IMPACT OF AIRPORTS ON SPATIAL PATTERNS OF METROPOLITAN EMPLOYMENT: THE CASE OF AUSTRALIA

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With 4 tables
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Summary: This paper aims to evaluate the localised effects of major airports on urban economies. We analyse employment change at privatised Australian airports, adjacent employment areas and major metropolitan employment centres. Time series employment data from 2001, 2006 and 2011 has been used to identify 61 employment centres in Sydney, Melbourne, Brisbane and Perth metropolitan areas. Regression models suggest that centre size, proximity to motorways and labour force accessibility are more important determinants of employment centre growth than airport accessibility. However, the privatisation of airports has also caused substantial development of commercial properties at airports, facilitating strong non-aviation-related employment growth at Brisbane and Perth airports. In contrast, Sydney and Melbourne airports have largely remained specialised centres with a strong focus on transport and warehousing. Due to significant increases in prices for land and real estate at privatised airports, spill-over effects can be identified around airports, transforming adjacent suburbs from industrial areas to more mixed use employment centres. The results of this study confirm research findings on employment growth around major US airports.

Zusammenfassung: Dieser Beitrag hat zum Ziel, die lokalen Effekte von Großflughäfen auf die Stadtökonomie zu messen. Zu diesem Zweck wird die Beschäftigungsentwicklung an privatisierten australischen Flughäfen, angrenzenden Gewerbegebieten sowie den größten regionalen Arbeitsplatzzentren untersucht. Um 61 Zentren in den vier Verdichtungsräumen Sydney, Melbourne, Brisbane und Perth abzugrenzen, wurden Beschäftigungsdaten aus den Jahren 2001, 2006 und 2011 verwendet. Die Ergebnisse der Regressionsanalysen zeigen, dass die absolute Größe der Zentren, die Nähe zu Stadtautobahnen sowie die lokale Verfügbarkeit von Arbeitskräften eine größere Erklärungskraft für das Wachstum der Zentren besitzen als deren Nähe zu Großflughäfen. Dennoch hat die Privatisierung der Flughafenbetreiber die Entwicklung von Gewerbeimmobilien auf den Flughafengeländen gefördert. Dies hat insbesondere in Brisbane und Perth den Aufbau von vielen Arbeitsplätzen geführt, die nicht mehr direkt mit dem Luftverkehr in Verbindung stehen. Im Gegensatz dazu sind die Flughäfen Sydney und Melbourne weitgehend auf Lager- und Logistikfunktionen spezialisierte Arbeitsplatzzentren geblieben. Aufgrund des starken Preisanstiegs für Grundstücke und Immobilien am Flughafen sind Spill-Over-Effekte im Flughafenumfeld zu beobachten, die schlussendlich die ehemals industriell geprägten Gebiete zunehmend in Orte mit stärkerer Nutzungsdurchmischung transformieren. Diese Ergebnisse bestätigen bisherige Befunde zum Beschäftigungswachstum um große US-amerikanische Flughäfen.

Keywords: airports, employment centre, transport accessibility, labour market, urban development, Australia, transport geography

1 Introduction

Multi-modal transport nodes have always been focal points of urban development. The emerging importance of airports as metropolitan gateways to global markets has led to significant public and private transport infrastructure investment in recent years. Improved intra-regional access to airports via motorways and railways has created a multi-modal transport environment and favourable locational conditions for international companies. The provision of high-quality infrastructure and attractive properties by airport operators has also driven demand for office, warehouse and retail space at airports. Since the mid-1990s many airports worldwide (with the exception of the US) have been partly or fully privatised. The new shareholders aim to increase profits and minimise business risks by promoting non-aviation activities. Car parking fees, retail and catering concessions in terminals, and the lease of commercial and industrial buildings on airport land are becoming more important revenue streams than aviation-related fees in some airports (Graham 2014).

In many cases, high accessibility to transport networks and the privatisation of operators have caused a spatial concentration of growth, densification and diversification of economic activities at and around airports (Appold and Kasarda 2013; Braun

and Schlaack 2014). Transport and warehousing companies have traditionally been located close to airports, however, these uses now have to compete for space with retail, wholesale, accommodation, high-tech manufacturing, and advanced producer services (Freestone and Baker 2011). As a result, emerging agglomeration economies have transformed many airports into activity and business centres of regional importance (Güller and Güller 2003). Empirical studies have provided clear evidence for local employment concentrations at airports (Appold and Kasarda 2013; Cidell 2015; Giuliano and Small 1991). Despite this, past research has failed to identify any significant impact of airport proximity on spatial patterns of employment across the metropolitan area in which the airport is located.

In order to conceptualise the impacts of airports on the spatial distribution of employment, the first part of this paper aims to link recent literature on the economic impact of airports with long-established concepts of studies on urban employment centres. In the empirical section of this paper, we answer two major research questions with regard to Australian metropolitan areas: (1) To what extent has the growth of employment centres across the metropolitan area been impacted by the existence of the airport? (2) Is there evidence of airport privatisation leading to distinct spatial patterns of economic growth and restructuring on airport land and in adjacent areas?

