Using Road Freight Movements Survey data to estimate road freight transport quotients and regional road freight flows in Australia

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Abstract

Australia comprises states of varying climates, natural resource endowments, geographic area and population size. This has resulted in a diversity of regional or state economies, regional road freight flows and road networks to serve these needs. In this paper, the concept of location quotients is first examined in terms of its theoretical basis. It is then applied to Australian Bureau of Statistics 2014 Australian Road Freight Movements survey data to calculate "road freight transport" quotients across states in Australia in terms of tonnes and tonne-km, by state of origin-destination and for different commodity types. Origin and destination flows are then compared to determine the extent to which the different states are "outward-orientated" in terms of direction of flows and in what types of goods. Finally, the paper also explores implications of the study for policy analysis as well as future uses of the data, taking account of issues regarding the reliability of the survey data.

Keywords: Road freight, location quotients, interregional freight flows.

1 Introduction

The Australian Bureau of Statistics (ABS) released the results of the 2014 Australian Road Freight Movements survey (ABS, 2015) in October 2015. This was the first such survey of national road freight movements in Australia since the 2001 Freight Movements survey (ABS, 2002). The 2014 survey data provide an overview of the distribution of regional and interregional road freight flows across states in Australia in terms of tonnes and tonne-km by origin and destination of different goods types. Meanwhile, the concept of location quotients is well known in regional analysis, usually calculated using population or employment data, to indicate areas of regional advantage or potential sectoral expansion. The objective of this paper is to apply the concept of location quotients to the 2014 Road Freight Movements survey data for Australia and develop a set of road freight transport quotients across states and commodity types.

The paper first reviews the concept of location quotients. It then examines how estimates of regional freight magnitudes and flows have been undertaken in Australia and whether the concept of location quotients has been applied to interregional freight flow data internationally. The paper next provides an overview of the approach used in the 2014 Road Freight Movements survey and data produced across states and commodity types. The paper then presents the methodology used and "road freight transport" quotients calculated across Australian states for different commodity types. The relative size of origin and destination flows is also examined to determine the extent to which states are 'outward-orientated' and in what commodities. Finally, the paper also explores implications of the study for policy analysis as well as future uses of the data.

2 Literature review

2.1 Location quotients

The location quotient (LQ) is a basic metric for regional analysis, usually based on variables such as population or employment, that can be used to differentiate between geographical areas. Despite featuring so extensively in regional analysis, the theoretical foundation of the concept is surprisingly difficult to pin down. There seems to be some consensus that it originated in the 1920s with Robert Murray Haig of Columbia University and stems from his work on Economic Base theory (New York State, 2017). This holds that a region's economy comprises *basic* sectors whose output exceeds local (regional) demand and therefore export their output to other regions (or internationally), and *non-basic* sectors whose output is insufficient for local use and needs to be supplemented by imports from other regions (or internationally). Growth of the region's economy is attained from the earnings of the (exporting) basic sector stimulating demand in the regional economy through a conventional multiplier effect. The rationale for location quotients is the identification of these *basic* sectors of the regional economy, i.e. those sectors with a disproportionately larger role in the regional economy than in the country as a whole.

The general form of the location quotient calculation (based on employment data in this case) is set out in Isard, et al. (1998), see Equation 1:

$$\frac{E_i^j / E^j}{E_i / E} \qquad (1)$$

Where:

E_i^j = Employment in activity i in region j

E^j = Total employment in region j

E_i = Employment in activity i in the country as a whole

E = Total employment in the country as a whole.

The form of the location quotient set out above provides the basis for the development of road freight transport quotients using the Road Freight Movements survey 2014 data.

2.2 Regional analysis of freight in Australia

Freight flows by major economic sectors in Australia have traditionally been estimated by the Bureau of Infrastructure, Transport and Regional Economics (BITRE), previously Bureau of Transport and Regional Economics (see BTRE, 2006), with modelling undertaken within the framework of the FreightSIM model. The approach underlying FreightSIM has been concerned with interregional freight transportation across Australia by commodity type and mode (road & rail), for both bulk and non-bulk freight.

The 2001 Freight Movements survey 2001 (ABS, 2002) did, however, provide a detailed picture of regional road freight flows using articulated vehicles, in addition to other modes. Since 2001, revised estimates of the road freight task by state for Australia were undertaken by BITRE (2010) in terms of its components (interstate, capital city & rest of state). However, the completion of the 2014 Road Freight Movements survey (ABS, 2015) enabled BITRE (2016) to update estimates of the road freight task using the BITRE (2010) methodology.

Wang (2012) used commodity flow surveys and input output (IO) coefficients to estimate regional freight flows in Australia. Freight production and attraction measures were derived from industry value added and employment data by sector, as well as by household and business consumption respectively. Sources of such data included Commodity Flow Surveys and The Enormous Regional Model (TERM) IO model comprising 144 sectors and 57 regions. A key component of the study was the conversion of values to tonnages and assignment to vehicle types. National Transport Commission (NTC, 2016) summarised the 2014 Road Freight Movements survey (ABS, 2015) data as an input to its "*Who Moves What Where*" representation of current passenger and freight transportation data in Australia, but did not use it to present detailed data by commodity type.

Prior to the release of the full results of the 2014 Road Freight Movements survey (ABS, 2015), Mitchell and Kurniawan (2015) undertook an estimation of freight flows for major commodities in Australia using a linear programming approach based on public domain R software. The approach broadly involved "estimates of freight flows by modelling commodity movements between sources of supply (e.g. mines, farms, quarries) and intermediate production facilities (e.g. mills, refineries) to points of final demand (e.g. ports, for commodity exports, power stations, domestic manufacturing plants) across domestic transport networks" (Mitchell & Kurniawan, 2015). Linear programming was then used to allocate commodity movements to minimise an objective function, i.e. total transport costs. The methodology was applied to iron ore as an example and identified as potentially applicable to other primary commodities such as coal, grains, cotton, rice and sugar.

The estimates undertaken in BITRE (2016) used the 2001 Freight Movements survey (ABS, 2002) and 2014 Road Freight Movements survey (ABS, 2015) to adjust the Survey of Motor Vehicle Use (SMVU) 'interstate[1]' road freight task in tonne-km to provide an origin-destination framework for the data. The estimates of road freight task by state estimated by BITRE are presented in Table 1.

Table 1: BITRE estimated road freight task in billion tonne-km as at 2014 by state

State	Interstate				Capital city	Rest of state	Total
	From	To	Through	Sub-Total			
New South Wales	13.05	12.46	6.23	31.75	12.39	19.41	63.54
Victoria	7.69	7.14	0.48	15.31	12.43	10.85	38.60
Queensland	2.46	2.43	0.00	4.89	9.23	25.05	39.17
South Australia	2.62	2.22	0.64	5.49	3.00	4.72	13.20
Western Australia	1.00	0.96	0.00	1.95	6.73	36.68	45.36
Tasmania	0.00	0.00	0.00	0.00	0.43	2.72	3.15
Northern Territory	0.57	1.00	0.00	1.57	0.30	0.46	2.32
ACT	0.01	0.04	0.00	0.04	0.33	0.00	0.38
Total Australia	27.40	26.25	7.35	61.00	44.84	99.89	205.72

Source: BITRE (2016)

Table 1 shows the prominence of NSW in terms of tonne-km (64 billion tonne-km), with a substantial portion of it comprising 'interstate' traffic (almost 50%) and 'rest of state' (30%). While Victoria and Queensland were estimated to have similar magnitudes of road freight tasks (39 billion tonne-km), Victoria had a larger portion of it designated as interstate (40% versus 13%) and Queensland had a much higher portion designated as 'rest of state' (64% versus 28%). Owing to the longer distances involved in the state and its relative remoteness, it was estimated that 81% of Western Australia's road freight tasks derived from 'rest of state', with much lower 'interstate' estimates.

