statistically significant. Neither of the non-neutral technical change parameters are statistically significant in the dynamic globally symmetric specification, implying that these terms could be dropped from the model. The partial adjustment parameter is statistically significant, and equal to 0.492, implying that 50 per cent of the total (long-run) adjustment occurs in the first year. The residuals of the road and rail expenditure share equations are not autocorrelated, but the cost equation residuals exhibit first and second order autocorrelation. The residuals all pass the Jarque-Bera normality test at the 5 per cent level of significance.

In the static, globally symmetric specification, all price terms but β_{33} are statistically significant, and the activity and non-neutral technical changes parameters are also significant. However, first and second order autocorrelation is present in the residuals of the expenditure share and total cost equations.

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[6] Following Oum (1979b), assuming a geometric adjustment process, the partial adjustment parameter implies a mean lag of $(1 - \lambda) / \lambda = 0.35$ years, with a variance of $(1 - \lambda) / \lambda^2 = 0.47$.

The empirical results for the dynamic and static locally symmetric cases are similar to their globally symmetric counterparts—the partial adjustment parameter is statistically significant, and the residuals are uncorrelated in the dynamic specification, but serially correlated in the static model.

Table 4: Translog cost function model results – aggregate inter-capital non-bulk freight

Parameter	*Dynamic specification*	*Static specification*
γ_0	1677.96 (1200)^	689.58 (1150)
γ_1	15.58 (2.77)***	15.10 (2.74)***
γ_2	–2.74 (2.77)	–0.141 (2.25)
γ_y	–276.13 (193)^	–115.78 (184)
γ_t	13.03 (6.15)*	7.22 (5.81)
γ_{11}	0.174 (0.021)***	0.172 (0.017)***
γ_{12}	–0.268 (0.035)***	–0.258 (0.027)***
γ_{13}	0.095 (0.025)***	0.086 (0.021)***
γ_{22}	0.251 (0.072)***	0.253 (0.055)***
γ_{23}	0.017 (0.042)	0.005 (0.032)
γ_{33}	–0.112 (0.035)***	–0.091 (0.028)***
γ_{1y}	–1.216 (0.222)***	–1.178 (0.219)^
γ_{2y}	0.248 (0.222)	0.040 (0.180)
γ_{1t}	0.042 (0.007)***	0.042 (0.007)
γ_{2t}	–0.009 (0.007)	–0.003 (0.006)
γ_{yy}	22.82 (15.60)^	9.82 (14.80)
γ_{yt}	–1.064 (0.494)*	–0.594 (0.467)***
γ_{tt}	0.046 (0.016)**	0.029 (0.015)
λ	0.738 (0.051)***	..
$\bar{R}_1^2, \bar{R}_2^2, \bar{R}_c^2$	0.9381, 0.9370, 0.9298	0.9173, 0.9220, 0.9765
$\hat{\sigma}_1, \hat{\sigma}_2, \hat{\sigma}_c$	0.0209, 0.0173, 0.0431	0.0242, 0.0193, 0.05
ln L	–221.99	–211.49
$AR(1)_1, AR(2)_1$	0.0299 (0.863), 0.326 (0.849)	0.896 (0.344), 0.984 (0.611)
$AR(1)_2, AR(2)_2$	1.02 (0.313), 1.56 (0.458)	4.16 (0.042), 4.17 (0.124)
$AR(1)_c, AR(2)_c$	0.0345 (0.853), 0.192 (0.909)	20.9 (< 0.001), 33.5 (< 0.001)
JB_1	0.44 (0.803)	1.39 (0.5)
JB_2	0.0094 (0.995)	0.594 (0.743)
JB_3	0.107 (0.948)	2.06 (0.357)

Note: Modal subscripts are: 1 – Road, 2 – Rail, 3 – Sea.

.. Not applicable.

a. FIML used to jointly estimate expenditure share equation and cost function parameters.

b. Standard errors in parentheses (computed from the analytic first derivatives of the likelihood function). Significance levels: 0–0.001: '***', 0.001–0.01: '**', 0.01–0.05: '*', 0.05–0.1: '^'.

c. AR(n) denotes Box-Pierce Portmanteau test for n-th order serial correlation in the residuals. The test statistic is distributed $\chi^2(n)$ under the null of serial independence. P-values in parentheses.

d. JB denotes the Bera and Jarque (1980) normality test, distributed $\chi^2(p)$ under the null hypothesis of symmetry and mesokurtosis. P-values in parentheses.