The remainder of this paper is structured as follows: In the second section, the broader role of airports as economic factors, locational advantages and drivers of economic restructuring is outlined. More specifically, we summarise the results of empirical investigations on airports as foci and drivers of local and regional employment growth. In the third section, specific hypotheses, methodologies and data are presented. Three regression models are used to determine the impact of airport proximity on employment centre growth in major Australian metropolitan areas. We discuss empirical results on employment change at airport sites and adjacent areas in comparison to the CBDs and the metropolitan area. In the final section, we conclude our major findings.

2 Airports, economic restructuring and employment centres

There is a reciprocal relationship between airport development and regional economic growth. On the one hand, airport operators invest strategically in aviation infrastructure and in non-aviation commercial facilities, generating jobs on airport land and in the wider metropolitan area (see Graham 2014). On the other hand, airport expansion is also a result of economic growth and long-distance exchange, as the demand for air transport is positively related to regional growth of economic activities. On a macro level this has been confirmed by quantitative studies on the causality between passenger/freight volumes and economic growth in the airport region (for a recent review see Bilotkach 2015). However, empirical studies have also shown that negative external effects of airports (noise emissions, local air, soil and water pollution, road traffic congestion) can significantly harm living and working conditions in the airport surroundings, and therefore may limit further economic growth (Cidell 2015; Kramer 2004; Stifflemire 2000).

2.1 Airports as drivers of economic restructuring

Although airports are often located close to established industrial areas to minimise negative externalities of airport operations, several academic studies show that airports increasingly attract firms from service-based industries, even if the explanatory power of airport proximity varies significantly across different sectors. Accessibility to air cargo services has always played a significant role for the locational choices of warehousing and distribution firms (Bowen 2008; Sivitanidou 1996; Warffemius et al. 2008). Goods are typically shipped by air if they have a high value and a low weight and are perishable and time-critical. The higher the share of these goods, the stronger the need of freight forwarders, ground transport and support service firms to be located in spatial proximity to an airport (Appold and Kasarda 2013).

More recently, retail and wholesale firms have located around airports, as they profit from the patronage of an increasing number of airport-based companies, airport employees, and passengers. They can also use the airport-related transport infrastructure to extend their service area and distribute their goods across the metropolitan area. A broad range of commercial accommodation serves the needs of air passengers in immediately adjacent areas, such as pre-flight overnight stays or business meetings (McNeill 2009).

Knowledge-intensive companies increasingly choose high-quality space at international hub airports because they rely on face-to-face contacts for knowledge exchange and in many cases profit from

the easy access to international markets (McDonough Kimelberg and Nicoll 2012; Yigitcanlar et al. 2008). Thus, airports create favourable environments for advanced producer service companies, high-tech manufacturing firms and research organisations (Conventz and Thierstein 2015). In addition, the growth of professional, scientific and technical service jobs at airports is the result of the provision of high end commercial office space. This in turn is facilitated by the growing importance of non-aviation revenue streams for airport operators to counterbalance risks with regard to the notoriously volatile aviation business, new investment strategies of the airports' shareholders, and the engagement of external developers in projects at airport sites (Graham 2014). Empirical evidence from the US and Germany, however, suggests that high concentrations of knowledge-intensive firms still seem to be a phenomenon of only a limited number of international hub airports, located in global gateway regions with a very strong knowledge economy base (Cidell 2015; Volgmann 2013).

All in all, the available empirical studies reveal varying net benefits of airports, as job growth in knowledge-intensive services is often offset by a loss of employment in low-level manufacturing. This leads to the assumption that the restructuring forces of airports might be stronger than their roles as facilitators of overall job growth (Sheard 2014).

2.2 Airports as foci and drivers of employment centre growth

Airport-driven economic restructuring and the location of different industries in airport proximity have led to the emergence of significant local job concentrations. Airport-focussed employment centres evolve within a hierarchy of competing sub-centres, driven by economies and diseconomies of agglomeration and resulting in a rather decentralised concentration of economic activities within today's cities (Garreau 1991; Giuliano and Small 1991; Prosperi 2015; Van Wijk 2007). Centres which are not genuinely airport-based but located nearby can also benefit from fast access to air transport services, even if empirical studies reveal mixed results with regard to the impact of airport proximity as a significant determinant of sub-centre growth (Giuliano and Small 1999; Giuliano et al. 2012).

Evidence from European, Australian and US metropolitan areas also suggests that a clear airport-centred land value and employment density gradient hardly exists because high building density around many airports allows much less development of new office or high-tech parks in the airport proximity than expected (Schubert and Conventz 2011; Sonnenburg 2014). Moreover, Appold (2015) found that CBDs and major motorways have the most significant impact on metropolitan employment distribution. Only in one sixth of the US metropolitan areas studied by Appold did airports have a significant positive effect on employment density in their vicinity.

