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Assessment of competitive hub status of cities in Europe and Asia from an international air traffic perspective

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Abstract:

The objective of this paper is to develop a refined gravity model for the quantitative assessment of competitive hub status of cities between 2000 and 2012 from the perspective of international air traffic movements. Its focus of attention is Europe and Asia, where cross border competition has been witnessed among major cities for the role as a key international air traffic hub. To this end, the research incorporates global network connectivity (GNC) as a measure of business connections into an established gravity model that previously relied on GDP per head, population and distance to account for international air links. The results confirm the dynamic change of the air transport city hierarchy, demonstrating a stronger presence of a number of previously secondly ranked cities as international air traffic hubs over this period. The paper concludes with suggestions that possible extension of geographical scope and incorporation of domestic air traffic could enrich the insight of this approach.

Keywords:

International air traffic movements; Competitive hub status of cities; Urban hierarchies; Gravity model; Europe and Asia

1. Introduction

Air passenger market has drastically expanded over the last decades in Europe with strong economic integration at both the global and regional levels. Passengers from, to and within this region are expected to have the annual growth rate of 2.7% in the next 20 years, with an overall market size of 1.4 billion. This region will still cater for an additional 591 million passengers a year (IATA, 2014a). As for air cargo traffic over the next 20 years, the markets between Europe and Asia, North America, Latin America, the Middle East and Africa will grow as fast as the world average annual growth rate of 4.7%, although intra-Europe market will show the lowest annual growth rate of 2.0% in the world (IATA, 2014b). Meanwhile, passengers from, to and within Asia are expected to account for nearly half of global passenger traffic in the next 20 years, with an overall market size of 2.9 billion (IATA, 2014a). This region will also lead the world in the growth of air cargo traffic. Domestic China and intra-Asia markets will expand at the annual growth rate of 6.7% and 6.5%, respectively, while Asia-North America and Asia-Europe markets will grow slightly faster than the world average growth rate of 4.7% (IATA, 2014b).

Meanwhile, Europe and Asia have witnessed the most intense cross border competition on the globe among major cities to become a key traffic hub for international aviation. This may be facilitated in Europe by the expansion of current airports in London/Heathrow, Madrid, Barcelona, Milan/Malpensa and Frankfurt and by the construction of a new international airport in Munich in 1992. Berlin is scheduled to open an international airport by expanding Schönefeld, which will become a single commercial airport serving this city. Asia has seen much more examples of that, where new international airports opened one after another in the 1990's and 2000's in Shenzhen (1991), Osaka/Kansai (1994), Macau (1995), Kuala Lumpur (1998), Hong Kong (1998), Shanghai/Pudong (1999), Seoul/Incheon (2001), Guangzhou (2004), Nagoya/Chubu (2005), Tianjin (2005) and Bangkok/Suvarnabhumi (2006). Tokyo/Narita, Tokyo/Haneda, Singapore/Changi and Taipei/Taoyuan responded by expanding their capacities, including new runways or terminals. Beijing and Ho Chi Minh City are scheduled to start the construction of a new international airport in 2019 and in 2023, respectively.

On the other hand, three global air-freight integrators, DHL, FedEx and UPS, have developed their hub-and-spoke networks in these regions by establishing global or regional hubs. Their European and Asian hubs are drastically changing the urban pattern of international air cargo transport in these regions. Within Europe, DHL puts its main hub in Leipzig and several regional hubs in Amsterdam, Brussels, Copenhagen, Frankfurt, London, Madrid, Milan, Paris, among others. FedEx has its main hub in Cologne and regional hubs in Frankfurt, London and Paris. Within Asia, Hong Kong is a main hub of DHL. Its regional hubs include Bangkok, Seoul, Shanghai, Singapore and Taipei. FedEx establishes its main hubs in Guangzhou and Shanghai and regional hubs in Hong Kong, Osaka, Singapore, Taipei and Tokyo. Meanwhile, Shenzhen is a main hub of UPS and Hong Kong, Shanghai and Singapore are its regional hubs.

Hence, there has been a major re-alignment in hub roles within these two regions, providing the potential to change the hierarchical structure of hub cities. The main purpose of the present paper is to quantitatively assess the competitive hub status of major cities in Europe and Asia in terms of international air traffic movements by refining an established gravity model that previously relied on GDP per head, population and distance to account for international air links. The remainder of the paper is organized as follows. The next section provides an overview of the literature on airport choice and global urban hierarchies. In Section 3, a model is specified to explore international air traffic movements and, in turn, the change of competitive hub status of major cities in Europe and Asia between 2000 and 2012, followed by a discussion on the results in Section 4. Finally, the paper ends with a conclusion and future research in Section 5.

