Australasian Transport Research Forum 2010 Proceedings
29 September – 1 October 2010, Canberra, Australia
Publication website: http://www.patrec.org/atrf.aspx

Heavy vehicle productivity trends and road freight regulation in Australia

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Abstract

Australia's road freight task has increased six-fold over the past 35 years, yet over the same period total kilometres travelled by commercial vehicles has increased only three-fold, implying a near two-fold increase in average heavy vehicle productivity. Several factors have contributed to this increase in heavy vehicle productivity, not least of which has been relaxation of heavy vehicle mass and dimension regulations, permitting larger, more productive vehicles wider access to the road network. In particular, the availability of larger heavy vehicle configurations—such as six-axle articulated trucks, introduced in the 1970s, and B-doubles, introduced in the late 1980s—with higher mass carrying capacity has facilitated both rapid growth in the articulated truck freight task and the transfer of freight from smaller to larger articulated trucks.

With road freight projected to nearly double over the next two decades, policy makers will be faced with significant heavy vehicle traffic growth without continued productivity growth. This paper presents an empirical model of aggregate heavy vehicle freight shares and heavy vehicle productivity growth. The model provides an objective means of forecasting future heavy vehicle productivity trends, and evaluating the impact of future reforms. The paper presents projections of future heavy vehicle productivity growth using the model. The results suggest that even without significant further reform, substitution to larger heavy vehicle combinations will continue, resulting in further increases in heavy vehicle productivity but at a much lower rate than previously.

1. Introduction

Since 1971 the Australian road freight task has grown from 27.2 billion tonne kilometres to approximately 184.1 billion tonne kilometres in 2007 (ABS 2008), an average annual growth rate of 5.4% per annum. Factors contributing to the growth in the road freight task include:

- investment-related improvements in inter-urban road infrastructure, leading to shorter travel times and lower costs
- improvements in heavy vehicle technology—e.g. engine management systems and more efficient engines
- more efficient fleet management—e.g. fleet vehicle tracking, computer assisted routing
- increased demand for more just-in-time and time-sensitive freight services
- increased average vehicle size/load carrying capacity.

While most of these factors will have contributed in some way to lowering the cost of road freight transport, the change in average vehicle size/carrying capacity has arguably been

[1] The author acknowledges the assistance of Pearl Louis in collecting the historical heavy vehicle regulatory information presented in section 3 and the comments of two anonymous referees. All errors remain the responsibility of the author.

among the most significant factors contributing to improvements in road freight productivity, and growth in road freight.

Growth in the size of articulated trucks and increased uptake of larger articulated truck combinations has enabled more freight to be carried by proportionately fewer trucks. For example, articulated trucks share of the total road freight task increased from around 55% in 1971 to around 78% in 2007. Over the same period the average load carried by articulated trucks more than doubled, from 9.7 tonnes per vehicle kilometre to over 20.7 tonnes per vehicle kilometre, and the average distance travelled by articulated trucks has increased almost 90% to over 90 000 kilometres per annum. In 2007, there were 70 000 articulated trucks in use. In absence of any increase in heavy vehicle average loads and average utilisation between 1971 and 2007, nearly 150 000 vehicles would have been required to undertake the 2007 articulated truck freight task.

1.1 Projected future freight task growth and heavy vehicle numbers

BTRE (2002) projected that the total road freight task would increase from around 135.5 billion tonne kilometres in 2000 to approximately 295.4 billion tonne kilometres by 2020, an average annual growth rate of 4% per annum. The articulated truck task was projected to grow from around 106 billion tonne kilometres to over 250 billion tonne kilometres over the same period—or by 4.5% per annum. Over that period, BTRE (2002) assumed, based on simple historical trends, that the average load carried by articulated trucks would grow by 1.64% per annum, from around 17.6 tonnes in 2000 to 26.6 tonnes in 2020. The average vehicle kilometres travelled by articulated trucks was also assumed to grow strongly, from 84 000 kilometres per annum to 107 000 kilometres per annum. The implication of these assumptions is that the number of articulated trucks required to undertake the freight task would increase from 63 000 to 88 700 vehicles by 2020.

In 2004 the Truck Industry Council and Commercial Vehicle Industry Association of Queensland (2004) highlighted concerns that without further productivity enhancing reforms, these projections could not be met and the number of heavy vehicles required to handle the projected freight task would be much higher. The model results presented in this paper provide more substantive quantitative modelling of the impact of past and likely future heavy vehicle reforms and other factors on future heavy vehicle productivity.

1.2 Paper structure

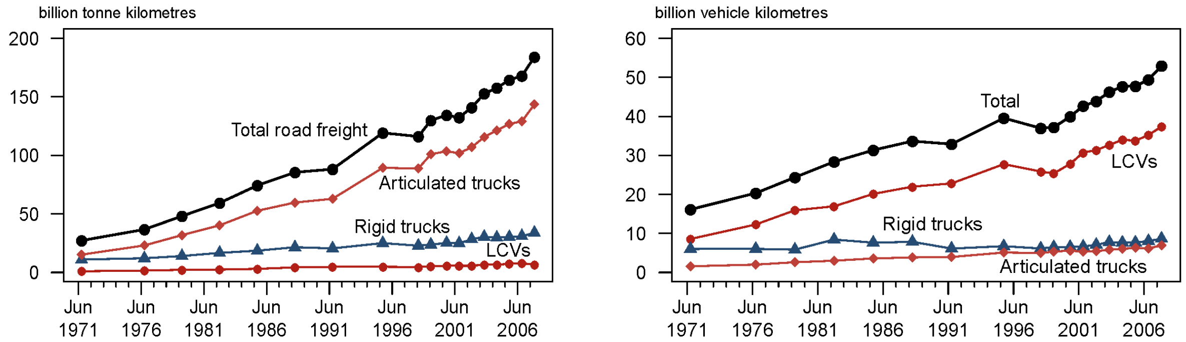
Section 2 outlines the trends in total heavy vehicle freight, heavy vehicle freight shares and heavy vehicle productivity growth over the past 35 years. Section 3 briefly outlines some of the major regulatory and technology factors that have influenced heavy vehicle productivity over the same period. Section 4 specifies and presents empirical estimates of several generalised extreme value (GEV) models of aggregate heavy vehicle freight shares and growth in heavy vehicle productivity. Section 5 presents projections of future heavy vehicle productivity growth derived from the GEV model estimates. The projections assume no significant further heavy vehicle productivity enhancing reforms, effectively estimating the continuing impact of past reforms on heavy vehicle freight and vehicle numbers. Some concluding remarks are made in Section 6.

2. Heavy vehicle productivity trends in Australia

2.1 Trends in aggregate road freight activity, 1971–2007

Since 1971 the non-bulk road freight task has grown at an average rate of 5.8% per annum (BTRE 2006). Articulated truck freight volumes have grown significantly faster, averaging 6.4% per annum since 1971, with substitution from rigid trucks to larger articulated truck combinations and stronger growth in long-distance line-haul road freight strongly influential. Over the same period, freight carried by rigid trucks has increased by around 3.2% per annum and freight carried by light commercial vehicles (LCV) by 5.3% per annum (see Figure 1a). By 2007, articulated trucks accounted for 78% of total road freight tonne kilometres, while rigid trucks comprised 18% and LCVs 4%. Over the same period, total VKT of LCVs grew by 4.2% per annum, 1.0% per annum for rigid trucks and 4.2% per annum for articulated trucks (Figure 1b).

Figure 1: Total road freight and vehicle use by commercial vehicle type, 1971–2007



(a) Total tonne kilometres (b) Total vehicle kilometres travelled

Sources: ABS (2008, and earlier issues) and BITRE estimates.