2.3 Airports as sub-centres in Australian cities

Major airports in Australia have been identified as specialised activity centres of regional significance by several metropolitan-wide empirical studies (see BITRE 2013b; Freestone and Murphy 1998; Pfister et al. 2000). Existing studies on individual cases, however, have obtained rather mixed results: Freestone and Tice (2013), for instance, found that Sydney airport's vicinities could not benefit as expected from air transport accessibility because of physical constraints and competition with other land uses in densely built-up areas, relocation of industrial companies to cheaper locations, and a strong locational preference of knowledge-intensive businesses for the northern parts of the metropolitan area. In contrast to Sydney, the effects of Brisbane airport are much less restricted by local conditions. Brisbane airport is the main driver of the metropolitan area's largest suburban employment centre, characterised by strong job growth and intense economic restructuring from port-related activities and manufacturing to knowledge- and service-oriented businesses (Sonnenburg 2014). However, the airports' impacts on the spatial distribution of employment across different Australian metropolitan areas is still unclear as a systematic comparative investigation has not been conducted yet.

Australian airports and their environments are interesting cases to study employment growth effects. The largest Australian airports were fully privatised between 1997 and 2002 (Forsyth 2002). A light-handed regulatory regime in land use planning put into place by the Federal Government has enabled airport operators to strengthen their non-aviation business and develop commercial property without direct approval of local councils (Baker and Freestone 2012). This has caused significant growth of non-aviation-related development, and subsequently jobs, at the major airports (BITRE 2013a). The regulatory framework adopted in 1996 resulted in several fierce land use conflicts between

airport operators, competitors in the property market, and local planning authorities. For example, a dispute between Westfield Corporation (developer and owner of shopping centres) and Brisbane Airport Corporation about a major retail development on airport land ended up in the Federal Court of Australia (Baker and Freestone 2011).

3 Hypotheses, methodology and data

Following the mainstream of the airport literature reviewed above, we assume that the strength of airport-related effects decreases with increasing distance to the terminals. More specifically, we aim to test two hypotheses:

1. Airport proximity is only one driver of employment centre growth among others, such as motorway and labour force accessibility.
2. Substantial property development in the post-privatisation era of airports has caused significant employment growth and sectoral change on airport land – where land banks were available - as well as spill-over effects in adjacent areas.

We use secondary statistical data from the Australian Bureau of Statistics' Censuses of Population and Housing for 2001, 2006 and 2011[1] for the Greater Capital City Statistical Areas of Sydney (pop. 5.0 million, 2016), Melbourne (pop. 4.6 million), Brisbane (pop. 2.4 million) and Perth (pop. 2.1 million). The land use dataset is based on ABS Mesh Block land use categories (ABS 2010). The latter have been manually adjusted by using 2013 aerial images[2].

As major airports in Australia have been leased to private investors around the turn of the millennium, we are able to identify the impact of commercialised airports during the post-privatisation decade. In order to better understand the impact of privatisation on strategies of airport operators and the employment structure at the airports, we also conducted 43 semi-structured expert interviews with airport operators, external developers, and planning authorities. The results of these interviews have been used to gain expert knowledge about the airport property development process and to validate our quantitative analyses.

The spatial patterns of employment have been analysed by aggregating the values for each Statistical Area Level 2 (SA2)[3] to the following spatial categories, covering areas where we expected to find airport-related development and other effects of localised job growth:

- the airport land itself;
- a buffer zone of 5 km around the terminal[4], covering almost all directly aviation-related activities, such as airline offices, ground handling, catering, maintenance, freight forwarding, security and customs, both at the airport itself and on land controlled by other public and private owners in the surrounding areas;
- a buffer zone of 5 km around the CBD as a basis of comparison to the terminal-focussed radius of the same extent and as an indicator for the degree of general job centralisation within the metropolitan area; and
- employment centres as crucial nodes of economic activity across the entire metropolitan area.

To identify metropolitan employment centres we applied a reference threshold method because we prioritised comparability across metropolitan areas over a potentially higher statistical robustness of parametric, non-parametric or functional approaches (see Cladera et al. 2009). Following García López (2007), a SA2 has been identified as an employment centre candidate if its employment density for 2011 was above the metropolitan average (Sydney: 1284 jobs per square kilometre; Melbourne: 1159; Brisbane: 924; Perth: 486). Continuous SA2s have been merged. If the sum of total number of jobs across all merged units exceeded 10,000, the identified SA2s have been classified as an employment centre. In addition, contiguous units in the inner suburbs have been separated into several sub-centres based on industrial structure. Moreover, we have merged

[1] Older data are not available on a consistent basis for all metropolitan areas. Industry-specific data based on the Australian and New Zealand Standard Industrial Classification 2006 are available for 2006 and 2011 only.

[2] We use ABS Mesh Block land use data to distribute jobs and resident population for 2001 from 404 Statistical Local Areas to the finer resolution of Statistical Area Level 2 (SA2). We have proofed and adjusted the category values manually by a comparison of the original data and 2013 aerial images of all metropolitan areas.

[3] Size, population and employment of SA2s strongly vary between city centre and outskirts. The average size in terms of area is 44 square kilometres, but most of the SA2s are only 15 square kilometres or less. On average SA2s comprised approximately 12,000 residents and 5,000 jobs in 2011.

[4] Data for a particular SA2 are included in the total value for the buffer zone if the straight-line distance between the terminals and the centroid of the SA2s is ≤ 5 km.

