Journal of Air Transport Management xxx (2016) 1–12

Contents lists available at ScienceDirect

Journal of Air Transport Management

journal homepage: www.elsevier.com/locate/jairtraman

Challenges to domestic air freight in Australia: Evaluating air traffic markets with gravity modelling

David W. Alexander, Rico Merkert*

Institute of Transport and Logistics Studies, The University of Sydney Business School, NSW 2006, Sydney, Australia

ARTICLE INFO

Article history:
Received 11 January 2016
Received in revised form
20 November 2016
Accepted 20 November 2016
Available online xxx

Keywords:
Air transport demand management
Air cargo
Gravity models

ABSTRACT

With two of the busiest air traffic corridors globally, Sydney-Melbourne (SYD-MEL) and Sydney-Brisbane (SYD-BNE), very liberal open skies agreements, and the world's most isolated large city in Perth, air freight in Australia should be destined for substantial growth, but has in contrast to other regions such as the US not yet materialised. This paper identifies challenges surrounding domestic air freight markets in Australia and compares the provision of road vs air freight services utilising gravity modelling methods. Our findings suggest the impedance of domestic air freight services in Australia is greater for regional areas between the primary cities (such as Canberra, between Sydney and Melbourne) than remoter areas (such as Cairns in Northern Australia). Our models show further that in addition to distance, air freight capacity on any of our analysed routes is despite being demand-pulled in terms of GDP dependency significantly attuned to factors at both the origin (in particular domestic trade capability, i.e. manufacturing and logistics) and destination.

1. Introduction

With the 6th largest landmass by country, after Russia, Canada, The United States, China and Brazil, the logistical challenges of the transport industry in Australia are notably considerable. With a GDP of $1.3 trillion (World Bank, 2015) generated by a population of just 23 million residents, primarily concentrated on the Eastern Seaboard (with 80% of the population; including the three largest cities of Sydney, Melbourne and Brisbane), domestic freight activity accounts for almost 600 billion tonne-kilometres (btkm) across road, rail, maritime and aviation modes (BITRE, 2014a). This represents an average of 26,000 freight tonne-km/capita, roughly comparable to the US (at 28,000 freight tonne-km/capita). The extensive road, rail, coastal shipping and regional aviation networks from Perth to Adelaide and the Eastern Seaboard, acts in coopetition across a combination of long-haul and short-haul services, including multi-modal activities (rail-road, sea-road, sea-rail, air-road and other combinations).

In total world air freight (both domestic and international) accounts for 188 btkm of all trade (World Bank, 2015a), whilst carrying almost 35% of the $18.3 trillion in global merchandise trade (WTO, 2014). International air freight (including intra-EU) accounts for 87% of all air freight traffic movements (IATA, 2016). Table 1 provides an overview of air freight statistics within significantly large regions. Indonesia (consisting of the world's largest island system) maintains the highest domestic air freight market proportion at 57.4%, with flights scheduled between Jakarta and nearby islands. Large, populated regions such as the US (49.5%), Russia (36.4%), Brazil (36.3%), China (33.8%) and India (30.8%) manage substantial domestic air freight markets. European domestic air freight statistics (sourced from Eurostat, 2014 and IATA) are based on internal country movements for large nations such as Germany or France and include air freight shipped by truck, however excludes intra-EU traffic under the Single European Sky agreement.

Compared to Australia, Canada, with similar geographic, population and economic indicators, also maintains a more sizeable domestic air freight component (28.8%). Of the sample, only Mexico (at 14.1%) has a similar proportion of domestic air freight volumes to Australia (at 15.8%). Factors contributing to the subdued Australian domestic air freight market include a limited number of large urban centres, with significant population aggregation on the east coast; extensive road, rail and shipping networks (with the nation's "girt by sea" status); a combination of service and capacity utilisation challenges and a limited manufacturing base of premium and/or heterogeneous products. The objective of this paper is to investigate and discuss the challenges of domestic air freight in

* Corresponding author.
E-mail address: rico.merkert@sydney.edu.au (R. Merkert).

http://dx.doi.org/10.1016/j.jairtraman.2016.11.008
0969-6997/

Table 1
Air transport statistics for large regions in 2015.

Country	Land mass (million km^2)	Population (million est, 2015)	GDP (US$b, 2015)	Total air freight (btkm)	Domestic airfreight (btkm)
Russia	16.38	144.10	1326.02	14.84	5.40
Europe (total)	10.18	742.50	22,804	41.92	7.52
China	9.39	1371.22	10,866.44	19.81	6.70
United States	9.15	321.42	17,947	37.22	18.44
Canada	9.09	35.85	1550.54	2.08	0.60
Brazil	8.36	207.85	1774.72	1.49	0.54
Australia	7.68	23.78	1339.54	1.89	0.30
India	2.97	1311.05	2073.54	1.83	0.56
Mexico	1.94	127.02	1144.33	0.71	0.10
Indonesia	1.81	257.56	861.93	0.75	0.43

Source: WorldBank, IATA, BTS (2015), Eurostat (2014), NATS (2016) and several national air transport departments.

Australia. We aim to provide evidence on why domestic air freight in Australia has continued to stall (which is in stark contrast to other markets such as the U.S. or Asia/Pacific) and revealing important determinants of air freight that can be used for demand analysis globally. Section 2 reviews the literature on the methodology to be used for the trade flow analysis, the gravity model, as applied to the research field of air transport. Section 3 provides a contextual overview of the Australian domestic air freight market. Section 4 then details the data used for the analysis and methodology of the gravity model, with discussion of the investigation forming Section 5. Section 6 provides a summary of the findings and some conclusive thoughts.

2. Literature on gravity modelling in aviation

Gravity models, a form of spatial interactive model, were originally derived from the physic based principle of the same name. The law of retail gravitation, developed by Reilly in 1931 was the first instance of this model used in economic literature, and has been followed by the gravity model of international trade initially utilised in 1962 (Anderson and van Wincoop, 2003). As trade is facilitated by transport networks (aviation, maritime, rail and road), gravity models have thus been strongly applied within the field of transport economics research. At the core of the gravity model is two masses (populations or economies) separated by an impediment (such as distance). The traditional form of the gravity model (Head, 2003*)* follows the form:

$$F_{ij} = GM_i^{\alpha} M_j^{\beta} d_{ij}^{\theta} \tag{1}$$

Where F_{ij} represents the interaction between two independent regions, i and j, G a constant, M represents size of the population or economy (GDP) of both regions, D represents the distance between the two independent regions and α, β and θ represent factorial components, positive for attraction and negative for impedance. Economic activity between two regions is a composite of both product volume and variety, driven by population and consumer income. Market competition can have a beneficial effect to air transport, through shorter lead times of new high value products to drive sales (the new iPhone); and also a negative impact, as companies seek to drive down costs, including transport. El-Sayad (2012) suggests that as economies double, consumerism is driven by product variety (i.e. increasing heterogeneity) rather than simply volume of goods. Additionally, Cheong et al. (2014) researched the distance impacts on trade and found that a negative relationship existed for product variety as distance increased. Distance, as impedance, has long been established within gravity modelling approaches, with terms such as “distance decay”. Disdier and Head (2008) performed a meta-analysis on gravity models and the impact of distance, finding average elasticity estimates of −0.9 (a 10% increase in distance reduced trade by 9%), although this value ranged from −0.28 to −1.55.

The application of the gravity model in the transport industry is inherent, as road, rail, maritime and aviation modes represent the physical activity of trade flow between regions, with key determinants including population, GDP, GDP/capita, distance, supply and demand of product as well as time/cost/quality service conditions. Modal choice factors are represented within an augmented gravity model formulation. Sjafruddin et al. (1999) provided a modal split approach to regional traffic in the Java islands citing an expanded gravity model formulation from Mathematica Inc (1967–69; quoted by Kanafani, 1983). This formulation incorporates shipping time and cost parameters, removing distance within the gravity model framework:

$$F_{ijm}=KP_i^{\alpha 1}P_j^{\alpha 2}Y_i^{\alpha 3}Y_j^{\alpha 4}M_j^{\alpha 5}M_j^{\alpha 6}N_{ij}^{\alpha 7}\left(T_{ijb}\right)^{\beta 1}\left(T_{ijm}^{r}\right)^{\beta 2}\left(C_{ijb}\right)^{\gamma 1}\left(C_{ijm}^{r}\right)^{\gamma 2} \tag{2}$$

With F representing volume of freight, i and j representing two independent regions, P representing population, Y gross regional product, M industrial activity, N modal activity, T time, C cost, b as the lowest factor, m as the modal attribute. Factors influencing the model are included as K, α, β and γ. While this version incorporates temporal and cost factors, it should be noted that spatial impedance has been removed, due to the potential collinearity with cost factors. Generalised cost functions, combining financial (direct costs) and non-financial factors (time and conversion by value of time estimates), are also considered as part of a gravity modelling formulation. Moreover, transport costs have been considered nonlinear (Lux, 2012; Armstrong and Read, 2014), typically as a result of the operating environment, with fleet utilisation (with back-haul and multi-leg routes), development of economies of scale (including using marginal cost pricing), substitution of services by competition and other factors impacting the nature of service costs to the customer.