Table 5: Logit share and cost function model results: Australian inter-capital non-bulk freight

Parameter	*Global symmetry*		*Local symmetry*	
	Dynamic specification	*Static specification*	*Dynamic specification*	*Static specification*
β_0	9.304 (0.048)***	9.329 (0.047)***	9.305 (0.044)***	9.322 (0.040)***
β_t	0.008 (0.007)	0.003 (0.007)	0.008 (0.006)	0.006 (0.006)
β_{tt}	0.001 (0.0002)***	0.001 (0.0002)***	0.001 (0.0002)***	0.001 (0.0002)***
β_1	54.436 (77.3)	211.378 (67.4)***	–40.676 (62.3)	73.542 (81.9)
β_2	32.917 (78.1)	219.49 (76.5)**	–62.052 (62.2)	50.222 (84.8)
β_{1y}	–4.318 (0.111)***	–16.841 (5.41)***	3.255 (5.00)	–5.908 (6.56)
β_{2y}	–2.606 (0.111)***	–17.495 (6.14)**	4.963 (4.99)	–4.051 (6.79)
β_1	0.106 (6.19)	0.521 (0.170)***	–0.162 (0.161)	0.156 (0.211)
β_2	0.031 (6.26)	0.520 (0.192)**	–0.218 (0.16)^	0.08 (0.218)
β_{11}	0.415 (0.028)***	0.229 (0.015)***	0.448 (0.038)***	0.329 (0.034)***
β_{12}	–0.341 (0.043)***	–0.333 (0.032)***	–0.66 (0.065)***	–0.651 (0.060)***
β_{13}	–1.555 (0.129)***	–0.29 (0.126)**	–0.54 (0.259)*	0.255 (0.248)
β_{22}	0.161 (0.084)*	0.459 (0.077)***	0.559 (0.13)***	0.417 (0.124)***
β_{23}	1.744 (0.114)***	0.524 (0.118)***	2.41 (0.264)***	2.904 (0.386)***
β_{33}	4.004 (0.489)***	–0.034 (0.437)	–5.665 (2.44)**	–13.128 (2.96)***
λ	0.492 (0.203)	..	0.57 (0.0917)***	..
$\bar{R}_1^2, \bar{R}_2^2, \bar{R}_c^2$	0.723, 0.723, 0.909	0.498, 0.379, 0.912	0.718, 0.735, 0.924	0.496, 0.491, 0.937
$\hat{\sigma}_1, \hat{\sigma}_2, \hat{\sigma}_c$	0.551, 0.568, 0.070	0.437, 0.573, 0.069	0.235, 0.234, 0.065	0.439, 0.470, 0.058
ln L	17.087, 37.410	16.976, 37.890	25.605, 39.928	15.835, 42.784
$AR(1)_1, AR(2)_1$	0.035 (0.852), 1.27 (0.53)	13.4 (< 0.001), 20.8 (< 0.001)	0.344 (0.557), 0.353 (0.838)	10.9 (< 0.001), 14.9 (< 0.001)
$AR(1)_2, AR(2)_2$	0.231 (0.631), 2.62 (0.27)	14.2 (< 0.001), 21.7 (< 0.001)	0.576 (0.448), 0.693 (0.707)	12.1 (< 0.001), 16.6 (< 0.001)
$AR(1)_c, AR(2)_c$	6.1 (0.014), 8.57 (0.014)	11.1 (< 0.001), 14.7 (< 0.001)	5.23 (0.022), 6.51 (0.039)	5.13 (0.024), 5.75 (0.056)
JB_1	3.07 (0.215)	1.05 (0.591)	4.58 (0.101)	17.9 (< 0.001)
JB_2	4.43 (0.109)	1.05 (0.592)	3.99 (0.136)	18.2 (< 0.001)
JB_3	0.356 (0.837)	0.356 (0.837)	0.356 (0.837)	0.356 (0.837)