SA2s containing airports with adjacent centres, even if airports do not exceed the density threshold due to the extensive land attributed to transport infrastructure. Across all four metropolitan areas studied, we have identified 196 candidates and have merged them into 61 employment centres. For these centres we calculated the set of variables used by GIULIANO et al. (2012) for their study on the impact of accessibility on US employment centre growth, adjusted to the Australian context (Tab. 1).

The impact of drive time distance to the airport on employment centre growth has been determined by estimating three regression models, using employment growth rates 2001-2011 in sub-centres as dependent variable: Our base model includes four productivity-related drivers of sub-centre growth – agglomeration economies (proxy: size of the centre), land availability (proxy: density), industrial composition (proxy: average regional industry sector growth) and urbanisation economies

Tab. 1: Variables and models of regression analyses – centre employment growth rates 2001-2011 as dependent variable

Group	Variable[a]	Description	Formula
Base model	EMP 2001[b]	2001 employment	
	DEN 2001[b]	2001 employment density	
	PRED GROW	Predicted growth rate 2006-2011[c] (PGR) based on average regional industry sector growth	$\Delta E_m^p = \left(\sum_i E_i \bar{g}\right) / E_i$ E_m^p = PGR of centre m; E_i = 2006 employment in sector *i;* $\bar{g}_i$ = regional growth rate of sector *i*
	DIST CBD[b]	Free-flow drive time distance[d] to CBD	
Airport access	DIST AIR[b]	Free-flow drive time distance[d] to nearest international airport terminal	
Motorway and road access	DIST MOT[b]	Straight line distance[d] to nearest motorway entrance in 2001	
	NET ACC	Free-flow network accessibility (FFNA)[e]	$A_i = \sum_j e^{\beta d_{ij}}$ A_i = FFNA of centre *i* d_{ij} = straight line distance *i* to *j* $\beta = \frac{1}{\text{average commuting distance in 2001}}$
Labour force access	ALFA 2001	Absolute labour force accessibility (weighted sum of population discounted by distance based on average commuting distance[e])	$A_m = \sum_j L_j e^{\beta d_{jm}}$ A_m = ALFA of centre *m* L_j = residences in spatial unit *j* d_{jm} = straight line distance *j* to *m*
	RLFA 2001	Relative labour force accessibility (same as ALFA[e] but considering competition of other centres)	$B_m = \sum_j L_j \left(E_m e^{\beta d_{jm}} / \sum_k E_k e^{\beta d_{km}}\right)$ B_m = RLFA of centre *m* E_m; E_k = employment in centres *m* and *k*

[a]For derivation and explanation of indices see GIULIANO et al. (2012).
[b]Variables transformed are in their natural log forms because of the skewness of their distributions.
[c]Predicted growth is calculated for 2006 to 2011 instead of 2001 to 2011 because of limited data availability of sector specific employment data.
[d]Calculated between centroids of the included SA2 characterised by the highest density, drive times have been determined by using the ESRI ArcGIS Online Service 'Generate Service Areas'.
[e]The average commuting distance in 2001 varied between 10.8 km and 11.5 km across the metropolitan areas.
Source: Own table, based on GIULIANO et al. (2012).

(proxy: distance to the CBD). In a second step, we add distance from the airport to the base model to examine the airport's impact on sub-centre growth. Thirdly, we additionally control for transport costs with regard to local and regional transactions (proxy: road network accessibility) and the local availability of workers and consumers (proxy: population around centres), both expected to be positively associated to employment centre growth because both accessibility of motorways and the spatial distribution of population – a standard proxy for labour force accessibility – are highly uneven in Australian metropolitan areas. The largely fragmented system of motorways in Australian metropolitan areas provides good accessibility to some centres, while others are disadvantaged. Whereas large parts of Australian suburban areas are characterised by low population densities and the dominance of single-family homes, many suburban centres and transport corridors experience ongoing densification, including the rise of multi-storey apartment buildings.

The calculation of proxies of network accessibility and generalised labour force accessibility across all sectors is based on the assumption that each centre creates its own service area of retail and distribution firms as well as a commuter zone of professional and technical services. The indicators also take into account competition between adjacent centres if their service areas and commuter zones overlap (Tab. 1).

The following section presents a description of characteristics of centres, results of regression models and an analysis of the five kilometres buffer zones around airports and CBDs.

4 Empirical results for Australian metropolitan areas

In spite of considerable decentralisation of economic activities over the last decades, the CBDs are still the largest and densest job concentrations in Australian metropolitan areas (Tab. 2). Growth rates across all CBDs fluctuate around 30 percent between 2001 and 2011 (with the exception of Sydney). Moreover, there is a positive relationship between the size of the metropolitan area and the number of identified sub-centres. Whereas Sydney and Melbourne tend to be increasingly polycentric metropolises, the smaller metropolitan areas of Brisbane and Perth are still characterised by a highly monocentric employment pattern. The strong position of the urban core is also indicated by the fact that employment centres within the inner suburban rings are significantly larger than their outer suburban counterparts.