Anderson and van Wincoop (2003) proposed an extensively used version of the gravity model with regards to their research on border impacts to trade in North America. Their version of the gravity model follows the derivation:

$$F_{ijt} = Y_{it}Y_{jt}/Y_{wt}\left(N_{ijt}/M_{it}M_{jt}\right)^{1-\sigma} \tag{3}$$

Where i and j represent the regions, w represents the world, Y represents income (GDP or GRP), with relative trade resistance as $N_{ij}M_iM_j$ (where N_{ij} stands for trade cost factor and M_i represents origin incidence with M_j indicating destination incidence) at a particular period t. This model incorporates elasticity of substitution (σ). Gravity models can also be expressed logarithmically, smoothing out volatility of results, with Equation (3) replaced by:

$$LnF_{ijt} = \ln Y_{it} + \ln Y_{jt} - \ln Y_{wt} + (1-\sigma)\ln N_{ijt} - (1-\sigma)\ln M_{it} - (1-\sigma)\ln M_{jt} \quad (4)$$

Versions of gravity trade models have been used in aviation as early as Wood (1970) with research conducted into general aviation within the domestic US market. His research focused on the applicability of gravity models for airport activity around Wisconsin, finding that "the activity of the adjacent area", commonly referred now as the hinterland, and the characteristics of destinations held significant importance to the level of air transport activity. Major institutions such as The World Bank, World Trade Organisation (WTO), Airports Council International (ACI) and IATA have used gravity models in air transport research (such as Piermartini and Rousova, 2008; Arvis and Shepherd, 2011; ACI Europe, 2014).

Matsumoto (2007) used gravity models for air transport flow estimations for passenger and freight traffic at the international level. Part of his study focused on the change over time of key air transport markets. Chi and Baek (2012) examined the US airfreight market to derive income elasticities of airfreight demand, finding a long-run elasticity measure of 9.35 (whilst citing price elasticities of −1.5 to −3), although this study failed to factor in the impacts of the GFC from 2008 to 2010 (which was more detrimental to the airfreight industry than the 9/11 terrorist attacks). Wadud (2014) utilised gravity models to assess passenger and cargo demand in Bangladesh. Part of the conclusions from his research indicated that air cargo price elasticity is higher than that of passenger demand. Thus the marketing and price structure of air freight provided by airlines and freight forwarders can impact cargo volumes (and airline revenues) substantially. Binova (2014) utilised gravity models for transatlantic air transportation, focussing on business numbers within key US markets as a trip generator and highlighted unemployment as an impedance. At the domestic level, gravity trade models have primarily been used for passenger traffic (Fridstrom and Thune-Larsen, 1989; Jamin et al., 2004) and relatively little research has focused on domestic air freight.

Gravity models have also been used to compare transport modes. Lux (2012) utilised the gravity model approach with regards to modal substitution, finding that welfare loss due to the unavailability of trade by air was just 0.8%. Moreover, this finding considered the costs of mode substitution only, and not the far reaching economic impacts from transfer of ownership in inventory (which can also vary based on the INCOTERMs arrangement including FOB, CIF, CFR etc.) and the cash-to-cash cycle which would be noticeably impacted by the loss of the capability of speed provided by air transport. Feyrer (2009) used gravity models to estimate trade flows between air and sea modes to the United States. The study determined the elasticity impacts of air and sea distances over time, with relative cost factors of air freight declining substantially between 1955 and 2004, and he indicated an increasing importance to air traffic. Gadala-Maria (2014) evaluated ocean and air infrastructure impacts to trade utilising gravity models, developing elasticities in regards to trade improvement between both export and import destinations.

Overall we find that studies of gravity models in the domestic air freight context have been limited thus far. Lack of data has often been cited as the issue (BITRE, 2010). In addition most air service arrangements (ASAs), even "open skies" agreements including those with the US, are often heavily regulated in the provision of domestic cabotage services (8th and 9th freedoms of the air). Many countries also have close land-locked borders with international partners, such as in Europe, the US and mainland Asia. The Australian air market is considered one of the most liberal in the world, with the ability of fully (100%) foreign owned airlines to provide domestic air services, albeit under the Australian industrial relations framework and corporation law. In that sense Australia is a useful laboratory for studying determinants of competitive domestic air service provision.

3. Overview and current challenges to the Australian domestic air freight market

The geographical size and nature of Australia, as the world's 6th largest country, with sparse inland communities and densely populated urban areas along the coastlines, naturally provides a background for air transport. However the extensive road and rail network (Fig. 1), short distances between some regional communities from a metropolitan centre and the handling and aggregation time for air, rail and sea freight enhances the opportunity of line-haul operations of trucking companies. The primary advantage of air transport, speed, is noticeably diminished, in particular within the closely nested urban centres (Sydney, Canberra and Melbourne) in the south-east of Australia. For the world's most isolated city with over 1 million population, Perth, air freight transport should provide a competitive advantage over other modes for accessing the rest of Australia, with dedicated freighter and wide-bodied aircraft (with large bellyhold capacity) utilised on key east coast destinations Brisbane, Sydney and Melbourne. Additionally the proximity of Perth, along with Darwin, to SE Asia is potentially more attractive for location of hubbing for import/export activities and leveraging the domestic transport network (including air).

In the financial year 2014–15, domestic air freight tonnage in Australia, including mail, totalled some 184,093 tonnes (BITRE, 2014b). Domestic air freight peaked during the post-Global Financial Crisis (GFC) period in 2010–11, reaching 235,447 tonnes (BITRE, 2014b), however has substantially declined since. As measured by weight, domestic air freight has achieved minimal net overall growth since 1984, despite the implementation of very liberal open skies policies, significant growth in domestic air passenger travel (from 13 m to over 57 m trips annually) and growth in air traffic movements (from 404,947 to 634,590 annually). A positive correlation between GDP and air freight volumes has been expressed numerous times (such as in Boeing, 2015). Since the 2008 GFC, the Australian economy (GDP) has expanded from $926 billion to $1.5 trillion (2012–13), with a more recent contraction to $1.3 trillion (World Bank, 2015). Escalation of demand for domestic air freight may, in addition to other GDP contributors, play an important part to economic growth in Australia in the future and vice versa.

When measured in tonne-km, the growth in Australian domestic air freight, has almost doubled, from 0.16 btkm in 1984 (Bureau of Transport Economics (1987)) to approximately 0.3btkm today, although down from a peak of 0.4btkm pre-GFC. Comparatively, the total domestic freight task has increased from 380.8btkm in 2000–01 to 599.2btkm in 2011–12 (BITRE, 2014a). Rail freight dominated the domestic freight task (2001: 136.9btkm; 2011: 290.6btkm), with the bulk commodities of iron ore and coal accounting for over 80% of rail freight movements; combined with coastal shipping to domestic locations for refining (such as Port Kembla in NSW) or exported to overseas markets. Total coastal shipping accounted for approximately 100btkm, relatively stagnant in growth across this period. Coastal shipping combines with rail, with bulk iron ore and coal representing over 50% of domestic coastal shipping volumes by tonne-km (in particular the Port Hedland-Port Kembla route spans over 6,000 km across the Indian Ocean to the Pacific). Road freight (2001: 139.4btkm; 2011: 207.5btkm) comprised primarily short haul domestic freight movements (from light commercial vehicles to B-double trucks

Please cite this article in press as: Alexander, D.W., Merkert, R., Challenges to domestic air freight in Australia: Evaluating air traffic markets with gravity modelling, Journal of Air Transport Management (2016), http://dx.doi.org/10.1016/j.jairtraman.2016.11.008

Fig. 1. National land transport network 2014.
Source: Department of Infrastructure and Regional Development (2014).

shipping products from distribution centres to retailers, including the last mile conduit for other transport modes) and intrastate (between regional distribution centres). Over 70% of tonne-km (and 95% of tonnage) of the road freight task was performed in this manner. Interstate road movements accounted for some 62.6btkm totalling 82 million tonnes of freight (ABS, 2014). Notably, during this period the combined road and rail freight market share increased from 72.56% in 2001 to 83.13% in 2011, with minimal impact from the GFC.