Note: Modal subscripts are: 1 – Road, 2 – Rail, 3 – Sea.
.. Not applicable.
a. FIML was used to estimate the share equation parameters and constrained OLS for the total cost function.
b. Standard errors in parentheses (computed from the analytic first derivatives of the likelihood function). Significance levels: 0–0.001: '***', 0.001–0.01: '**', 0.01–0.05: '*', 0.05–0.1: '^'.
c. AR(n) denotes Box-Pierce Portmanteau test for n-th order serial correlation in the residuals. The test statistic is distributed $\chi^2(n)$ under the null of serial independence. P-values in parentheses.
d. JB denotes the Bera (1980) normality test, distributed $\chi^2(p)$ under the null hypothesis of symmetry and mesokurtosis. P-values in parentheses.

4.4 Implied demand elasticities

4.4.1 Aggregate intercapital non-bulk freight demand

Tables 6 and 7 show the estimated short-run and long-run substitution, own-price, cross-price and activity elasticities evaluated, at the estimated mean expenditure shares, for the dynamic translog and dynamic linear logit models of aggregate intercapital non-bulk freight, respectively.

Concavity of the cost function may be tested by computing the eigenvalues of the matrix of substitution elasticities—if all eigenvalues are negative the cost function is concave. For the dynamic translog cost function, concavity is violated across much of the sample. For the linear logit model, Urga and Walters (2003) state that the inclusion of the (squared) time trend term in the static logit model prevents violation of concavity for all observations. Averaged across the sample, the linear logit model preserves concavity, however, concavity does not hold across periods of the sample.[7] That concavity does not hold across the sample period, under both the translog and linear logit specifications, may indicate that other inputs, particularly storage and warehousing costs, or other factors not included in the specification, e.g. service quality, may be influencing mode choice. The findings could also indicate measurement issues associated with the freight task and/or freight rate data.

Table 6: Translog elasticities – aggregate Australian intercapital non-bulk freight

	Dynamic specification		*Static specification*
Elasticity	*Short-run*	*Long-run*	
	Substitution elasticities		
σ_{11}	–0.344 (0.055)	–0.208 (0.063)	–0.562 (0.151)
σ_{12}	–0.038 (0.152)	–0.407 (0.184)	–0.544 (0.392)
σ_{13}	2.314 (0.357)	2.782 (0.479)	6.041 (0.942)
σ_{22}	–0.328 (0.516)	0.281 (0.666)	2.056 (1.31)
σ_{23}	1.421 (1.020)	1.57 (1.390)	–4.251 (2.760)
σ_{33}	–19.75 (2.93)	–23.25 (4.12)	–25.42 (6.41)
	Own– and cross–price elasticities		
η_{11}	–0.199 (0.032)	–0.121 (0.037)	–0.33 (0.089)
η_{12}	–0.013 (0.050)	–0.134 (0.061)	–0.179 (0.129)
η_{13}	0.212 (0.033)	0.255 (0.044)	0.509 (0.079)
η_{21}	–0.022 (0.088)	–0.236 (0.107)	–0.319 (0.230)
η_{22}	–0.108 (0.170)	0.092 (0.219)	0.677 (0.433)
η_{23}	0.130 (0.094)	0.144 (0.127)	–0.358 (0.233)
η_{31}	1.341 (0.207)	1.612 (0.278)	3.542 (0.552)
η_{32}	0.467 (0.336)	0.516 (0.458)	–1.40 (0.910)
η_{33}	–1.808 (0.268)	–2.129 (0.377)	–2.142 (0.540)

Note: Modal subscripts are: 1 – Road, 2 – Rail, 3 – Sea. Standard errors in parentheses.

The Le Châtelier principle—that is, that long-run impacts exceed short-run impacts—is violated by the own-price substitution elasticity for both road freight and rail freight in the dynamic translog model. The linear logit model preserves the Le Châtelier principle.