2.3 International experience

Commodity based Input Output (IO) tables have been used to estimate commodity flows based on economic activities for the Freight Analysis Framework (FAF) as stated in Transportation Research Board (TRB, 2010), with allocation to truck assignments or freight trips using data on average payloads. These and other methods such as multimodal network and logistics models used to deal with route assignment are reviewed in detail in TRB (*Ibid*). These approaches were also reviewed in TRB (2008) on a statewide level specifically, addressing the gap in freight origin-destination data in

[1] Where the interstate road freight task is defined by ABS as tonne-kilometres performed by trucks registered in other states on a state's roads.

the U.S. and providing a toolkit for the estimation of freight flows to forecast origin-destination of freight movements within cities and between regions. This approach involves estimation of interregional freight movements with commodity flow (tonnage) data derived from an IO table, converted to county-level truck assignments using a $/tonne conversion factor and subsequently allocated to zones using location quotients derived from employment data. Estimation of interregional IO tables using a (modified) location quotient approach is explained in Hewings and Oosterhaven (2014). However, location quotients are used to allocate or distribute interregional IO activities (including supply and use tables), not freight flows. This is attributed by Hewings and Oosterhaven (*Ibid*) to the absence of "intra-national, interregional trade data" in all but a few countries, e.g. Japan, the U.S. and some European countries.

The University of Minnesota's National Freight Economy Atlas (http://freighteconomyatlas.org) stands out from other sources as it uses 2012 Bureau of Transportation Statistics Commodity Flow Survey data[2], across the U.S. to calculate *location quotients* for rail freight and road freight on a national as well as a state level. These are defined as the proportion of commodities (e.g. agricultural goods) from a particular state transported by road / rail compared to the national average, or the proportion of commodities from a particular sub-region compared to the state average. This overall approach of freight quotients is the closest to the objectives of this paper and provides some confirmation of the methodology required for development of road freight quotients for Australia.

3 Data

The 2001 Freight Movements survey for 2001 (ABS, 2002) encompassed air, sea, rail and road freight movements. The road freight component focussed on articulated vehicles only and employed different sampling techniques, so is not directly compatible with the 2014 Road Freight Movements survey (ABS, 2015). However, the latter involved estimates of road freight tonnes and tonne-km for an extensive list of commodity types produced by primary and secondary sectors transported by rigid trucks exceeding 3.5 tonnes gross vehicle mass (GVM) *and* articulated trucks. Given the extensive list of freight types and statistical areas, and the reliance on varied inputs from road freight transport operators, the survey results exhibited variations in relative standard error (RSE)[3] identified in ABS (2015). The ABS has recommended that results with an RSE of 25-50% should be used with caution, while those >50% are deemed to be too unreliable for general use. Finally, the data refer to road freight volumes by state of origin and destination, not the volumes actually originating in one state and destined for another.

3.1 Vehicle types and freight movements

The 2014 Road Freight Movements survey included vehicles registered with a motor vehicle authority during the 12 months ending 31 October 2014. Unregistered vehicles and those below the GVM threshold were excluded, as was freight moved by the military or pipeline. The survey related to road freight movements by transport operators for hire or reward, as well as ancillary transport (i.e. farmers, manufacturers, retailers on their own account). Movements included both laden and unladen trips. In the case of trips involving more than one transport mode, only the road freight component was included.

3.2 Sample size and vehicle attributes

The survey sample comprised 16,000 articulated and rigid trucks and was identified by ABS using information obtained from state and territory motor vehicle registration authorities, as part of the ABS Motor Vehicle Census (ABS cat. no. 9309.0 of 31 January 2013 in ABS, 2015). This included state / territory of registration, vehicle type (articulated or rigid), area of registration (capital city or rest of

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[2] Across 11 industry clusters: agricultural products, animal products, base metals, electronics, fertilisers, finished metals, machinery, other foodstuffs, plastics & rubbers, textiles and wood products.

[3] Measure of sampling variability "obtained by expressing the standard error as a percentage of the estimate to which it refers" (ABS, 2015).

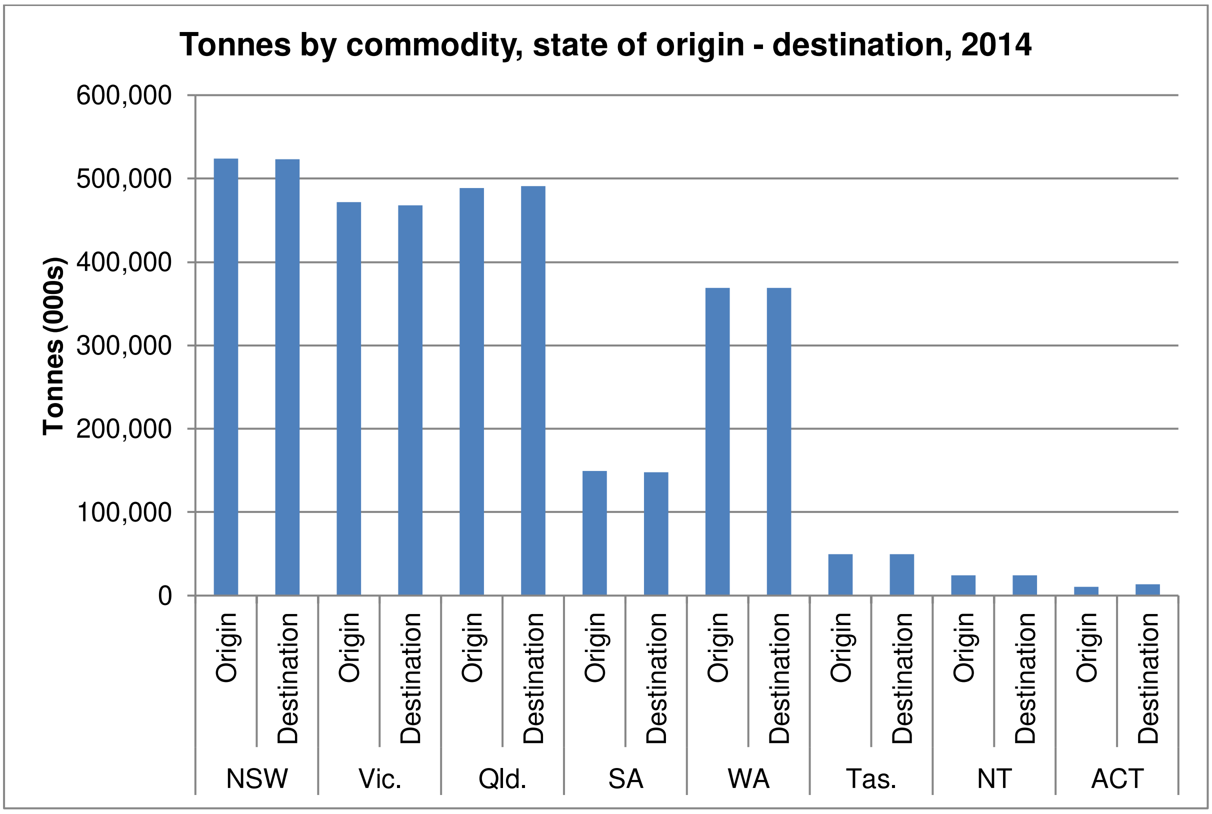
state), vehicle age (year of manufacture) and vehicle size (based on gross consolidated / combination mass or GCM)[4].

3.3 Survey period and data requested

Owners of vehicles included in the survey were asked to provide details of freight movements for a randomly-selected one week period which was then annualised. This included start and finish odometer reading for the week, usual garaged address and vehicle use and movements (i.e. origin & destination of each trip, commodity type, weight of load, distance travelled, trailer configuration and method of transportation).