Domestic air freight in Australia holds various challenges. The factors influencing a consumer's (such as freight forwarders) choice of transport mode include nature of the goods, such as perishability, fragility, weight and volume; service factors such as timeliness, reliability, availability and frequency; the distance to be transported; and, finally but most importantly, cost (Allen Consulting Group, 2010). A simplified workflow diagram of a consignment is depicted in Fig. 2.

3.1. Nature of goods carried by domestic air freight in Australia

In line with that implicit demand function the market for air freight services is derived by goods that are perishable or subject to rapid obsolescence, time-sensitive, and/or valuable. Demand for typical air cargo items may be unpredictable, seasonal or intermittent with specific needs of the shipper, such as the convenience of short notice arrangements or special handling requirements (Wensveen and Merkert, 2015). Products utilising the domestic air freight network in Australia include gold and precious gems (diamonds and jewellery), perishable goods such as Tasmanian seafood and other agricultural produce (of high-value to weight composition), newspapers and express next-day postal deliveries.

Domestic demand for precious metals and gems is currently outweighed by supply, with gold, diamonds and other precious gems mined predominantly in Western Australia and exported to overseas markets (gold accounting for over 50% of total international air freight export value). Unlike most bulk materials, gold (and other precious metals) is processed and refined at site. As

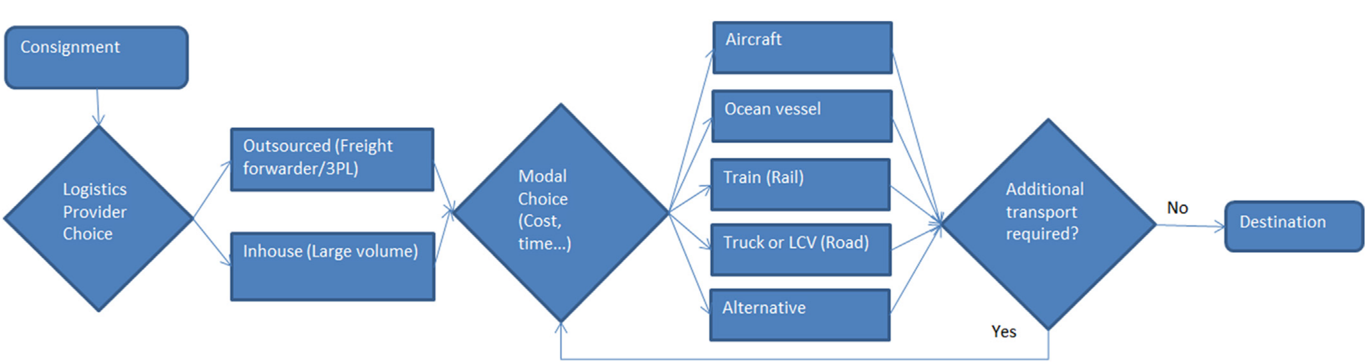


Fig. 2. Simplified workflow diagram for shipment of a consignment.

these commodities are high value, requiring appropriate considerations on security, air freight movements are kept to a minimum to reduce handling. At the domestic level, regional aircraft may be involved in transport of these commodities to a major city airport for connection to an outbound international flight. Increases to the demand of these commodities will have a direct impact to the service levels of domestic air transport.

Other primary markets of goods for domestic air freight in Australia include newspapers, mail and express post services. Early editions of State newspapers are printed for transport to regional centres (such as Townsville and Cairns from Brisbane or Sydney). The national postal service provides express delivery options to capital city centres and nearby suburban locations on a next business day schedule, with outer suburbs (especially on long haul routes) requiring an additional day for service. With the transition to digital media, as well as a dilution of the national mail delivery service provided by the government owned Australia Post (2015), it can be expected that this type of market will be negatively impacted.

The strategic decision by vehicle manufacturers General Motors (Holden) and Toyota to follow Ford and exit domestic car manufacturing in Australia from 2017 is expected to include broader supply chain impacts with the shift from a primary market for components (construction) to the secondary market (namely parts replacement). Air freight of electronic systems, in particular transhipments between Sydney (within easier reach of key airport hubs in NE Asia and the US) and Melbourne (the car manufacturing centre) will noticeably be impacted as a result. Finally, air transport of capital goods, such as specialised machinery especially in the cyclical mining sector, may also be impacted by factors such as management operational reviews during economic downturns.

3.2. Service factors of Australian domestic air freight providers

Air services in Australia are provided by a mixture of narrow-bodied jets and turboprops, wide-bodied jets and dedicated freighters. Regional services are primarily provided by the major city airports, which operate as hubs such as Sydney Kingsford-Smith Airport for regional NSW locations such as Albury, Dubbo, Wagga and Coffs Harbour. Intercity air traffic services are primarily provided by the two main airline groups Qantas (incl. QantasLink and the low-cost subsidiary Jetstar), and the Virgin Australia/Tiger Airlines group, with some additional regional services provided by Rex. Market share of domestic air freight services are provided primarily by QantasFreight, with large commercial agreements with Toll (formerly collaborating with Virgin Australia, Allen, 2015) and Australia Post. TNT, another large freight contract, was won by Virgin in 2016 (Bingemann, 2016). Popular tourist locations (Gold Coast, Cairns) also provide heavily trafficked, frequent direct services from major cities such as Sydney and Melbourne. An overview of the busiest air routes, with over 5000 air traffic movements (over 12 per day) is provided in Appendix 1.

Air freight represents a premium transport product and shippers consider trade-offs between cost, time and quality of service offered as compared to other modes of transport (Wensveen and Merkert, 2015). Servicing costs of freight, as published by BITRE (2008), indicate that air transport (at 135.88c/km) is 18 times more expensive than the average for road freight (7.53c/km), which includes predominantly local delivery services (only 20% of the domestic road freight task by tonne-km and 5% by tonnage is longer haul interstate transport). Cost of service includes direct variable costs such as labour and fuel, a provision for indirect variable costs such as vehicle maintenance and financing, as well as some contribution to fixed costs.

Quotations for air freight for a small package (10 kg) by a 3rd party logistics provider represent a significantly increasing premium of air freight services to road as distance increases, as indicated in Fig. 3. Moreover, short haul routes appeared to have a high fixed cost component, whilst transnational routes (ex-Perth) incurred a significantly higher expense (based on consumables such as jet fuel). Pricing for a freight consignment equivalent to 1 workload unit (WLU) at dimensions of 100 kg, 180 cm*60 cm*30 cm (or roughly equivalent to the size of an “average” passenger) carried by road was only 3.5 to 4.5 times more expensive than the 10 kg consignment by the same mode. Moreover, air freight premiums for the 1 WLU consignment were in the order of 7–12 times the respective air freight charge, increasing more significantly with distance, up to A$1500 for a Sydney-Perth delivery. Comparatively passengers enjoy a one-way ticket from Sydney to Perth (excluding special offers) from A$179 some 2–3 weeks in advance (Tiger Airlines, 2016), with prices up to A$500 for last-minute bookings, a substantial discount to the equivalent cargo charge. Unlike passengers who only need direction, air freight requires handling and ground support crews to load and unload the belly-hold of aircraft and dedicated freighters, apparently at a substantial premium.

The dedicated air freighter network, operating across an overnight schedule comprising intercity and regional services, has changed minimally in network structure and frequency since 1984. The network operates as a hub-and-spoke system, similar to the air freight network in the United States (along with the use of passenger aircraft belly-holds to facilitate freight for direct services). At the centre of the national domestic network is Melbourne, incorporating trans-Tasman flights to Hobart and Launceston, a shorter route leg to Perth (compared to Sydney) and flights to Sydney (which acts as a transhipment hub for flights to New Zealand and other destinations) and Brisbane (acting as a regional hub for northern centres Townsville and Cairns). The value of domestic air freight between Melbourne and Sydney was estimated at A$5.5 billion in 1995–96, double that of the international import/export market through Melbourne airport (FDF Management, 2001). Fig. 4 displays the scheduled freighter network across Australia, as drawn from data provided in Appendix 2.