Both specifications imply that intercapital road freight demand is relatively price inelastic, with a long-run own-price elasticity of demand of –0.12 and –0.46 in the translog and logit models, respectively. In the translog specification, the aggregate rail freight own-and cross-price elasticity estimates are not significantly different from zero. However, the dynamic logit specification implies that aggregate intercapital non-bulk rail freight demand is relatively elastic (–1.66) in the long-run. Both specifications imply that non-bulk coastal shipping is relatively responsive—with the own-price elasticity equal to –2.1 in the translog specification and –1.55 in the linear logit specification—to changes in shipping freight rates in the long run. The cross-price terms in the aggregate logit model imply that road and rail, and rail and

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[7] For the dynamic translog model the eigenvalues of the long-run substitution elasticity matrix, evaluated at the sample means, are $EV_1 = 0.05$, $EV_2 = 0$ and $EV_3 = –23.4$. The eigenvalues of the short-run substitution elasticity matrix, evaluated at the sample means, are $EV_1 = 0$, $EV_2 = –0.30$ and $EV_3 = –20.1$. For the dynamic linear logit model, the eigenvalues, averaged across the sample are $EV_1 = –0.2$, $EV_2 = –3.8$ and $EV_3 = –46.7$.

sea freight are gross substitutes, but that road and sea freight are complements. Aggregate road freight demand is relatively unresponsive to cross-modal freight rates. Rail freight demand is relatively responsive to changes in road freight rates, but much less responsive to changes in coastal shipping freight rates. And coastal shipping demand is relatively responsive to changes in both road and rail freight rates. In contrast, the dynamic translog specification implies that road and rail are complements (i.e. negative substitution elasticity) in the long-run. Similar to the logit model results, the cross-price terms are relatively inelastic; only coastal shipping freight demand exhibits significant responsiveness to changes in road freight rates.

Table 7: Logit elasticities – aggregate Australian intercapital non-bulk freight

	Dynamic specification		*Static specification*
Elasticity	*Short-run*	*Long-run*	
		Substitution elasticities	
σ_{11}	–0.335 (0.028)	–0.899 (0.393)	–0.521 (0.015)
σ_{12}	0.659 (0.043)	1.767 (0.588)	0.667 (0.032)
σ_{13}	–0.555 (0.129)	–1.488 (0.857)	0.71 (0.126)
σ_{22}	–2.05 (0.084)	–5.51 (2.05)	–1.76 (0.077)
σ_{23}	2.744 (0.114)	7.357 (2.76)	1.524 (0.118)
σ_{33}	–23.33 (0.489)	–62.55 (34.4)	–27.37 (0.437)
		Own– and cross–price elasticities	
η_{11}	–0.170 (0.016)	–0.457 (0.188)	–0.279 (0.009)
η_{12}	0.217 (0.015)	0.582 (0.199)	0.220 (0.0108)
η_{13}	–0.047 (0.015)	–0.125 (0.10)	0.060 (0.015)
η_{21}	0.386 (0.0254)	1.036 (0.349)	0.391 (0.0189)
η_{22}	–0.618 (0.028)	–1.656 (0.578)	–0.519 (0.026)
η_{23}	0.231 (0.0133)	0.620 (0.322)	0.128 (0.014)
η_{31}	–0.326 (0.076)	–0.873 (0.508)	0.417 (0.0747)
η_{32}	0.904 (0.0384)	2.423 (0.931)	0.502 (0.040)
η_{33}	–0.578 (0.057)	–1.551 (0.962)	–0.919 (0.051)

Note: Modal subscripts are: 1 – Road, 2 – Rail, 3 – Sea. Standard errors in parentheses.

4.4.2 Temporal intercapital non-bulk freight demand

The dynamic translog and linear logit specifications imply non-constant elasticity values across the observation period. How the elasticity estimates vary across the sample can be instructive. Tables 8 and 9 show the short-run and long-run own-and cross-price elasticities at five-year intervals across the sample period, for the translog and linear logit specifications, respectively.

In both the translog and logit specifications, the own-price road freight elasticity declines in absolute terms over the sample period. Conversely, the price responsiveness of coastal shipping demand appears to have increased over that time. The most notable differences between the translog and linear logit model elasticity estimates is for rail—the own-price elasticity estimates are of the expected sign and statistically significant across the sample period in the logit model but not statistically significant in the translog specification.