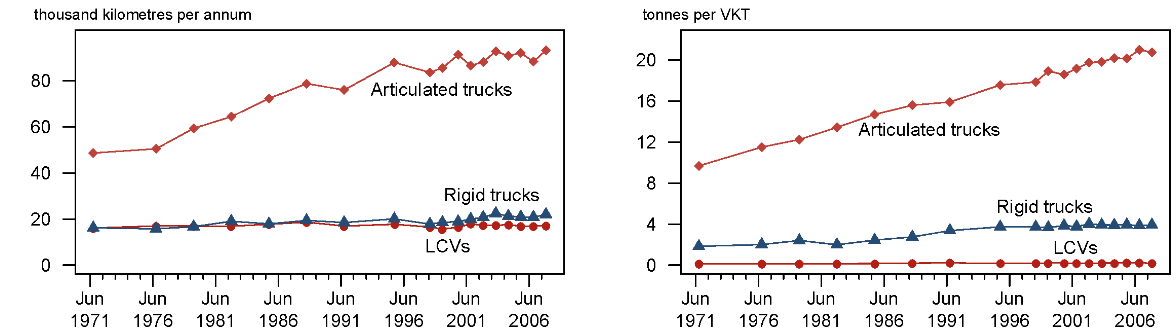
2.2 Commercial vehicle productivity trends

Physical heavy vehicle productivity may be measured as total tonne kilometres per vehicle, which comprises two components: (i) average vehicle utilisation, and (ii) average vehicle load. Figure 2 shows the growth in average vehicle kilometres travelled and average vehicle loads, by broad heavy vehicle type, between 1971 and 2007.

2.2.1 Average vehicle use trends

Figure 2(a) shows that articulated truck average vehicle kilometres travelled (VKT) almost doubled from around 50 000 kilometres in 1971 to over 90 000 kilometres in 2005, an annual average growth rate of 1.9% per annum. Over the same period, the average vehicle kilometres travelled of rigid trucks has increased from 16 200 kilometres per annum to 20 900 kilometres per annum (approximately 0.76% per annum), and the average vehicle kilometres travelled of LCVs has increased also, from 16 100 kilometres per annum to 16 900 kilometres per annum.

Figure 2: Heavy vehicle productivity trends, by commercial vehicle type, 1971–2007



(a) Average VKT (b) Average load

Sources: ABS (2008, and earlier issues) and BITRE estimates.

Across all commercial vehicle classes the increase in average utilisation has been far less pronounced since 1991. Articulated truck average vehicle kilometres travelled has increased by approximately 0.57% per annum, from 76 000 kilometres per annum in 1991. And rigid truck average vehicle kilometres travelled has increased by 0.36% per annum, from approximately 18 500 kilometres in 1991.

2.2.2 Average load trends

Average loads have also increased significantly across all vehicle classes over the past 30 years. Figure 2(b) shows trends in average heavy vehicle loads between 1971 and 2007. Over this period, the average load of articulated trucks increased by over 100%, from 9.7 tonnes (per vehicle kilometre travelled) to 20.1 tonnes—an average annual increase of 2.2% per annum. The average load carried by rigid trucks also increased by over 100%, from around 1.8 tonnes (per vehicle kilometre travelled) in 1971 to 3.9 tonnes in 2007, and the average load of LCVs increased from 0.12 tonnes (per vehicle kilometre travelled) in 1971 to 0.22 tonnes in 2007.[2]

Like the trend in average vehicle kilometres travelled, growth in average heavy vehicle loads has been less pronounced since 1991. For articulated trucks average loads have increased by around 0.7% per annum, from 15.9 tonnes in 1991. Similarly, for rigid trucks and LCVs, average loads have increased by 0.46% and 0.11% per annum, respectively.

2.3 Commercial vehicle productivity decomposition

Total commercial vehicle productivity may be decomposed into input share and individual vehicle productivity improvement terms for each vehicle class. The share term represents the contribution of growth in the size of the fleet to overall productivity growth, and the VKT and average load terms indicate the relative contribution to overall vehicle productivity of increases in average loads and average VKT, respectively. Table 1 shows the vehicle productivity decomposition for road freight vehicles in Australia, by broad freight vehicle class, between 1971 and 2007. Heavy vehicles comprise rigid and articulated trucks.

Table 1: Commercial vehicle productivity growth 1971–2006

(per cent)

		Productivity effects			
Vehicle type	*Share*	*Load*	*VKT*	*Total*	*Total*
	(%)	*(%)*	*(%)*	*(%)*	*(%)*
LCVs	2.6	2.7	0.2	2.9	5.5
Rigid trucks	–52.8	34.9	14.1	54.0	1.2
Articulated trucks	–35.3	72.1	56.5	128.6	93.3
All Heavy Vehicles	–237.5	226.5	105.6	332.0	94.5
All Commercial Vehicles	0	84.8	15.2	100	100

Sources: ABS (2008, and earlier issues) and BTRE estimates.

The share impact is relatively small and positive for LCVs, but negative for rigid and articulated trucks, which reflects the strong growth in LCV numbers over the last thirty years relative to that of rigid and articulated trucks. The vehicle share impact is dwarfed by the productivity terms.

The productivity terms—vehicle average loads and average utilisation (VKT)—are far more significant influences on overall road vehicle productivity. Increased articulated truck average loads and average VKT have had the greatest impact on overall vehicle productivity, contributing 68% and 32%, respectively, of the total road freight vehicle productivity improvement since 1971. In relative terms, approximately 56% of the improvement in articulated truck productivity, between 1971 and 2007, has come from increased average

[2] There were two changes to the Australian Bureau of Statistics (ABS) heavy vehicle classification between 1971 and 1991, with both changes resulting in some vehicles that were previously classed as rigid trucks reclassified as LCVs. The effect of both vehicle re-classifications slightly inflate LCV average load growth and decrease rigid truck average load growth.

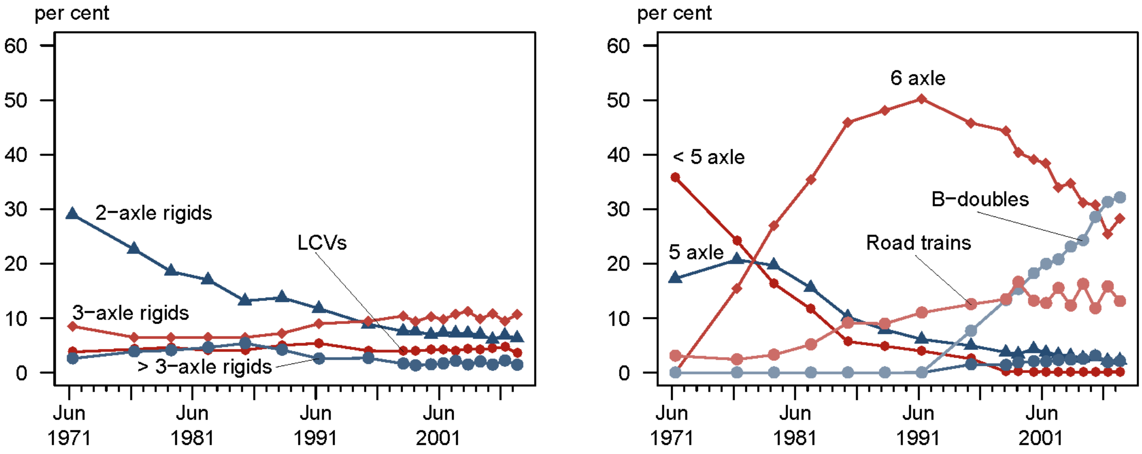
loads and 44% from increases in average vehicle utilisation. By contrast, increased rigid truck average loads and vehicle use have contributed approximately 35 and 14%, respectively, of the total improvement in road freight vehicle productivity. Growth in LCV average loads and average vehicle use, not unexpectedly, contributed little to the overall improvement in commercial road vehicle productivity. Over 93% of the overall increase in commercial vehicle productivity is attributable to growth in the productivity of articulated trucks.