2. Literature review

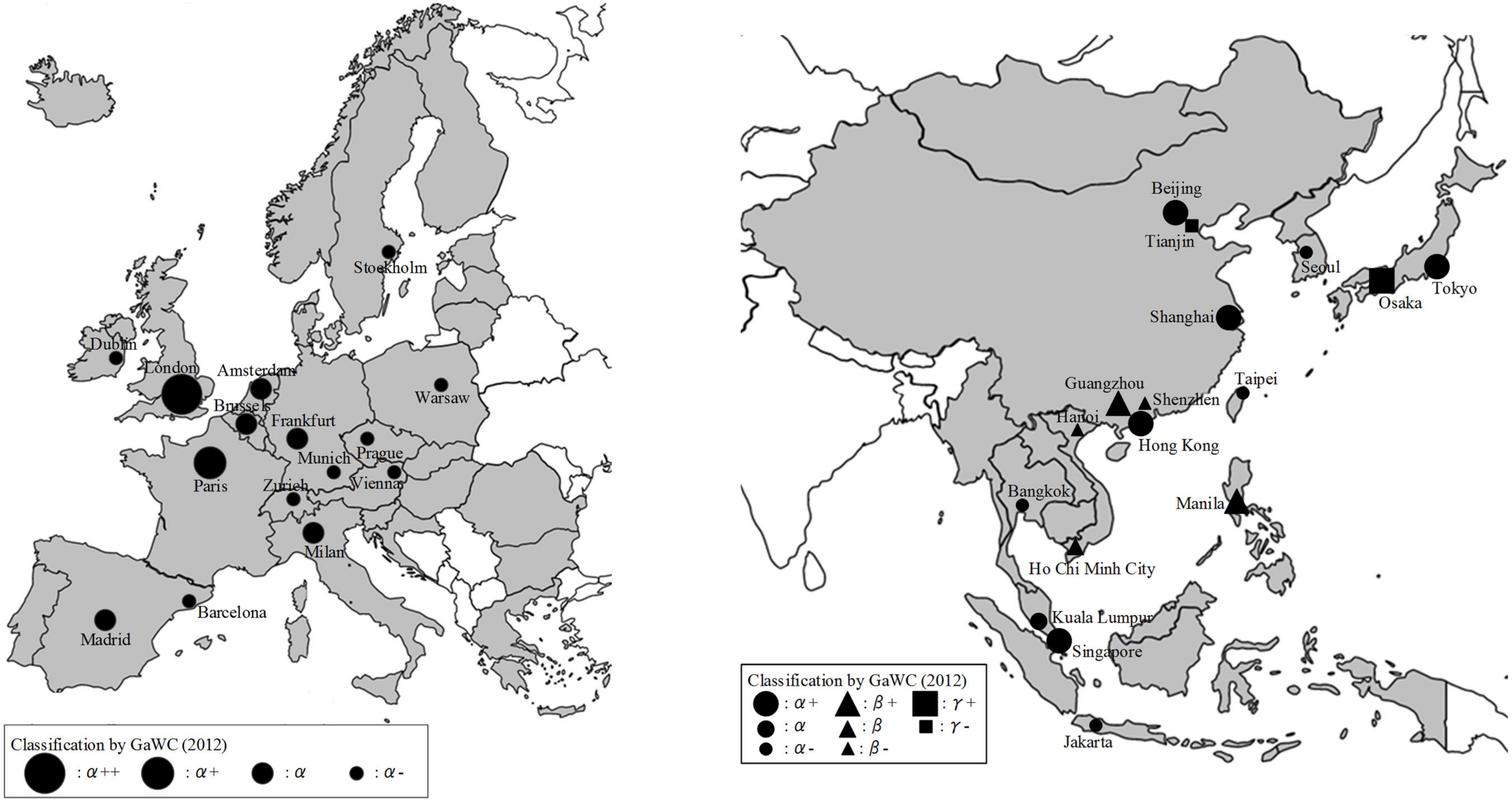
The demand for international air service is initiated, in the first place, by the larger economic markets. Therefore, the geographical location of airports is crucially important, as identified by Dennis (1994) in a study of passenger airline hub operations in Europe and by Zhang (2003) analyzing Hong Kong as an international air cargo gateway. In support of this, it is widely reported in the previous research on airport choice of passenger airlines and freighter operators that a central geographical location in relation to the economic markets serves as the most important factor to minimize flying time and cost (O'Kelly, 1986, 1998; Hall, 1989). However, location alone does not establish the comparative advantage of a hub site. Adler and Berechman (2001) found that runway and terminal capacity, local labor force costs and the reliability of air traffic control were important for passenger airline location. Meanwhile, customs efficiency was identified as an important factor from the cargo carriers' viewpoint by Zhang and Zhang (2002). Berechman and De Wit (1996) found that airport charges had a significant impact on passenger airlines' location decision in assessing a main gateway hub in Western Europe. From the empirical perspective, Schwieterman (1993) evaluated the prospective hub sites for express air cargo in the Asia-pacific rim in terms of airport capacity, locational advantages, market size and terminal services. Park (2003) assessed the competitive status of major airports in the East Asia region, based on five factors: service, demand, managerial, facility and spatial qualities. Ohashi et al. (2005) identified the critical factors influencing air cargo transshipment route choice decisions in Northeast Asia.

Meanwhile, we can draw on the substantial research that has connected business services, the location of multi-national firms and air transport (Taylor et al., 2002; Alderson et al., 2010; Derudder et al., 2013; Liu et al., 2013, 2014). Keeling (1995) provided an initial insight on the way that hierarchies of global cities in terms of international air traffic flows closely matched the location of headquarters of multi-national firms. Sassen (2012) underpinned that empirical observation by showing that the connections between the operations of multi-national firms and global business services together would influence air connections between cities. Liu et al. (2013) explored the co-evolution of the geographies of aviation and corporate networks and confirmed that insight, showing that cities with well-developed aviation networks attract more globalized business service firms, while globalized business service firms in turn stimulate the development of aviation networks. Much attention has been focused on world cities, which are significant clusters of multi-national firms and global business service firms and so play a prominent role in international air traffic movements. From this perspective, Europe and Asia are experiencing the dynamic change in the mobility of global cities in urban hierarchies, which has been documented by the considerable studies (O'Connor, 1995; Douglass, 2000; Shin and Timberlake, 2000; Smith and Timberlake, 2001; Taylor et al., 2002; Ng and Hills, 2003; Matsumoto, 2004, 2007; Hall, 2005; Derudder et al, 2010). Smith and Timberlake (2001) and Derudder et al. (2010) showed how connections between world cities changed over time. This paper will explore that dimension of the recent experience of cities in Europe and Asia between 2000 and 2012.

3. Analysis of international air traffic movements

3.1. Study areas

The focus of attention in this research is Europe and Asia, which have been selected as these two regions have witnessed the most intense cross border competition among major cities for the role as a key international air traffic hub since the 1990's. There is a hub competition in North America (the US), but it is the one in the domestic aviation market. Countries in the Middle East are also experiencing a keen hub competition (mainly among Dubai, Abu Dhabi, Doha and Istanbul), but it is a story in the recent years. Our research question is relevant to the dynamic change of hub status of major cities in a region's urban hierarchy from an international air traffic perspective over the last 12 years. From this point of view, Europe and Asia are the best regions to be analyzed on the globe, leaving other regions out of the paper's scope.



(1) Europe (2) Asia

Fig. 1. Countries and primary cities in Europe and Asia.

Note: EU single aviation market includes the 28 EU members (Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and United Kingdom) and 4 external countries (Iceland, Liechtenstein, Norway and Switzerland). According to the UN definition, East Asia comprises China, Japan, Democratic People's Republic of Korea, Mongolia, Republic of Korea and Taiwan province of China. Southeast Asia includes Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, Philippines, Singapore, Thailand, Timor-Leste and Viet Nam.

As shown in Fig. 1, Europe is a EU single aviation market, including twenty-eight EU members and four external countries. Asia in this paper comprises six countries and one region in East Asia and eleven countries in Southeast Asia. The figure also shows fifteen cities in Europe and seventeen cities in Asia, which are classified above the Alpha minus category and above the Gamma minus category, respectively, by the GaWC analysis discussed in detail in Section 3.3 below (GaWC, 2012). As discussed earlier, some of these cities in Europe and Asia have opened a new international airport, whereas others have expanded their airport capacities, including runways or terminals.