3.4 Overview of 2014 survey data

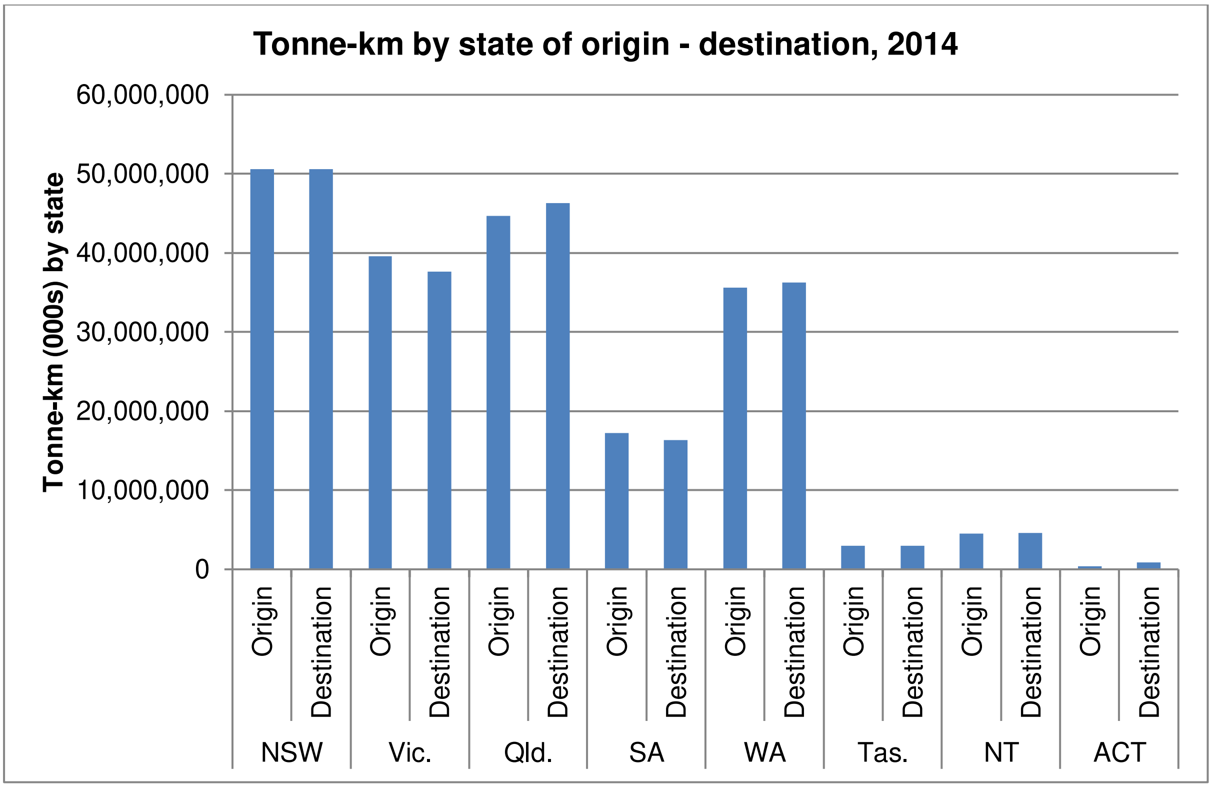
Data for the 2014 Road Freight Movements survey were broken down by commodity / freight type in terms of tonnes and tonne-km by state of origin and destination as summarised in Figures 1 and 2. Most states showed differences in origin and destination for both tonnes and tonne-km, indicating differences in interregional flows, with the exception of Tasmania (with no interregional road freight movements as such), as well as extensive, remote states of WA and NT.



Source: ABS (2015)

Figure 1: Road freight tonnes by state of origin-destination, 2014

[4] Gross vehicle mass (GVM) relates to rigid vehicles while gross combination (consolidated) mass (GCM) relates to combination or articulated vehicles.



Source: ABS (2015)

Figure 2: Road freight tonne-km by state of origin-destination, 2014

Table 2 shows the percentage composition of road freight transport estimated in the 2014 Road Freight Movements survey by tonnes and tonne-km respectively. For most commodities, there is little difference either way, but not so for others. Food and general freight show a sizeable increase in percentage when measured in tonne-km, while sand, stone and gravel is characterised by a significant decrease when measured in tonne-km. The estimated total tonne-km for 2014 (i.e. 196 billion tonne-km) is reasonably close to the estimates produced by BITRE in Table 1, i.e. approximately 206 billion tonne-km.

Table 2: Road freight transport volumes by commodity type, tonnes and tonne-km, 2014

Commodity type	Tonnes		Tonne-km	
	Tonnes (millions)	% of total	Tonne-km (billions)	% of total
Cereal grains	102.246	4.9	11.946	6.1
Food	209.791	10.1	30.544	15.6
Live animals	33.191	1.6	5.960	3.0
Beverages and tobacco	50.932	2.4	5.602	2.9
Crude materials	53.871	2.6	3.293	1.7
Metalliferous ores and metal scrap	96.697	4.6	10.568	5.4
Sand, stone and gravel	492.691	23.6	18.614	9.5
Cork and wood	62.085	3.0	6.091	3.1
Coal	44.679	2.1	1.274	0.7
Gases	12.865	0.6	1.500	0.8
Petroleum and petroleum products	72.164	3.5	9.135	4.7
Animal and vegetable oils, fats and waxes	2.116	0.1	0.519	0.3
Chemicals	24.629	1.2	2.430	1.2
Fertilisers	18.395	0.9	3.516	1.8
Tools of Trade	45.333	2.2	1.624	0.8
Cement and concrete	124.862	6.0	4.948	2.5
Iron and steel	28.062	1.3	3.974	2.0
Other manufactured articles	81.607	3.9	8.850	4.5
Machinery and transport equipment	81.475	3.9	7.713	3.9
Miscellaneous manufactured articles	23.720	1.1	3.234	1.7

Commodity type	Tonnes		Tonne-km	
	Tonnes (millions)	% of total	Tonne-km (billions)	% of total
General freight	277.724	13.3	43.759	22.4
Other commodity	192.570	9.2	10.524	5.4
Total	2,086.371	100.0%	195.619	100.0%

Source: Own calculation using Road Freight Movements survey data from ABS (2015)

4 Methodology

4.1 Calculation of 'road freight transport' quotients

The concept of the location quotient is applied in this paper to the 2014 Road Freight Movements survey (ABS, 2015) data to provide a basic, initial representation of the distribution of freight flows by state and commodity type across Australia. The form of the estimation is therefore set out in Equation 2:

$$\frac{RF_i^j / RF^j}{RF_i / RF} \qquad (2)$$

Where:

RF_i^j = Road freight by commodity type *i* originating or ending in state *j*

RF^j = Total road freight originating or ending in state *j*

RF_i = Road freight by commodity type *i* in Australia as a whole

RF = Total road freight in Australia as a whole.

Thus, the form of the 'road freight transport' quotient calculation undertaken for the paper follows that used to estimate the conventional location quotient set out in Equation 1.

As described in Equation 2, 'road freight transport' quotients were calculated in this study using the breakdown of commodity types transported to and from each state in terms of tonnes and tonne-km. The results of the calculation for 'road freight transport' quotients are presented in Tables A.1 and A.2 for tonnes and tonne-km respectively in Appendices to this paper.

4.2 States' outward orientation by commodity type

This is an important metric for assessing interregional freight flows. A measure of outward orientation by state and commodity type presented in Equation 3 was compiled in terms of estimated origin and destination road freight transport quotients, results of which are contained in Tables B.1 and B.2 in Appendices to this paper. Where the origin > destination of volumes, this indicates a potential for surplus of that freight type which could be 'exported' to another state as an 'outward' interregional freight flow, after intra-state freight demand was met through the 'destination' volumes. Where origin < destination, this would indicate an 'inward' interregional freight flow or an 'import' requirement, as demand was higher than could be met through intra-state freight volumes alone and would have to be met by interstate freight flows.

$$\frac{RFQ_{Origin}}{RFQ_{Destination}} \qquad (3)$$

Where:

RFQ_{Origin} = Road freight transport quotient for Origin by commodity type and state

$RFQ_{Destination}$ = Road freight transport quotient for Destination by commodity type and state.

