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(Citation)
Journal of Air Transport Management,10(4):239-247

(Issue Date)
2004-07

(Resource Type)
journal article

(Version)
Accepted Manuscript

(URL)
https://hdl.handle.net/20.500.14094/90000416

International urban systems and air passenger and cargo flows: some calculations

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Abstract

This paper examines international urban systems from the standpoint of international air traffic flows and analyzes the patterns of international air passenger and cargo flows within and among the Asian, European and American regions. After evaluating the international air network structures in 1982 and in 1998, the degree of 'hub-ness' for prospective hub cities from 1982 to 1998 is clarified by a basic gravity model composed of GDP, population and distance introducing city-dummy variables. The results reveal that Tokyo, Hong Kong and Singapore in Asia, London, Paris, Frankfurt and Amsterdam in Europe and New York and Miami in the US are strengthening their positions as international hubs.

Keywords: International urban systems; International aviation flows; Gravity model; Hubbing

1. Introduction

Studies of urban systems have been mainly been concerned with their accumulation of headquarters and branch offices of firms, flows of population or local transportation, and industrial structures. These studies also tend to be limited to intra-country or intra-region analysis with few considering international urban systems. Some research has analyzed international urban systems from the viewpoint of international air traffic flows, including worldwide urban systems (Keeling, 1995; Rimmer, 1996), urban systems dealing with the US and Canada (Murayama, 1991a, b), and Asian urban systems focusing in particular on Japan and Korea (Park, 1995). These studies though have not

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fully delineated the overall international urban systems in detailed. On the other hand, work has been conducted in the fields of economic geography and regional science to determine the spatial orders or rules of air passenger and cargo flows. Taaffe (1962), for example, attempted to apply the gravity model to air passenger flows in the US from the viewpoint of spatial organization. Simple gravity models using population and distance variables have been used to predict the number of passengers (Harvey, 1951; Richmond, 1955) and later modified to embrace other variables such as income, education level, accumulation level of enterprises and measures of city characteristics such as location advantages and climate (Lansing and Blood, 1958; Lansing et al., 1961). Studies have also focused on the supply side by introducing fare, time and service frequencies (Howrey, 1969), and with delineations for business passengers, tourist passengers and cargoes (Long, 1970).

Many factors influence new urban systems formation. In this study, the focus is on the role of air traffic flows. The location of airports influences the geographic distribution of industries and can be a significant factor in the decisions of certain industries to locate in a specific state or region. A large hub airport serving many destinations with frequent flights has the potential of exerting a major impact on adjacent urban areas. Some national governments have responded by opening new airports – Munich (1992), Osaka (1994), Denver (1995), Kuala Lumpur (1998), Hong Kong (1998), Shanghai (1999) and Seoul (2001). In addition, Bangkok, Nagoya and Guangzhou are now building a new international airports with Tokyo, Singapore, Taipei, etc. expanding their current runways or terminal buildings. Furthermore, several airports in the world are now under expansion.

This paper analyzes the current international air passenger and cargo flows in the context of the relationships or connectivity across major cities for 1982 and 1998. The regions analyzed are those defined by the Airports Council International (ACI).[1] The ACI definitions reflect the economic relationships among countries.

The data used comes from a variety of sources.

- Since the data on international air traffic flows between cities from the International Civil Aviation Organization (ICAO) are available only from 1982 in standard format, the analysis applies to this period. ICAO data was also used for distance between

[1] The regions are defined as Asia (East Asia, Southeast Asia, West Asia up to Pakistan, Central Asia and Oceana), Europe (West Europe, East Europe, North Europe and South Europe including the former Soviet Union up to the Ural Mountains), and America (North America, Latin America and the Caribbean).

cities.

- The data on GDP per capita, taken mainly from International Monetary Fund (IMF) , are adjusted to constant US dollar 1990 prices. The purchasing parity index is applied to some countries such as those in Eastern Europe, the former Soviet Union and Latin America, because these countries have experienced high inflation.
- Regarding population data, the concept of urban agglomeration, rather than that of city proper, is used since this is seen as better reflecting the populations of hinterlands of airports – United Nations data is used.
- To reflect air traffic volume, workload unit (WLU) is used. This is a traffic measure combining passengers and cargoes. A WLU is equivalent to one terminal passenger or a hundred kilograms of cargo handled (Doganis, 1992).
- The cities and city-pairs are those having airport traffic volume exceeding five million WLU and those having air traffic flows exceeding three hundred thousand WLU.
- Cities are the basic unit of analysis, so airport numbers are aggregated when cities have multiple airports.

2. International urban systems in terms of air traffic flows

Figs. 1 and 2 show the international air network structures in Asia for 1982 and 1998. In 1998 Hong Kong had the largest international airport traffic volume with 44 million WLU, comprising 27 million passengers and 1.7 million tons of cargo. The second largest was Tokyo with 39 million WLU (22 million passengers and 1.7 million tons of cargo), followed by Singapore with 36 million WLU (23 million passengers and 1.3 million tons of cargo). Seoul (25 million WLU), Bangkok (24 million WLU) and Taipei (23 million WLU) were ranked in the second tier, followed by Osaka (17 million WLU), Kuala Lumpur (12 million WLU) and Sydney (10 million WLU) in the third tier. In 1982 Hong Kong-Taipei (2.6 million WLU) had been ranked first, followed by Tokyo-Seoul (2.4 million WLU), Tokyo-Hong Kong (2.4 million WLU) and Hong Kong-Bangkok (2.2 million WLU). Between one million and two million WLU level were 11 city-pairs including Singapore-Kuala Lumpur.

Fig. 1 and Fig. 2.

Over the years, Tokyo, Hong Kong and Singapore are strengthening their positions in international aviation in the region. In particular, Hong Kong underwent a dramatic increase in the amount of passengers and cargoes handled, reflecting its having China as its hinterland. At the same time, air networks are becoming increasingly dense despite the strong negative impact of the 1997 Asian financial crisis. In 1982, there were no air networks with over two million WLU and only six city-pairs with over a million WLU but by 1998 cities in the region were densely connected with each another, including Chinese cities such as Beijing and Shanghai.

Figs. 3 and 4 show the international air network structures in Europe for 1982 and 1998. Regarding international airport traffic volume in 1998, London was origin/destination for this region, as well as globally, with 106 million WLU – 88 million passengers and 1.8 million tons of cargo – followed by Paris with 51 million WLU (40 million passengers and 1.1 million tons of cargo), Frankfurt with 48 million WLU and Amsterdam with 46 million WLU. Following these four cities were Brussels (24 million WLU) and Zurich (21 million WLU), both of which might be considered second tier. In addition, there were 11 cities with over 10 million WLU including Copenhagen (18 million WLU) and Rome (16 million WLU). In regard to international air passenger and cargo flows among the cities with over two million WLU in 1998, there was only one city pair, London-Amsterdam (2.3 million WLU) while two city pairs – London-Paris (1.9 million WLU) and London-Frankfurt (1.6 million WLU) – had between a million and two million WLU.

Fig. 3 and Fig. 4.

Regarding changes on international airport traffic and international air traffic flows, London, Paris, Frankfurt and Amsterdam have increasing their air traffic volume, with London registering the greatest increase. The air networks in the Europe region were very dense compared with other regions, although the air traffic flows for each route were not so heavy. In 1982, the London-Paris route was the only city-pair with more than two million WLU, while London-Amsterdam was the lone city-pair having a WLU between one and two million. By 1998, although a decrease in air traffic flows on some routes could be observed, the general picture was that of increase.

Figs. 5 and 6 show the international air network structures in the American region. With regard to the international airport traffic volume in 1998, New York ranked first in the region with 39 million WLU – 25 million passengers and 1.4 million tons of cargo, followed by Miami with 30 million WLU and Los Angeles with 23 million WLU. Next were Chicago (15 million WLU), Toronto (15 million WLU) and San Francisco (10 million WLU). As for the international air passenger and cargo flows among the cities, except for Miami-Bogota (1.2 million WLU), there were no city-pairs with over a million WLU. In this region, the international air traffic flows among cities were less heavy than in other regions.

Fig. 5 and Fig. 6.

Regarding international airport traffic and air traffic flows, New York continued to increase its air traffic volume, while Los Angeles and Miami were becoming important centers in international aviation. The latter continued to play an increasingly greater role in international aviation throughout North America, the Caribbean and South America.