The apparent decline in the responsiveness of road freight demand to prices may reflect the growing dominance of road carriage of total intercapital freight—due to the strong volume growth in the shorter distance corridors: Sydney–Melbourne and Sydney–Brisbane—and the productivity-induced cost improvements of road freight. Conversely, the increased responsiveness of coastal shipping demand may be partly due to the contraction of its market to more price sensitive freight traffic.

Table 8: Dynamic translog elasticities – Australian intercapital non-bulk freight

Elasticity	*1975*	*1980*	*1985*	*1990*	*1995*	*2000*
Short-run						
η_{11}	–0.264 (0.041)	–0.243 (0.037)	–0.22 (0.034)	–0.175 (0.030)	–0.128 (0.027)	–0.146 (0.028)
η_{12}	–0.145 (0.064)	–0.027 (0.058)	0.062 (0.053)	0.056 (0.047)	–0.034 (0.042)	–0.074 (0.044)
η_{13}	0.408 (0.042)	0.27 (0.038)	0.158 (0.035)	0.119 (0.031)	0.162 (0.028)	0.220 (0.029)
η_{21}	–0.226 (0.100)	–0.037 (0.079)	0.079 (0.068)	0.092 (0.077)	–0.091 (0.114)	–0.215 (0.128)
η_{22}	–0.072 (0.192)	–0.128 (0.152)	–0.139 (0.131)	–0.131 (0.148)	–0.019 (0.219)	0.045 (0.246)
η_{23}	0.298 (0.106)	0.166 (0.084)	0.060 (0.073)	0.040 (0.082)	0.110 (0.121)	0.170 (0.136)
η_{31}	0.728 (0.074)	1.034 (0.145)	2.863 (0.630)	12.168 (3.14)	1.849 (0.316)	1.270 (0.166)
η_{32}	0.341 (0.121)	0.463 (0.235)	0.846 (1.02)	2.474 (5.10)	0.466 (0.514)	0.337 (0.270)
η_{33}	–1.068 (0.096)	–1.497 (0.187)	–3.708 (0.817)	–14.642 (4.07)	–2.315 (0.410)	–1.608 (0.215)
Long-run						
η_{11}	–0.163 (0.047)	–0.152 (0.042)	–0.136 (0.039)	–0.101 (0.034)	–0.061 (0.031)	–0.077 (0.032)
η_{12}	–0.300 (0.077)	–0.168 (0.070)	–0.067 (0.064)	–0.058 (0.057)	–0.137 (0.051)	–0.180 (0.053)
η_{13}	0.463 (0.056)	0.319 (0.051)	0.203 (0.047)	0.159 (0.041)	0.198 (0.037)	0.257 (0.039)
η_{21}	–0.468 (0.121)	–0.229 (0.096)	–0.086 (0.083)	–0.095 (0.093)	–0.367 (0.138)	–0.526 (0.155)
η_{22}	0.154 (0.248)	0.051 (0.196)	0.016 (0.170)	0.044 (0.192)	0.239 (0.283)	0.336 (0.319)
η_{23}	0.314 (0.144)	0.178 (0.114)	0.071 (0.0987)	0.052 (0.111)	0.127 (0.164)	0.19 (0.185)
η_{31}	0.825 (0.100)	1.223 (0.194)	3.687 (0.845)	16.277 (4.21)	2.263 (0.424)	1.488 (0.223)
η_{32}	0.358 (0.164)	0.498 (0.320)	0.995 (1.39)	3.22 (6.94)	0.542 (0.70)	0.377 (0.367)
η_{33}	–1.183 (0.136)	–1.721 (0.264)	–4.683 (1.15)	–19.497 (5.72)	–2.804 (0.577)	–1.864 (0.303)

Note: Modal subscripts are: 1 – Road, 2 – Rail, 3 – Sea. Standard errors in parentheses.