2.4 Road freight growth by vehicle class and axle configuration

Subdividing total road freight further, by vehicle type and broad axle configuration, suggests the apparent source of much of the growth in commercial vehicle average loads, and particularly articulated truck average loads, is growth in the share of freight carried by larger articulated truck types. Figure 3 shows the road freight task share split across the following ten separate vehicle type/axle configuration classes:

- LCVs
- Two-axle rigid trucks
- Three-axle rigid trucks
- Four-axle rigid trucks
- Less than five-axle articulated trucks
- Five-axle articulated trucks
- Six-axle articulated trucks
- Other single-trailer articulated trucks
- B-doubles
- Road trains.

Figure 3: Total road freight by broad vehicle type and vehicle axle configuration, 1971–2007



(a) Rigid trucks (b) Articulated trucks

Sources: ABS (2008, and earlier issues) and BITRE estimates.

Between 1971 and 1998, rigid trucks' share of the total road freight task fell from around 40% to 20%. Since 1998 the share of road freight carried by rigid trucks has remained at around 20%. For rigid trucks the share of freight carried by two-axle rigid trucks, which includes two-axle rigid trucks towing trailers, has declined from near 30% of total road freight in 1971 to 6% in 2007. The share of road freight carried by three-axle rigid trucks, which includes three-axle rigid trucks towing trailers, has increased from around 6% in 1971 to around 10% in 2007. And four-axle rigid trucks have generally carried less than 5% of total road freight—in 2007 four-axle rigid trucks accounted for less than 2% of total road freight.

Freight carried by LCVs has remained between 4 and 5% of total road freight. A large proportion of this 'freight' is tradesman's supplies (or 'tools of trade'), rather than goods being transported between different parts of the supply chain.

3. Heavy vehicle regulation

Heavy vehicle regulatory reform has arguably been the major driver of improvements in heavy vehicle productivity over the last three decades. Increases in heavy vehicle mass and dimension limits, network access for higher productivity heavy vehicle classes, harmonisation of driving hours, changes in heavy vehicle highway speed limits, and the removal of State-based economic regulation of road freight have all contributed to the growth in road freight and heavy vehicle productivity over the last 35 years. Rising fuel costs are also likely to have increased the relative cost advantage of higher productivity vehicle use. This section briefly outlines the major heavy vehicle regulatory reforms that have occurred since 1971.

It can be observed from Figure 3 that up until very recently, single trailer articulated trucks, and in particular six-axle articulated trucks, have been the predominant articulated truck type used for hauling road freight. The share of road freight carried by single trailer articulated trucks increased to as much as 60% of total road freight in 1998. However, since the introduction of B-doubles in the late 1980s, the share of road freight carried by single trailer articulated trucks has declined and the share of road freight carried by B-doubles has increased from near zero in 1988 to around 32% of the total road freight in 2007, supplanting six-axle articulated trucks as the predominant vehicle type for road freight transport. Road trains have been operating in remote areas in Australia since the Second World War. Road train’s share of the road freight task has increased from around 5% in 1971 to somewhere between 15 to 20% since 2000.

3.1 Vehicle mass and dimension limits

Regulations limiting the maximum mass and dimensions of heavy vehicles have traditionally been set to limit the road wear impacts and minimise adverse safety outcomes of heavy vehicle road use. Heavy vehicle mass and dimension limits are governed by State and Territory legislation. Up until 1995 limits were set separately in each jurisdiction, and there was some inconsistency between jurisdictions resulting in a higher compliance burden for interstate operators. Since then, national uniform heavy vehicle mass and dimension limits have applied, governed by State/Territory legislation based on national model legislation.

3.1.1 Mass limits regulation

Progressive relaxation of regulations governing general vehicle mass and dimension limits over the past thirty years has facilitated the use of larger and heavier vehicles across the road network. This has generally involved both progressive additions to road network access for larger heavy vehicle configurations and increasing dimension limits for individual vehicle classes. We describe the major changes to heavy vehicle mass limits for general access that have occurred since 1971. For network protection and asset preservation, specific mass limit restrictions apply on many roads and bridges that were not designed to cater for today’s larger heavy vehicle classes—for example, B-doubles must be split over certain bridges and may not travel through some towns at night.

Since 1971, there have been six major revisions to heavy vehicle mass limits, and several less significant changes. The major revisions have been:

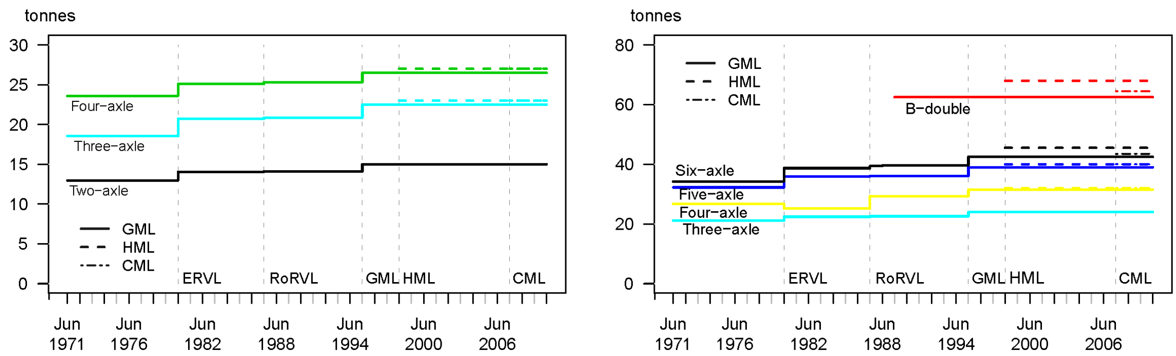
- 1979–1980: Implementation of the *Economics of Road Vehicle Limits* (ERVL) study (NAASRA 1976) mass and dimension limit recommendations, which recommended raising mass limits for six-axle articulated trucks to 38.4 tonnes GVM.[3]

[3] The ERVL recommendations were implemented in all jurisdictions but South Australia and Australian Capital Territory.

- 1986: National agreement to implement the *Review of Road Vehicle Limits* (RoRVL) study (NAASRA 1985) mass and dimension limit recommendations.[4]
- 1993–1995: Uniform national heavy vehicle mass and dimension limits (general mass limits) legislation and regulations introduced[5] and adopted by all jurisdictions.
- 1998: Higher Mass Limits (HML) reform package approved by Australian Transport Council (ATC).
- 2006: Concessional Mass Limits (CML) reforms introduced.
- 2007: Performance Based Standards (PBS) heavy vehicle regulatory reforms.

As a result of changes in mass limit regulations the maximum allowable mass for rigid and articulated trucks operating under general mass limits (GML) has increased by between 12 and 24% since 1971—the maximum allowable mass for six-axle articulated trucks operating under GML has increased 24%. For vehicles operating under HML, regulatory changes have increased the maximum allowable mass for rigid and articulated trucks by between 14 and 33% since 1971. Figure 4 illustrates the increase in regulated heavy vehicle mass limits for rigid and articulated trucks between 1971 and 2010. (Note that the mass limit estimates prior to the adoption of uniform mass limits in the mid-1990s are an approximate freight-weighted average of separate State/Territory regulated mass limits.)