Finally, Figs. 7 and 8 show the international air network structures among the Asia, Europe and America regions for 1982 and 1998. Concerning the international airport traffic volume in 1998, Tokyo (38,970 WLU) in Asia, London (106,040 WLU) in Europe and New York (39,430 WLU) in America were ranked first in each region. As for the international air passenger and cargo flows among these regions, London-New York had 3.9 million WLU, the highest in the world. Tokyo-London and Tokyo-New York had 1.1 million WLU and 1.4 million WLU, respectively. In addition, there were fourteen pairs with more than one million WLU – e.g., Paris-New York (1.7 million WLU) and Tokyo-Los Angeles (1.6 million WLU).

Fig. 7 and Fig. 8.

Regarding developments on international airport traffic and international air traffic flows, those of Tokyo, London and New York grew steadily from 1982, while air networks among the three regions became denser. In 1998, there was one city pair with over three million WLU – London-New York. There were no city-pairs between two and three million WLU and 16 city-pairs between one and two million (Tokyo-London, Tokyo-New York, etc.). In short, Tokyo, London and New York had become the three main global cores in terms of international aviation.

3. Analysis of international air passenger and cargo flows

A gravity model is deployed to look at the hubness of cities. Separate specifications of the model are used for each region, and for passenger and cargo (the dependent variables). The explanatory variables are GDP, population and distance. In addition, and in order to examine the hubness of cities, city-dummy variables are introduced for cities with annual international airport traffic of more than 20 million WLU. ‘e’ raised to the power of the coefficients of the dummy variables is used to indicate how many times cities of over 20 million WLU generate and absorb the traffic volume explained by the basic gravity model composed of GDP, population and distance. These values are interpreted as the hubness of cities. The model used is thus:

$$T_{ij} = A \frac{(G_i G_j)^{\alpha} (P_i P_j)^{\beta} e^{\delta D_1} e^{\varepsilon D_2} e^{\zeta D_3} \ldots e^{\eta D_{13}} e^{\theta D_{14}} e^{\iota D_{15}}}{(R_{ij})^{\text{fÁ}}}$$

Where *Tij* is the volume of net international air passengers over ten thousand or volume of net international air cargo over one hundred tons between city *i* and city *j* in 1998, *Gi* is real GDP per capita in 1998 of the country of city *i* expressed in US dollars at the 1998 exchange rate in 1990 prices, *Gj* is real GDP per capita in 1998 of the country of city *j* expressed in US dollars at the 1998 exchange rate in 1990 prices, *Pi* is the population of urban agglomeration *i* in 1998 in thousands, *Pi* is population of urban agglomeration *j* in 1998 in thousands, *Rij* is the distance between city *i* and city *j* in kilometers, and D_1-D_{15} are city-dummy variables (Table 1).

Table 1

After transforming this equation to log-form, ordinary least squares regression analysis was applied. Table 2 shows the Asian results for 1998. The overall model fit is relatively good and the estimated values of parameters are significant at the 1% level except for those of Seoul and Taipei for passengers, and that of distance for cargo, with most of the others significant at the 5% level.

Table 2

The estimated values of the GDP parameter for passenger and cargo are relatively small. This expresses GDP’s lessening importance in explaining air traffic flows. The estimated value of the parameter for the population variable in the cargo model is about twice that for passengers. This may partly reflect the vertical division of labor in high-tech industries among developed and developing countries as well as among developing countries. For example, intermediate goods in such industries are produced in countries that are abundant in cheap labor. On the other hand, the estimated value of parameter for distance is more than twice as large for passengers as for cargo, indicating the greater sensitivity of passengers to journey length. Statistics involving the raising of ‘e’ by the dummy variable coefficients partly reveal the hubness of Tokyo, Hong Kong and Singapore. In particular, the results for cargo reflect the hubness of Hong Kong, the hinterland of which is China, and that of Singapore which functions as the transshipment base in the Asia region.

To examine temporal changes in the values of parameters, the analysis was applied to the air traffic flows in 1982, 1986, 1990 and 1994. The results for passengers are shown in Fig. 9 and those for cargo in Fig. 10 – with each value divided by that for 1982. The GDP, population and distance parameters for passengers, as a whole, declined over the period. This is also the case with respect to GDP and distance for cargo, although the population coefficient increased in size. The decline in the passenger parameter for distance implies air travelers are increasingly making trips with less regard to their length that may have implications for the development of HASS in international aviation. Regarding GDP, the analysis reflects the its decreasing importance as a driver for air traffic flows as differences in the economic power of Asian countries has diminished. Regarding cargo, the declining GDP effect may be a reflection the increased vertical division of labor, e.g., caused by Japanese companies moving their production to ASEAN countries. Regarding the individual cities, the rise of Tokyo’s passenger flow was remarkable from 1990 to 1994. This was almost certainly due to the appreciation of the yen during that period. For cargo, the dummy variables indicate that Seoul and Hong Kong were on a positive trend, with Taipei and Singapore remaining nearly constant and Tokyo and Bangkok declined. Tokyo’s decline may be attributed to the limited capacity of its international airport. In summary, the hubness of Tokyo and Hong Kong seems to have increased between 1982 and 1998, while Singapore retained its strong hubness.

Fig. 9. and Fig. 10.

Table 3 shows the results of Europe for 1998. The diagnostic statistics suggest a modestly good overall fit with individual parameters significant at the 1% level except for distance and the Brussels dummy in the cargo specification, with both having counter intuitive signs. The parameter for distance in the passenger specification is smaller than those in other regions, possibly because it is a relative compact geographical region, while for cargo flows there is a negative, albeit insignificant, coefficient. London and Amsterdam can be said to be hubs for passenger and Frankfurt and Amsterdam for cargo – Amsterdam having the largest parameter for both passenger and cargo.

Table 3

Changes in the values of parameter are, for passenger, shown in Fig. 11 and for cargo in Fig. 12. The Amsterdam dummy for passengers reflects a strong upward trend, as does the dummy for London's cargo activities.

Fig. 11 and Fig. 12.

Table 4 gives the results for intra America for 1998. The overall model fit is not good, although the estimated values of parameters in the passenger model are significant at the 1% level except for the Los Angeles dummy. In the case of cargo, the Los Angeles variable, GDP and distance are insignificant and also have counter intuitive signs. There are relatively limited international air traffic flows in this region and few between North and South America. Historically, South America has strong links with Spain and Portugal, former because of former colonial links. There may thus be an omitted variable problem in the models for this region.

Table 4

Miami can be said to be a hub in this region for both passenger and cargo traffic. Miami had a particular dominance for cargo, reflecting its role as a connecting point for North America, Latin America and the Caribbean traffic. Conversely, Los Angeles does not play a very important role in the region. Concerning changes over time, the results for passenger are shown in Fig. 13 and for cargo in Fig. 14. For passenger, New York increased in its importance, especially from 1994 to 1998.

Fig. 13. and Fig. 14.

Finally, Table 5 shows the regression results across the three regions for 1998. The model offers modest fit to the data and the estimated parameters for the basic explanatory variables (GDP, population and distance) are significant at the 1% level for both passenger and cargo specifications. Many city-dummy variables are not, however significant even at the 5 % level. Some cities, such as Taipei, Zurich and Brussels are significant within their own region but insignificant across regions. Meanwhile, others, like Los Angeles, are insignificant in their own region but significant across regions. From the viewpoint of international urban systems, these reflect each city's position in the global urban structure..

Table 5

The results for passenger over time are shown in Fig. 15 and for cargo in Fig. 16. First, the rise in value of Taipei for both passenger and cargo is striking. However, this finding must be tempered by the fact that some airline data are not available, such as for Air China, China Airlines, and Eva Airways. The lack of data on air traffic flows for China Airlines strongly influences Taipei's position. Second, the change in population parameter for the passenger traffic is large – in 1982 it was about –0.01, in 1990 about 0.18 and in 1998 about 0.16. Hence in 1982, the standardization year used, may bias the results and explain why the population variable coefficient has a rather extreme upward path

Fig. 15 and Fig. 16.

Acknowledgements

The author wishes to express his gratitude to two anonymous referees for their valuable comments on an earlier version of this paper. Any remaining errors in the paper are the sole responsibility of the author.