The centres around major airports are among the largest employment centres of their respective metropolitan areas. At the same time, airport-focused centres are characterised by strong growth in both absolute and relative terms over the period 2001 to 2011. The centres around Brisbane and Perth airports experienced much stronger growth of jobs in professional, scientific and technical services (PSTS) than of more traditional jobs in transport, postal and warehousing (TPW) between 2006 and 2011 (Tab. 2). This clearly indicates a restructuring process which has not only been driven by increasing demand of directly airport-related service companies, but has been also facilitated by substantial development of new office space by privatised airport operators (Freestone 2011). Growth of PSTS jobs at airport-based centres has also been stronger than in most other employment centres. However, the growth of employment in TPW exceeded the increase of jobs in PSTS in the employment centres around Sydney and Melbourne airports. This suggests a key difference between larger, more polycentric and smaller more CBD-centred metropolitan areas in terms of the sectoral structure of employment growth around airports. While the relatively low total number of employment centres in Australian metropolises does not allow to include this difference in our regression models, this aspect should be explored in more detail in future analyses.

In addition to job growth around the four major airports in Sydney, Melbourne, Brisbane and Perth, the centre around the older and formerly run-down general aviation airport in Essendon (Melbourne metropolitan area) has gained new jobs (33.2 % growth 2001-2011) because its operator has developed the site into a large-scale retail park and office campus (Freestone and Wiesel 2014).

4.1 Impact of airport proximity on employment centre growth

We evaluate the impact of the four airports on the growth of 61 identified employment centres by estimating three linear regression models. We use the ordinary least square method and include stepwise control variables for both productivity related factors and other forms of network accessibility (Tab. 3). All models are significant at the five percent level. Their explanatory power is weaker than in the study of Giuliano et al. (2012) but still considerable.

Tab. 4: Employment structure and change in different spatial categories

	Variable	Sydney	Melbourne	Brisbane	Perth
Airport territory (SYD, MEL, BNE, PER)	Passengers 2015-16 [m]	41.1	33.7	22.3	12.6
	Freight[a] 2015-16 ['000 t]	482.9	296.1	124.8	97.0
	Metropolitan population 2011 [m]	4.4	4.0	2.1	1.7
	Airport-CBD distance [km][b]	8.1	18.9	12.2	9.9
	Size of airport site [ha]	905	2,647	2,700	2,105
	Total on-site jobs[c] 2011	12,275 (28,821)[d]	13,910	14,371	11,023
	On-site employment per million passengers 2011	344	503	707	970
	Employment growth rate 2001-2006 [%]	25 (2)[d]	19[e]	45	50
	Employment growth rate 2006-2011 [%]	1 (2)[d]	34[e]	38	121
	Share of TPW jobs 2011 [%]	59 (58)[d]	59	50	46
	Share of jobs in public administration and safety 2011 [%]	16	10	11	8
5 km terminal buffer	Employment share of metro total 2011 [%]	9.2	1.2	5.6	6.3
	Job density 2011 [jobs/km^2]	1,964	431	645	575
	Employment growth rate 2001-2011 [%]	-3.8	19.3	44.9	42.7
	Share of TPW jobs[f] 2011 [%]	17.1	45.9	23.3	19.1
	Growth rate of jobs in PSTS 2006-2011 [%]	9.6	3.1	78.5	59.2
5 km CBD buffer	Employment share of metro total [%]	26.6	28.4	33.4	26.9
	Job density 2011 [jobs/km^2]	8,484	7,309	4,116	3,140
	Employment growth rate 2001-2011 [%]	11.1	24.2	30.1	32.4
	Share of TPW jobs[f] 2011 [%]	3.1	3.5	3.7	1.6
	Growth rate of PSTS jobs 2006-2011 [%]	16.9	27.7	30.6	36.2
Job centres located ≥5km from CBD and airport	Employment share of metro total 2011 [%]	27.9	25,2	14.4	15.3
	Job density 2011 [jobs/km^2]	2,115	1,567	1,370	1,006
	Employment growth rate 2001-2011 [%]	16.8	11.6	35.8	28.8
	Share of TPW jobs[f] 2011 [%]	3.4	3.0	7.7	4.0
	Growth rate of PSTS jobs 2006-2011 [%]	20.7	3.8	25.4	33.2
Metropolitan area	Total number of jobs 2011	1,837,714	1,700,628	906,856	745,070
	Job density 2011 [jobs/km^2]	149	170	57	116
	Employment growth rate 2001-2011 [%]	9.6	17.6	32.4	32.6
	Share TPW jobs[f] 2011 [%]	5.2	4.7	5.7	4.3
	Growth rate of PSTS jobs 2006-2011 [%]	15.8	19.5	29.4	33.8

Note: Data from ABS Census of Population and Housing 2001, 2006, 2011.

[a]Sum of international air freight and air mail.

[b]Straight-line distance between the centroid of the CBD and the midpoint of terminals.

[c]Sum of full- and part-time employees, the share of full-time employees is about 70 percent for each airport.

[d]Parenthetical values relate to the airport site and the adjacent suburb of Mascot where (due to the small airport site) a high share of directly airport-related jobs is located.