Figure 4: Heavy vehicle mass limits, 1971–2010



(a) Rigid trucks (b) Articulated trucks

Sources: NAASRA (1976), NAASRA (1985), ISC (1990), NTC (2009b), NTC (2008) and BITRE estimates.

3.1.2 Dimension limits regulation

Vehicle length, width and height influence the volumetric freight capacity of heavy vehicles—larger dimension vehicles provide more volumetric freight carrying capacity and reduce the average cost of road freight transport. For lower density freight cargoes volumetric capacity is more significant than mass limits. However, the length of heavy vehicles affects the distance and time required for faster vehicles to overtake heavy vehicles, which adversely affects road safety outcomes, especially on undivided carriageways.

Regulated heavy vehicle dimension limits have also increased since 1971, usually in coordination with mass limit revisions. There have been five significant changes in heavy vehicle length limits since 1971:

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4 RoRVL gross mass limit recommendations:
- 38.0 tonnes – New South Wales and Victoria
- 41.0 tonnes – Queensland and Tasmania
- 42.5 tonnes – South Australia, Western Australia and Northern Territory.

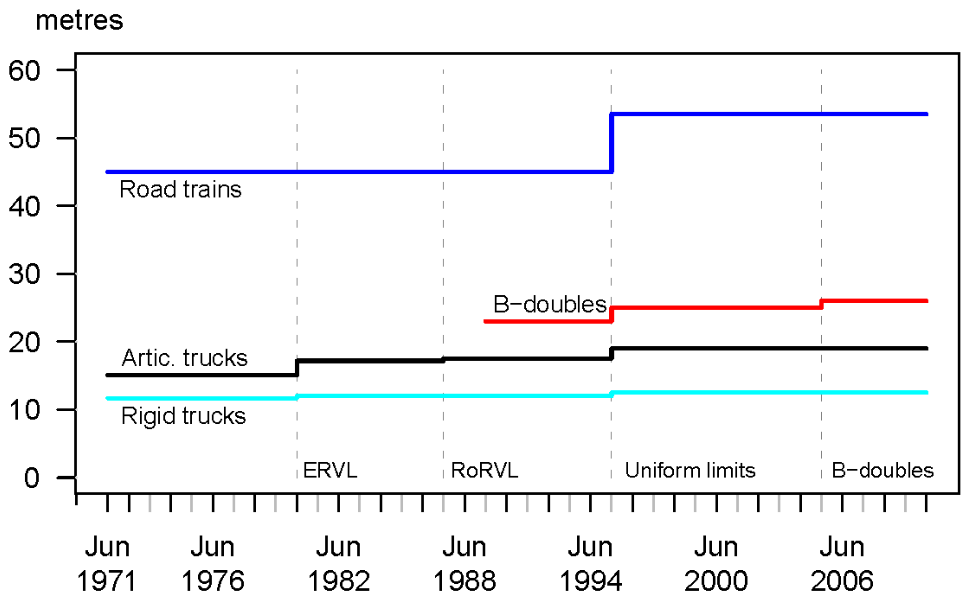
New South Wales and Victoria later (September 1987) agreed to implement RoRVL Option A (i.e. gross mass limit 41.0 tonnes for six-axle articulated trucks) (NAASRA 1985, p. 1).

5 *Road Transport Reform (Vehicles and Traffic) Act 1993* and *Road Transport Reform (Mass and Loading) Regulations*

- 1979–1980: Implementation of ERVL study (NAASRA 1976) dimension limit recommendations.
- 1986: National agreement to implement the RoRVL study (NAASRA 1985) dimension limit recommendations.
- 1993–1995: Uniform national heavy vehicle mass and dimension limits (GML) legislation and regulations introduced and adopted by all jurisdictions. Allowable length for B-doubles increased from 23 metres to 25 metres, complementing the increase in the mass limits.[6]
- 1997: Maximum allowable length for single semi-trailers (i.e. trailers towed by articulated trucks) increased from 13.7 metres to 14.6 metres.
- 2005: Maximum allowable length of B-doubles increased from 25 metres to 26 metres.

Figure 5 illustrates the increase in regulated heavy vehicle dimension limits for rigid, single-trailer articulated trucks, B-doubles and road trains between 1971 and 2010. (Note that the dimension limit estimates prior to the adoption of uniform limits in the mid-1990s are an average of separate State/Territory regulated limits.) The maximum allowable length of rigid trucks increased by 7% between 1971 and 2010. The maximum allowable length of single-trailer articulated trucks increased 26% between 1971 and 2010. Road train maximum length limits have increased 19% since 1971.

Figure 5: Heavy vehicle length limits, 1971–2010



Sources: NAASRA (1976), NAASRA (1985), ISC (1990), NTC (2009b), NTC (2008) and BITRE estimates.

3.2 Network access

Network access for heavy vehicles has also expanded significantly since 1971, particularly for larger heavy vehicle combinations such as road trains and B-doubles.

Road trains have been operating in Australia in some form or other since the 1930s, but did not become widespread until after the Second World War. In 1971, road trains accounted for 3% of total road freight and were allowed only on a limited set of roads. The set of roads on

[6] National length limits for multi-articulated vehicles are codified in *Australian Vehicle Standards* Rule 69.

which road trains are allowed to operate has increased incrementally since then. For example, non-livestock carrying road trains were not allowed in New South Wales at all before 1989 but have since been permitted access to major highways west of the Newell Highway. The current road train network includes all major roads between Adelaide and Perth, all major roads in the Northern Territory, most major roads in New South Wales (NSW) west of the Newell Highway, and all major roads in Queensland west of the Great Dividing Range.

B-doubles were first used in Australia in the late 1980s. They were originally introduced as substitutes for road trains (NTC 2007). Since then B-double road network access has been progressively expanded. For example:

- B-double access to entire the Hume Highway (Sydney–Melbourne) was granted in 1991
- B-double access to the entire Pacific Highway in NSW first granted in August 2002 (following upgrade of the Yelgun–Chinderah section), allowing continuous B-double transport between Sydney and Brisbane.

B-doubles are now permitted on all intercapital routes and on most major arterial roads within metropolitan areas. More recently, road network access has been granted to new large heavy combination vehicles, such as B-triples and AB-triples, operating under the Intelligent Access Program (IAP). B-triples are currently limited to existing road train routes.

3.3 Speed limits

Until the mid-1980s, heavy vehicles were limited to 80 kilometres per hour outside built-up areas.[7] The *National Road Freight Industry Inquiry* report (NRFII 1984) identified speed limit differentials between light and heavy vehicles as a significant contributor to poorer road safety outcomes—contributing to increased overtaking movements by light vehicles and increased crash risks—and recommended removal of the light–heavy vehicle speed limit differential by raising heavy vehicle speed limits to match existing light vehicle limits. In 1986 the Australian Transport Advisory Council (ATAC) adopted a trial maximum speed limit of 90 kilometres per hour for heavy vehicles. In December 1987 ATAC subsequently endorsed a maximum speed limit of 100 kilometres per hour for heavy vehicles, excepting road trains, to apply from 1 July 1988. Road trains remain limited to 90 kilometres per hour.[8]

3.4 Driving hours regulations

Regulations governing heavy vehicle driving hours limit the number of hours a driver can drive without a break, within a 24-hour period and over the course of a week. Prior to 1999, heavy vehicle driving hour regulations were set separately in each State and Territory. The maximum continuous driving time without a rest break varied between 5.0 and 5.5 hours. Maximum driving hours in a 24-hour period varied between 11 and 12 hours across jurisdictions. In 1999 national model driving hours were adopted, to be implemented through State/Territory legislation. Current 'standard' driving hour regulations require drivers to take a 15-minute break in each 5.5 hour working period and limit driving to 12 hours in each 24-hour period.[9] As of 2009 the model legislation had been implemented in all jurisdictions except Western Australia. Current Western Australian driving hour limits differ only slightly to the national model limits—the maximum continuous work time is 5 hours, with at least a 10

7 Within built-up areas heavy vehicles were subject to posted speed limits.

8 *Australian Vehicle Standards Rules 1999* stipulates the maximum speed limit of road train prime movers is 90 kilometres per hour. Western Australia (WA) and Northern Territory (NT) allow road trains to operate at speeds up to 100 kilometres per hour.