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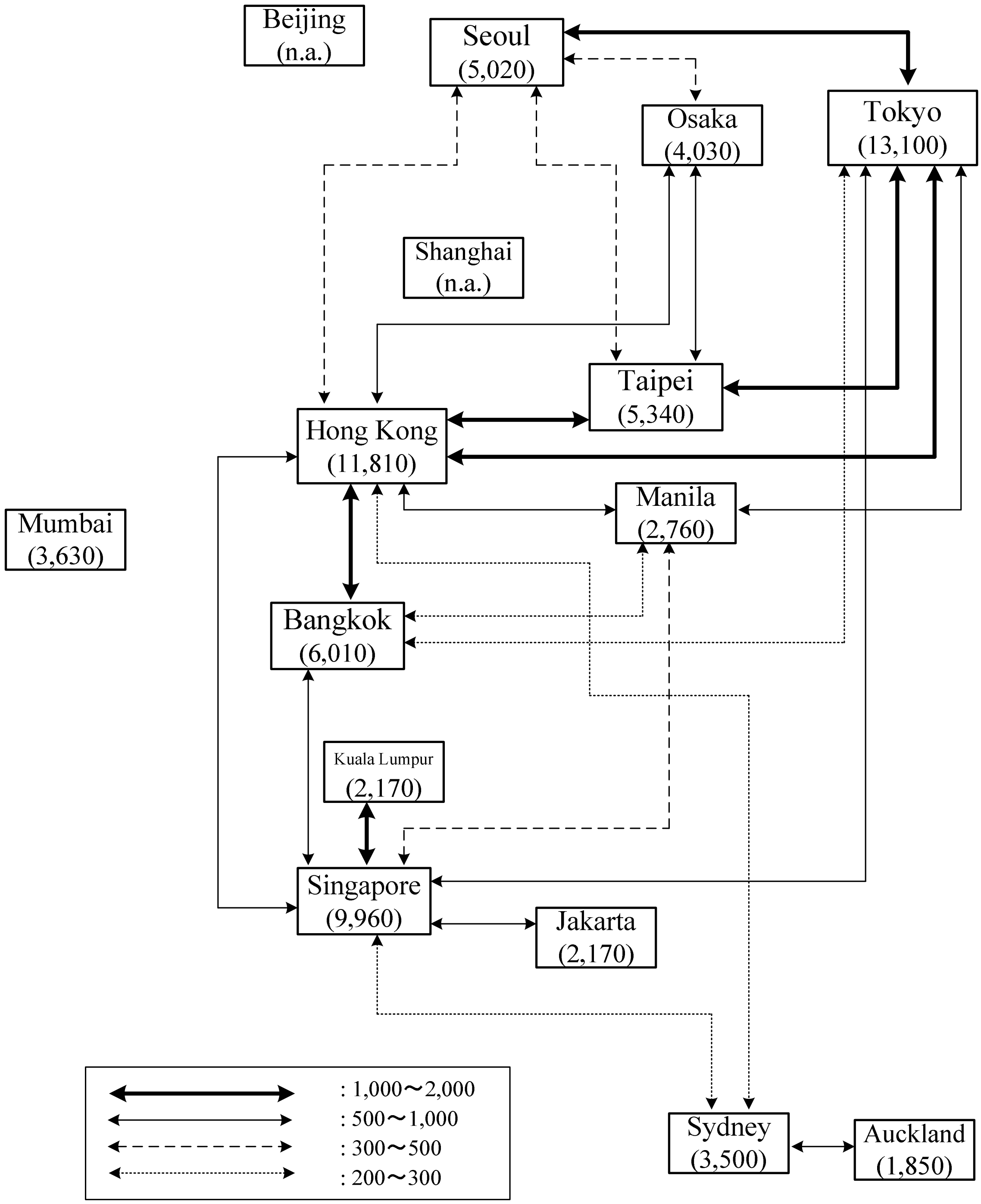

Fig. 1. International air network structure in Asia, 1982.

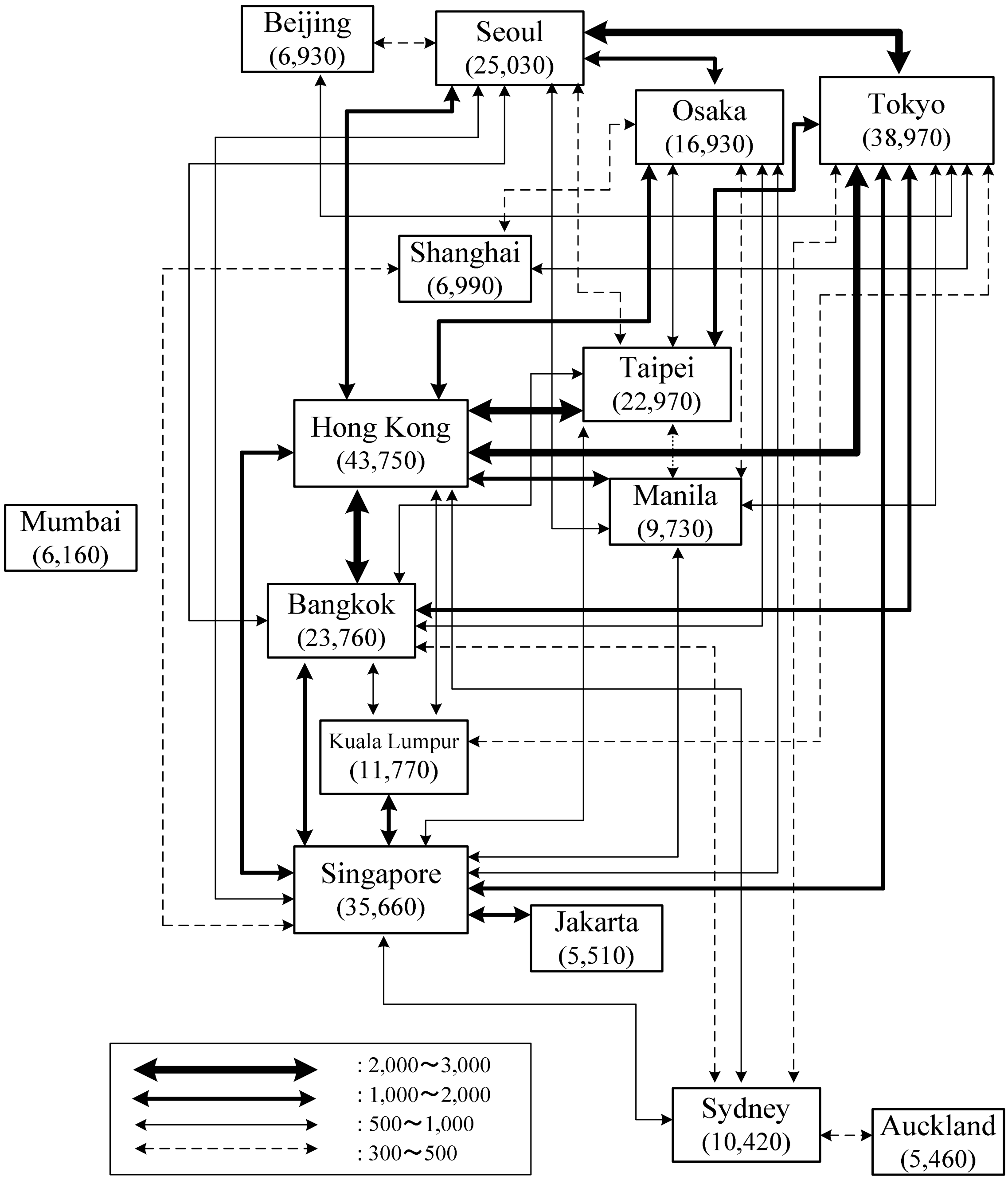

Fig. 2. International air network structure in Asia, 1998.