3.2. Model

A gravity model is employed to analyze international air traffic movements in this paper. The model is frequently used to determine the spatial orders or organization of air passenger and cargo flows (Harvey, 1951; Richmond, 1955; Lansing and Blood, 1958; Lansing et al., 1961; Taaffe, 1962; Howrey, 1969; Long, 1970; Wojahn, 2001; Grosche et al., 2007; Hwang and Shiao, 2011).

The idea on the gravity model in the current paper was first published in Matsumoto (2004), which analyzed international air traffic flows within and among the Asian, European and American regions separately over the years from 1982 to 1998. It incorporated into a gravity model GDP per head, population, distance and some city-dummy variables. In Matsumoto (2004), workload unit (WLU), a traffic measure combining passengers and cargoes, was used to reflect air traffic volume. A WLU is equivalent to one terminal passenger or a hundred kilograms of cargo handled (Doganis, 1992). Matsumoto (2007) separated passengers and cargoes in the analysis, using the extended dataset up to 2000. Meanwhile, Matsumoto and Domae (2018) developed these two studies by: (1) focusing on Asia, which has experienced the keenest airport competition on the globe with the starting-up of new international airports and the establishing of global air-freight integrators' hubs one after another. The significant growth of Chinese cities since 2000 was embedded in the analysis; (2) using the extended dataset up to 2012. Another improvement on data was the inclusion of much more observations of city-pairs; and (3) including in the analysis all international air traffic flows from, to and within Asia. Unlike the previous two studies, this change led to the inclusion of international air traffic flows from/to Asia to/from other regions than Europe and America (the Middle East, Africa etc.) in analysis.

The approach adopted here is a development of that used by Matsumoto et al. (2016), which explored the effect of business connectivity between cities on their air traffic connections, and, in turn, on their place in an East Asian urban hierarchy. The development involves the inclusion of global network connectivity (GNC) as a better measure of business connectivity. In Matsumoto et al. (2016), a variable was created for the model by assigning a number to each level in the classification: twelve for Alpha plus cities, eleven for Alpha cities, ten for Alpha minus cities, nine for Beta plus cities, eight for Beta cities, seven for Beta minus cities, six for Gamma plus cities, five for Gamma cities, four for Gamma minus cities, three for High sufficiency cities, two for Sufficiency cities and one for cities below Sufficiency with no classification. Here in this paper, a relative value of GNC is used for each city, which is based upon the office networks of advanced producer services (APS) firms interlocking cities through their worldwide distribution of offices.

The dependent variables are international air passenger and cargo flows between cities (T). The explanatory variables include GDP per head (G), population (P), global network business connectivity (B) and distance (D). In addition, city-dummy variables (C) are embedded into the model to explore the competitive hub status of major cities shown in Fig. 1. The entry rule for introducing them is their rank as a global city classified above the Alpha minus category for Europe and above the Gamma minus category for Asia by GaWC (2012), respectively (see Table 1 for a listing). We give a number of 'e' to city-dummy variables when either or both of cities in a city-pair correspond to one of these cities, so 0 value is given if neither are among them.

Technically, the size of 'e' raised to the power of a city-dummy parameter partly gives an indication of its hub status, as it accounts for international air passenger or cargo movements above those explained by the basic four factors (GDP per head, population, GNC and distance). This means that a city with this dummy has more international air traffic movements than expected, having considered its basic four factors, and this may be partly due to its hub status that attracts more international air traffic than locally generated. For example, an effect of transferring passengers is included in this value. If one flies from Osaka to London via Amsterdam, two tickets are issued: Osaka to Amsterdam and Amsterdam to London. In this case, Amsterdam functions as a hub airport and thus this value for Amsterdam becomes larger. Of course, this dummy variable is not solely related to the hub status of cities and changes in its size result from various factors. The parameter of this variable will become smaller for cities which face airport capacity shortage with limited opportunity to expand. Other than that, the growth of national economies, developments in aircraft technology (e.g. longer haul aircraft), changes in the type of passengers carried (e.g., the split between business and leisure travel) or changes in bilateral air service agreements will affect the size of city-dummy parameter.

Finally, the model utilized the measures of GDP per head, population, business connectivity, city-dummies and distance. The structure of the model is as follows:

$$T_{ij} = A \frac{(G_i G_j)^{\alpha} (P_i P_j)^{\beta} (B_i B_j)^{\gamma} exp(\varepsilon C_1) exp(\zeta C_2) exp(\eta C_3) \cdots exp(\tau C_{15}) exp(\upsilon C_{16}) exp(\varphi C_{17})}{(D_{ij})^{\delta}} \quad (1)$$

After transforming Eq. (1) into log form, ordinary least-squares (OLS) regression analysis is conducted separately to international air passenger and cargo flows from, to and within Europe and Asia on the segment level.

Table 1
City-dummy variables.

Dummy variable		C_1	C_2	C_3	C_4	C_5	C_6
Europe	City	London	Paris	Milan	Frankfurt	Madrid	Amsterdam
	GaWC (2012)	Alpha++	Alpha+	Alpha	Alpha	Alpha	Alpha
Asia	City	Beijing	Hong Kong	Shanghai	Singapore	Tokyo	Kuala Lumpur
	GaWC (2012)	Alpha+	Alpha+	Alpha+	Alpha+	Alpha+	Alpha
Dummy variable		C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
Europe	City	Brussels	Vienna	Zurich	Warsaw	Barcelona	Dublin
	GaWC (2012)	Alpha	Alpha-	Alpha-	Alpha-	Alpha-	Alpha-
Asia	City	Bangkok	Jakarta	Seoul	Taipei	Guangzhou	Manila
	GaWC (2012)	Alpha-	Alpha-	Alpha-	Alpha-	Beta+	Beta+
Dummy variable		C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	
Europe	City	Munich	Stockholm	Prague			
	GaWC (2012)	Alpha-	Alpha-	Alpha-			
Asia	City	Ho Chi Minh City	Hanoi	Shenzhen	Osaka	Tianjin	
	GaWC (2012)	Beta	Beta-	Beta-	Gamma+	Gamma-	

3.3. Data

City-pairs selected were those that had international air traffic movements exceeding ten thousand passengers and one hundred tons of cargo. Since cities are the basic unit of analysis, airport numbers were aggregated in cities that have multiple international airports. We obtained international air traffic data from the International Civil Aviation Organization (ICAO). As addressed in Derudder and Witlox (2005a, 2005b, 2008), the relevance of research based on the international air traffic statistics of the ICAO is potentially undermined because these data will be imperfect in some cases. One possible weakness in this first data is reduced by utilizing both of On-flight Origin and Destination (OFOD) and Traffic by Flight

Stage (TFS). The data on GDP per head was taken from the World Bank (WB), the Organisation for Economic Co-operation and Development (OECD), the United Nations (UN) and the International Monetary Fund (IMF), which was converted to US dollar at the constant 2005 prices. With regard to the population data taken from the UN, the concept of an urban agglomeration, rather than that of a city proper, was used, since the former is considered to be a better reflection of population in the areas surrounding airports. The distance between cities was calculated by using the website: Great Circle Mapper. The data sources are displayed in Table 2.