9 The model legislation provides three driver work/rest hours options: (i) standard hours; (ii) basic fatigue management (BFM) scheme hours; and (iii) advanced fatigue management (AFM) scheme hours. Most heavy vehicle drivers operate under standard hours.

minute break for each five-hour work period. Drivers are also expected to have had a 7-hour minimum continuous sleep break in the last 24 hours.

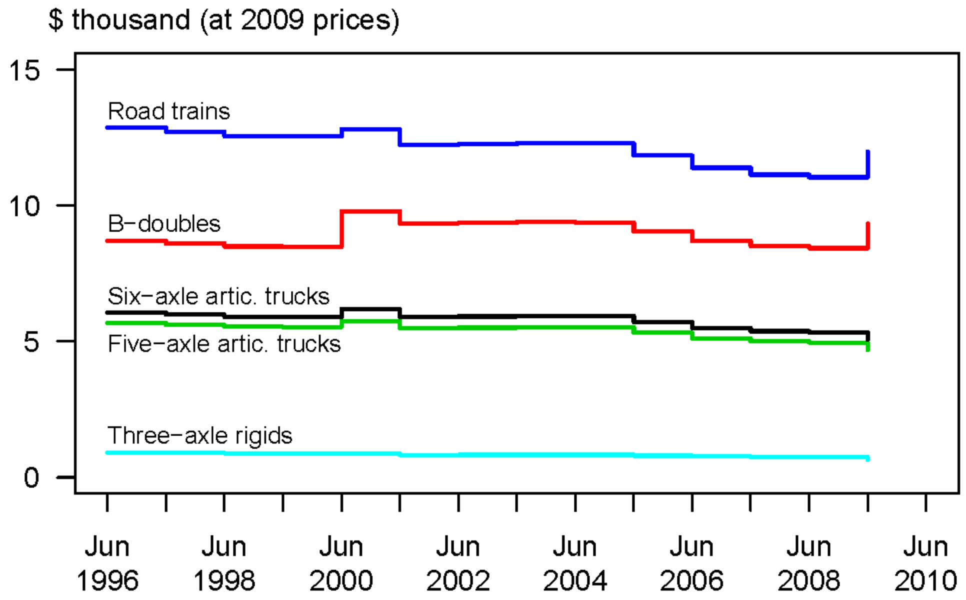
3.5 Other factors

Other factors that influence the relative cost of operating different heavy vehicle classes, will also have affected heavy vehicle freight shares. The principle variables considered here are heavy vehicle registration charges, fuel costs and road network improvements.

3.5.1 Vehicle registration charges

Up until 1995, heavy vehicle registration charges and variable road use charges were set independently by each state and territory. Variation in charges prevailing across jurisdictions led to considerable 'shopping around' by heavy vehicle operators. Nationally-uniform heavy vehicle charges were first implemented in 1995, and since 2001 have been revised annually. Figure 6 shows real heavy vehicle registration charges (relative to movements in the GDP deflator) since 1995 for three-axle rigid trucks, five-and six-axle articulated trucks, B-doubles and triple road trains. In real terms, heavy vehicle registration charges have generally declined since 1996—three-axle rigid truck registration charges by approximately 30%, five- and six-axle articulated truck registration charges by 16 to 21%, and road train registration charges by 7 to 12%. Only B-double registration charges increased in real terms between 1996 and 2010.

Figure 6: Real heavy vehicle registration charges, 1971–2009



Sources: NRTC (1992), NRTC (1999), NTC (2006), NTC (2009a, and earlier issues) and BITRE estimates.

3.5.2 Road network improvements

Improvements to the road network since 1971 through investment in new infrastructure, upgrading road surfaces, and duplication and realignment of the existing network have been significant, especially on the National Land Transport Network (NLTN) corridors. Cumulative real construction expenditure on the NLTN between 1974 and 2008 is estimated to have totalled over $24 billion (at 2009 prices). These improvements have significantly reduced the cost of, and boosted growth in, intercapital road freight. Cumulative investment in the NLTN, for example, together with increases in heavy vehicle speed limits, has reduced heavy vehicle travel times between Sydney and Melbourne from around 15 hours in 1971 (BTE 1990) to around 11 hours today.

4. Modelling heavy vehicle productivity

In this section, we posit a GEV model that relates observed heavy vehicle freight shares to heavy vehicle costs and regulatory factors. The GEV model specification encompasses a large variety of models and wide range of substitution responses (Train 2003). The multinomial logit (MNL) and nested logit (NL) models are members of the GEV family. The GEV freight share model predictions can, in turn, be used to predict fleet average heavy vehicle loads. The model provides a tool for predicting the impact of past and future regulatory policy changes on future heavy vehicle freight shares and fleet average loads.

4.1 Model specification

The general form of the GEV model is:

$$P_{it} = \frac{Y_i G_i}{G} \tag{1}$$

where $G = G(Y_1, \ldots, Y_J)$, $Y_i = e^{V_i}$ and $G_i = \partial G / \partial Y_i$ and V_i represents the observed 'utility' of choosing alternative i.

GEV models are typically used to estimate choice probabilities using discrete choice data, where the data relates to choices by individual decision makers. Typical transport-related applications include analysis of transport mode choice from household travel survey data. The GEV model also naturally lends itself to analysis of grouped data, where the data comprises a set of counts or proportions (market shares). The heavy vehicle freight share data used here comprises grouped market shares observed over time—referred to as a grouped panel data set. Grouped panel data can be easily accommodated in the GEV specification, and lagged variables can be included in the model.

4.1.1 Observed 'utility'

The road freight industry is highly competitive. Market concentration is low and relatively low start-up costs and readily transferable capital facilitate easy entry and exit. Consequently, there is considerable pressure on operators to minimise operating costs, and operators will choose that heavy vehicle combination which minimises the cost of hauling freight, subject to meeting customer needs. Shipment characteristics—e.g. commodity type, shipment size, total shipment volume and origin and destination—also influence cost, with smaller trucks more cost effective for very small shipment volumes and larger trucks for loads above 20 tonnes.

The probability that vehicle type i is chosen, in preference to all other vehicle types, is the probability that the average cost $C_{it} = V_{it} + \varepsilon_{it}$ is less than the average cost of all other heavy vehicle types. V_{it} is the observed component of average costs (defined in equation 2) and ε_{it} covers the unobserved components.

$$V_{it} = \alpha_i + \beta c_{it} + \phi \ln S_{i,t-1} \tag{2}$$

where c_{it} is the average variable cost per tonne kilometre, defined as the average operating cost per vehicle kilometre (c^*_{it}) divided by an index of the carrying capacity of each heavy vehicle type (z_{it}). The average operating cost per vehicle kilometre includes fuel, labour and vehicle registration costs. Carrying capacity is defined as a linear function of GML, HML and maximum allowable length. Dynamic effects are captured by the lagged share term, ln $S_{i,t-1}$.