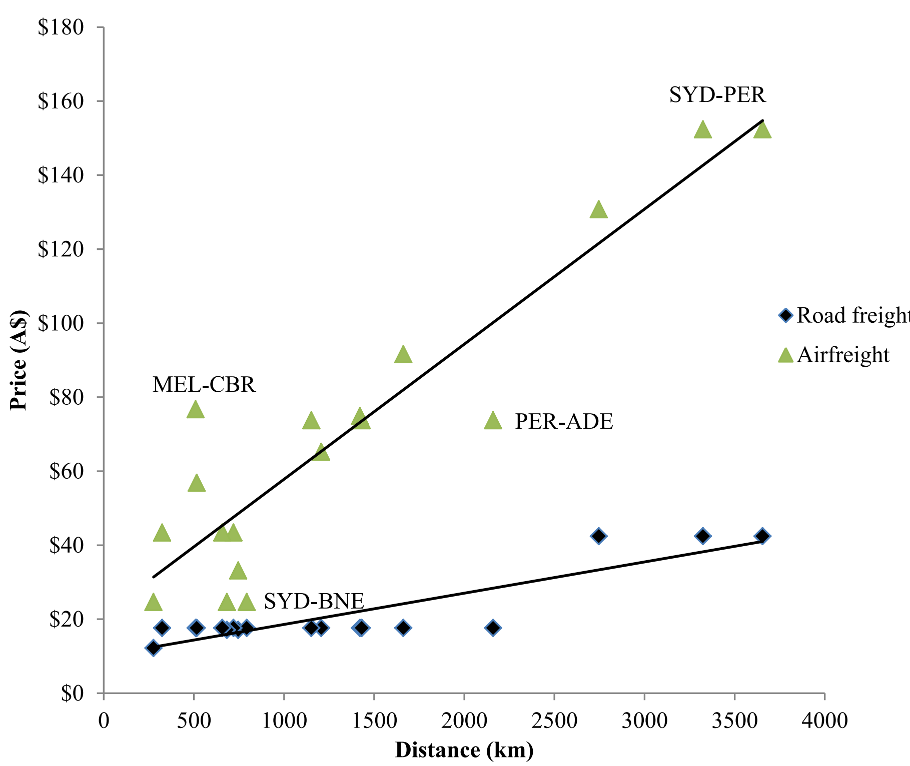
Reviewing Porter's five forces of competition (Porter, 2008), the domestic air freight industry in Australia faces a significant challenge from substitution, namely services provided by other modes of transport, in particular road. Whilst new entrants to Australia's aviation market can benefit from the relatively openness of the Australian market, where domestic services can be provided by 100% foreign owned airlines (although foreign ownership restrictions protect the national carrier Qantas), the even lower barriers of entry of road freight provide a substantial obstacle. Bargaining power of suppliers, particularly major airports, and current competition has been a concern to the aviation industry and regulators, particularly as many of the large airports in Australia have been privatised in the 1990s. However, Brisbane (with Gold Coast, Sunshine Coast and the new Brisbane West airports), Melbourne (Avalon and Tullamarine) and the future of Sydney with the Western Sydney Airport at Badgery's Creek will be home to large secondary airports, increasing capacity, accessibility and, hopefully, opportunity (although Avalon is currently serviced almost exclusively by Jetstar currently). The oligopolistic structure of the airport market is also shared by airlines and major 3rd party logistical support, providing very little scope for opportunity of price competition between the pseudo-duopoly of Qantas/JetStar and Virgin Australia/Tiger Airlines.

3.3. Capacity utilisation within the Australian domestic air freight market

The domestic air freight network acts in coopetition to the

Please cite this article in press as: Alexander, D.W., Merkert, R., Challenges to domestic air freight in Australia: Evaluating air traffic markets with gravity modelling, Journal of Air Transport Management (2016), http://dx.doi.org/10.1016/j.jairtraman.2016.11.008

Fig. 3. Courier Service Charge by mode and route (Air vs Road freight Pricing).
Note: Pricing based on 10 kg package (33 cm*33 cm*33 cm).Source: Own calculations based on data sourced from Temando (2015).



Note: Pricing based on 10kg package (33cm*33cm*33cm).
Source: Own calculations based on data sourced from Temando (2015).

Fig. 4. Network map of scheduled Australian domestic air freight services.
Source: Google Maps (2015) and Qantas (2015).

international air freight network, with intercity and regional flights feeding the five key cities- Sydney, Melbourne, Brisbane, Perth and Adelaide, which are regularly serviced by international direct flights. Total available capacity for air freight, measured by the available hold capacity and frequency of services provided by the combined narrow-bodied, wide-bodied aircraft and dedicated freighter fleets across the Australian domestic air freight market, was over 1 million tonnes. Based on 2014-15 tonnage statistics, this represents an average load factor of only 18.49% for domestic air freight across a fleet of over 100 domestic aircraft. In contrast, the industry average for air freight is approximately 41.3% (IATA, 2016).

Most domestic and international air freight in Australia is carried within the belly-hold of passenger aircraft (Merkert and Ploix, 2014). Narrow-bodied aircraft such as the Airbus A320 and smaller Boeing 717, employed on most domestic routes in Australia, provide only a small (1 ton) capacity for cargo. This is equivalent to the handling of most light commercial vehicles (LCV) or small trucks within the road logistics industry. Dedicated cargo carriers employed in Australia still provide only 7–17 tonnes of cargo capacity, by weight and volumetric capacity this is equivalent to one shipping container (TEU) or a fully laden heavy rigid truck. Air freight available capacity, therefore, is a significant supply constraint due to differentials in fleet sizes between road, rail, maritime and aviation modes.

Between Perth and east coast destinations (Brisbane, Sydney and Melbourne), air freight capacity was found to be in excess (Department of Transport (2013)) and wide-bodied aircraft continue to be used despite the range of the smaller narrow-bodied Airbus A320. Charter air freighter services are also available from airlines (QantasFreight, Virgin). Moreover, despite the high value of goods utilising domestic air freight, limited data availability (BITRE, 2010) prohibits a detailed review of interstate freight movements between the primary cities.

4. Methodology and data

The methodological approach for this research involved the collection of reliable secondary data sources (Australian Bureau of Statistics, BITRE) for development of gravity models to compare domestic freight across road and air modes. The Australian domestic air freight market was chosen for analysis due to low urban complexity, with five primary cities and a number of key regional centres dispersed across the nation. Selection of regional centres was based on a threshold of 5000 to more annual air traffic movements, and inland routes to mining communities (fly-in, fly-out on smaller turboprop aircraft) were excluded from the analysis, predominantly due to the transient nature of the population. Distances between the sample cities ranged from 278 km (Sydney to Canberra) to 3,655 km (Brisbane to Perth) as provided in Table 2. Regions were separated based on Greater Capital City Statistical Area (GCCSA), Statistical Area 4 (SA4) and Statistical Area 3 (SA3) divisional boundaries. In total 18 routes were identified for consideration in the gravity model as listed in Table 2.

Non-direct air freight movements (such as Brisbane to Cairns via Townsville) and modal combinations were also considered, however given the pricing schedules for air freight was generally cost prohibitive (Melbourne-Canberra at 4 times the road freight quote for instance) and that air-sea, air-rail and air-road combinations involve quality considerations such as security (which varies depending upon the value of a consignment and the requirements of the consignor), arbitrage was not efficiently possible. As a result of limited data on volumes of shipped products, perishability, unit value and other factors, generalised cost functions (such as value of time estimates) were not possible to calculate.

The basic model, the augmented version and the Anderson and van Wincoop (2003) model were all considered within the context of this study. Dummy variables were included for the utilisation of wide-bodied aircraft and dedicated freighters across the sample. Information on private operators and airports were obtained from open access sources (such as annual reports) where available or from the operators directly. Limitations of the data sources include minimal data availability on freight handled at the airports. Supply of air transport capacity, despite annual schedules posted, is affected by seasonal factors, aircraft maintenance and demand fluctuations; thus capacity for annual freight traffic was approximated based on the data available from the Centre of Aviation (CAPA, 2015).