Table 2
Data sources.

Data	Sources
International air traffic flows between cities	On-flight Origin and Destination, International Civil Aviation Organization (ICAO) Traffic by Flight Stage, International Civil Aviation Organization (ICAO)
Real GDP per head	World Bank National Accounts Data, World Bank (WB) OECD National Accounts Data Files, Organisation for Economic Co-operation and Development (OECD) Statistical Yearbook, Fifty-sixth Issue, United Nations (UN) World Economic Outlook Database (April 2014), International Monetary Fund (IMF)
Population of urban agglomeration	World Urbanization Prospects (The 2011 Revision), United Nations (UN) Demographic Yearbook (1982-2012), United Nations (UN)
Distance between cities	Great Circle Mapper (http://www.gcmap.com/)

Meanwhile, the measure of business connectivity was obtained from GaWC (2012), which determines the hierarchy of cities basically every four years after 2000. As outlined in Taylor and Derudder (2016), this data source is based on the connections between the offices of 175 global APS firms in finance, banking, accountancy, insurance, law, consultancy or advertising across 526 cities. Measures of the number and importance of firm offices in each city are compressed into a score, which is then used to rank and classify the cities. Five groups are identified: Alpha, Beta, Gamma, High sufficiency and Sufficiency. Alpha, Beta and Gamma cities are again sub-divided into three or four categories. In this paper, original scores on the connections between the offices of global APS firms, GNC, were obtained from Derudder and Taylor (2016). In their analysis, a total of 100 firms were identified in six sectors, accountancy, advertising, banking and finance, insurance, law and management consultancy, across 315 cities in 2000 from Taylor (2004). Meanwhile, the data gathering in 2012 features 175 firms in five sectors, accountancy, advertising, finance, law and management consultancy, in 526 cities from Taylor and Derudder (2016), as explained above. Finally, operational roster of 157 cities from all regions worldwide with at least one fifth of the connectivity of the most connected city, London, was presented, featuring in at least one of the operational rosters in 2000 and 2012 (see Appendix A for a listing of cities). For example, when GNC of London in 2012 is set as 100, that of New York is 95.34, followed by Hong Kong (77.61), Paris (73.68), Singapore (68.29), Tokyo (64.89), Shanghai (64.07), Dubai (63.56), Sydney (63.05) and Beijing (61.72). Outside these top 10 cities, the 22nd is Amsterdam (53.67) ,･･･, the 35th is Melbourne (47.19) ,･･･, the 61st is Philadelphia (35.50) ,･･･, the 86th is Rio de Janeiro (27.49) ,･･･, the 111th is Antwerp (23.77) ,･･･, the 140th is Osaka (19.43),･･･ and the 157th is Hamilton (9.31). In this way, the measures are converted into the proportion of the maximum value, 100.

GNC influences air traffic, not the other way round, as explained in Matsumoto et al. (2016). For example, the connectivity between firms in the division of production relies upon business services to initiate investment, manage production and arrange logistics. This activity stimulates air transport links as corporate management staff move between production locations. Recognizing the importance of connectivity between business services, along with the movement of management personnel, means that change in the scale of business service connections of a city is likely to play a critical role in its place in the regional air transport network.

3.4. Results

Table 3 shows the regression results for Europe and Asia in 2000 and 2012. As a whole, the estimated values of parameters for Asia and in the passenger specification are more significant than for Europe and in the cargo specification, respectively. This means that there will be other factors to be considered for explaining international air traffic movements in Europe and international air cargo flows than the basic four variables presented in the model. Furthermore, the overall model fit was better in 2000 than in 2012, indicating that more variables should be considered in the model in the later year of the analysis.

As a whole, the influence of the GDP, population and distance parameters declined over the period analyzed. In contrast, the business connectivity variable has become much more prominent for Asia, confirming the fundamental role that the intra-regional connectivity between firms now plays as a dynamic influence upon air transport activity, even though its relative importance slightly declined for Europe. Insofar as the distance parameters in the passenger specification are concerned, the analysis shows that international air passengers move with less and less regard to their journey length. That may also reflect a growing complexity in connectivity in these regions, where longer length connections have an importance. That change will have some implications for the development of hub-and-spoke systems (HSS) and also low-cost carriers (LCCs) with lower fares on longer-haul flights. That trend may also be linked to the technological innovation of aircraft, which has allowed more point-to-point services on intra-regional routes, resulting in more direct city-to-city services within these regions. Meanwhile, those in the cargo specification become larger, probably indicating the establishments of global or regional hubs by air-freight integrators in some cities, as discussed earlier.

Looking at the effectiveness of the model in groups of cities for Europe, it seems that the outcomes among the cities in the larger Alpha class, London, Paris, Frankfurt and Amsterdam, were more consistent, confirming that this group of top four cities retains a prominent role in the network of cities in this region. The particular significance of Frankfurt and Amsterdam is confirmed in the cargo specification. Regarding cities in the smaller Alpha class, some are establishing a stronger presence in the network of cities, while others are losing their influence. The analysis shows the increased importance of Milan, Madrid, Vienna and Barcelona, positioned below the top ranked global cities. Among these cities, the hub status of Vienna rose strikingly over the years from 2000 to 2012 in the passenger and cargo models, which has come to act as a European gateway between the East and the West (Musil, 2009). In contrast, the experience is very uneven among cities in Asia. The model's estimates for cities in the Alpha class confirm that cities that have been seen as major hubs in the previous research (Matsumoto, 2004, 2007), Hong Kong, Singapore and Tokyo, retain their supremacy in the network of cities in this region. Hong Kong's particular significance is confirmed here, consistent with the conclusions drawn by Taylor and Derudder (2016) which was exploring its position in the global hierarchy. Meanwhile, the estimates provide a stronger role for a number of previously secondly ranked cities, such as Seoul, Taipei, Kuala Lumpur, Bangkok and Jakarta. Two Vietnamese cities, Ho Chi Minh City and Hanoi, and Guangzhou have had the strongest gains in terms of the hub status and appear much more important in 2012 than in 2000. In particular, the analysis in the cargo specification confirms the increased importance of Hong Kong, Shanghai and Guangzhou, an outcome linked to the opening of a new international airport and also the establishment of main or regional hubs by global air-freight integrators, along with the strength of the Chinese economy.