4.2 Data

The freight share data were sourced from the Survey of Motor Vehicle Use (SMVU, ABS 2008). The SMVU was undertaken more or less triennially between 1971 and 1998 and annually between 1998 and 2007, and so provides 17 observations spanning the 35-year period between 1971 and 2007. The SMVU estimates were interpolated using Stineman (1980) interpolation to provide a time series of annual observations. Heavy vehicle operating costs and regulatory covariate data—mass and dimensions limits, vehicle speed limits, driving hours and heavy vehicle registration—were derived from various sources, including the SMVU and published reports on heavy vehicle pricing and regulation. Missing observations were also interpolated using Stineman's (1980) method.

4.3 Estimation and empirical results

Several alternative GEV model specifications were estimated, including a MNL model, two NL specifications—one with three freight vehicle nests and one with four freight vehicle nests—and a paired combinatorial logit (PCL) specification. All estimates were derived via maximum likelihood estimation (MLE) using R (Ihaka & Gentleman 1996). Maximum likelihood estimation produces estimates that are both consistent and efficient.

The maximum likelihood estimate (MLE) results for the simple MNL model, the two NL specifications and the preferred PCL model specification are shown in Table 2 and the actual and predicted freight shares (for the preferred PCL specification) are shown in Figure 7. It may be observed that the model predictions match the actual freight shares very closely across most of the sample period. In particular, the model captures the both the initial increase and subsequent reduction in freight share carried five- and six-axle articulated trucks, the gradual reduction in freight share of two-axle rigid and four-axle articulated trucks, and the rapid uptake of B-doubles, albeit with a slight lag. The MNL and NL specifications also fit the observed heavy vehicle freight shares quite well.

The parameter estimates are generally statistically significant. Across all specifications, the lagged share term parameter values are highly significant and lie between 0.74 and 0.90, which implies a significant lagged response to changes in costs and regulatory factors.[10] The inclusive value parameters in the NL specifications are statistically significant and several of the independence parameter estimates in the PCL model are also statistically significantly different from 1, which implies a richer correlation structure than the MNL specification allows.

The signs of the explanatory variable parameter estimates are generally as expected. The average cost parameter estimate is negative across all model specifications, implying that an increase in the average cost of truck type *i* reduces its freight share. Freight shares are positively correlated with increased GML and HML. Somewhat surprisingly, the estimates imply that freight shares are negatively correlated with maximum length limits.

4.4 Heavy vehicle productivity growth

We can use the predicted heavy vehicle tonne kilometres (TKM) freight shares to predict heavy vehicle average loads for all rigid and articulated trucks. The fleet-wide average load of vehicle class k, L_k, is defined as the VKT-weighted sum of the average load for each heavy vehicle type within class k:

$$\bar{L}_{kt} = \sum_{j \in k} \frac{\mathrm{VKT}_{kt} \bar{L}_{kt}}{\sum_{j \in k} \mathrm{VKT}_{jt}} \tag{4}$$

Rearranging terms, this may be transformed into a relationship between average load of class k and estimated (tonne kilometre) freight shares ($\hat{S}_{jt}$):

$$\bar{L}_{kt}^{-1} = \sum_{j \in k} \hat{S}_{jt} \bar{L}_{jt}^{-1} \tag{5}$$

10 A lagged share parameter of 0.90 implies a period of 5–6 years to 50 per cent of full adjustment.

Figure 8 provides a comparison of the actual growth in total rigid and articulated truck average loads between 1971 and 2007, and predicted rigid and articulated truck average loads, assuming growth in average loads within each heavy vehicle type/axle configuration class have increased only with increases in mass limits. Changes in articulated truck freight shares account for much of the observed growth in articulated truck average loads over the past 35 years. Changes in rigid truck average loads are almost entirely accounted for by the reclassification of smaller rigid trucks as LCVs, mentioned in Section 2, that occurred between 1976 and 1991. Outside of this period rigid truck average loads have changed very little.

Table 2: Heavy vehicle freight share GEV model estimation results

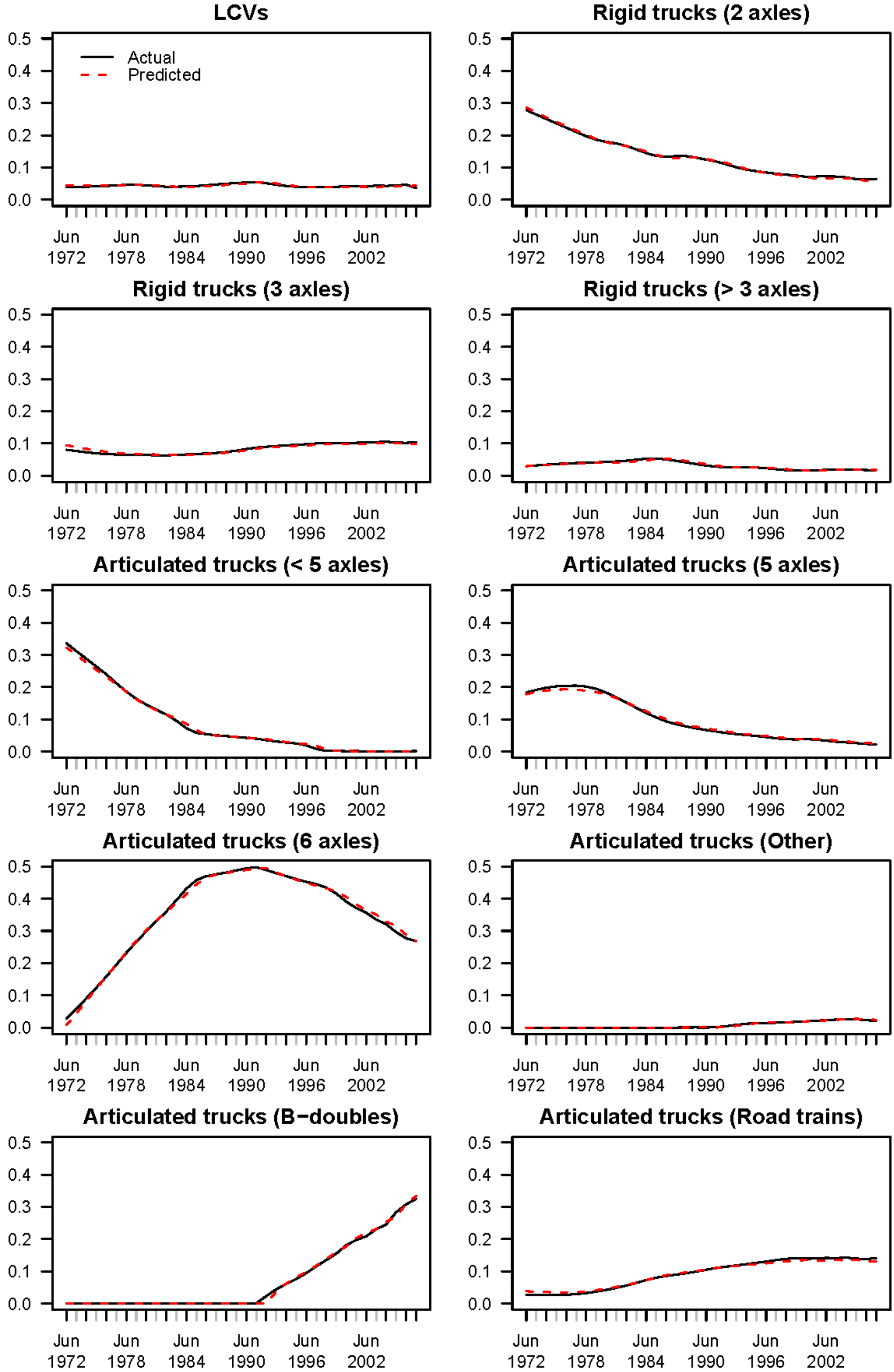
	Model specification			
	MNL	Three-branch NL	Four-branch NL	PCL
Specific constants				
Two-axle rigid trucks	0.0183	0.3679	0.134	0.07612
	(1.501e–05)	(0.0002142)	(3.165e–05)	(0.004843)
Three-axle rigid trucks	0.0379	0.3987	0.1871	0.1179
	(1.503e–05)	(0.0002288)	(3.207e–05)	(0.00649)
Four-axle rigid trucks	–0.0876	0.3824	0.1607	0.06096
	(1.388e–05)	(0.0002365)	(3.596e–05)	(0.00617)
Four-axle articulated trucks	–0.0722	0.3986	0.006704	0.02995
	(1.62e–05)	(0.0002401)	(3.765e–05)	(0.005972)
Five-axle articulated trucks	–0.0097	0.4606	0.06737	0.1129
	(1.669e–05)	(0.0002462)	(3.754e–05)	(0.006524)
Six-axle articulated trucks	0.2149	0.6644	0.2967	0.3016
	(1.704e–05)	(0.0002516)	(3.727e–05)	(0.00388)
B-doubles	–7.503e–05	0.5007	0.06903	–0.05299
	(3.729e–07)	(0.0002434)	(4.036e–05)	(0.007498)
Road trains	0.2921	0.7414	0.369	0.3932
	(1.599e–05)	(0.000259)	(3.688e–05)	(0.007728)
Other articulated trucks	0.1013	0.5718	0.1251	0.09767
	(1.605e–05)	(0.0002629)	(2.603e–05)	(0.005319)
Dependent variables				
Avg. cost	–0.03835	–0.1111	–0.04302	–0.02216
	(8.197e–05)	(0.000876)	(5.649e–05)	(0.004525)
Length	–0.2362	–0.2543	–0.2319	–0.2513
	(0.000304)	(0.001564)	(7.98e–05)	(0.00808)
HML	0.1259	0.5277	0.1249	0.08817
	(0.001695)	(0.004141)	(0.000577)	(0.008767)
Dummy variables				
B doubles	–0.5454	–0.2213	–0.5677	–0.6423
	(5.113e–05)	(0.005639)	(0.0001996)	(0.01107)
Other articulated trucks	0.0678	0.0261	0.0231	0.09736
	(4.271e–05)	(9.991e–05)	(0.0004745)	(0.01399)
	0.8987	0.7364	0.8662	0.8117
ϕ	(1.117e–06)	(3.97e–07)	(6.531e–06)	(0.001698)
Inclusive value parameters				
LCVs	..	..	1	..
Rigid trucks		0.7428	0.8725	
	..	(5.565e–07)	(8.721e–06)	..
GA articulated trucks		0.8199	0.9716	
	..	(2.444e–06)	(6.63e–06)	..
RA articulated trucks	..	..	1	..
ln *L*	–63.5129	–63.4970	–63.5085	–63.5025
No. parameters	15	17	17	27