[e]Values relate to the airport site and an adjacent industrial area.

[f]Within the zone.

Sources: Own calculations, based on ABS (2015); BITRE (2013a), (2016).

Tab. 3: Results of regression models – dependent variable: employment centre job growth 2001-2011

	Base model		Add airport access		All access measures	
	Beta	**T**	**Beta**	**T**	**Beta**	**T**
Constant		3.609		3.558		4.488
Ln EMP 2001	-0.412**	-2.088	-0.433**	-2.179	-1.051**	-3.584
Ln DEN 2001	-0.283	1.553	-0.197	-0.972	-0.203	-1.017
PRED GROW	0.003	0.018	0.027	0.173	0.037	0.209
Ln DIST CBD	-0.415**	-2.051	-0.316	-1.398	-0.188	-0.757
Ln DIST AIR			-0.138	-0.969	-0.222	-1.619
Ln DIST MOT					-0.271**	-2.081
NET ACC					0.064	0.324
ALFA 2001					-0.149	-1.023
RLFA 2001					0.662**	2.306
Adjusted R^2	0.188		0.187		0.305	

Notes: **p < 0.05; *p < 0.10.

First, the results show that in relative terms, smaller centres grow significantly faster than larger centres, probably due to less road congestion, better availability of land, and lower land prices. Distance to CBD has a significant effect on sub-centre growth solely within the base model, implying that urbanisation economies play an important role for growth of centres in proximity to the CBD.

Second, we add 'distance to airport' to the base model. Airports have no significant impact either on sub-centre growth or overall goodness-of-fit of the model. Many companies with links to the airport obviously do not necessarily demand space in immediate airport proximity or nearby sub-centres. The spatial patterns of airport-related effects are much more dispersed.

Third, in order to improve the explanatory power of the model, we add different variables of road network and labour force accessibility. This highlights the importance of other forms of transport network accessibility for predicting employment change in sub-centres. Proximity to a motorway access point is positively related to employment centre growth because the motorway network in Australian cities is still underdeveloped in comparison to US metropolitan areas where this form of transport accessibility is nearly ubiquitous. Moreover, the significance of relative labour force accessibility shows that spatial proximity to the labour force and to consumers is crucial for employment centre growth. This is in line with results of the study of Giuliano et al. (2012) for US cities. Our results suggest that for many companies, costs for intra-metropolitan commuting and delivery of goods are more important for location decisions than fast access to air transport.

4.2 Development and structure of employment at airport sites

Because we could not find a significant impact of airport proximity on spatial patterns of employment growth across the entire metropolitan area, in this section the analysis is focused on developments at airport sites and in their immediate vicinities. As illustrated in table 4, Sydney Airport is the dominant airport in Australia in terms of passengers and freight. The airport site contains also the highest number of directly airport-related jobs, comparable to similar-sized airports in the US, such as Phoenix and Houston (Appold and Kasarda 2013). Sydney and Melbourne airports are particularly strong in terms of freight because their metropolitan areas are larger and more manufacturing/industry-focussed than the almost exclusively service-based economies of Brisbane and Perth. Brisbane and Perth airports have very high and fast-growing employment numbers in comparison to the volume of passengers and amount of cargo because their privatised operators have extensively developed new commercial and industrial properties, often in cooperation with external developers and institutional investors (Freestone 2011; Freestone and Wiesel, 2015). Expert interviews with airport operators revealed that airport-based property development in Australia is strongly supply-driven; as

a result, the airport operators in Brisbane and Perth have developed high-quality buildings. The lease prices in most of these properties are higher than of comparable properties in other suburban locations. Target groups have been both airport-related and non-airport-related tenants. The latter were attracted by comparatively low prices for land, floor space and car parking (compared to CBD locations) as well as land reserves for expansion rather than by air transport accessibility. Between 2001 and 2011 Melbourne, Brisbane and Perth airports have been able to satisfy the demand for development sites on their own land due to substantial land reserves and moderate absorption rates. This seems to suggest that the ability of the operators of these three airports to attract tenants is more important for further growth than the amount of land that can be made available for commercial real estate development.

All four airports have substantially invested in their aviation infrastructure, including extensions of runways (Brisbane is currently undertaking construction of a new parallel runway), taxiways, aprons and terminals. The accessibility of the airport to its surrounding region has been enhanced by improvements of on-site road and rail infrastructure. Accordingly, aviation-related growth of economic activity has not been harmed by shortages in transport capacities or an unjustified increase in airport service fees (Productivity Commission, 2011). Of the four case study airports, only Sydney airport is facing challenges in property development due to its relatively small site size.

Job growth between 2001 and 2011 at Brisbane, Perth and Melbourne airports was faster than in the CBD buffer zones, other employment centres (located more than 5 km away from the airport) or the entire metropolitan area (Tab. 4). In contrast, job growth has slowed down at Sydney airport between 2006 and 2011 because of the airport operator's focus on the optimisation of the use of existing assets rather than on the development of new commercial facilities. Job growth at Sydney airport was nevertheless slightly faster than on the metropolitan average but slower than in other employment centres, such as the North Shore business parks.