Table 3

Regression results.

(1) Europe.

Variable	GaWC (2012)		2000				2012			
			Passenger		Cargo		Passenger		Cargo	
Ln A		lnA	2.81	(5.91**)	-7.49	(-9.87**)	5.91	(14.95**)	-2.83	(-3.64**)
Ln (G_iG_j)		α	0.27	(17.37**)	0.27	(11.65**)	0.17	(12.18**)	0.10	(3.63**)
Ln (P_iP_j)		β	0.19	(8.31**)	0.26	(7.18**)	0.11	(7.65**)	0.11	(3.53**)
Ln (B_iB_j)		γ	0.17	(11.99**)	0.17	(7.37**)	0.15	(16.65**)	0.11	(5.40**)
Ln D_{ij}		δ	0.16	(7.06**)	0.49	(13.08**)	0.11	(6.06**)	0.71	(18.22**)
London	Alpha++	ε	0.81 [2.25]	(10.89**)	0.41 [1.50]	(3.51**)	0.78 [2.19]	(11.78**)	0.43 [1.53]	(3.46**)
Paris	Alpha+	ζ	0.60 [1.82]	(7.33**)	0.43 [1.54]	(3.52**)	0.69 [1.99]	(9.57**)	0.20 [1.22]	(1.49)
Milan	Alpha	η	-0.28 [0.76]	(-2.13*)	-0.38 [0.69]	(-1.78)	0.11 [1.11]	(1.11)	0.19 [1.21]	(0.91)
Frankfurt	Alpha	θ	1.08 [2.94]	(13.06**)	1.38 [3.96]	(11.34**)	0.78 [2.18]	(11.65**)	0.49 [1.63]	(3.97**)
Madrid	Alpha	ι	0.40 [1.49]	(3.82**)	-0.06 [0.94]	(-0.37)	0.51 [1.67]	(5.49**)	-0.08 [0.93]	(-0.44)
Amsterdam	Alpha	κ	0.91 [2.48]	(11.22**)	0.91 [2.48]	(7.04**)	0.84 [2.31]	(11.22**)	0.51 [1.66]	(3.81**)
Brussels	Alpha	λ	-0.13 [0.88]	(-0.98)	-0.12 [0.88]	(-0.61)	-0.10 [0.90]	(-0.86)	-0.38 [0.69]	(-1.82)
Vienna	Alpha-	μ	-0.32 [0.73]	(-2.28*)	-0.24 [0.78]	(-0.99)	0.30 [1.36]	(3.51**)	0.10 [1.11]	(0.54)
Zurich	Alpha-	ν	0.54 [1.71]	(6.27**)	0.62 [1.87]	(4.70**)	0.29 [1.34]	(3.48**)	-0.02 [0.98]	(-0.09)
Warsaw	Alpha-	ξ	-0.06 [0.94]	(-0.39)	-0.20 [0.82]	(-0.88)	-0.05 [0.95]	(-0.41)	-0.51 [0.60]	(-2.07*)
Barcelona	Alpha-	ο	-0.04 [0.96]	(-0.27)	-0.80 [0.45]	(-3.50**)	0.07 [1.07]	(0.60)	-0.78 [0.46]	(-2.92**)
Dublin	Alpha-	π	0.06 [1.06]	(0.38)	-0.30 [0.74]	(-1.21)	-0.24 [0.78]	(-1.30)	-0.50 [0.61]	(-1.39)
Munich	Alpha-	ρ	0.55 [1.74]	(4.79**)	-0.06 [0.94]	(-0.33)	0.52 [1.68]	(6.71**)	0.06 [1.07]	(0.34)
Stockholm	Alpha-	σ	0.25 [1.29]	(1.86)	-0.20 [0.82]	(-0.88)	0.03 [1.03]	(0.21)	-0.59 [0.55]	(-2.38*)
Prague	Alpha-	τ	-0.11 [0.89]	(-0.90)	-0.41 [0.66]	(-2.03*)	-0.16 [0.85]	(-1.58)	-0.36 [0.70]	(-1.55)
Adj.R^2			0.54		0.38		0.49		0.22	
Observations			1,643		1,336		3,152		1,629	

(2) Asia.