.. Not applicable.

a. Maximum likelihood estimates. Standard errors in parentheses are based on the asymptotic (robust) covariance matrix (see Train 2003).

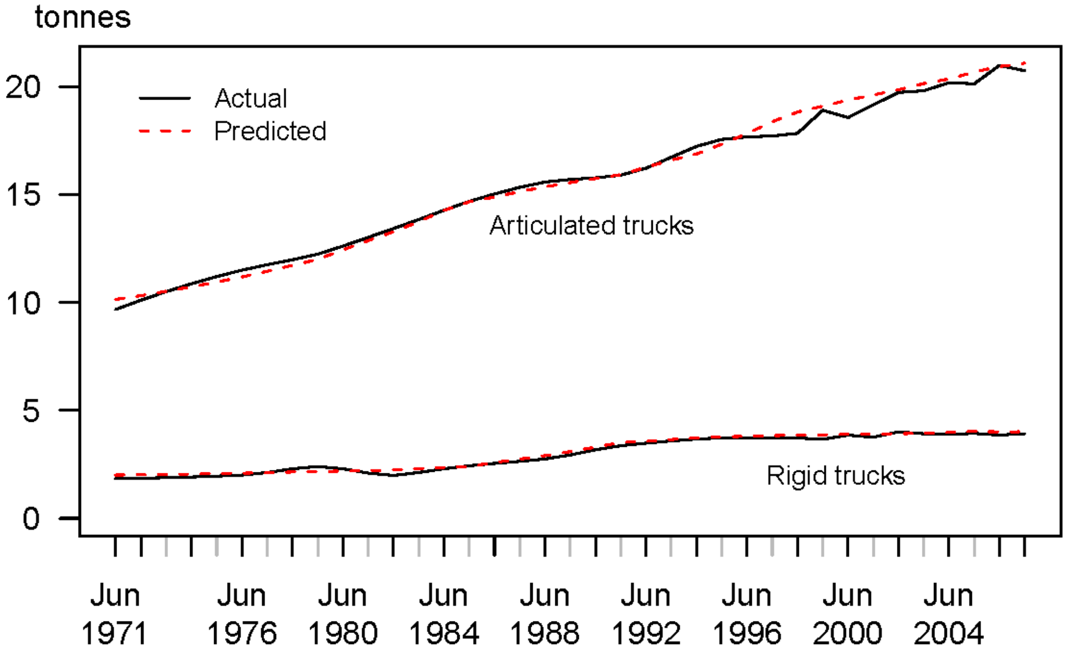
b. The PCL model independence parameter set and estimates are: LCV–Rig2A: 1; Rig2A–Rig3A: 0.2871 (6.846e-5); Rig3A–Rig4A: 0.3901 (0.0014); Rig4A–Art4A: 0.3265 (0.0019); Art4A–Art5A: 0.284 (0.001); Art5A–Art6A: 0.3454 (0.0001); Art6A–ArtOt: 1; Art6A–ArtBd: 0.2293 (0.0021); Art6A–ArtRt: 1; ArtOt–ArtBd: 1; ArtBd–ArtRt: 1; Other: 0.8551 (0.0033).

Figure 7: Actual and predicted road freight shares, by broad vehicle type and vehicle axle



Sources: BITRE estimates.

Figure 8: Actual and predicted rigid and articulated truck average loads, 1971–2007



Sources: BITRE estimates.