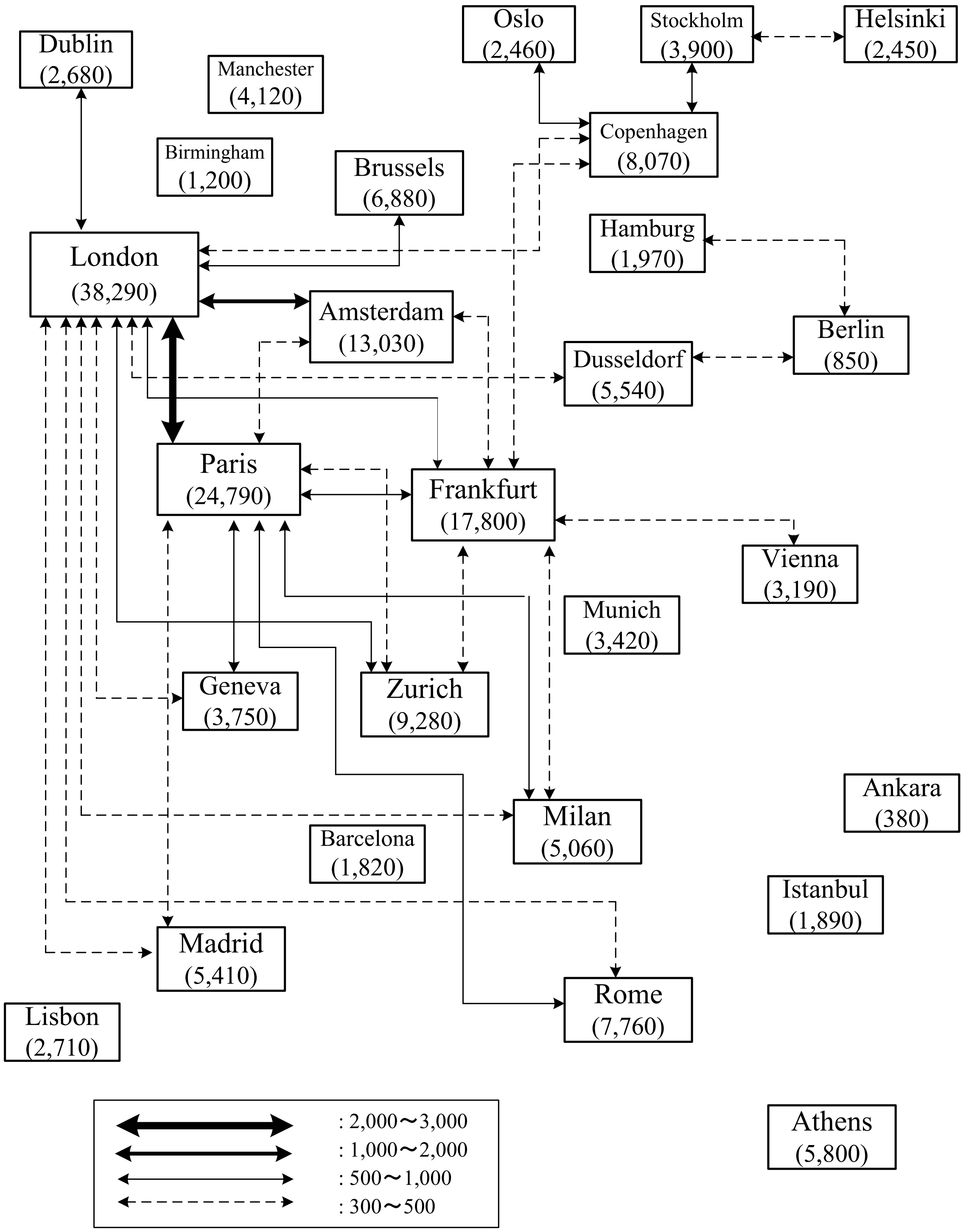

Fig. 3. International air network structure in Europe, 1982.

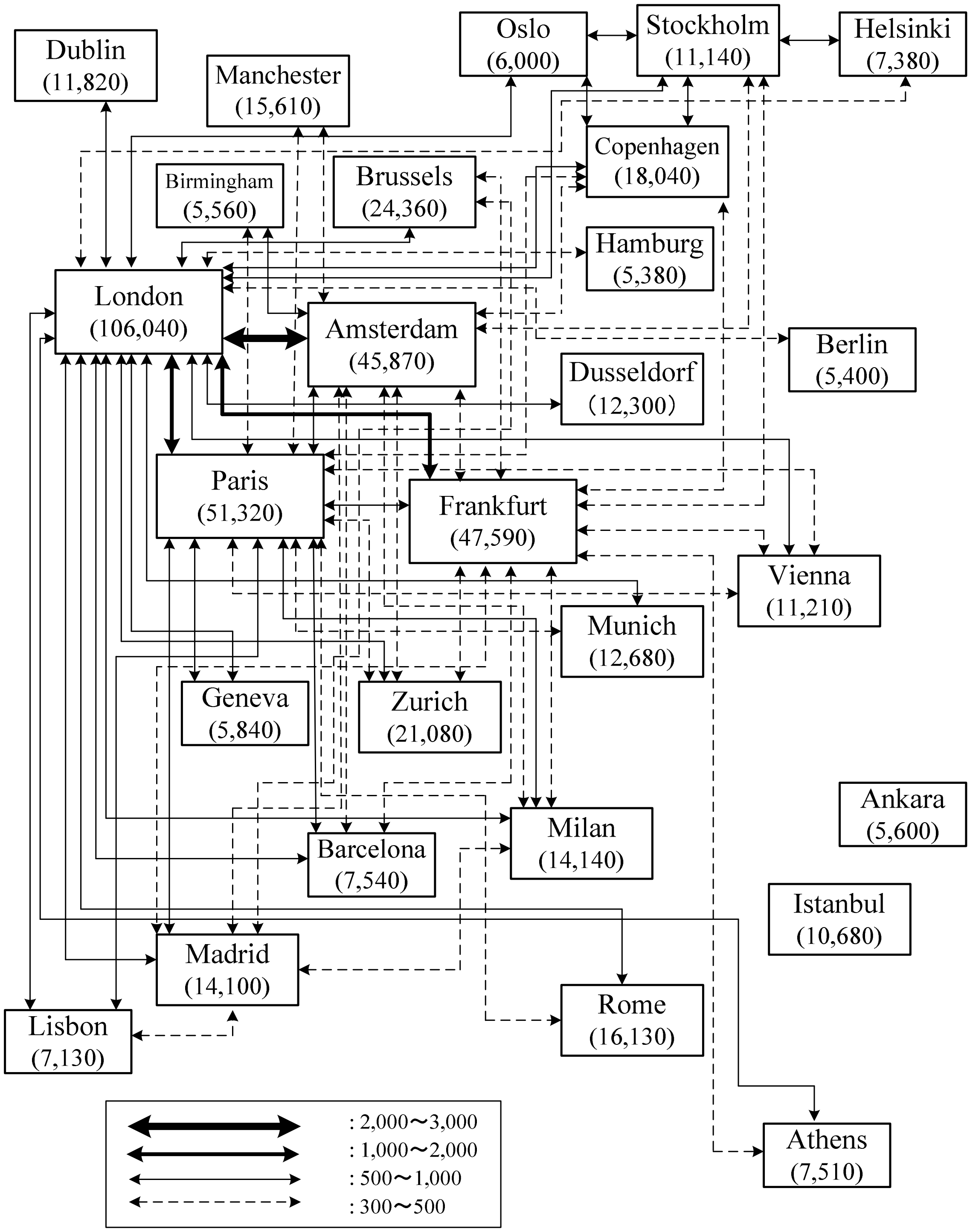

Fig. 4. International air network structure in Europe, 1998.