Table 9: Dynamic linear logit elasticities – Australian intercapital non-bulk freight

Elasticity	*1975*	*1980*	*1985*	*1990*	*1995*	*2000*
Short-run						
η_{11}	–0.357 (0.013)	–0.290 (0.014)	–0.229 (0.015)	–0.126 (0.017)	–0.031 (0.019)	–0.067 (0.018)
η_{12}	0.192 (0.013)	0.242 (0.016)	0.280 (0.018)	0.248 (0.016)	0.168 (0.011)	0.149 (0.010)
η_{13}	–0.141 (0.033)	–0.073 (0.017)	–0.017 (0.004)	–0.003 (.001)	–0.033 (0.008)	–0.063 (0.015)
η_{21}	0.299 (0.019)	0.331 (0.022)	0.359 (0.023)	0.407 (0.026)	0.451 (0.029)	0.435 (0.028)
η_{22}	–0.662 (0.024)	–0.574 (0.031)	–0.507 (0.036)	–0.563 (0.032)	–0.704 (0.021)	–0.737 (0.019)
η_{23}	0.699 (0.029)	0.36 (0.015)	0.083 (0.003)	0.017 (0.001)	0.164 (0.007)	0.313 (0.013)
η_{31}	–0.252 (0.059)	–0.279 (0.065)	–0.303 (0.070)	–0.343 (0.080)	–0.38 (0.088)	–0.366 (0.085)
η_{32}	0.798 (0.033)	1.007 (0.042)	1.166 (0.048)	1.032 (0.043)	0.70 (0.029)	0.621 (0.026)
η_{33}	0.275 (0.125)	–0.344 (0.064)	–0.849 (0.015)	–0.97 (0.003)	–0.7 (0.029)	–0.429 (0.056)
Long-run						
η_{11}	–0.704 (0.132)	–0.571 (0.105)	–0.451 (0.081)	–0.248 (0.044)	–0.061 (0.033)	–0.131 (0.032)
η_{12}	0.378 (0.072)	0.476 (0.090)	0.552 (0.105)	0.488 (0.093)	0.331 (0.063)	0.294 (0.056)
η_{13}	–0.279 (0.098)	–0.143 (0.050)	–0.033 (0.012)	–0.007 (0.002)	–0.066 (0.023)	–0.125 (0.044)
η_{21}	0.590 (0.112)	0.652 (0.124)	0.708 (0.134)	0.802 (0.152)	0.889 (0.169)	0.856 (0.162)
η_{22}	–1.305 (0.256)	–1.131 (0.221)	–0.999 (0.196)	–1.11 (0.217)	–1.387 (0.274)	–1.453 (0.287)
η_{23}	1.378 (0.295)	0.709 (0.152)	0.163 (0.035)	0.033 (0.007)	0.324 (0.069)	0.617 (0.132)
η_{31}	–0.497 (0.174)	–0.549 (0.192)	–0.596 (0.209)	–0.676 (0.236)	–0.749 (0.262)	–0.721 (0.252)
η_{32}	1.573 (0.337)	1.984 (0.424)	2.297 (0.491)	2.034 (0.435)	1.379 (0.295)	1.223 (0.262)
η_{33}	0.542 (0.643)	–0.678 (0.164)	–1.674 (0.284)	–1.911 (0.377)	–1.379 (0.174)	–0.845 (0.112)

Note: Modal subscripts are: 1 – Road, 2 – Rail, 3 – Sea. Standard errors in parentheses.

Table 10: Australian intercapital non-bulk freight demand elasticities, by route length