All airports show strong employment specialisation in the transport and warehousing sectors. This sectoral growth is not only driven by air transport, but also by the good integration of airports into the motorway network, enabling companies to quickly distribute goods across the metropolitan area. This freight hub function is supported by state governments through extensive investments in the road networks. The Airport Link tunnel in Brisbane and the current WestConnex project in Sydney connecting the airport and the inner suburbs to Western Sydney are among the largest urban infrastructure projects in Australia.

The extraordinary growth between 2006 and 2011 at Perth Airport was mainly triggered by the mining-driven internationalisation of the Western Australian economy and the rising number of 45,000 fly-in fly-out commuters (Dwyer 2011). Jobs in mining accounted for 9 percent of the total number of jobs at the airport in 2011, followed by retail trade (9 %) and public administration and safety (8 %). At Sydney, Melbourne and Brisbane airports jobs in public administration and safety totalled up to 16 percent, representing the highest share of all employment sectors. This is mostly the result of the relocation of offices of the Australian Federal Police, Australian Customs and Border Protection, and the Civil Aviation and Safety Authority from their established locations to capital city airports in the early 2000s.

4.3 Development and structure of employment in 5 km buffer zones

Even if on-site employment has grown substantially, airports are still much less important job concentrations than the CBDs. In Sydney 9.2 percent of total metropolitan employment is located within 5 km around the terminals, which is by far the highest share of all airports (Tab. 4). In contrast, within a 5 km buffer zone around the CBD the same share varies from about one fourth (Sydney, Melbourne, Perth) to one third (Brisbane).

Airport vicinities within a 5 km radius (with the notable exception of Sydney) have remained largely low-density environments. However, our findings suggest that this might change in future. The 5 km buffer zones of Brisbane and Perth airports were already characterized by high growth rates over the period 2001 to 2011 (Tab. 4), much higher than the growth rates in other employment centres and the CBD buffer zones. An important driver of this development was the mining boom and the need for mining-related manufacturing and service companies for air travel. Jobs in mining within the buffer zones grew by 131 percent in Brisbane and by 212 percent in Perth between 2006 and 2011. These two airport buffer zones also attracted a significant amount of office-based employment: Jobs in professional, scientific and technical services

Tab. 2: Employment centre characteristics and growth in Sydney, Melbourne, Brisbane and Perth (centres >20,000 jobs)

	Employment 2011	Employment density 2011 [jobs/km²]	Job growth rate (GR) 2001-2011 [%]	GR of transport, postal and warehousing (TPW) jobs 2006-2011 [%]	GR of professional, scientific and technical services (PSTS) jobs 2006-2011 [%]	Distance from CBD [min]	Distance from airport [min]
Sydney City (incl. CBD)	294,475	47,561	18.8	36.8	17.3	1	25
South Sydney	142,545	6,864	2.6	-30.5	35.8	6	18
North Shore	122,109	3,135	12.9	-21.5	35.2	13	29
Olympic Park	78,856	1,832	31.9	-3.2	32.0	27	27
Parramatta	69,679	2,869	17.5	9.9	-1.2	34	31
Sydney Airport-Port	57,808	1,826	12.8	20.8	10.6	18	7
East Sydney	56,362	2,291	14.1	-59.7	3.9	15	19
Sydney Inner West	33,377	1,716	-3.8	0.8	0.9	12	25
Bankstown	27,918	1,627	-0.2	-29.3	9.7	35	20
Melbourne City (incl. CBD)	272,263	24,006	34.3	5.2	31.6	1	26
North Melbourne	100,544	4,042	14	-22.3	29.2	6	25
South Melbourne	81,684	4,539	2.6	-53.4	26.7	9	26
Clayton	64,409	1,976	9.7	2.7	7.4	26	45
Richmond-Hawthorn	52,422	3,336	28.3	35.1	14.3	14	33
Box Hill	33,355	1,636	12	38.9	-1.7	26	43
Melbourne Airport Area	31,576	610	45.4	99.0	10.8	22	6
Malvern	23,304	1,465	13	3.4	-5.6	18	36
Port Melbourne Area	22,585	2,360	12.3	152.6	-31.8	11	22
Brisbane City (incl. CBD)	216,068	9,125	30.9	29.1	26.2	1	21
Brisbane South - East	60,469	3,050	33	-6.9	79.4	6	23
Brisbane Airport Area	34,320	580	52.3	16.7	65.7	16	11
Nathan - Rocklea	32,459	1,127	17.4	-14.4	-1.0	15	29
Chermside - Northgate	28,770	2,122	22.2	1.3	41.7	17	15
Mount Gravatt	21,436	1,335	71.7	43.5	25.1	12	22
Perth City (incl. CBD)	179,764	4,569	31.6	52.5	36.0	1	16
Freemantle - Melville	54,598	715	18	15.8	26.4	23	30
Osbourne Park	41,780	1,612	25.1	-16.3	91.1	11	23
Canning	37,206	1,283	22.3	52.6	-2.0	15	11
Perth Airport Area	35,352	765	40.8	28.6	94.1	16	7
Cottesloe - Claremont	28,073	1,232	24.2	-14.8	-11.8	13	27
South Perth	22,586	1,046	31.8	49.3	31.3	8	14

Note: Data from ABS Census of Population and Housing 2001, 2006, 2011.
Source: Own calculations, based on ABS (2015).

grew by 79 percent in Brisbane and by 59 percent in Perth. Expert interviews and site visits revealed that many airport-related office tenants in Brisbane and Perth relocated from the CBD fringe and suburban business parks to the airport vicinities to get better air transport access without paying a premium rent at the airport site itself.