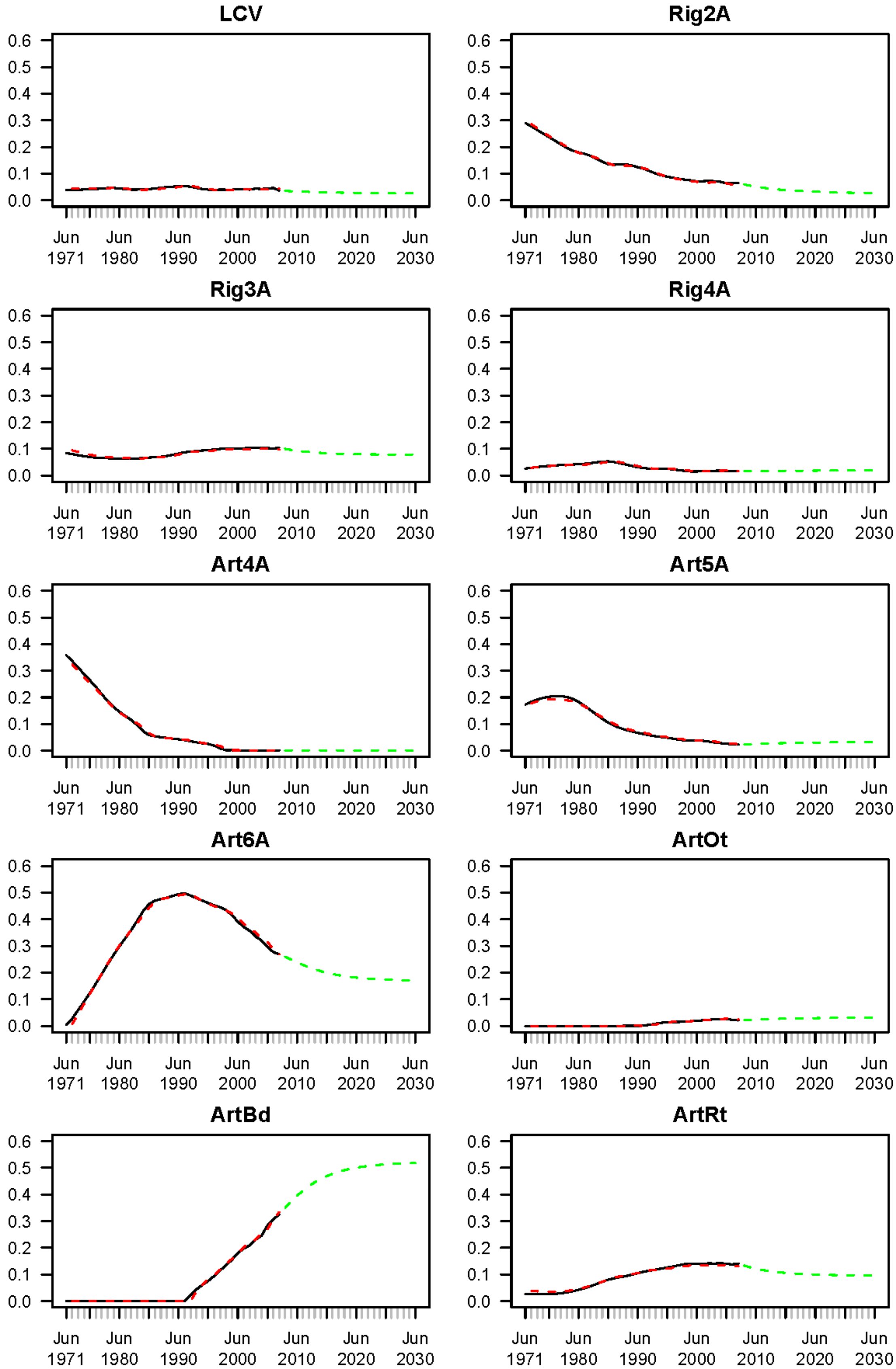
5. Forecasting future heavy vehicle productivity trends

The heavy vehicle freight share model can be used to predict likely future heavy vehicle productivity growth, taking into account future heavy vehicle regulatory settings. Here we present projections of future freight shares and heavy vehicle productivity trends to 2030, assuming no significant change to heavy vehicle mass and dimension, that real heavy vehicle registration charges remain constant, and that there are no significant new heavy vehicle types introduced into the fleet.

Figure 9 illustrates the predicted and projected freight task shares for each heavy vehicle type. The results imply that with no further regulatory changes B-double freight volumes will grow to over 50% of the total road freight task by 2030. The share of freight carried by six-axle articulated trucks will decline to around 17% and road trains to around 12% of total road freight in 2030. Overall, the share of freight carried by articulated trucks is projected to increase from 78% in 2007 to 84% in 2030 and the share of freight carried by rigid trucks decline from 18% in 2007 to 12% by 2030. The share of freight carried by LCVs is also projected to decline as a result of the strong growth in B-double freight traffic.

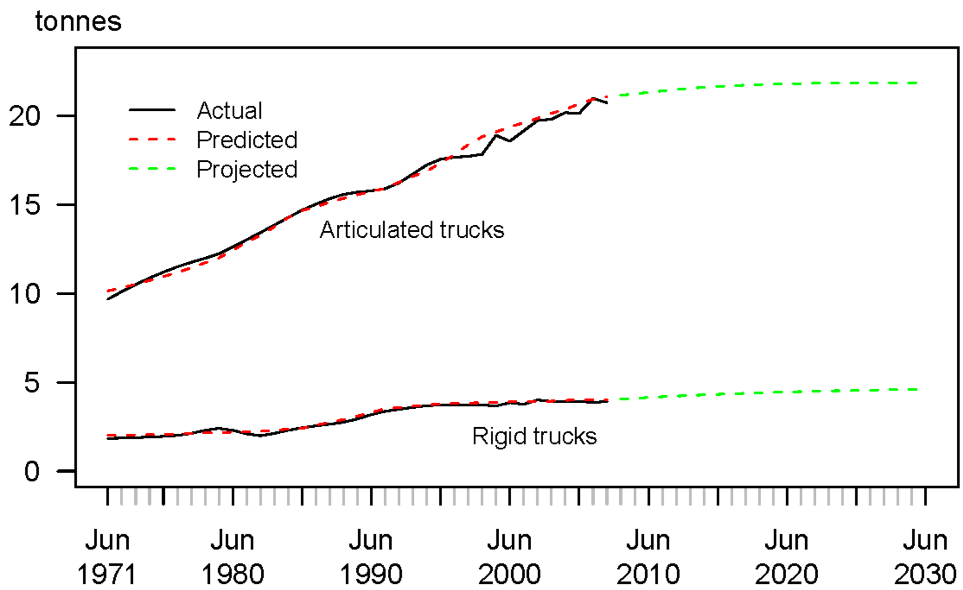
Assuming that average loads for each modelled heavy vehicle type/axle load class remain unchanged to 2030, the projected heavy vehicle freight shares imply that the average load across all rigid trucks will increase from around 3.9 tonnes (per vehicle kilometres travelled) in 2007 to 4.6 tonnes in 2030 (see Figure 10), equivalent to annual average growth of 0.6% per annum, which is below the rate of trend growth experienced since 1991 (approximately 1.0% per annum since 1991), and that the average load of articulated trucks will increase from around 20.7 tonnes (per vehicle kilometre travelled) in 2007 to 21.9 tonnes in 2030, equivalent to annual average growth in articulated truck average loads of 0.2% per annum, which is well below trend growth experienced since 1991 (approximately 1.64% per annum). The implication of these results is that past heavy vehicle reforms continue to contribute to increasing heavy vehicle productivity (average loads). However, in the absence of further heavy vehicle productivity enhancing reforms the impact of past reforms will diminish resulting in slower productivity growth in the future.

Figure 9: Actual, predicted and projected road freight shares, by broad vehicle type and vehicle



Sources: BITRE estimates.

Figure 10: Actual, predicted and projected rigid and articulated truck average loads, 1971–2020



Sources: BITRE estimates.

6. Concluding Remarks

This paper has provided an overview of historical trends in heavy vehicle road freight and heavy vehicle productivity, and presented a model for estimating the share of freight carried by different heavy vehicle classes, and in turn projecting future heavy vehicle average loads. The model also provides a tool for evaluating the heavy vehicle productivity impact of potential regulatory policy changes. The results of the model will help inform policy and analysis of future heavy vehicle road use trends in Australia.

The projections of future heavy vehicle freight shares and heavy vehicle average loads presented here assume no further change in heavy vehicle regulatory settings. Further work could involve estimating the impact of alternative assumptions about future heavy vehicle regulatory settings, for example, the impact of increased uptake of Performance Based Standards compliant vehicle combinations, such as B-triples and AB-triples.

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