Next an estimated total flight time (including landslide activities and door-to-door transport services) was developed to provide a comparative between modal speeds, also included in Table 2. Total road distance was based from the most efficient travel across the actual road network, potentially representing up to 20% greater travel distance than air (and local road delivery of up to a total of 40 km for both origin and destination). For short leg routes (Sydney-Canberra, Townsville-Cairns), road services were highly competitive in speed to air (excluding congestion in urban centres, which would impact both road and air-road service considerations). Ex-Tasmania services (Hobart-Melbourne, Launceston-Melbourne) incorporated an estimate for trans-Tasman ferries on a daily departure schedule.

In consideration of the low average air freight load factors (at an average of 18%) between these key domestic centres, demand factors (population, gross regional product (GRP), and some local industry employment statistics) were included within the model parameters. Manufacturing components/industrial activity is identified as a component of unemployment rate, technicians and trades workers, labourers, sales workers and machinery operators and drivers. These employment sectors were considered as either impediments (such as unemployment) or potential attractors for trade (sales worker level identifying the importance of products to the economy product/service mix). Larger key centres with access to greater resources (such as Sydney or Melbourne) are able to provide economies of scale and scope in manufacturing, providing potential heterogeneity in product offerings (national and state newspapers are printed on scale and distributed to regional centres including interstate). As with all gravity models the strength of the attractiveness of these elements can be refined or substituted over time. Table 3 provides an overview of the 11 domestic centres that form an origin or destination point within the sample.

Domestic industrial activity (M) for the augmented model (see equation (2)) that we use in our analysis can therefore be expressed as follows:

$$M_i = K(\beta_1 U_i + \beta_2 (TTW_i + L_i + MOD_i)) \tag{5}$$

$$M_j = K(\beta_4 U_j + \beta_6 SW_j)$$

where industrial activity, M_i and M_j representing the origin and destination trade factors respectively, U representing unemployed (expected to be an impediment to industrial and retail sales activity), TTW as technicians and trades workers, L represent unskilled labourers, and MOD as machine operators and drivers, all of which are direct components of the logistical processes of manufacturing to delivery of products and SW as Sales Workers, a proxy for the level of retail presence within the community with K and β representing weighting values comprising domestic activity. As only 5% of the domestic freight volume by tonnage is carried interstate, between major cities, of which 0.22% is carried by air (0.01% of the total domestic freight task), intercity air freight

Table 2
Distance, time and speed characteristics of air/road transport on key routes in 2014.

Route	Total travel distance (air-km + truck-km)[a]	Estimated total flight time (hours, minutes)[b]	Air transport avg. speed (km/h)	Road distance (km)[c]	Est total road time [d]	Road transport avg. speed (km/h)
Sydney-Melbourne	746	4:05	182.7	842	10.5 h	80.0
Sydney-Brisbane	793	4:15	186.6	941	13 h	72.0
Sydney-Canberra	276	3:25	80.8	274	3.5 h	75.8
Sydney-Gold Coast	720	3:50	187.8	835	12 h	71.1
Sydney-Adelaide	1207	4:45	254.1	1399	26 h	53.1
Sydney-Perth	3324	7:05	469.3	3911	4 days	40.7
Melbourne-Brisbane	1421	5:05	279.5	1777	31 h	57.1
Melbourne-Adelaide	683	4:10	163.9	726	10 h	71.4
Melbourne-Perth	2746	6:20	433.6	3433	3 days	47.7
Melbourne-Canberra	510	3:55	130.2	647	8.5 h	76.3
Melbourne-Hobart	658	4:05	161.1	747	36 h	20.6
Melbourne-Launceston	516	4:00	129.0	583	34 h	17.2
Brisbane-Cairns	1431	5:10	277.0	1702	31 h	54.1
Brisbane-Townsville	1152	4:55	234.3	1359	26 h	50.7
Brisbane-Adelaide	1662	5:40	293.3	2054	35 h	58.6
Brisbane-Perth	3655	9:10	398.7	4362	4 days	45.4
Perth-Adelaide	2160	6:15	345.6	2692	2 days	54.8
Cairns-Townsville	324	4:00	81.0	349	5.5 h	63.4

Note:
[a] Includes data sourced from BITRE (2015a,b) and estimated 40 truck-km for door-to-door service comparison.
[b] Includes flight time, clearance, average headway and hinterland accessibility costs.
[c] Includes data sourced from Google Maps (2015).
[d] Includes estimates on optimal road travel time, breaks and loading/unloading.

Table 3
Economic key indicators for gravity model consideration.

	Population [a]	GRP ($m) [b, c, d, e]	Unemployment rate (%) [f]	Technicians and trades worker (%) [f]	Labourer (%) [f]	Sales worker (%) [f]	Machinery operator and driver (%) [f]
Sydney	4,920,970	353,146	5.7	12.2	7.3	9	5.7
Melbourne	4,529,496	276,667	5.5	13.4	8	9.7	5.9
Brisbane	2,308,720	147,408	5.9	13.5	9.2	9.4	6.4
Perth	2,039,193	149,485	4.8	16.1	8.8	9	6.6
Adelaide	1,316,779	73,310	5.8	14	9.9	9.9	5.8
Gold Coast	569,951	25,744	7.4	15.5	9.8	12.6	5.1
Canberra (ACT)	390,706	35,570	3.5	10.5	5	6.9	2.7
Cairns	244,052	7623	7	15.9	11.8	10.3	6.6
Townsville	238,233	11,426	5.1	16.6	10.9	9.4	9
Hobart	220,953	5594	5.7	13.8	8.8	9.9	4.6
Launceston	83,279	4000	6.6	14.6	10.3	11.4	6.4

Note.
[a] Source: ABS (2015).
[b] Sydney, Melbourne, Brisbane, Perth, Adelaide and Canberra GRP sourced from SGS Economics and Planning (2014).
[c] Gold Coast, Cairns and Launceston (estimate) GRP sourced from Economy id (2015).
[d] Townsville GRP sourced from Townsville Enterprise (2013).
[e] Hobart GRP sourced from ABS (2013).
[f] Source: Quickstats (2011).

volumes are constrained by both the level of development of the local manufacturing industry and international imports. International imports (at some A$240 billion) provide airport hubs such as Sydney with the potential of additional domestic (and Trans-Tasman flights to New Zealand) air freight volumes; moreover due to the frequency of direct international flights to other populated cities, such as Melbourne and Brisbane, leverage of the domestic air freight network is limited.

Cost (data provided for Fig. 3), time and distance characteristics (as presented previously in Table 2) are the next considerations for the augmented gravity model. In real terms, the differential savings of air to road can be measured by time and distance against cost. Table 4 presents the cost premiums of air freight over road, and the impacts to each of the sample routes.

Based on our calculations, Sydney (SYD)-Brisbane (BNE) potentially represents a very attractive route for air freight as the additional cost (in real terms) provide a significant advantage in distance and time savings. Sydney (SYD)-Canberra (CBR) and

Table 4
Differentials between Air and Road freight transport on key routes (10 kg package).

Origin	Destination	Route cost premium (Air)	Distance saving (Air)	Air premium (Cost $/km)	Est. time saving (Air)	Air premium ($/hr)
Sydney	Melbourne	$16.05	96	0.17	6:24	2.51
Sydney	Brisbane	$7.01	148	0.05	8:47	0.80
Sydney	Canberra	$12.42	0*	N/A*	0:12	62.10
Sydney	Gold Coast	$25.76	115	0.22	7:55	3.26
Sydney	Adelaide	$47.61	192	0.25	21:15	2.24
Sydney	Perth	$109.90	587	0.19	88:55	1.24
Melbourne	Brisbane	$57.24	356	0.16	25:55	2.21
Melbourne	Adelaide	$7.55	43	0.18	6:00	1.26
Melbourne	Perth	$88.32	687	0.13	65:40	1.34
Melbourne	Canberra	$59.10	137	0.43	4:34	12.85
Melbourne	Hobart	$25.76	89	0.29	31:55	0.81
Melbourne	Launceston	$39.24	67	0.59	30:00	1.31
Brisbane	Cairns	$56.12	271	0.21	26:50	2.09
Brisbane	Townsville	$56.12	207	0.27	21:05	2.66
Brisbane	Adelaide	$73.98	392	0.19	29:20	2.52
Brisbane	Perth	$109.90	707	0.16	86:50	1.27
Perth	Adelaide	$56.12	532	0.11	41:45	1.34
Cairns	Townsville	$25.76	25	1.03	1:30	17.17

Note: *No realisable distance savings by air.