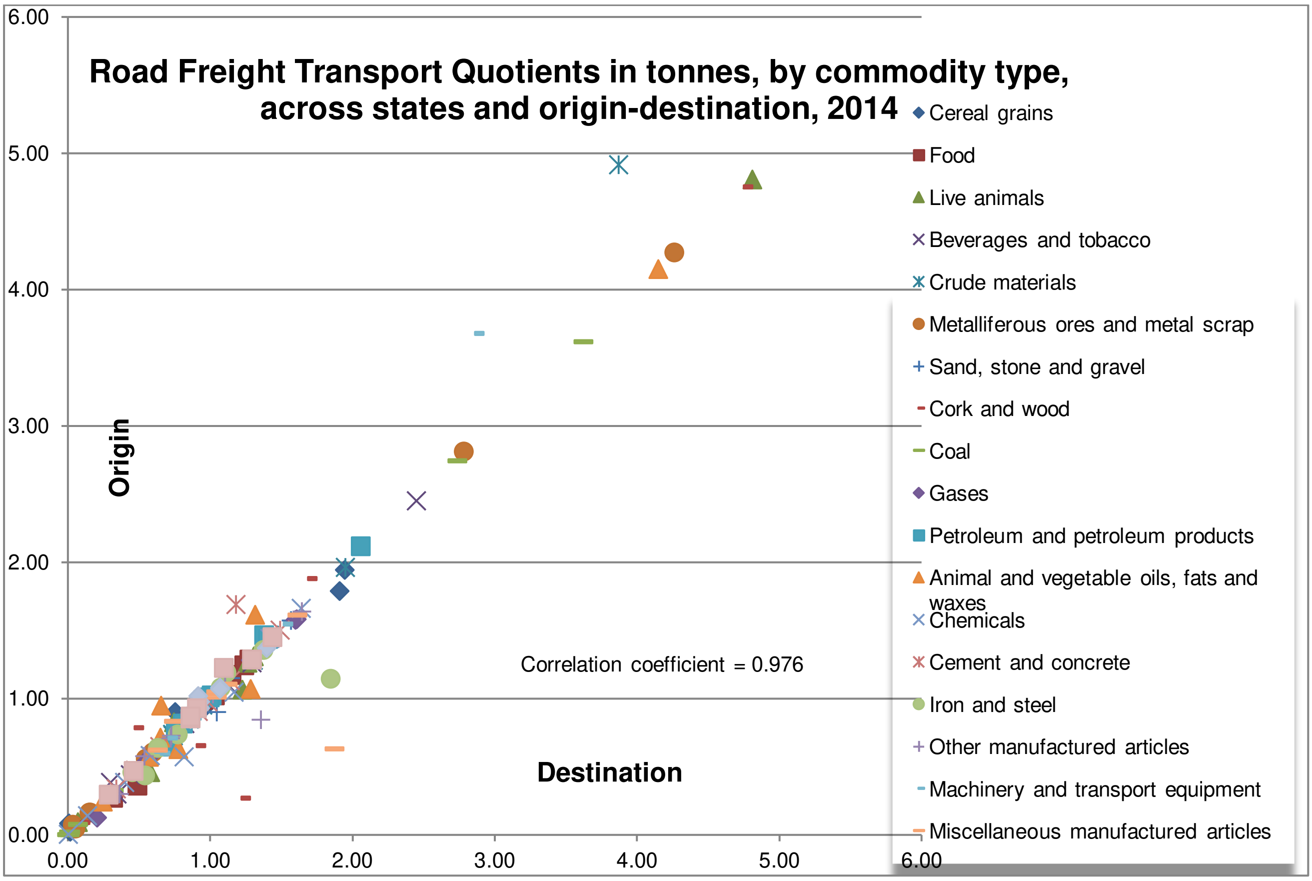
5 Results

Road freight transport quotients estimated in terms of tonnes and tonne-km are set out in detail in Appendices (Tables A.1 and A.2 respectively), and summarised in Figures 3 and 4 below. Estimates of the 'outward-orientation' derived from these quotients are likewise contained in Tables B.1 and B.2, and presented in Figures 5 and 6 of this paper. Estimates derived from results with an RSE of 25-50% (to be treated with caution) are identified by yellow shading in the tables, while those with an RSE >50% (too unreliable for general use) are indicated by red shading.

5.1 Road freight transport quotients in tonnes and tonne-km

Figures 3 and 4 show an important difference in the relative size of origins and destinations when measured in tonnes versus tonne-km. In terms of tonnes, Figure 3 shows the variation in origin-destination as relatively small, with the values following an almost 45 degree angle and a correlation coefficient of 0.976. However when viewed in tonne-km in Figure 4, the data is more spread out as distance becomes more varied across states, hence a correlation coefficient of 0.865.

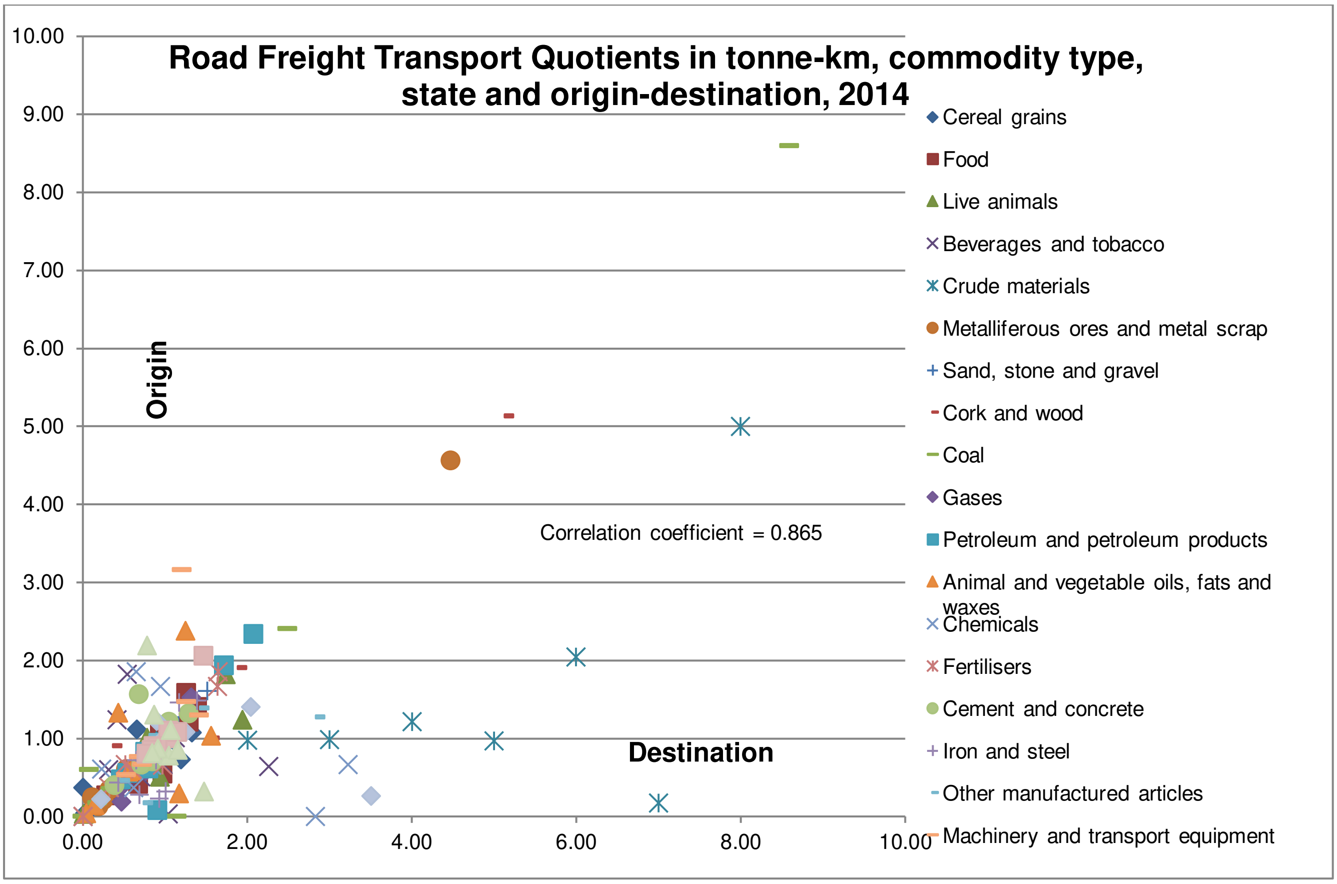
The Road Freight Transport quotients in Tables A.1 and A.2 calculated for tonnes and tonne-km by commodity type, state and origin-destination show the prevalence of various commodities in certain states, as well as origin and destination. Some states show strong origin and destination quotients in certain commodities, e.g. a major source of coal is NSW with a road freight quotient of 3.63 indicating its importance as a freight type on that state's roads, while others, e.g. Victoria with a coal quotient of 0.02, are relatively minor in the transportation of these commodities by road, as are major coal-producing states such as Queensland where power stations would be located close to coal mines. Another notable example would be that of chemicals, where NSW shows road freight origin-destination quotients of 0.4 while Victoria, Queensland and South Australia all have quotients greater than 1 for this commodity type.