Variable	GaWC (2012)		2000				2012			
			Passenger		Cargo		Passenger		Cargo	
Ln A		lnA	5.78	(7.53**)	1.48	(1.26)	8.37	(11.99**)	2.42	(1.96)
Ln (G_iG_j)		α	0.31	(11.08**)	0.29	(7.02**)	0.11	(4.76**)	0.26	(6.27**)
Ln (P_iP_j)		β	0.15	(4.35**)	0.08	(1.57)	0.08	(2.90**)	0.04	(0.99)
Ln (B_iB_j)		γ	0.06	(1.93)	0.17	(3.75**)	0.14	(5.49**)	0.31	(7.71**)
Ln D_{ij}		δ	0.45	(6.85**)	0.25	(2.59**)	0.21	(4.40**)	0.29	(3.71**)
Hong Kong	Alpha+	ε	0.71 [2.03]	(3.72**)	1.21 [3.35]	(4.51**)	0.96 [2.61]	(5.92**)	0.92 [2.51]	(4.10**)
Singapore	Alpha+	ζ	0.79 [2.21]	(4.63**)	1.19 [3.30]	(4.78**)	0.69 [1.99]	(4.54**)	0.57 [1.77]	(2.43*)
Shanghai	Alpha+	η	0.52 [1.68]	(1.94)	0.81 [2.24]	(2.30*)	0.60 [1.82]	(3.43**)	1.04 [2.84]	(4.09**)
Tokyo	Alpha+	θ	0.47 [1.60]	(2.35*)	0.96 [2.62]	(3.37**)	0.78 [2.18]	(4.27**)	0.62 [1.85]	(2.41*)
Beijing	Alpha+	ι	0.77 [2.16]	(3.21**)	0.77 [2.15]	(2.19*)	0.43 [1.54]	(2.58*)	0.38 [1.46]	(1.50)
Kuala Lumpur	Alpha	κ	0.90 [2.47]	(4.98**)	0.90 [2.45]	(3.35**)	0.83 [2.29]	(4.81**)	0.68 [1.97]	(2.51*)
Seoul	Alpha-	λ	0.24 [1.27]	(1.30)	0.85 [2.35]	(3.25**)	0.50 [1.64]	(3.36**)	0.72 [2.05]	(3.28**)
Jakarta	Alpha-	μ	0.48 [1.61]	(1.74)	0.44 [1.56]	(1.14)	0.06 [1.06]	(0.23)	0.23 [1.26]	(0.58)
Bangkok	Alpha-	ν	1.51 [4.51]	(7.91**)	1.57 [4.79]	(5.73**)	1.01 [2.74]	(6.31**)	1.44 [4.24]	(6.02**)
Taipei	Alpha-	ξ	0.48 [1.62]	(2.17*)	0.72 [2.04]	(2.40*)	0.59 [1.81]	(2.39*)	0.27 [1.31]	(0.82)
Guangzhou	Beta+	ο	-0.29 [0.75]	(-0.77)	-0.60 [0.55]	(-1.04)	0.50 [1.65]	(2.71**)	0.50 [1.64]	(1.78)
Manila	Beta+	π	0.78 [2.19]	(3.37**)	0.61 [1.85]	(1.86)	0.61 [1.84]	(3.18**)	0.37 [1.44]	(1.22)
Ho Chi Minh City	Beta	ρ	0.65 [1.91]	(2.43*)	0.12 [1.12]	(0.29)	1.20 [3.33]	(5.68**)	0.87 [2.40]	(2.67**)
Hanoi	Beta-	σ	0.46 [1.59]	(1.26)	-0.48 [0.62]	(-0.81)	1.19 [3.29]	(5.62**)	0.49 [1.63]	(1.47)
Shenzhen	Beta-	τ	-	-	1.69 [5.39]	(1.60)	-0.14 [0.87]	(-0.21)	-0.46 [0.63]	(-0.82)
Osaka	Gamma+	υ	0.38 [1.46]	(1.96)	0.99 [2.69]	(3.63**)	0.29 [1.33]	(1.54)	0.23 [1.26]	(0.84)
Tianjin	Gamma-	φ	-0.32 [0.72]	(-0.57)	0.95 [2.58]	(1.10)	-0.36 [0.69]	(-0.74)	1.52 [4.55]	(3.45**)
Adj.R^2			0.61		0.57		0.52		0.43	
Observations			608		667		923		900	

Notes: Figures in ( ) are t-values; ** and * indicate significance at the 1% and the 5% levels, respectively. Figures in [ ] are ‘e’ raised to the power of a city-dummy parameter.

The results presented here show that secondly ranked global cities, such as Milan, Madrid and Vienna in Europe and Seoul, Shanghai, Guangzhou and Ho Chi Minh City in Asia, are establishing a stronger presence in the network of cities. It seems that the complex patterns of intra-regional business connectivity since 2000 have drawn more cities into its air transport network. Thus, the results on these dummy variables have refined our understanding of the importance of this aspect of cities outside their basic factors of GDP per head, population, business connectivity and distance.

4. Discussion

The development of the current paper involves the inclusion of business connectivity expressed by GNC, alongside GDP per head, population and distance, into a gravity model, confirming that business connectivity plays an influential role in international air traffic movements from, to and within Europe and Asia. As a result of refining an established model, the paper has successfully extracted the economic factor left in the city-dummy parameter in the previous research and quantitatively assessed the competitive hub status of cities in these two regions.

The analyses underline the changing competitive hub status among major cities from the perspective of international air traffic movements. In Europe, London, Paris, Frankfurt and Amsterdam retain a prominent role in the network of cities in this region, while Milan, Madrid, Vienna and Barcelona are establishing a stronger presence. Among these cities, the hub status of Vienna has strikingly risen, acting as a European gateway between the East and the West. In Asia, a number of previously secondly ranked cities, such as Seoul, Taipei, three capital cities in ASEAN and two Vietnamese cities, are strengthening their competitive hub status in the network of cities in this region, in addition to three established hubs of Hong Kong, Singapore and Tokyo. Meanwhile, Hong Kong, Shanghai and Guangzhou have had the strongest gains, an outcome no doubt linked to the opening of a new international airport and the establishing of global air-freight integrators’ hubs over the last decades. This results has confirmed that decisions associated with the construction of a new international airport and the establishment of an integrator's hub have a major influence on the city air transport activity hierarchy, which provides a significant implication for the planning and development of airports.

It is important, however, to recognize that there are some data problems for GDP per head and population of urban agglomeration used in the analysis. As for the data on GDP per head, there is a variation among cities within the same country, which is relatively large in the Asian countries. Regarding the data on population of urban agglomeration, these figures published by the UN are a simple gathering of national figures, which are based on their own definition of urban agglomeration. Refinement of the approach will need to incorporate more accurate data. Another drawback of the current paper relates to the interpretation of a city-dummy parameter. As mentioned above, it is not only connected to the competitive hub status of cities, but also to other factors, such as the growth of national and international economies, economic integration at both the global and regional levels, changes in the availability of airport capacity or changes in bilateral air service agreements. At the same time, airlines worldwide are being integrated into the three branded alliances (SkyTeam, Oneworld, and Star Alliance). The competitive hub status of cities is strongly affected by the strategy of airlines to join or seek alliances with other carriers.

5. Conclusion and future research

The main purpose of this paper is to quantitatively assess the competitive hub status of cities in Europe and Asia, where cross border competition has been witnessed among major cities for the role as a key international air traffic hub. To this end, the research has refined an established gravity model that previously relied on GDP per head, population and distance by incorporating global network connectivity (GNC) as a measure of business connections into the model to account for international air links. The results confirm the dynamic change of the air transport city hierarchy, demonstrating a stronger presence of a number of previously secondly ranked cities as international air traffic hubs over this period.

In future, the research will need to open up further to include other variables. An important consideration relates to the impact of domestic air traffic movements on the hub status of cities, something that has been outside the agenda of the present paper. Domestic air links could continue to re-shape the hierarchy of cities beyond the patterns detected in the current research. Another extension of this research is relevant to a worldwide analysis, including recent airport competition among Dubai, Abu Dhabi, Doha and Istanbul in the Middle East etc. These considerations will provide more new insights to our understanding of the development of cities from an air traffic perspective.

Appendix A

List of 157 cities.