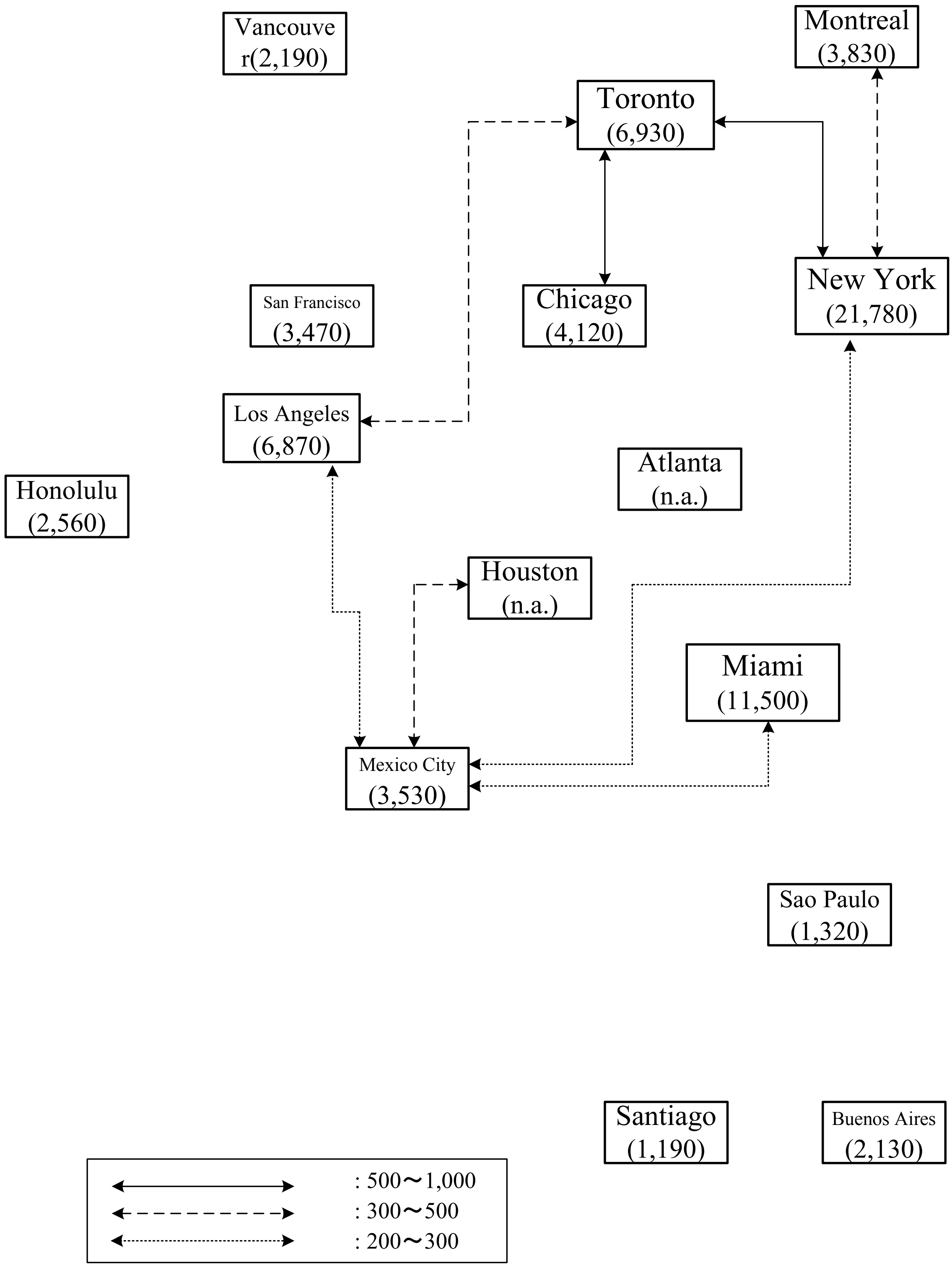

Fig. 5. International air network structure in America, 1982.

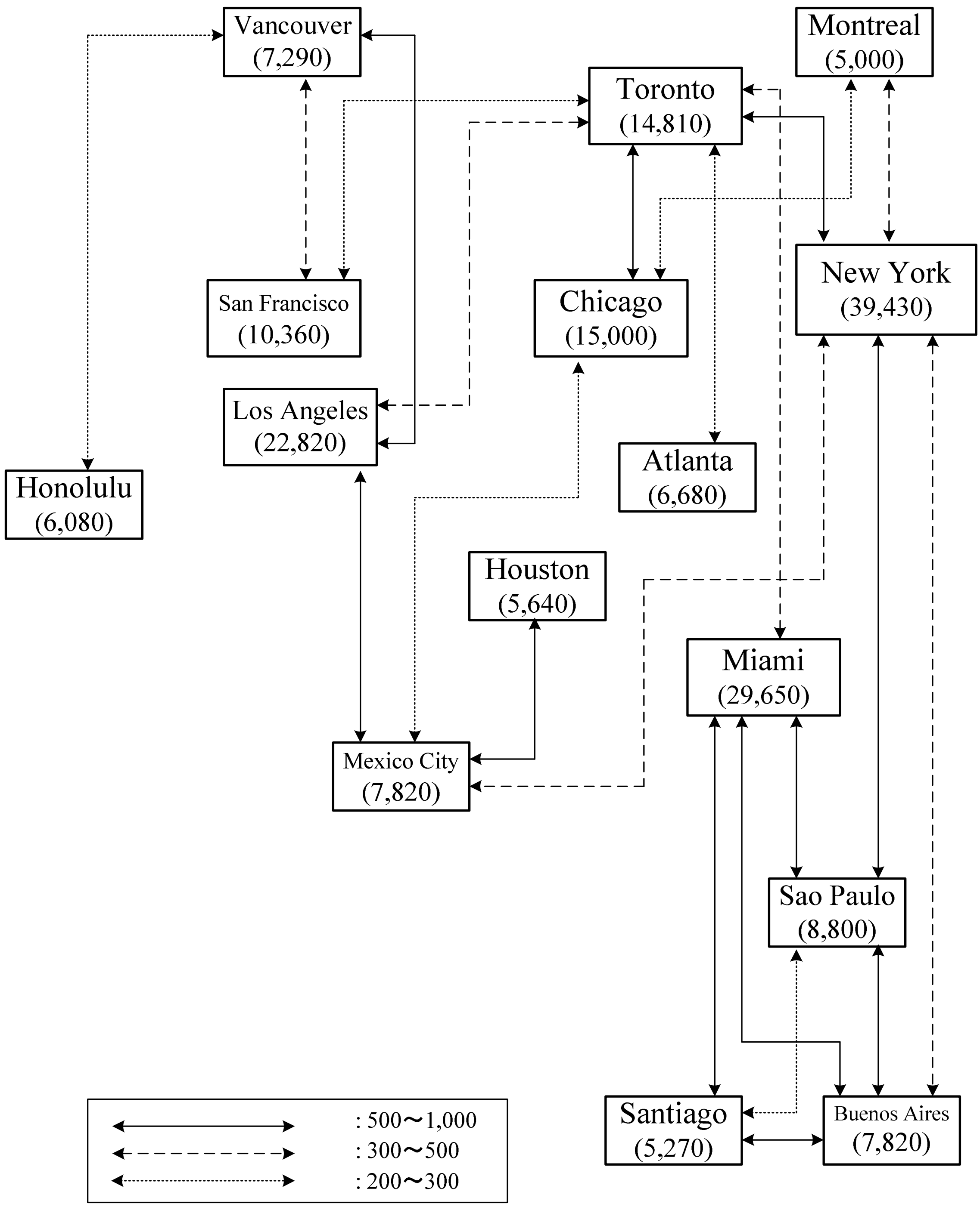

Fig. 6. International air network structure in America, 1998.