Melbourne (MEL)-Canberra (CBR) routes are significantly impaired with cost premiums for air freight of $62.10/hour and $12.85/hour respectively (for time sensitive goods). The Cairns-Townsville route (at $17.17/hour) by itself also suggests an impairment to air freight, moreover only between these two regional centres as Brisbane with 10 times the population (and greater economic size) has significantly more attractive air freight pricing (based on distance and time factors) to both Townsville and Cairns, including capacity provided by the dedicated freight network. Due to the low demand for air freight services, multi-leg freighter operations and minimal price differentiation between origin and destination, backhaul routes were not thoroughly examined. A graphical representation of the air/road differential of transport is provided in Fig. 5.

Potential time savings by air transport, one of the premium aspects of the service, are hindered by fleet utilisation considerations, airport curfews and hours of operation. Short haul flights (such as Sydney-Melbourne) utilise narrow-bodied aircraft (notably less capital intensive than wide-bodied aircraft) provide greater daily belly-hold capacity through increased service frequency (also an important factor for critically time-sensitive customers) compared to the longer haul flights (such as Sydney-Perth) with wide-bodied aircraft. Transnational "red-eye" passenger flights, utilising wide-bodied aircraft from Perth, depart prior to midnight servicing Brisbane, Melbourne, Sydney and Cairns for an early morning arrival, providing complementary (or competing) capacity to the overnight dedicated freighter service. Logistics providers also value capture time savings, by offering a quoted time period for service, from 1 to 2 days for air freight and 1–10 days for the equivalent road transport (1–2 days for east coast, 4–10 days for transnational), irrespective of actual timing of delivery and thus distorting the customers perception of time savings.

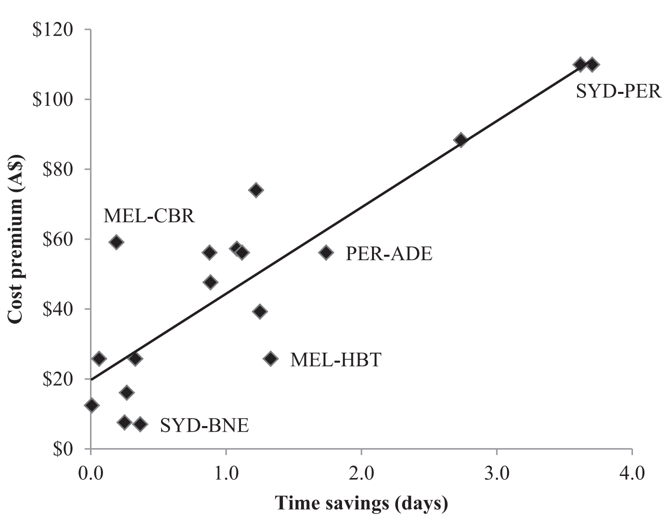


Fig. 5. Cost impedance/premium for air freight transport vs potential time savings.

Finally, our formulation of an air freight gravity model involved the log-linear variation for the basic, augmented and Anderson/van Wincoop models (as expressed in Equation (4)), increasing the consistency and robustness of the results.

5. Results

As discussed, the basic, augmented and Anderson/van Wincoop gravity models were considered for the analysis. As the methodology was applied to a single year only, Y_{wt} in the Anderson/van Wincoop model became a constant, and was removed from the equation modelling process. An ordinary least squares (OLS) approach was undertaken as the sample is exogenous, homoscedastic and not derived from a longitudinal analysis. Table 5 presents the results of these models in comparison.

Under the basic model, Gross Regional Product of the origin (GRP 1) has more significance than that of the destination (GRP 2) as well as the distance (including power-based derivatives) between them. The economic output of the origin, therefore, has a significant impact to the demand for air freight services, and concurrently the destination demands products shipped by air freight (where local supply is limited or constrained). Population (P) was removed by the software due to multi-collinearity with GRP. Under the augmented and Anderson/van-Wincoop models, the importance of GRP is exchanged for trade factors M_i and M_j, as local production capabilities may not attract sufficient economies of scale (such as printing of newspapers in regional areas) where larger economic centres (such as the capital cities) have the capital and resources to meet these supply requirements. It should be noted that GRP constitutes factors that do not involve the movement of freight (such as the professional services industry) which can subsequently increase (or decrease) with minimal flow-on

Table 5
Gravity model results.

Model	Basic model ($R^2 = 0.323$)	Augmented model ($R^2 = 0.953$)	Anderson-van Wincoop model ($R^2 = 0.914$)
Constant	−27.845**	88.368**	−34.741
ln GRP 1	0.524**	−1.820**	−0.973
ln GRP 2	0.307	−0.589*	−0.223
ln d	−0.070	−0.232**	
ln M_i		2.392***	1.618*
ln M_j		1.082***	0.691**
$Dummy_{wide}$		0.272**	0.153
$Dummy_{Freighter}$		0.366**	0.515***
ln N_{ij}		−0.035	−0.127

Note: * significant at $p < 0.1$, ** significant at $p < 0.05$, *** significant at $p < 0.01$.

impacts to domestic air freight.

As expected and in line with previous literature, distance is an important impediment for air freight. Attributes of air transport, such as premium pricing (whether taken at face value or as an additional cost over comparable road freight) held a similarly negative impact, however was not as significant to the model across the sample. Notably the quotations sourced are limited in scope, and do not provide for discounts for regular custom or marginal cost pricing strategies, whilst road freight consumers benefit at greater scale. Unique to air freight, short haul legs compete with other modes, road in particular, and can be economically unfeasible (Sydney to Canberra for example). Long haul air freight requires significantly larger economic regions for trade, and a degree of hetereogeneity in the products shipped (as larger economic regions also develop economies of scale in local production, or may be sourced by closer neighbours), resulting in lower freight volumes. Conversely, long haul freight is also shipped by rail and sea, where quotations are not easily accessible. All air freight requires additional transport (i.e. by road and landside activities) from source to destination.

Components of air transport supply for each route, whether it was air traffic movements or available freight capacity proved highly insignificant. This is expected; load factors of air freight on aircraft are typically low and thus supply of additional air freight capacity will not significantly impact upon current demand (rather pricing of current capacity may yield improved results in this area). Of noticeable importance is if the route constitutes part of the dedicated freighter network, where economies of scale and density have formed.

We used the Anderson/van Wincoop model to estimate a mean elasticity of substitution value (σ) of 1.34 for domestic air freight across the sample routes (with a low of 1.25 for the Cairns-Townsville route). Whilst this estimate is not product specific (some products will always utilise air freight due to time sensitivities or security requirements), it indicates that some air freight volumes may be impacted by competition from other modes. The results of these models indicate that the domestic air freight volume on any route is, despite being demand-pulled in terms of GDP dependency, significantly attuned to demand factors at both the origin (production for interstate trade) and destination (demand for goods neither locally produced nor imported directly).

6. Conclusions and further research

This paper aimed at evaluating some of the issues regarding the domestic air freight markets in Australia by examining the time and cost of service provided by air and road transport modes by utilising gravity modelling methods. The models employed have identified regional economic factors (unemployment, employment within logistics and transport sectors, retail service levels) that may indicate the strength (or weakness) of attraction for any domestic air freight route. As expected distance factors were significant to the analysis (although cost was not as significant), and these factors influence the substitution effect between road and air services.

We have shown that some corridors, such as all routes to Perth (as a result of its distance to any other Australian major urban centre), should pose competitive advantages for air freight over any other mode of transport. Transnational passenger routes from Perth utilise wide-bodied aircraft and provide coopetition to the dedicated freighter network, whilst the long distances for intercity freight movements (to Sydney, Melbourne and Brisbane) provide significant time savings. On short-haul routes, such as Sydney to Canberra, air freight is simply not competitive to road at all. The fact that routes which would benefit from air freight are not growing (by tonnage, despite subsequent growth in capacity) may be related to a combination of demand factors such as the type of commodity that is transported between those cities, as well as anti-competitive pricing strategies, thus creating market inefficiencies.