GaWC (2000)		GaWC (2012)	
Alpha++	London, New York	Alpha++	London, New York
Alpha+	Hong Kong, Tokyo, Paris, Singapore	Alpha+	Hong Kong, Paris, Singapore, Tokyo, Shanghai, Dubai, Sydney, Beijing
Alpha	Chicago, Milan, Madrid, Los Angeles, Sydney, Frankfurt, Toronto, Amsterdam, Brussels, Sao Paulo, San Francisco	Alpha	Chicago, Milan, Mumbai, Moscow, Sao Paulo, Frankfurt, Toronto, Madrid, Los Angeles, Mexico City, Brussels, Amsterdam, Kuala Lumpur
Alpha-	Zurich, Taipei, Jakarta, Mexico City, Buenos Aires, Mumbai, Melbourne, Miami, Bangkok, Shanghai, Kuala Lumpur, Dublin, Prague, Stockholm, Barcelona, Atlanta	Alpha-	Seoul, Istanbul, Johannesburg, Washington, Zurich, Warsaw, San Francisco, Buenos Aires, Jakarta, Vienna, Miami, Melbourne, New Delhi, Barcelona, Bangkok, Boston, Stockholm, Munich, Dublin, Taipei, Prague, Atlanta
Beta+	Beijing, Seoul, Warsaw, Istanbul, Johannesburg, Moscow, Manila, Lisbon, Auckland, Budapest, Washington, Vienna, Copenhagen	Beta+	Santiago, Rome, Dusseldolf, Lisbon, Hamburg, Bangalore, Montreal, Manila, Athens, Tel Aviv, Copenhagen, Dallas, Cairo, Guangzhou, Budapest, Philadelphia, Kiev, Bucharest, Berlin, Lima, Cape Town, Houston, Beirut, Luxembourg
Beta	Dusseldorf, Hamburg, Montreal, Munich, Bogota, Athens, New Delhi, Santiago, Berlin, Caracas, Rome, Cairo, Boston, Dubai	Beta	Ho Chi Minh City, Bogota, Auckland, Riyadh, Caracas, Chennai, Casablanca, Montevideo, Helsinki, Doha, Oslo, Brisbane, Karachi, Manchester, Vancouver, Geneva, Rio De Janeiro, Stuttgart
Beta-	Dallas, Houston, Luxembourg, Geneva, Beirut, Vancouver, Seattle, Oslo, Rio De Janeiro, Montevideo	Beta-	Guatemala City, Bratislava, Abu Dhabi, San Jose, Lyon, Panama City, Minneapolis, Sofia, Tunis, Lagos, Nairobi, Riga, Detroit, Seattle, Hanoi, Manama, Calgary, Perth, Cleveland, Port Louis, Denver, Belgrade, Calcutta, Antwerp, Quito, Almaty, San Diego, Amman, Kuwait City, Nicosia, Edinburgh, Birmingham, Monterrey, Hyderabad, Rotterdam, Shenzhen
Gamma+	Rio De Janeiro, Montevideo, Philadelphia, Denver, Helsinki, Minneapolis, Brisbane, Rotterdam, Stuttgart, Panama City, Bucharest, Karachi, Perth, Bangalore, St Louis, Lima	Gamma+	Zagreb, Jeddah, Lahore, San Salvador, St Petersburg, Santo Domingo, Guayaquil, Baltimore, St Louis, Phoenix, Islamabad, Charlotte, Durban, Cologne, Adelaide, Tampa, Osaka, Georgetown, Bristol
Gamma	Ho Chi Minh City, Manama, Calcutta, Cologne, Detroit, Wellington, Jeddah, Antwerp, Tel Aviv, Riyadh, Chennai, San Diego, Nairobi, Adelaide, Quito, Lyon, Cape Town, Manchester	Gamma	Vilnius, Glasgow, Tallinn, Colombo, Baku, Marseille, Leeds, Guadalajara
Gamma-	Guangzhou, Calgary, Portland, Nassau, Hamilton, Kiev, Casablanca, Port Louis, Abu Dhabi, Charlotte, Birmingham, Cleveland, Sofia, Bratislava, Pittsburgh, Indianapolis, Kuwait City, Nicosia, Kansas City	Gamma-	Kansas City, Portland
High sufficiency	Osaka, Zagreb, Hanoi, Guayaquil, Lagos, Amman, Almaty, Baltimore, St Petersburg, Colombo, Guatemala City, Monterrey, San Jose, San Salvador, Marseille, Phoenix, Glasgow, Edinburgh, Bristol, Lahore, Leeds, Tunis, Santo Domingo, Islamabad, Tampa, Riga, Durban	High sufficiency	Pittsburgh, Indianapolis, Nassau, Wellington
Sufficiency	Shenzhen, Tallinn, Guadalajara, Doha, Vilnius, Baku	Sufficiency	Hamilton
Others	Hyderabad, Belgrade, Georgetown		

Note: The classification of cities by GaWC doesn't precisely correspond to the ranking of cities by GNC.

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References

Adler, N., Berechman, J., 2001. Measuring airport quality from the airlines' viewpoint: an application of data envelopment analysis. *Transport Policy* 8(3), 171–181.

Alderson, A. S., Beckfield, J., Sprague-Jones, J., 2010. Intercity relations and globalisation: the evolution of the global urban hierarchy, 1981–2007. *Urban Studies* 47(9), 1899–1923.

Berechman, J., De Wit, J., 1996. An analysis of the effects of European aviation deregulation on an airline's network structure and choice of a primary West European hub airport. *Journal of Transport Economics and Policy* 30(3), 251–274.

Dennis, N., 1994. Airline hub operations in Europe. *Journal of Transport Geography* 2(4), 219–233.

Derudder, B., Witlox, F., 2005a. An appraisal of the use of airline data in assessing the world city network: a research note on data. *Urban Studies* 42(13), 2371–2388.

Derudder, B., Witlox, F., 2005b. On the use of inadequate airline data in mappings of a global urban system. *Journal of Air Transport Management* 11(4), 231–237.

Derudder, B., Witlox, F., 2008. Mapping world city networks through airline flows: context, relevance, and problems. *Journal of Transport Geography* 16(5), 305–312.

Derudder, B., Taylor, P. J., Ni, P., De Vos, A., Hoyler, M., Hanssens, H., Bassens, D., Huang, J., Witlox, F., Shen, W., Yang, X., 2010. Pathways of change: shifting connectivities in the world city network, 2000–08. *Urban Studies* 47(9), 1861–1877.