	Translog model			*Logit model*		
	Dynamic specification		*Static specification*	*Dynamic specification*		*Static specification*
Elasticity	*Short-run*	*Long-run*		*Short-run*	*Long-run*	
			Short-distance routes			
η_{11}	–0.036 (0.030)	0.038 (0.025)	0.029 (0.022)	–0.282 (0.014)	–0.362 (0.058)	–0.287 (0.013)
η_{12}	–0.047 (0.040)	–0.136 (0.037)	–0.122 (0.034)	0.274 (0.003)	0.351 (0.054)	0.275 (0.003)
η_{13}	0.083 (0.019)	0.099 (0.024)	0.093 (0.021)	0.009 (0.017)	0.011 (0.022)	0.012 (0.017)
η_{21}	–0.114 (0.099)	–0.334 (0.091)	–0.305 (0.085)	0.683 (0.007)	0.875 (0.129)	0.685 (0.007)
η_{22}	0.214 (0.173)	0.467 (0.188)	0.45 (0.174)	–0.722 (0.005)	–0.926 (0.137)	–0.721 (0.005)
η_{23}	–0.099 (0.087)	–0.133 (0.108)	–0.146 (0.099)	0.039 (0.017)	0.05 (0.026)	0.036 (0.017)
η_{31}	2.433 (0.569)	2.907 (0.697)	2.963 (0.654)	0.275 (0.351)	0.352 (0.448)	0.392 (0.341)
η_{32}	–1.191 (1.04)	–1.592 (1.29)	–1.859 (1.26)	0.500 (0.144)	0.641 (0.216)	0.457 (0.140)
η_{33}	–1.243 (0.711)	–1.315 (0.909)	–1.105 (0.835)	–0.774 (0.334)	–0.993 (0.451)	–0.849 (0.325)
			Medium-distance routes			
η_{11}	–0.425 (0.050)	–0.518 (0.085)	–0.467 (0.057)	–0.294 (0.004)	–0.431 (0.037)	–0.3 (0.005)
η_{12}	0.338 (0.077)	0.418 (0.131)	0.322 (0.086)	0.227 (0.002)	0.333 (0.029)	0.230 (0.002)
η_{13}	0.087 (0.041)	0.101 (0.069)	0.144 (0.047)	0.067 (0.005)	0.098 (0.016)	0.070 (0.006)
η_{21}	1.087 (0.247)	1.342 (0.423)	1.045 (0.280)	0.737 (0.005)	1.080 (0.091)	0.744 (0.006)
η_{22}	–2.139 (0.487)	–3.064 (0.843)	–2.305 (0.549)	–0.785 (0.002)	–1.151 (0.100)	–0.789 (0.003)
η_{23}	1.052 (0.270)	1.722 (0.467)	1.26 (0.302)	0.048 (0.005)	0.071 (0.016)	0.045 (0.007)
η_{31}	0.926 (0.439)	1.072 (0.732)	1.812 (0.584)	0.836 (0.033)	1.225 (0.100)	0.885 (0.041)
η_{32}	3.477 (0.892)	5.69 (1.540)	4.888 (1.170)	0.188 (0.010)	0.275 (0.033)	0.173 (0.013)
η_{33}	–4.40 (0.55)	–6.76 (0.933)	–6.70 (0.703)	–1.024 (0.045)	–1.501 (0.137)	–1.058 (0.056)
			Long-distance routes			
η_{11}	–0.429 (0.150)	–0.158 (0.274)	0.076 (0.165)	–0.616 (0.021)	–1.078 (0.133)	–0.596 (0.022)
η_{12}	0.027 (0.280)	–0.419 (0.510)	–0.343 (0.274)	0.377 (0.055)	0.660 (0.133)	0.328 (0.058)
η_{13}	0.401 (0.176)	0.577 (0.336)	0.266 (0.195)	0.239 (0.056)	0.418 (0.104)	0.268 (0.059)
η_{21}	0.017 (0.173)	–0.26 (0.316)	–0.215 (0.172)	0.237 (0.037)	0.415 (0.089)	0.206 (0.039)
η_{22}	–0.257 (0.319)	0.003 (0.611)	–0.115 (0.332)	–0.445 (0.080)	–0.778 (0.180)	–0.395 (0.086)
η_{23}	0.240 (0.170)	0.257 (0.338)	0.331 (0.183)	0.208 (0.062)	0.363 (0.128)	0.188 (0.065)
η_{31}	0.532 (0.234)	0.765 (0.445)	0.390 (0.285)	0.350 (0.067)	0.612 (0.125)	0.392 (0.070)
η_{32}	0.515 (0.364)	0.549 (0.725)	0.771 (0.426)	0.484 (0.109)	0.846 (0.231)	0.439 (0.117)
η_{33}	–1.047 (0.265)	–1.315 (0.526)	–1.160 (0.321)	–0.834 (0.061)	–1.458 (0.213)	–0.831 (0.066)

Note: Modal subscripts are: 1 – Road, 2 – Rail, 3 – Sea. Standard errors in parentheses.

4.4.3 Sub-market intercapital non-bulk freight demand

As mentioned, separate estimates were also produced for short-, medium- and long-distance corridors. The estimated own-and cross-price elasticity estimates are listed in Table 10.