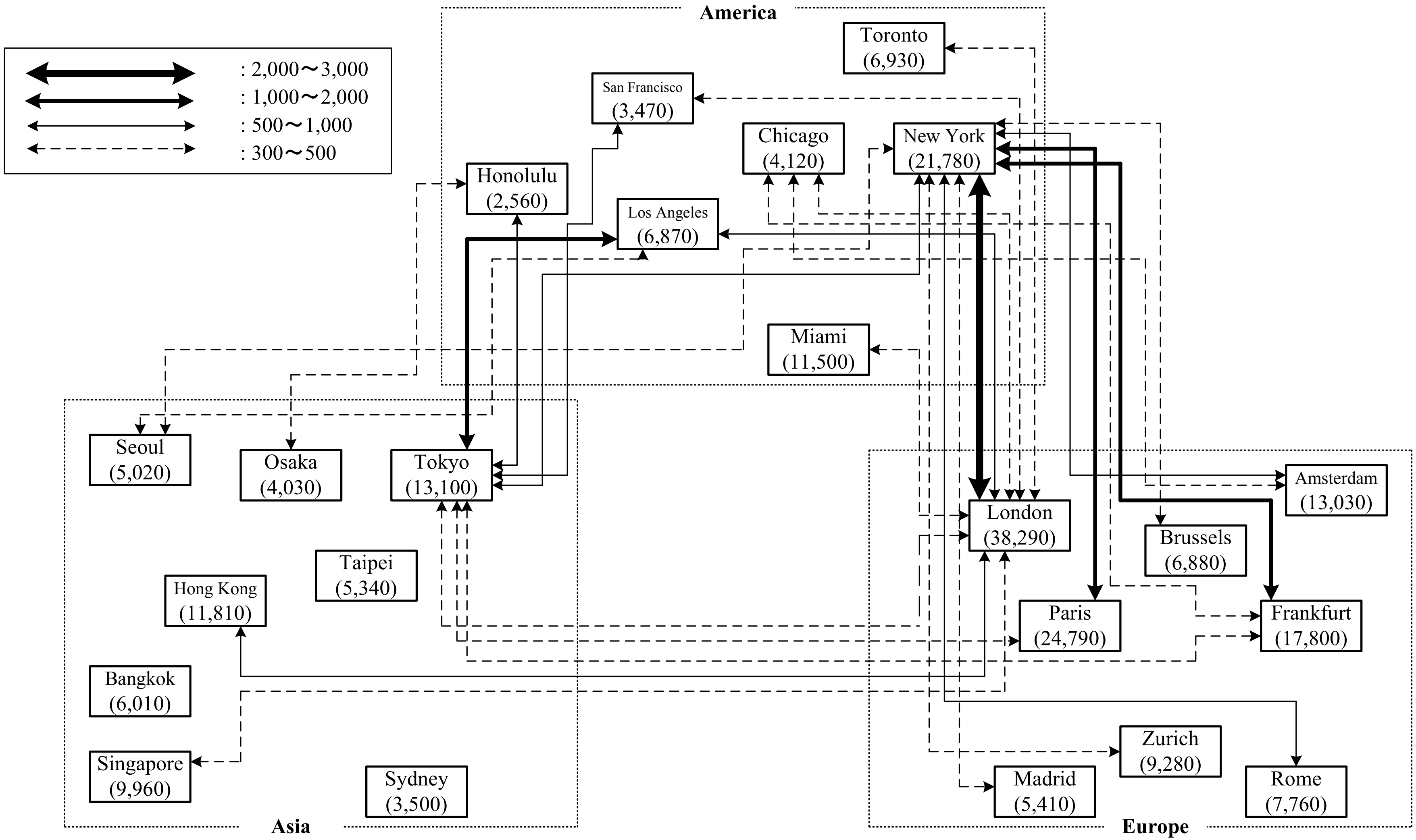

Fig. 7. International air network structure in Asia, Europe and America, 1982.

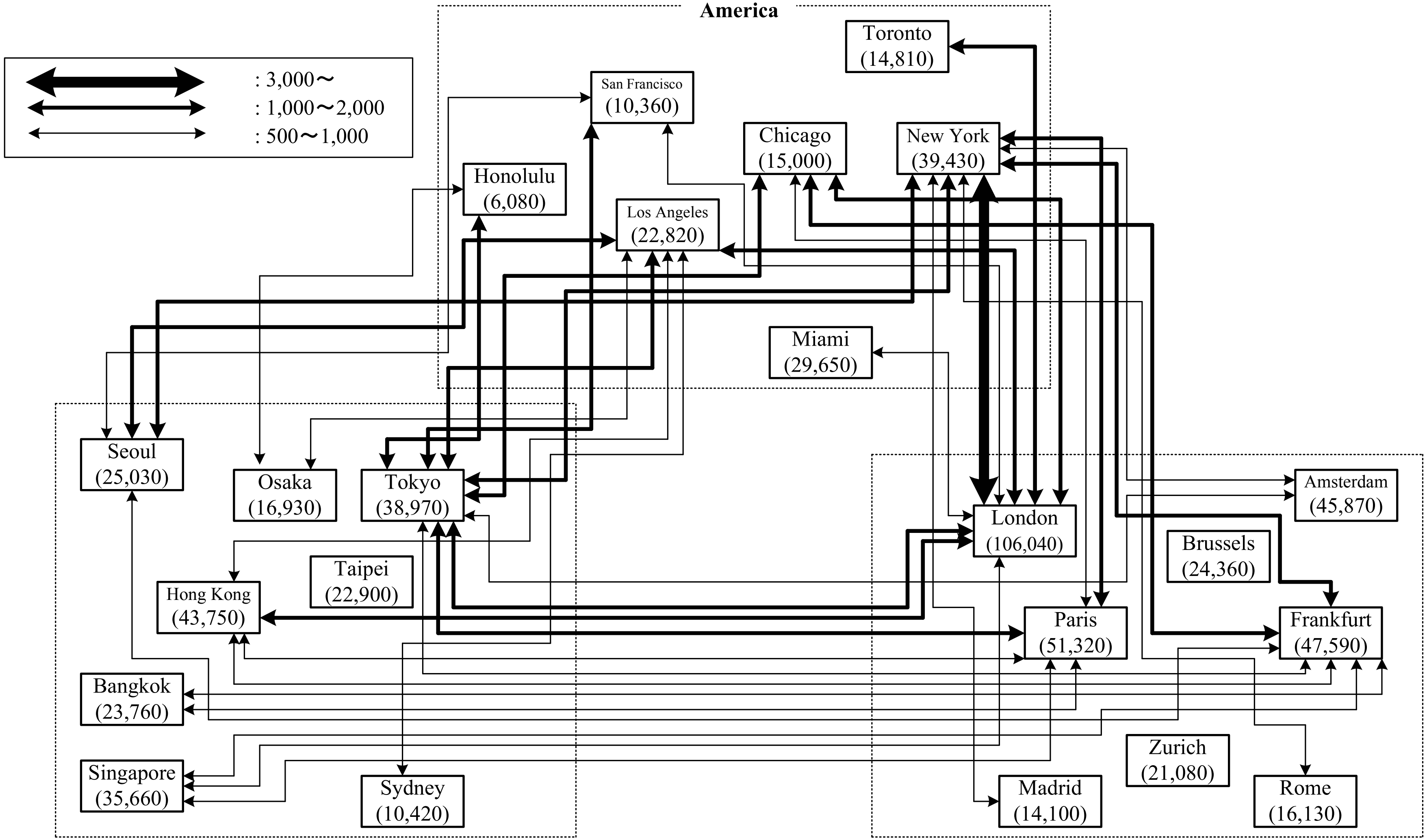

Fig. 8. International air network structure in Asia, Europe and America, 1998.

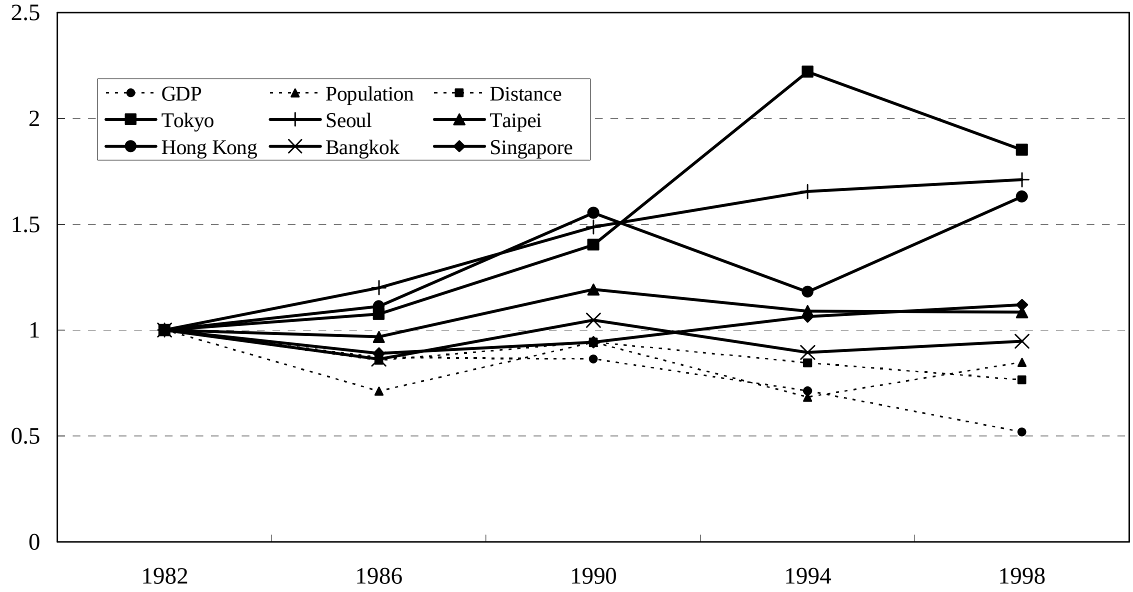

Fig. 9. Time-series changes on each estimated value of parameters, intra-Asian (Passenger).