Source: Own calculation using Road Freight Movements survey data from ABS (2015)

Figure 3: Road freight transport quotients tonnes, by commodity type, 2014

Substantial variation also occurs between states in tonne-km, as in the case of metalliferous ores in NSW, Victoria, Queensland and SA (all showing road freight quotients of less than 0.3), versus that of WA which showed a quotient of 4.5. Another example would be that of cork and wood products in Tasmania (road freight quotient of 5.13) or metalliferous ores in WA (road freight quotient of 4.5). Differences in road freight tonne-km quotients between origin-destination can be observed in the case of cereal grains in NSW (1.12-0.65), cork and wood in SA (0.91-0.37), chemicals in NT (0.52-2.82) and animal and vegetable oils, fats & waxes in Victoria (0.29-1.17).



Source: Own calculation using Road Freight Movements survey data from ABS (2015)

Figure 4: Road freight transport quotients in tonne-km, by state and commodity type, 2014

Table 3 shows the correlation of origin and destination for road freight quotients measured in tonnes and tonne-km in each state for all commodity types. As might be expected due to the variation in distances involved, the correlations of origins and destinations are higher in all states when measured in tonnes than in tonne-km (except the states of Tasmania and WA which are relatively isolated or self-contained). The largest variation in tonne versus tonne-km quotients occurs in states which need to 'import' or 'export' substantial amounts of material or products interstate due to the characteristics of their economies, e.g. South Australia, Northern Territory and ACT.

Table 3: Correlation coefficients for road freight transport quotients in terms of origin-destination, by state, tonnes and tonne-km, 2014

State	Tonnes	Tonne-km
New South Wales	0.986	0.808
Victoria	0.987	0.909
Queensland	0.995	0.885
South Australia	0.979	0.747
Western Australia	1.000	0.999
Tasmania	1.000	1.000
Northern Territory	0.996	0.699
ACT	0.916	0.491

Source: Own calculation using Road Freight Movements survey data from ABS (2015)

Similarly, when measured for each commodity type across all states in Table 4, the correlations of quotients for origins and destinations are higher overall when measured in tonnes than those measured in tonne-km. Substantial variations in quotients occur when measured in tonnes and tonne-km which gives important clues as to which commodity types feature in interregional freight flows, e.g. animal and vegetable oils, fats and waxes, chemicals, cement and concrete, as well as iron and steel and other manufactures.

Table 4: Correlation coefficients for road freight transport quotients in terms of origin-destination, by commodity type, tonnes and tonne-km, 2014

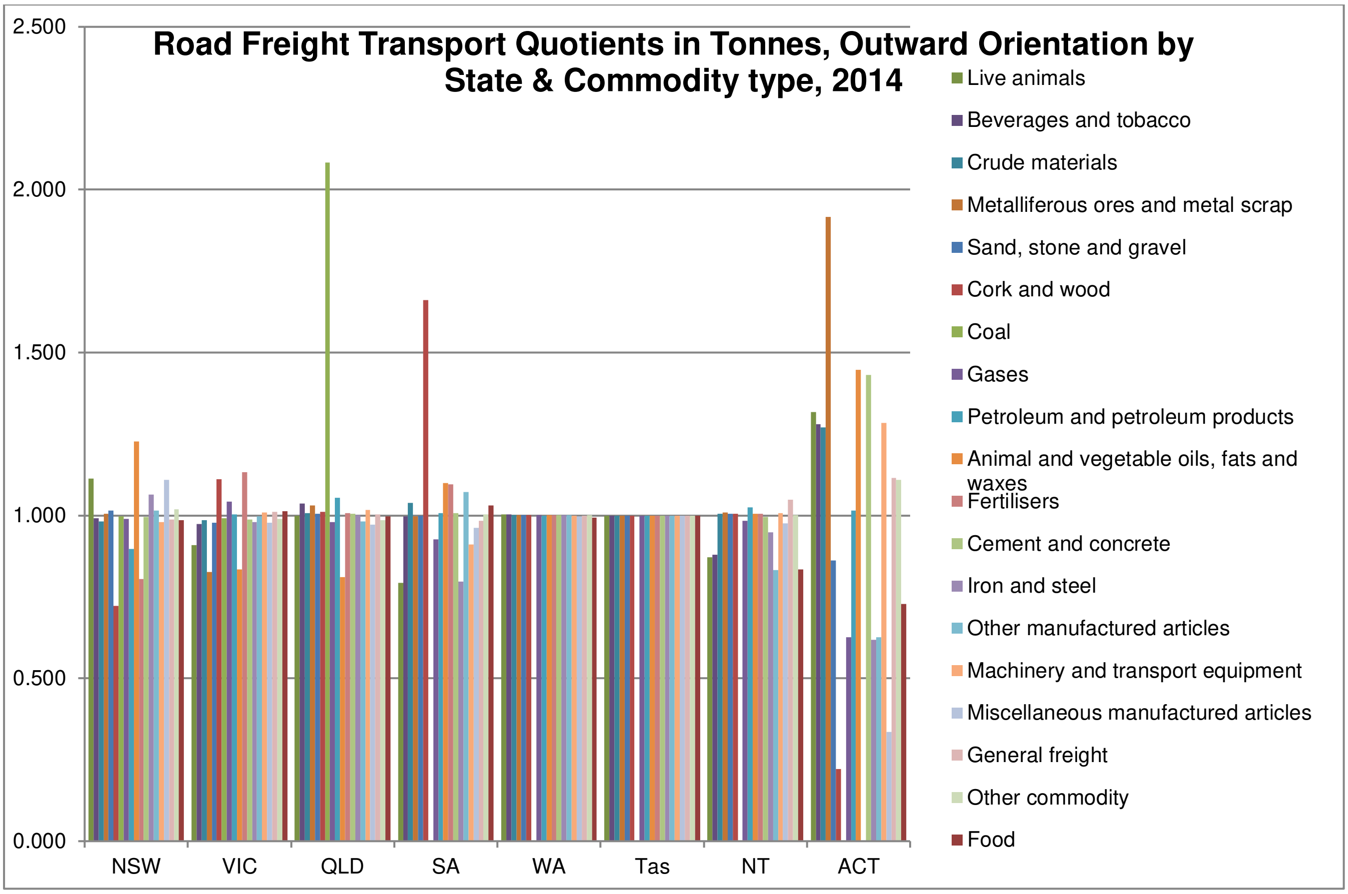
Commodity type	Tonnes	Tonne-km
Cereal grains	0.994	0.859
Food	0.995	0.892
Live animals	0.999	0.875
Beverages and tobacco	0.998	0.921
Crude materials	0.995	0.821
Metalliferous ores and metal scrap	1.000	0.996
Sand, stone and gravel	0.981	0.992
Cork and wood	0.968	0.981
Coal	1.000	0.821
Gases	0.999	0.972
Petroleum and petroleum products	0.998	0.914
Animal and vegetable oils, fats and waxes	0.989	0.541
Chemicals	0.988	0.690
Fertilisers	0.982	0.976
Tools of trade	0.986	0.992
Cement and concrete	0.932	0.590
Iron and steel	0.856	0.684
Other manufactured articles	0.908	0.611
Machinery and transport equipment	0.995	0.620
Miscellaneous manufactured articles	0.292	-0.130
General freight	0.974	0.935
Other commodity	0.994	0.990

Source: Own calculation using Road Freight Movements survey data from ABS (2015)

5.2 Use of road freight transport quotients to determine outward orientation

The variation in origin-destination volumes is shown in the 'outward orientation' metric (see Tables B.1 and B.2) which is calculated by dividing each origin quotient by the destination quotient for each commodity type and state. A factor of <1 indicates that origin < destination volumes, i.e. the state is more of a destination than an origin for freight flows of that commodity; a factor of >1 indicates that origin > destination for freight flows of that commodity.