Growth in Melbourne has been modest but is still considerably higher than in a 2.5 mile radius around the 25 busiest airports in the US (Appold and Kasarda 2013, 1249) and higher than in other (suburban) employment centres. The sectoral focus of this growth was on financial and insurance services, TPW, and information media

and telecommunications (more than 70 % each between 2006 and 2011).

The office market in development adjacent to Sydney airport traditionally contained many tenants involved in the air transport value chain. However, airport-related job growth in the five kilometres buffer zone was offset by a decline in traditional industrial employment, even if strong population growth in new residential areas has led to an increase in jobs in education and training (+53.2 %) as well as health care and social assistance (+34.4 %) between 2006 and 2011. Expert interviews indicate that airport-related negative externalities, such as aircraft noise, have not significantly harmed commercial development around Sydney airport.

4.4 Limitations of the research

The persistency of urban form usually requires a long time period for investigations of changes across the entire metropolitan area. We have focussed on only one decade, due to the limited availability of consistent data. Second, spatial resolution of even the smallest spatial units available has been insufficient for some analyses, impeding our opportunities to precisely define nodal centres. This leads to an underestimation of employment centre densities and a selection bias in sub-centre identification. Third, we included 61 sub-centres across four different metropolitan areas in the regression models because the variance in the characteristics of centres would be not sufficient within a single city. As a result, our methodology does not consider that the impact of airports on employment patterns in different cities might vary with population size and the share of employment in the central city. Finally, the reciprocal causality between the development of airports and metropolitan areas is not comprehensively covered by the regression models (Brueckner 2003; Green 2007).

5 Conclusions

Australian metropolitan areas have experienced a significant decentralisation of jobs in recent decades. In this respect, they follow the path of US cities with a time lag of 10 to 20 years (compare Braun 1996; Giuliano and Small 1991). As a part of this process, Australian airports in suburban areas have become regional foci of employment, large-scale infrastructure hubs, multi-modal transport nodes and international gateways. As Australian cities are generally fast-growing in comparison to many metropolitan areas in the US and in Europe, we expected a positive effect of airports on adjacent areas and nearby employment centres. Although we identified strong local job growth at Brisbane, Perth and Melbourne airports, our regression models indicate that growth of (suburban) employment centres is determined mainly by metropolitan centre size as well as accessibility of motorways and labour force, rather than the existence of airports. Thus, our first hypothesis, postulating airport proximity is only one driver of employment centre growth among others has been confirmed. Airport proximity is a factor of comparatively minor importance for employment centre growth on a metropolitan scale. These findings complement both the equally mixed results of Appold (2015) for US airports and cities as well as the significant impact of local access to highways and labour force in the study of Giuliano et al. (2012) of Los Angeles, using the same set of indicators. The effects of airports on employment appear to be spatially much more dispersed than often assumed. One reason might be that good ground access to airports via motorways and/or rail networks creates considerable locational freedom for airport-related companies (see Freestone and Tice 2013). These findings support Cidell's (2015) empirical results for US metropolitan areas, showing that existing patterns of urban development strongly determine the spatial distribution and concentration of airport-affine jobs in professional, technical and scientific services. Airports can have, but not necessarily do have, a major impact on local employment growth.

Our second hypothesis postulated that, in addition to direct positive effects of airports on air transport-related employment, non-aviation-related employment at and adjacent to airports has been affected positively in recent years. Although the employment structure of airport sites suggests that they are still specialised activity centres within their respective metropolitan areas, their characteristics are developing into multi-sectoral and multi-functional employment centres. These processes have been facilitated by commercialisation and privatisation of the airport operators, leading to substantial office and retail developments at the airport and a strong growth of jobs in professional, scientific and technical services in airport-based employment centres. For example, the majority of office development on airport land occurred after privatisation. This is at least true for airports like Melbourne,

Brisbane and Perth, where ample land was and still is available for development. Moreover, the evidence from expert interviews indicates considerable spill-over effects in areas adjacent to airports. These spill-over effects are spurred partly by air transport accessibility and partly by privatisation-induced land price increases on the airport land itself. Around Sydney, airport spill-over effects are particularly obvious due to its relatively limited site and an ongoing decline in urban manufacturing. In Brisbane, many areas around the airport have also transformed into mixed use zones, whereas areas adjacent to Melbourne airport are part of a fast-growing area of employment in transport and warehousing. In the vicinities of Perth airport economic restructuring is less obvious, as most development has happened on airport land. Broadly speaking, our study has identified that privatised airports are not only facilitators of aviation-related economic growth but also promoters of local and regional economic restructuring. This should be considered in future urban planning and economic development strategies.

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