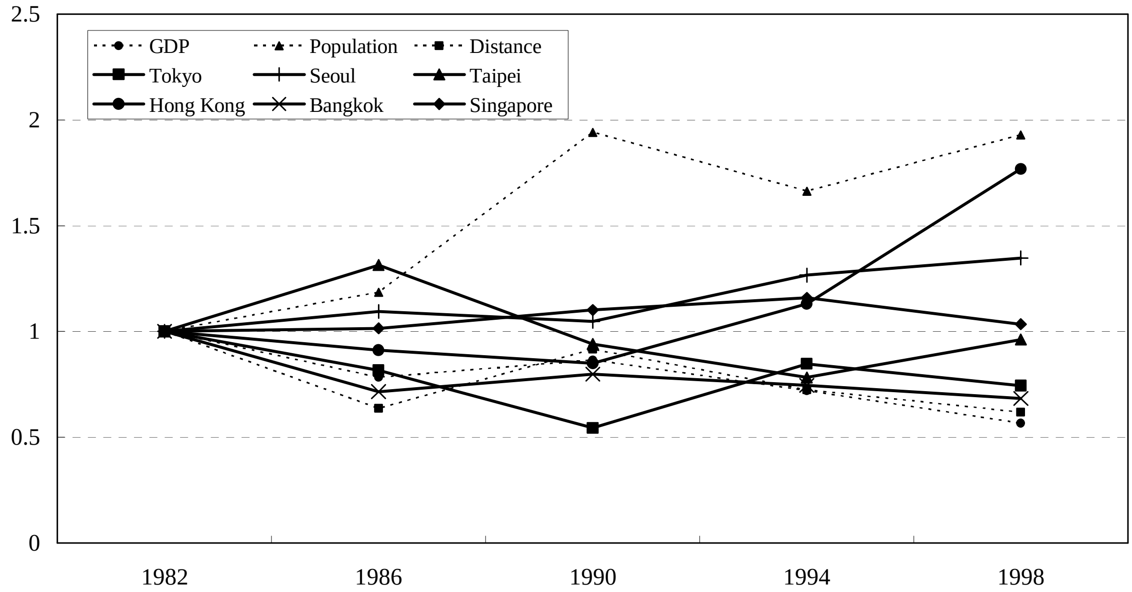

Fig. 10. Time-series changes on each estimated value of parameters, intra-Asian (Cargo).

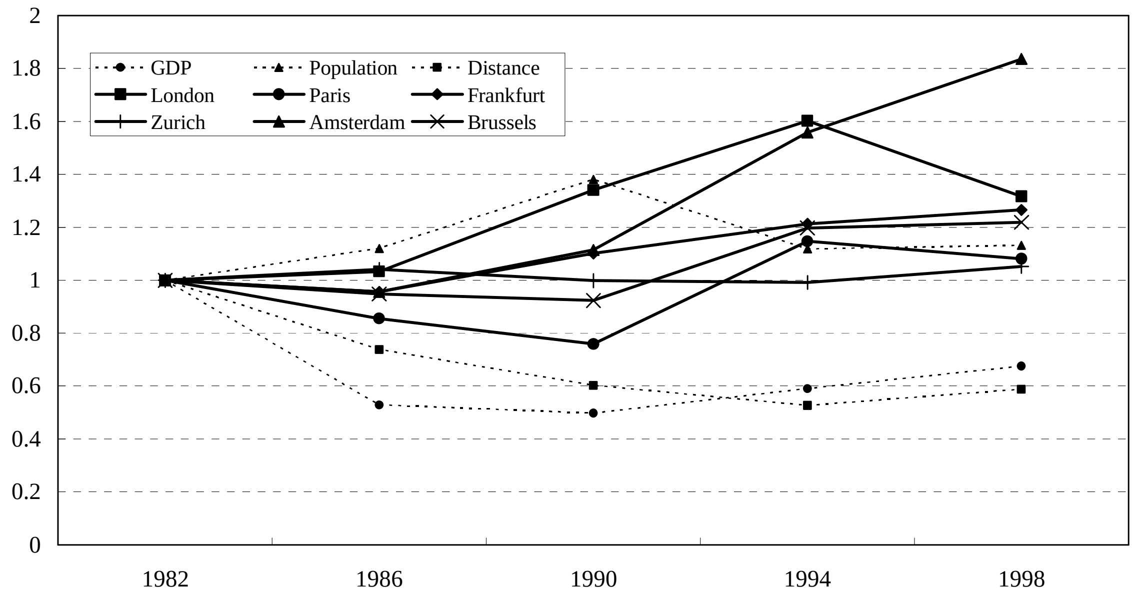

Fig. 11. Time-series changes on each estimated value of parameters, intra-Europe (Passenger).

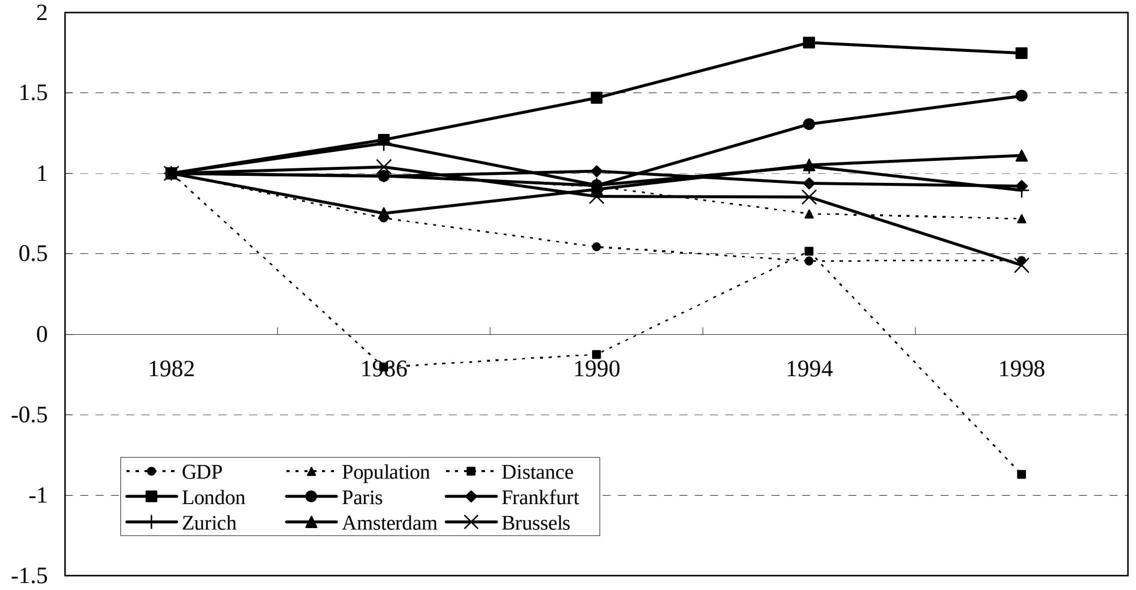

Fig. 12. Time-series changes on each estimated value of parameters, intra-Europe (Cargo).

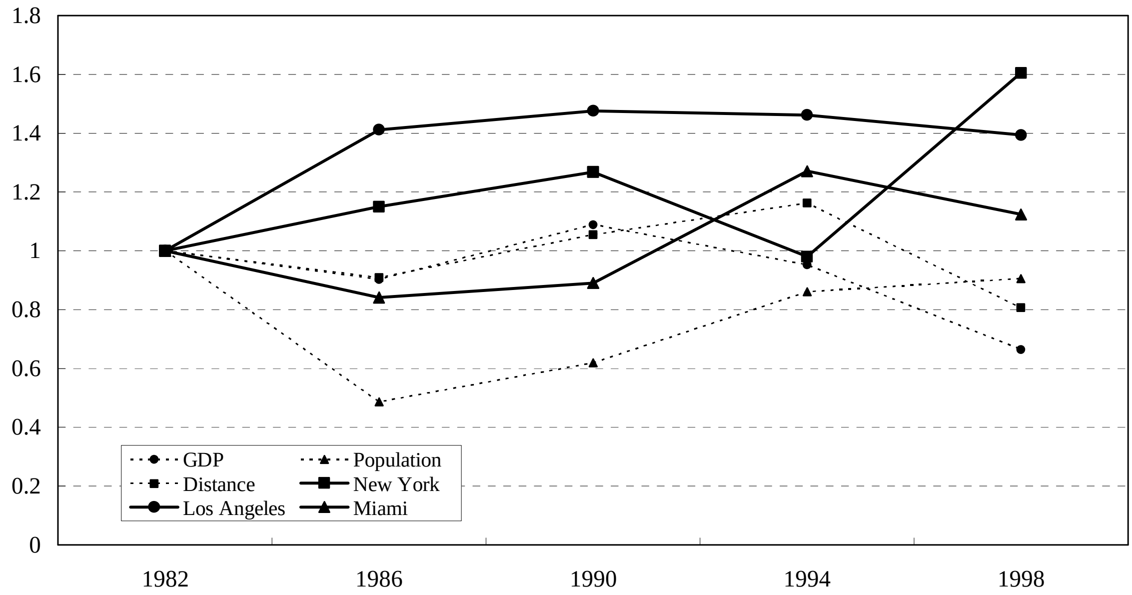

Fig. 13. Time-series changes on each estimated value of parameters, intra-America (Passenger).