Figures 5 and 6 provide these results in terms of tonnes and tonne-km respectively.

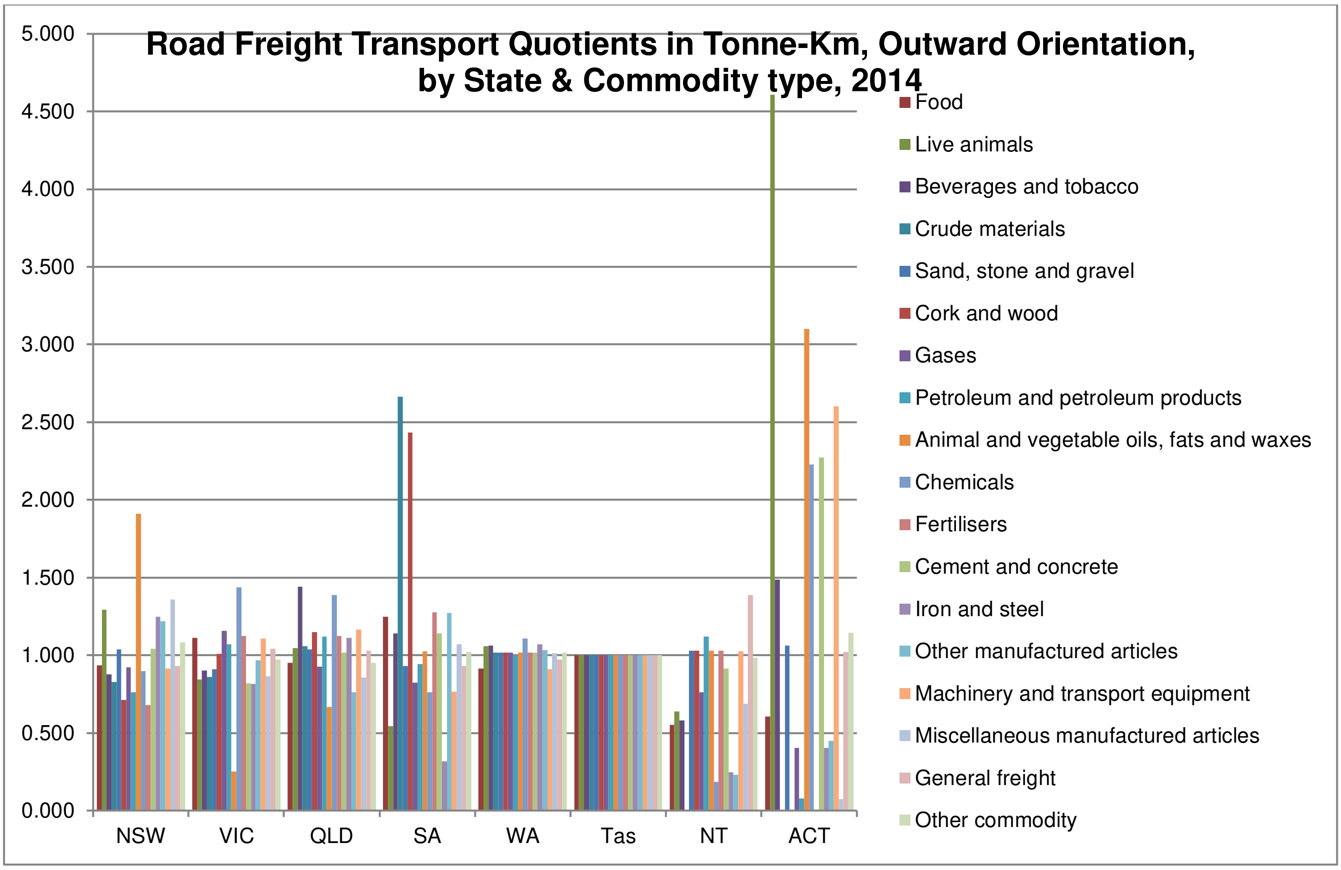


Source: Own calculation using Road Freight Movements survey data from ABS (2015)

Figure 5: Road freight transport quotients in tonnes, Outward Orientation by state and commodity type, 2014

Figure 5 (summarising the results in Table B.1) shows that Queensland stands out because of its outward orientation in coal tonnage, South Australia as a generator of cork and wood volumes and NSW in live animals and animal and vegetable fats. The ACT shows a range of outward and inward movements across a range of commodities when measured in tonnes and tonne-km[5]. Moreover when measured in tonne-km, results in Figure 6 (summarising the results in Table B.2) exhibit greater variation in outward and inward orientation across a range of commodities in most states. South Australia shows outward orientation for crude materials and cork and wood, NSW for animal and vegetable oils and Queensland for beverages and tobacco; Northern Territory is heavily reliant on inward flows of most commodities.

[5] Noting, however, sampling variability in the survey results for ACT and other states in terms of RSE.



Source: Own calculation using Road Freight Movements survey data from ABS (2015)

Figure 6: Road freight transport quotients in tonne-km, Outward Orientation by state and commodity type, 2014

6 Conclusions

While taking account of the questions regarding the reliability of some of the survey results in terms of RSE, road freight transport quotients nevertheless indicate the direction and relative magnitude of interregional road freight flows (and estimated truck volumes if extended to this) within and between states via origin-destination (direction of movement), tonnes, tonne-km and commodity type. This is a critical input for commonwealth and state road authorities' road network management, as well as assisting in the allocation of funds for road investment across states. The measure of outward orientation also indicates the relative magnitude of origin-destination (outward-inward movement) for each state and commodity type. As location quotients, they also indicate the extent to which the state is over-or underrepresented in directional freight flows in that commodity type and could be used to augment location quotients based on population or employment data. In this way, they could also help in determining the *economic base* of the various states and identify which sectors could be targeted for investment to enhance consumption and processing of output within the state. Moreover, improvements in the reliability of some of the results in terms of the RSE in future surveys will enhance the credibility of the results and the road freight quotients; it could also result in a revised set of quotients that differ from those presented in this paper. Reliability of the data is all the more important given that the scale of the survey and the expense involved means that it can only be undertaken periodically.

7 Further research

The following possibilities for further research in the use of road freight transport quotients were identified:

- Development of a national and state level Freight Flow Atlas for Australia based on location quotients, initially at a state-level, similar to the National Freight Economy Atlas developed for the U.S. by the University of Minnesota. This could include Road Freight Flows and Rail Freight Flows and would be an important input to the analysis of freight demand and mode choice
- Research ways of improving the reliability of road freight data, especially for the commodity types identified in the Road Freight Movements survey 2014 as having an RSE >50%
- Undertake an *economic base* analysis to indicate which states are more outward-orientated and therefore which sectors / industry types might be targeted for investment. This could be compared to conventional analysis using location quotients derived from population, sectoral employment or output data
- Commodity type data provides a basis for the estimation of future interregional freight flows using available industry / economic sectoral data and projections, possibly linked to a regional economic model.