As a limitation of our research it should be noted that some operators are bound by framework contracts (such as Qantas' contract with Australia Post or Virgin Australia's contract with TNT; both set up in 2016) further reducing the flexibility in their short to medium term mode choice decisions. The next day postal delivery service guarantee, for instance, is undergoing a transition to save on logistical costs (Australia Post, 2015) which will inevitably impact domestic air freight and mail servicing arrangements across the national network.

Undertaking further research into the spatial and temporal effects within gravity models would provide greater insights into the impacts of air freight (and other) markets. Identifying market impediments has been the importance of the iterations of many gravity model equations, however also identifying opportunities for service provisions (via arbitrage of air-road freight transport options as one example) could provide alternative transport options for end users to utilise for improved service. Competition for freight services in future by logistics organisations may extract additional value for consumers with improved coordination of door-to-door services, quoting in specified hours (based on timing of activities) rather than days, especially with time-sensitive goods, a key market for air freight services.

Acknowledgements

The authors would like to thank guest editor Professor Eddy Van de Voorde and two anonymous reviewers for their insightful and constructive comments which have helped to improve previous versions of this paper.

Appendix

Appendix 1
Top Australian domestic markets.

Top city-pair routes [a]	Location	ATM 2015 [a]	GC (km)[a]	Hinterland population (Origin and destination)[b]		Wide-body aircraft[c]	Scheduled freighter[d]
Sydney-Melbourne	NSW-VIC	58,282	706	4,920,970	4,529,496	Y	Y
Sydney-Brisbane	NSW-QLD	34,053	753	4,920,970	2,308,720	Y	Y
Sydney-Canberra	NSW-ACT	18,526	236	4,920,970	390,706	–	–
Sydney-Gold Coast	NSW-QLD	17,970	680	4,920,970	569,951	–	–
Sydney-Adelaide	NSW-SA	14,186	1,167	4,920,970	1,316,779	–	–
Sydney-Perth	NSW-WA	8,972	3,284	4,920,970	2,039,193	Y	–
Sydney-Cairns	NSW-QLD	6,996	1,971	4,920,970	244,052	Y	–
Sydney-Albury	intra-NSW	6,131	452	4,920,970	61,905	–	–
Sydney-Dubbo	intra-NSW	6,400	310	4,920,970	71,174	–	–
Sydney-Wagga Wagga	intra-NSW	5,644	367	4,920,970	94,540	–	–
Sydney-Coffs Harbour	intra-NSW	5,336	443	4,920,970	137,022	–	–
Melbourne-Brisbane	VIC-QLD	25,654	1,381	4,529,496	2,308,720	–	Y
Melbourne-Adelaide	VIC-SA	18,943	643	4,529,496	1,316,779	–	Y
Melbourne-Perth	VIC-WA	12,338	2,706	4,529,496	2,039,193	Y	Y
Melbourne-Canberra	VIC-ACT	10,681	470	4,529,496	390,706	–	–
Melbourne-Hobart	VIC-TAS	11,616	618	4,529,496	220,953	–	Y
Melbourne-Gold Coast	VIC-QLD	11,134	1,330	4,529,496	569,951	–	–
Melbourne-Launceston	VIC-TAS	8,913	476	4,529,496	83,279	–	Y
Brisbane-Rockhampton	intra-QLD	9,960	518	2,308,720	120,654	–	–
Brisbane-Mackay	intra-QLD	8,001	797	2,308,720	123,724	–	–
Brisbane-Cairns	intra-QLD	9,885	1,391	2,308,720	244,052	–	Y
Brisbane-Gladstone	intra-QLD	8,750	434	2,308,720	82,675	–	–
Brisbane-Townsville	intra-QLD	9,070	1,112	2,308,720	238,233	Y	Y
Brisbane-Emerald	intra-QLD	5,596	653	2,308,720	32,455	–	–
Brisbane-Canberra	QLD-ACT	6,144	956	2,308,720	390,706	–	–
Brisbane-Newcastle	QLD-NSW	5,770	614	2,308,720	370,945	–	–
Brisbane-Adelaide	QLD-SA	6,480	1,622	2,308,720	1,316,779	–	–
Brisbane-Perth	QLD-WA	5,389	3,615	2,308,720	2,039,193	Y	–
Perth-Karratha	intra-WA	7,789	1,250	2,039,193	65,859	–	–
Perth-Adelaide	WA-SA	5,570	2,120	2,039,193	1,316,779	–	–
Adelaide-Port Lincoln	intra-SA	7,166	246	1,316,779	58,694	–	–
Cairns-Townsville	intra-QLD	5,216* (2013)	284	244,052	238,233	–	Y

Note.
[a] Data sourced from BITRE (2015a,b).
[b] Data sourced from ABS (2015).
[c] Source: Qantas (2015), Virgin Australia (2015).
[d] Source: Qantas Freight (2015).

Appendix 2
Dedicated freight schedules 2015 (Australia)[a].

Freighter type	Capacity	Origin	Destination	Departure time	Arrival time	Schedule	Route legs
Bae 146–300 [b]	10 tonnes	HBA	LST	19:50	20:20	M, T, W, H	HBA-LST-MEL-BNE-MEL-HBA
		LST	MEL	20:45	21:45	M, T, W, H	
		MEL	BNE	22:20	0:35	M, T, W, H	
		BNE	MEL	1:05	3:30	T, W, H, F	
		MEL	HBA	4:00	5:10	T, W, H, F	
		ADL	MEL	20:00	21:50	M, T, W, H	ADL-MEL-SYD-MEL-ADL
		MEL	SYD	22:20	23:45	M, T, W, H	
		SYD	MEL	0:20	1:50	T, W, H, F	
		MEL	ADL	2:20	3:10	T, W, H, F	
		SYD	BNE	23:15	0:45	M, T, W, H	SYD-BNE-SYD
		BNE	SYD	1:15	2:50	T, W, H, F	
Bae 146–100 [c]	7 tonnes	BNE	SYD	20:50	22:25	M, T, W, H	BNE-SYD-MEL-SYD-BNE
		SYD	MEL	22:55	0:25	M, T, W, H	
		MEL	SYD	1:30	2:55	T, W, H, F	
		SYD	BNE	3:25	4:55	T, W, H, F	
Boeing 737–300 [b]	17 tonnes	MEL	SYD	20:10	21:30	M, T, W, H	MEL-SYD-MEL-LST-MEL
		SYD	MEL	22:20	23:40	M, T, W, H	
		MEL	LST	0:20	1:20	T, W, H, F	
		LST	MEL	1:50	2:50	T, W, H, F	
		CNS	BNE	18:40	20:40	T, W, H	CNS-BNE-MEL-BNE-TSV-CNS
		BNE	MEL	21:30	23:45	M, T, W, H	
		MEL	BNE	1:15	3:20	T, W, H, F	
		BNE	TSV	3:50	5:45	T, W, H, F	
		TSV	CNS	6:15	7:00	T, W, H, F	
		PER	MEL	19:15	0:45	M, T, W, H	PER-MEL-PER
		MEL	PER	3:20	5:30	T, W, H, F	
		MEL	PER	1:40	3:50	T, W, H, F	MEL-PER-MEL
		PER	MEL	5:10	10:40	T, W, H	
		PER	MEL	6:30	12:00	F	

Note:
[a] Schedules sourced from Qantas. Virgin Australia does not currently provide a schedule of dedicated freighters.
[b] Operated by Qantas Freight.
[c] Operated by QantasLink.

References

Australian Bureau of Statistics(ABS), 2013. Hobart Regional Statistics. Australian Government, Canberra.

Australian Bureau of Statistics(ABS), 2014. 9223.0 Road Freight Movements, Australia, 12 months ended 31 October 2014. Australian Government, Canberra.

Australian Bureau of Statistics(ABS), 2015. 3218.0 Regional Population Growth, Estimated Resident Population. Statistical Areas Level 2 datacube, Australia 2014-2015. Australian Government, Canberra.

ACI Europe, 2014. Airport Industry Connectivity Report. ACI Europe, Brussels and SEO Economic Research, Amsterdam.

Allen, L., 2015. Qantas Grabs Virgin's Toll Group Freight Contract. The Australian 23rd June 2015.