Derudder, B., Taylor, P. J., Hoyler, M., Ni, P., Liu, X., Zhao, M., Shen, W., Witlox, F., 2013. Measurement and interpretation of connectivity of Chinese cities in world city network, 2010. *Chinese Geographical Science* 23(3), 261–273.

Derudder, B., Taylor, P. J., 2016. Change in the world city network, 2000–2012, *The Professional Geographer* 68(4), 624–637.

Doganis, R., 1992. The airport business. Routledge, London.

Douglass, M., 2000. Mega-urban regions and world city formation: globalisation, the economic crisis and urban policy issues in Pacific Asia. *Urban Studies* 37(12), 2315–2335.

Grosche, T., Rothlauf, F., Heinzl, A., 2007. Gravity models for airline passenger volume estimation. *Journal of Air Transport Management* 13(4), 175–183.

Hall, R., 1989. Configuration of an overnight package air network. *Transportation Research Part A* 23(2), 139–149.

Hall, P., 2005. The world's urban systems: a European perspective. *Global Urban Development* 1(1), 1–12.

Harvey, D., 1951. Airline passenger traffic pattern within the United States. *Journal of Air Law and Commerce* 18, 157–165.

Howrey, E. P., 1969. On the choice of forecasting models for air travel. *Journal of Regional Science* 9, 215–224.

Hwang, C. C., Shiao, G. C., 2011. Analyzing air cargo flows of international routes: an empirical study of Taiwan Taoyuan International Airport. *Journal of Transport Geography* 19(4), 738–744.

IATA, 2014a. New IATA Passenger Forecast Reveals Fast-growing Markets of the Future. Press Release No.: 57, Date: 16 October 2014.

IATA, 2014b. Air Freight Strong Performance Continues. Press Release No.: 64, Date: 3 December 2014.

Keeling, D. J., 1995. Transport and the world city paradigm. In: Knox, P. L., Taylor, P. J. (Eds.), World Cities in a World System. Cambridge: Cambridge University Press, pp. 115–131.

Lansing, J. B., Blood, D. M., 1958. A cross section analysis of non-business air travel. *Journal of the American Statistical Association* 53, 928–947.

Lansing, J. B., Liu, J., Suits, D. B., 1961. An analysis of interurban air travel. *Quarterly Journal of Economics* 75, 87–95.

Liu, X., Derudder, B., García, C. G., 2013. Exploring the co-evolution of the geographies of air transport aviation and corporate networks. *Journal of Transport Geography* 30, 26–36.

Liu, X., Derudder, B., Taylor, P. J., 2014. Mapping the evolution of hierarchical and regional tendencies in the world city network, 2000–2010. *Computers, Environment and Urban Systems* 43, 51-66.

Long, W. H., 1970. The economics of air travel gravity model. *Journal of Regional Science* 10, 353–363.

Matsumoto, H., 2004. International urban systems and air passenger and cargo flows: some calculations. *Journal of Air Transport Management* 10(4), 239–47.

Matsumoto, H., 2007. International air network structures and air traffic density of world cities. *Transportation Research Part E* 43(3), 269–82.

Matsumoto, H., Domae, K., O'Connor, K., 2016. Business connectivity, air transport and the urban hierarchy: a case study in East Asia. *Journal of Transport Geography* 54, 132–139.

Matsumoto, H., Domae, K., 2018. The effects of new international airports and integrator's hubs on the mobility of cities in urban hierarchies: a case study in East and Southeast Asia. *Journal of Air Transport Management*, in press.

Musil, R., 2009. Global capital control and city hierarchies: an attempt to reposition Vienna in a world city network. *Cities* 26(5), 255–65.

Ng, M. K., Hills, P., 2003. World cities or great cities? A comparative study of five Asian metropolises. *Cities* 20(3), 151–165.

O'Connor, K., 1995. Airport development in Southeast Asia. *Journal of Transport Geography* 3(4), 269–279.

Ohashi, H., Kim, T. S., Oum, T. H., Yu, C., 2005. Choice of air cargo transshipment airport: an application to air cargo traffic to/from Northeast Asia. *Journal of Air Transport Management* 11(3), 149–59.

O'Kelly, M. E., 1986. The location of interacting hub facilities. *Transportation Science* 20(2), 92–106.

O'Kelly, M. E., 1998. A geographer's analysis of hub and spoke networks. *Journal of Transport Geography* 6(3), 171–186.

Park, Y., 2003. An analysis for the competitive strength of Asian major airports. *Journal of Air Transport Management* 9(6), 353–60.

Richmond, S. B., 1955. Forecasting air passenger traffic by multiple regression analysis. *Journal of Air Law and Commerce* 22, 434–443.

Schwieterman, J. P., 1993. Express air cargo in the pacific rim: evaluation of prospective hub sites. *Transportation Research Record* 1461, 1–7.

Shin, K. H., Timberlake, M., 2000. World cities in Asia: cliques, centrality and connectedness. *Urban Studies* 37(12), 2257–2285.

Smith, D. A., Timberlake, M., 2001. World city networks and hierarchies, 1977-1997. An empirical analysis of global air travel links. *American Behavioral Scientist* 44(10), 1656–1678.

Taaffe, E. J., 1962. The urban hierarchy: an air passenger definition. *Economic Geography* 38, 1–14.

Taylor, P. J., Walker, D. R. F., Catalano, G., Hoyler, M., 2002. Diversity and power in the world city network. *Cities* 19(4), 231–241.

Taylor, P. J., 2004. World city network: A global urban analysis. London and New York: Routledge.

Taylor, P. J., Derudder, B., 2016. World city network. second ed. Taylor & Francis, London and New York.

The Global and World City Project. The World According to GaWC 2012. (http://www.lboro.ac.uk/gawc/world2012t.html (posted 13 January 2014)).

Wojahn, O. W., 2001. Airline network structure and the gravity model. *Transportation*

Research Part E 37(4), 267–279.
Zhang, A., Zhang, Y., 2002. Issues on liberalization of air cargo services in international aviation. *Journal of Air Transport Management* 8(5), 275–287.
Zhang, A., 2003. Analysis of an international air-cargo hub: The case of Hong Kong. *Journal of Air Transport Management* 9(2), 123–138.

Highlights

1. Hub status of cities is assessed from an international air traffic perspective.
2. Networks of inter-city air traffic flows in Europe and Asia are explored.
3. Business connectivity is the most powerful in explaining international air links.
4. Secondly ranked cities are now more prominent in the region's urban hierarchies.
5. New airports and integrators’ hubs have significant effect on cities’ mobility.