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Appendices

Table A.1: Road Freight Transport Quotient: Tonnes by Commodity (2014)

	NSW		Vic.		Qld.		SA		WA		Tas.		NT		ACT	
	Origin	Dest.	Origin	Dest.	Origin	Dest.	Origin	Dest.	Origin	Dest	Origin	Dest	Origin	Dest	Origin	Dest
Cereal grains	0.90	0.75	0.93	0.96	0.37	0.49	1.79	1.91	1.95	1.95	0.08	0.08	0.08	0.01	0.03	0.02
Food	1.02	1.04	1.17	1.15	1.24	1.24	0.99	0.96	0.47	0.47	1.28	1.28	0.27	0.32	0.36	0.49
Live animals	0.83	0.74	0.47	0.51	1.26	1.26	0.46	0.58	1.31	1.31	4.81	4.81	1.07	1.22	0.09	0.07
Total Food & live animals	0.97	0.93	1.03	1.03	0.99	1.02	1.17	1.20	0.99	0.99	1.26	1.26	0.29	0.32	0.24	0.31
Beverages and tobacco	1.11	1.12	1.26	1.30	1.01	0.97	0.82	0.82	0.44	0.44	2.45	2.45	0.30	0.35	0.39	0.30
Crude materials	0.73	0.74	1.28	1.30	0.96	0.95	1.47	1.41	0.74	0.74	0.85	0.85	1.96	1.95	4.92	3.87
Metalliferous ores & metal scrap	0.55	0.55	0.05	0.06	0.16	0.16	0.16	0.16	4.27	4.27	0.60	0.60	2.81	2.79	0.07	0.04
Sand, stone and gravel	1.10	1.08	0.78	0.80	1.15	1.15	1.00	1.00	0.94	0.94	0.70	0.70	1.58	1.57	0.90	1.05
Cork and wood	0.65	0.91	1.88	1.69	0.56	0.56	0.78	0.47	0.61	0.61	4.75	4.75	0.09	0.09	0.27	1.22
Total Crude materials, excl. fuels	0.96	0.97	0.82	0.81	0.95	0.94	0.90	0.87	1.35	1.35	1.05	1.05	1.64	1.63	1.04	1.14
Coal	3.62	3.63	0.02	0.02	0.02	0.01	0.00	0.02	0.08	0.08	2.74	2.74	0.33	0.32	0.00	0.00
Gases	1.58	1.60	0.87	0.84	0.53	0.54	0.30	0.33	1.28	1.28	0.59	0.59	1.58	1.61	0.13	0.20
Petroleum and petroleum products	0.64	0.72	1.02	1.02	1.46	1.39	1.01	1.00	0.81	0.81	0.76	0.76	2.11	2.06	1.43	1.41
Total mineral fuels, lubricants & related materials	1.76	1.81	0.66	0.66	0.87	0.83	0.59	0.60	0.61	0.61	1.43	1.43	1.45	1.42	0.81	0.81
Animal and vegetable oils, fats and waxes	1.62	1.32	1.07	1.28	0.63	0.78	0.72	0.65	0.24	0.24	4.15	4.15	0.57	0.57	0.95	0.66
Chemicals	0.39	0.40	1.67	1.64	1.44	1.42	1.05	1.17	0.58	0.58	0.14	0.14	0.57	0.82	0.00	0.00
Fertilisers	0.85	1.06	1.50	1.33	0.48	0.48	1.35	1.24	1.21	1.21	0.96	0.96	0.02	0.02	0.00	0.00
Total chemicals & related products	0.59	0.68	1.60	1.51	1.03	1.02	1.18	1.20	0.85	0.85	0.49	0.49	0.34	0.48	0.00	0.00
Tools of Trade	1.30	1.30	0.85	0.85	1.07	1.06	1.05	1.07	0.61	0.61	0.97	0.97	1.37	1.34	1.98	1.69
Cement and concrete	1.14	1.14	0.91	0.92	1.50	1.49	0.65	0.65	0.47	0.47	0.34	0.34	0.98	0.98	1.69	1.18
Iron and steel	1.19	1.12	1.35	1.38	0.64	0.64	0.43	0.55	1.08	1.08	0.46	0.46	0.74	0.78	1.14	1.85
Other manufactured articles	1.03	1.02	1.64	1.64	0.71	0.72	0.58	0.54	0.73	0.73	1.10	1.10	0.30	0.36	0.85	1.36
Total manufactured goods classified by materials	1.11	1.09	1.21	1.23	1.12	1.12	0.60	0.60	0.64	0.63	0.62	0.62	0.71	0.74	1.33	1.32
Machinery and transport equipment	0.86	0.88	0.93	0.92	1.54	1.52	0.60	0.66	0.71	0.71	0.61	0.61	1.08	1.08	3.68	2.86
Miscellaneous manufactured articles	0.83	0.75	1.10	1.13	0.62	0.64	1.01	1.05	1.61	1.62	1.05	1.05	1.02	1.04	0.63	1.88
General freight	0.85	0.86	1.08	1.07	1.07	1.07	1.37	1.40	0.87	0.87	0.93	0.93	0.98	0.93	1.02	0.92
Other commodity	0.93	0.91	1.28	1.30	0.85	0.87	1.45	1.44	0.87	0.87	0.47	0.47	0.29	0.29	1.22	1.10
Total Commodities and transactions	0.88	0.88	1.16	1.16	0.98	0.99	1.40	1.42	0.87	0.87	0.74	0.74	0.70	0.67	1.10	0.99

Source: Own calculation using Road Freight Movements survey data from ABS (2015)

Table A.2: Road Freight Transport Quotient: Tonne-km by Commodity (2014)

	NSW		Vic.		Qld.		SA		WA		Tas.		NT		ACT	
	Origin	Dest.	Origin	Dest.	Origin	Dest.	Origin	Dest.	Origin	Dest	Origin	Dest	Origin	Dest	Origin	Dest.
Cereal grains	1.12	0.65	1.18	1.21	0.73	1.19	1.07	1.32	1.11	1.10	0.10	0.10	0.37	0.00	0.04	0.03
Food	1.21	1.29	1.05	0.94	1.12	1.18	1.58	1.27	0.26	0.29	1.39	1.39	0.54	0.98	0.41	0.68
Live animals	1.01	0.78	0.64	0.76	1.82	1.74	0.51	0.93	0.60	0.57	0.67	0.67	1.24	1.94	0.03	0.01
Total Food & live animals	1.16	1.07	1.03	0.99	1.11	1.25	1.32	1.24	0.51	0.52	0.99	0.99	0.58	0.85	0.27	0.44
Beverages and tobacco	0.98	1.12	2.03	2.26	0.78	0.54	0.80	0.70	0.33	0.31	0.98	0.98	0.24	0.42	1.54	1.04
Crude materials	0.97	1.17	0.97	1.13	0.98	0.93	1.21	0.45	0.96	0.95	2.04	2.04	0.17	0.17	5.00	2.26
Metalliferous ores & metal scrap	0.21	0.26	0.13	0.19	0.24	0.12	0.19	0.22	4.56	4.48	0.37	0.37	0.60	0.53	0.33	0.01
Sand, stone and gravel	1.13	1.08	0.75	0.82	1.07	1.03	0.88	0.94	1.03	1.01	1.16	1.16	1.17	1.14	1.61	1.51
Cork and wood	0.77	1.07	1.90	1.89	0.61	0.53	0.91	0.37	0.64	0.63	5.13	5.13	0.01	0.01	1.00	1.55
Total Crude materials, excl. Fuels	0.80	0.86	0.78	0.84	0.76	0.69	0.72	0.61	1.93	1.90	1.65	1.65	0.74	0.71	1.45	1.17
Coal	2.40	2.49	0.17	0.18	0.60	0.08	0.00	1.14	0.35	0.35	8.60	8.60	0.46	0.45	0.00	0.00
Gases	0.93	1.01	1.53	1.32	0.87	0.94	0.40	0.49	1.07	1.05	0.54	0.54	0.58	0.76	0.19	0.47
Petroleum and petroleum products	0.61	0.80	0.82	0.77	1.93	1.72	0.85	0.91	0.55	0.55	0.47	0.47	2.33	2.08	0.07	0.91
Total mineral fuels, lubricants & related materials	0.84	1.01	0.84	0.77	1.65	1.45	0.71	0.88	0.59	0.59	1.35	1.35	1.91	1.74	0.08	0.76
Animal and vegetable oils, fats and waxes	2.38	1.25	0.29	1.17	1.04	1.56	0.57	0.56	0.14	0.14	0.59	0.59	0.04	0.04	1.33	0.43
Chemicals	0.75	0.83	0.93	0.65	0.85	0.61	2.46	3.22	1.05	0.95	0.23	0.23	0.52	2.82	0.00	0.00
Fertilisers	0.66	0.97	1.85	1.65	0.37	0.32	0.66	0.52	1.67	1.64	0.60	0.60	0.00	0.00	0.00	0.00
Total chemicals & related products	0.69	0.91	1.48	1.24	0.57	0.44	1.40	1.62	1.42	1.36	0.45	0.45	0.21	1.16	0.00	0.00
Tools of Trade	0.24	0.23	0.20	0.19	0.27	0.27	0.07	0.08	0.15	0.17	0.02	0.02	0.05	0.03	0.02	0.02
Cement and concrete	1.10	1.05	0.70	0.85	1.32	1.29	1.21	1.06	0.79	0.77	0.39	0.39	0.66	0.72	1.56	0.69
Iron and steel	1.46	1.17	0.72	0.89	0.72	0.65	0.32	1.01	1.48	1.39	0.43	0.43	0.23	0.93	0.28	0.69
Other manufactured articles	1.19	0.98	1.38	1.43	0.73	0.96	1.03	0.81	0.77	0.75	0.46	0.46	0.17	0.74	1.27	2.84
Total manufactured goods classified by materials	1.23	1.04	1.05	1.15	0.89	0.98	0.92	0.92	0.93	0.90	0.43	0.43	0.32	0.78	1.13	1.76
Machinery and transport equipment	0.67	0.73	0.76	0.69	1.47	1.27	0.77	1.00	1.29	1.42	0.53	0.53	0.86	0.84	3.16	1.21
Miscellaneous manufactured articles	1.22	0.90	1.08	1.25	0.80	0.93	0.88	0.82	0.93	0.92	0.22	0.22	1.40	2.04	0.26	3.51
General freight	1.00	1.07	1.09	1.04	0.89	0.87	1.07	1.15	0.89	0.91	0.84	0.84	2.05	1.48	0.79	0.78
Other commodity	1.10	1.02	0.78	0.80	1.31	1.37	0.85	0.84	0.87	0.86	0.81	0.81	0.32	0.33	2.19	1.92
Total Commodities and transactions	1.02	1.06	1.03	1.00	0.97	0.97	1.03	1.09	0.89	0.90	0.84	0.84	1.71	1.25	1.07	1.00