The relative size of the estimated price elasticities for different length corridors varies between the translog and logit specifications. The translog cost function implies that road freight demand is relatively more elastic on medium-distance intercapital corridors than on short-and long-distance corridors. However, the logit model estimates imply that intercapital road freight demand is more responsive on longer distance corridors. Either finding might be plausible—the translog model results could be read to reflect that there is greater scope for modal substitution to/from road on medium-distance corridors than on short-and long-distance corridors. Both the translog and linear logit specifications imply rail freight demand is relatively more price responsive on medium-distance corridors, where it has a reasonable market share and is more competitive with road on price and service quality. Sea freight demand is relatively elastic across all intercapital corridors.

The linear logit specification implies road, rail and sea are substitutes across different length corridors. In contrast, the translog specification implies that road and rail, and rail and sea freight are complements on short-distance corridors, although only long-run road–rail cross-prices elasticities are statistically significant. The linear logit specification estimates preserve concavity across all corridor lengths. The translog specification is concave for the medium-distance corridor, but concavity is not preserved on short- and long-distance corridors.

5 Concluding remarks

This paper provides estimates of Australian intercapital non-bulk freight demand for road, rail and sea, using both a dynamic translog and dynamic linear logit functional form. The estimates update previous estimates of intercapital freight demand, providing both short-and long-run own-price, cross-price and substitution elasticities for intercapital non-bulk freight transport, using the best available time series data.

5.1 Translog or linear logit specification?

The translog and linear logit specifications produce quite different own-and cross-price elasticity estimates for some modes. Which estimates are to be preferred? The translog model results violate concavity and the short-run elasticity estimates are, in many cases, larger than their long-run counterpart, violating the Le Châtelier principle. The linear logit model, however, preserves concavity and the long-run elasticities exceed short-run elasticities. Urga and Walters (2003), in an application to US energy consumption, also found significant differences between the dynamic translog and linear logit model results. In Urga and Walters's study, the translog model also violated concavity and produced short-run elasticity estimates larger than their long-run counterparts. They concluded that the dynamic translog is not as good as the dynamic linear logit model for estimating unstable cost shares or factor prices. Based on the empirical analysis presented here, the linear logit specification also provides more satisfactory results for Australian intercapital non-bulk freight demand than the translog cost specification.

5.2 Implications

The linear logit model results imply that road freight transport is relatively price inelastic in the short-run across all intercapital corridors, and relatively price inelastic in the long-run on short-and medium-distance intercapital corridors. Non-bulk rail freight is also relatively price inelastic, but slightly more responsive, on average, than road freight. Intercapital sea freight is relatively elastic on medium- and long-distance intercapital corridors. The own-price and cross-price elasticity estimates are generally below earlier studies, such as BTE (1979) and BTE (1990), particularly for intercapital road freight. The temporal elasticity estimates support this—the own-price elasticity of inter-capital road freight has declined over the sample period.

5.3 Further work

The parameter estimates would not have been possible without the estimates of interstate non-bulk freight movements and freight rate indexes, developed within BITRE. However, in the absence of regular freight data collections, most particularly for road freight, the estimates used in this paper have had to be compiled from a variety of sources, and are quite dated. More regular collection of intercapital freight movements data is required to better model potential policy impacts.

Anecdotal evidence suggests that non-price factors, such as transit time, reliability and service availability, may also be significant influences on modal choice. Although freight rates should, in principle, incorporate the effects of changes in non-price factors—for example, transport infrastructure investment, advances heavy vehicle engine and aerodynamic efficiency, and increases in heavy vehicle mass and dimension regulations—there may be important non-price factors not included in this analysis. Explicitly including non-price factors could potentially improve the reliability of the elasticity estimates.

The substitutability between different freight modes is also likely to vary across different market segments/commodities—for example, express freight requiring urgent delivery tends to be moved by road, since it provides shortest transit times, and would presumably be much less likely to switch modes in response to changed prices. Modelling market segment/commodity-specific freight demands would require considerably more detailed data than is presently readily available. A discrete choice analysis of shipment-level freight movements data, undertaken in cooperation with industry, would provide more detailed estimates and complement the aggregate time series estimates presented here.

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