Allen Consulting Group, 2010. National Freight Network Strategy: Background Paper (Report to Infrastructure Australia, Melbourne).

Anderson, J.E., van Wincoop, E., 2003. Gravity with gravitas. Am. Econ. Rev. 93, 170–192.

Armstrong, H.W., Read, R., 2014. The significance of geographic location in island studies: a rejoinder. Isl. Stud. J. 9 (No 2), 367–372.

Arvis, J.-F., Shepherd, B., 2011. The Air Connectivity Index: Measuring Integration in the Global Air Transport Network. The World Bank.

Australia Post (2015) Changes to your letters service as viewed at http://auspost.com.au/changes-to-your-letters-service.html.

Bingemann, M., 2016. Virgin Australia Nets $150 Million TNT Freight Deal. The Australian April 2, 2016.

Binova, H., 2014. Modified method of gravity model application for TransAtlantic air transportation. Neural Netw. World 2/15 203–217.

Boeing, 2015. Current Market Outlook 2015-2034. Available athttp://www.boeing.com/resources/boeingdotcom/commercial/about-our-market/assets/downloads/Boeing_Current_Market_Outlook_2015.pdf.

Bureau of Infrastructure, Transport and Regional Economics(BITRE), 2008. Freight Rates in Australia 1964-65 to 2007-2008. Department of Infrastructure, Transport, Regional Development and Local Government, Australian Government, Canberra.

Bureau of Infrastructure, Transport and Regional Economics(BITRE), 2010. Interstate Freight in Australia. Department of Infrastructure, Transport, Regional Development and Local Government, Australian Government, Canberra.

Bureau of Infrastructure, Transport and Regional Economics(BITRE), 2014a. Freightline 1- Australia Freight Transport Overview. Department of Infrastructure and Regional Development, Australian Government, Canberra.

Bureau of Infrastructure, Transport and Regional Economics(BITRE), 2014b. Monthly Airline Performance. Department of Infrastructure and Regional Development, Australian Government, Canberra.

Bureau of Infrastructure, Transport and Regional Economics(BITRE), 2015a. Australian Air Distances. Department of Infrastructure and Regional Development, Australian Government, Canberra.

Bureau of Infrastructure, Transport and Regional Economics(BITRE), 2015b. Domestic Totals & Top Routes July 2004-June 2015. Department of Infrastructure and Regional Development, Australian Government, Canberra.

Bureau of Transport Economics, 1987. Domestic Air Cargo Industry in Australia. Australian Government, Canberra.

Bureau of Transport Statistics, 2015. Freight Facts and Figures 2015. United States department of transportation, Washington D.C.

CAPA, 2015. Airport Database- Top Ten Domestic Cargo Routes for 1st June to 7th June 2015. Centre of Aviation.

Cheong, J., Kwak, D.W., Tang, K.K., 2014. The Distance Effects on the Intensive and Extensive Margins of Trade over Time. University of Queensland.

Chi, J., Baek, J., 2012. Price and income elasticities of demand for air transportation: empirical evidence from US airfreight industry. J. Air Transp. Manag. 20, 18–19.

Department of Infrastructure and Regional Development, 2014. The National Land Transport Network – Road and Rail – Australia. Australian Government, Canberra.

Department of Transport, 2013. Western Australian State Aviation Strategy, Draft for Public Comment- August 2013. Government of Western Australia, Perth.

Disdier, A.-C., Head, K., 2008. The puzzling persistence of the distance effect on bilateral trade. Rev. Econ. Stat. 90 (No 1), 37–48.

Economy id, 2015. Economic Profile Gold Coast, Cairns and Launceston. accessible. http://economy.id.com.au/.

El-Sayad, M.A., 2012. A Gravity Model Analysis of Egypt's Trade and Some Economic Blocks. International Conference on Applied Life Sciences, Turkey, September 10-12, 2012.

Eurostat, 2014. EU Transport in Figures, Statistical Pocketbook. European Commission, Brussels.

FDF Management, 2001. Aspects of the Greater Melbourne Freight Task, Melbourne Metropolitan Strategy Technical Report 7. Flagstaff Consulting Group.

Feyrer, J., 2009. Trade and Income – Exploiting Time Series in Geography. NBER Working Paper No 14910, April 2009.

Fridstrom, L., Thune-Larsen, H., 1989. An econometric air travel demand model for the entire conventional domestic network: the case of Norway. Transp. Res. B 23B (No 3), 213–223.

Gadala-Maria, I., 2014. Evaluating the Impact of Ocean and Air Infrastructure on Trade: a Gravity Model Approach, University of Maryland.

Google Maps (2015) Australia, as retrieved on 30th May 2015 at https://www.google.com.au/maps/preview.

Head, K., 2003. Gravity for Beginners. University of British Columbia.

IATA, 2016. Air Freight Market Analysis. January 2016.

Jamin, S., Schafer, A., Ben-Akiva, M.E., Waitz, I.A., 2004. Aviation emissions and abatement policies in the United States: a city-pair analysis. Transp. Res. Part D 9, 295–317.

Kanafani, A., 1983. Transportation Demand Analysis. McGraw-Hill, New York.

Lux, M., 2012. Defying Gravity: the Substitutability of Transportation in International Trade. New York University.

Matsumoto, H., 2007. International air network structures and air traffic density of world cities. Transp. Res. Part E 43, 269–282.

Merkert, R., Ploix, B., 2014. The impact of terminal re-organisation on belly-hold freight operation chains at airports. J. Air Transp. Manag. 36, 78–84.

North American Trade Society (NATS), 2016. Table 5–2 Domestic Freight Activity by Mode (Billions of Metric Ton-kilometres). http://nats.sct.gob.mx.

Piermartini, R., Rousova, L., 2008. Liberalization of Air Transport Services and Passenger Traffic. World Trade Organization Economic Research and Statistics Division Staff Working Paper. Available at: http://www.wto.org/english/res_e/reser_e/ersd200806_e.pdf.

Porter, M.E., 2008. The five competitive forces that shape strategy. Harv. Bus. Rev. 2008, 25–40.

Qantas, 2015. Our Company: Our Fleet. retrieved via. www.qantas.com.au.

Qantas Freight, 2015. Scheduled Flight Information. https://www.qantas.com.au/qfreight/qfe/operational-notices-archive/au/en (Accessed 1 December 2015).

Quickstats, 2011. Census Data-population, Employment Characteristics, Australian Bureau of Statistics. Australian Government, Canberra.

SGS Economics and Planning, 2014. Australian Cities Accounts 2013-14. available. http://www.sgsep.com.au/assets/GDP-by-Major-Capital-City-1314.pdf.

Sjafruddin, A., Astutit, R.D., Frazila, R.B., 1999. Regional freight transport demand modeling in the Java island. J. East. Asia Soc. Transp. Stud. 3 (No 3). September 1999.

Temando (2015) Quote details sourced at Courier Quotes website www.freightcalculator.com.au; (Accessed 01 December 2015).

Tiger Airlines, 2016. Ticket Price Quotations, for Sydney to Perth October 2016 Departure at tiger.com.au.

Townsville Enterprise, 2013. Economic Snapshot. accessible at. http://www.movetotownsville.com.au/economic-snapshot.

Virgin Australia (2015) Virgin Australia Aircraft Fleet Cargo Capability retrieved via www.virgin.com.au.

Wadud, Z., 2014. Simultaneous modeling of passenger and cargo demand at an airport. Transp. Res. Rec. J. Transp. Res. Board 2336, 63 Î 74.

Wensveen, J., Merkert, R., 2015. Economic characteristics of airlines (chapter 7). accepted for publication. In: Wensveen, J. (Ed.), Air Transportation: a Management Perspective, eighth ed. Ashgate.

Wood, D.F., 1970. Analysis of general aviation activity. Transp. Res. 4, 349–357.

World Bank, 2015. Aviation, GDP and Population Statistics (Washington D.C).

World Trade Organisation(WTO), 2014. International Trade Statistics 2014. https://www.wto.org/english/res_e/statis_e/its2014_e/its2014_e.pdf.

Please cite this article in press as: Alexander, D.W., Merkert, R., Challenges to domestic air freight in Australia: Evaluating air traffic markets with gravity modelling, Journal of Air Transport Management (2016), http://dx.doi.org/10.1016/j.jairtraman.2016.11.008