Source: Own calculation using Road Freight Movements survey data from ABS (2015)

Table B.1: Tonnes by commodity (2014): Outward orientation

	NSW	Vic.	Qld.	SA	WA	Tas.	NT	ACT
Cereal grains	1.201	0.971	0.766	0.938	1.000	1.000	12.636	1.529
Food	0.985	1.013	0.998	1.031	0.993	1.000	0.834	0.727
Live animals	1.113	0.909	0.999	0.793	1.002	1.000	0.872	1.317
Total Food & live animals	1.047	0.997	0.965	0.976	0.999	1.000	0.923	0.753
Beverages and tobacco	0.991	0.974	1.037	0.997	1.004	1.000	0.879	1.281
Crude materials	0.982	0.985	1.006	1.039	1.001	1.000	1.005	1.270
Metalliferous ores & metal scrap	1.005	0.827	1.031	0.998	1.001	1.000	1.009	1.917
Sand, stone and gravel	1.014	0.977	1.005	1.000	1.001	1.000	1.005	0.862
Cork and wood	0.722	1.112	1.012	1.661	1.001	1.000	1.005	0.221
Total Crude materials, excl. Fuels	0.988	1.001	1.006	1.036	1.001	1.000	1.006	0.912
Coal	0.998	0.992	2.083	0.000	1.001	1.000	1.005	0.000
Gases	0.990	1.043	0.979	0.927	1.001	1.000	0.983	0.626
Petroleum and petroleum products	0.898	1.004	1.054	1.006	1.000	1.000	1.024	1.015
Total mineral fuels, lubricants & related materials	0.975	1.009	1.054	0.991	1.000	1.000	1.018	1.005
Animal and vegetable oils, fats and waxes	1.227	0.833	0.811	1.099	1.001	1.000	1.005	1.448
Chemicals	0.971	1.015	1.016	0.899	1.012	1.000	0.701	1.274
Fertilisers	0.805	1.132	1.008	1.095	1.001	1.000	1.005	0.000
Total chemicals & related products	0.861	1.059	1.014	0.985	1.005	1.000	0.707	1.274
Tools of Trade	1.002	0.997	1.005	0.976	0.999	1.000	1.024	1.169
Cement and concrete	0.996	0.987	1.006	1.006	1.001	1.000	0.996	1.432
Iron and steel	1.065	0.980	1.001	0.797	1.001	1.000	0.948	0.618
Other manufactured articles	1.014	0.997	0.982	1.073	1.001	1.000	0.833	0.626
Total manufactured goods classified by materials	1.010	0.991	1.000	1.004	1.001	1.000	0.962	1.008
Machinery and transport equipment	0.979	1.010	1.018	0.912	0.999	1.000	1.007	1.285
Miscellaneous manufactured articles	1.109	0.978	0.972	0.961	0.997	1.000	0.976	0.336
General freight	0.987	1.011	1.002	0.983	0.999	1.000	1.049	1.114
Other commodity	1.018	0.989	0.986	1.004	1.001	1.000	1.001	1.108
Total Commodities and transactions	1.000	1.001	0.996	0.992	0.999	1.000	1.040	1.112

Source: Own calculation using Road Freight Movements survey data from ABS (2015)

Table B.2: Tonne-km by commodity (2014): Outward orientation

	NSW	Vic.	Qld.	SA	WA	Tas.	NT	ACT
Cereal grains	1.705	0.971	0.615	0.810	1.008	1.000	1186.331	1.552
Food	0.933	1.111	0.950	1.246	0.914	1.000	0.552	0.605
Live animals	1.293	0.842	1.046	0.542	1.057	1.000	0.638	4.608
Total Food & live animals	1.082	1.043	0.888	1.066	0.982	1.000	0.682	0.627
Beverages and tobacco	0.877	0.900	1.440	1.139	1.061	1.000	0.582	1.486
Crude materials	0.826	0.861	1.058	2.664	1.018	1.000	1.028	2.210
Metalliferous ores & metal scrap	0.790	0.652	1.975	0.861	1.018	1.000	1.129	61.591
Sand, stone and gravel	1.039	0.911	1.038	0.932	1.018	1.000	1.028	1.064
Cork and wood	0.714	1.009	1.147	2.433	1.018	1.000	1.028	0.644
Total Crude materials, excl. Fuels	0.930	0.924	1.098	1.178	1.018	1.000	1.049	1.242
Coal	0.965	0.951	7.330	0.000	1.018	1.000	1.028	0.000
Gases	0.922	1.158	0.926	0.823	1.018	1.000	0.762	0.405
Petroleum and petroleum products	0.761	1.069	1.121	0.941	1.000	1.000	1.118	0.078
Total mineral fuels, lubricants & related materials	0.835	1.085	1.143	0.802	1.005	1.000	1.096	0.103
Animal and vegetable oils, fats and waxes	1.909	0.249	0.665	1.025	1.018	1.000	1.028	3.101
Chemicals	0.898	1.438	1.389	0.762	1.108	1.000	0.185	2.229
Fertilisers	0.680	1.126	1.126	1.276	1.018	1.000	1.028	0.000
Total chemicals & related products	0.761	1.192	1.275	0.859	1.043	1.000	0.185	2.229
Tools of Trade	1.049	1.053	0.983	0.824	0.902	1.000	1.690	0.714
Cement and concrete	1.043	0.819	1.018	1.142	1.018	1.000	0.915	2.274
Iron and steel	1.248	0.816	1.112	0.315	1.070	1.000	0.246	0.404
Other manufactured articles	1.218	0.966	0.760	1.272	1.032	1.000	0.228	0.447
Total manufactured goods classified by materials	1.176	0.910	0.906	0.997	1.041	1.000	0.410	0.642
Machinery and transport equipment	0.914	1.108	1.163	0.767	0.912	1.000	1.025	2.604
Miscellaneous manufactured articles	1.361	0.863	0.856	1.072	1.013	1.000	0.686	0.074
General freight	0.931	1.044	1.028	0.931	0.973	1.000	1.388	1.022
Other commodity	1.084	0.972	0.952	1.022	1.018	1.000	0.985	1.146
Total Commodities and transactions	0.959	1.033	1.007	0.944	0.981	1.000	1.367	1.068

Source: Own calculation using Road Freight Movements survey data from ABS (2015)