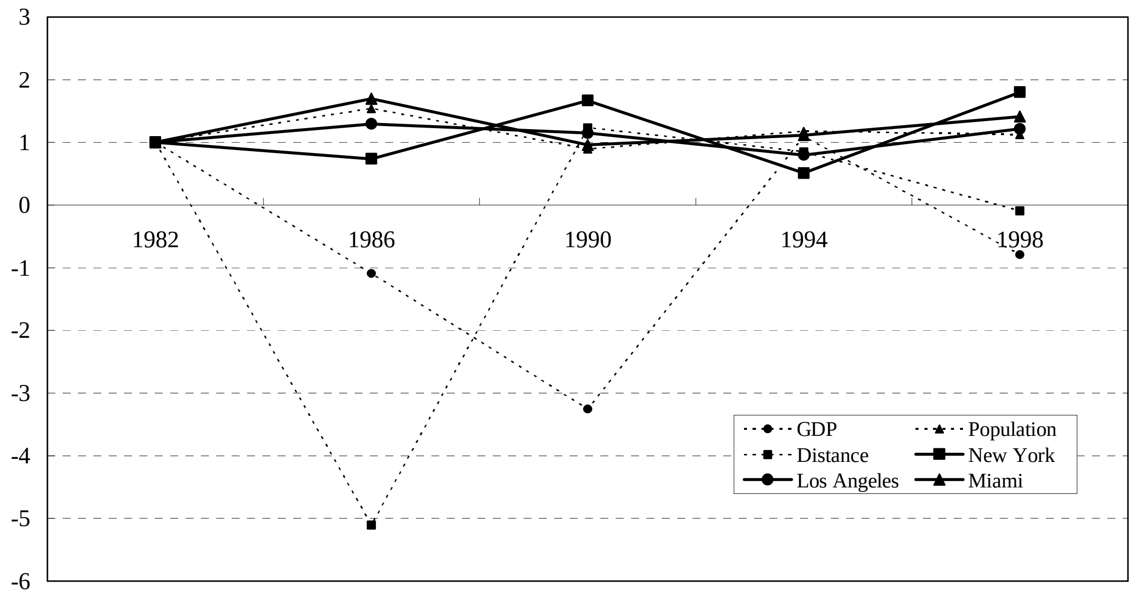

Fig. 14. Time-series changes on each estimated value of parameters, intra-America (Cargo).

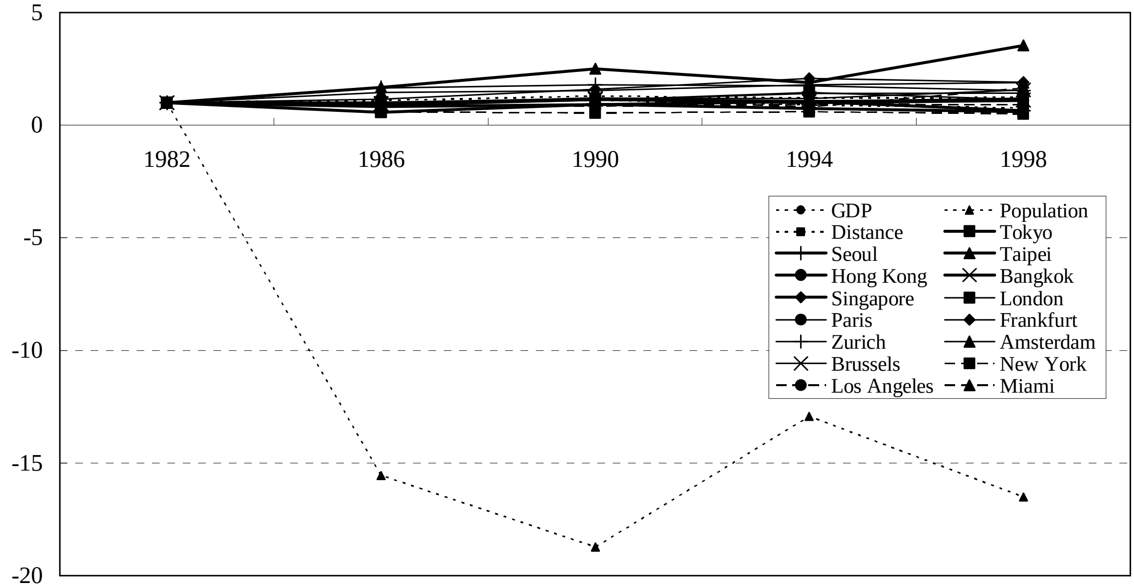

Fig. 15. Time-series changes on each estimated value of parameters intra-continental (Passenger).

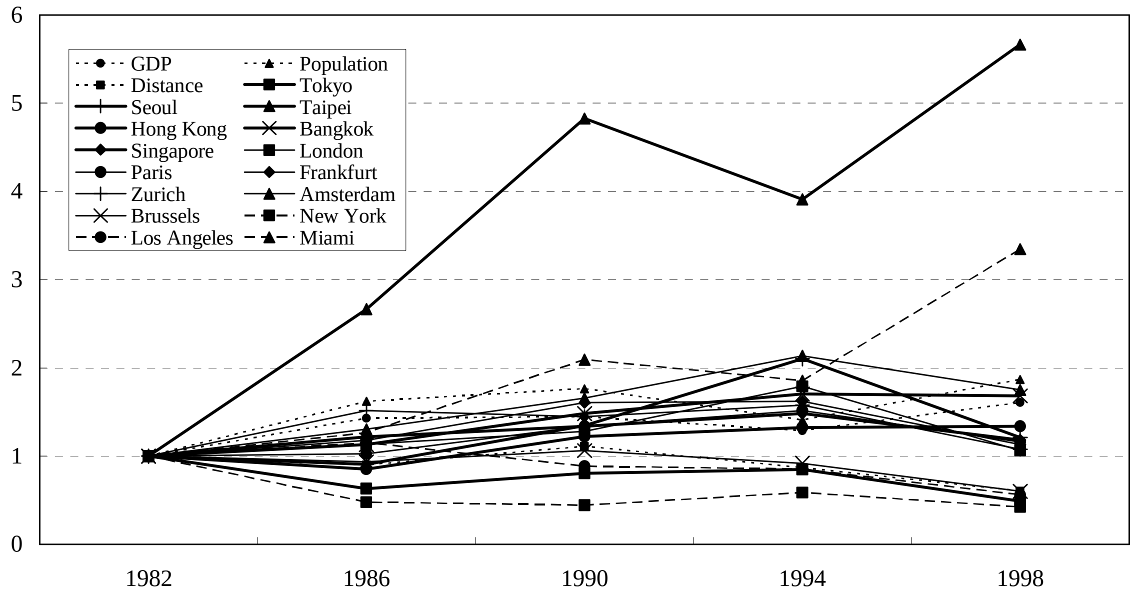

Fig. 16. Time-series changes on each estimated value of parameters intra-continental (Cargo).

Table 1

Dummy-variables for regions

	D1	D2	D3	D4	D5	D6	D7	D8
Intra-Asia	Tokyo	Seoul	Taipei	Hong Kong	Bangkok	Singapore		
Intra-Europe	London	Paris	Frankfurt	Zurich	Amsterdam	Brussels		
Intra-America	New York	Los Angeles	Miami					
Inter-Continent	Tokyo	Seoul	Taipei	Hong Kong	Bangkok	Singapore	London	Paris

	D9	D10	D11	D12	D13	D14	D15
Inter-Continent	Frankfurt	Zurich	Amsterdam	Brussels	New York	Los Angeles	Miami

Table 2

Regression coefficients for intra-Asia traffic (1998)

		Passenger	Cargo
Constant	lnA	10.47	1.96
GDP	α	0.13**	0.16**
Population	β	0.17**	0.30**
Distance	γ	0.55**	0.23*
Tokyo	δ	0.79** (2.20)	0.78** (2.19)
Seoul	ε	0.35 (1.42)	0.82** (2.27)
Taipei	ζ	0.62* (1.87)	0.94** (2.57)
Hong Kong	η	0.83** (2.30)	1.23** (3.42)
Bangkok	θ	0.78** (2.19)	0.75** (2.12)
Singapore	ι	1.01** (2.76)	1.26** (3.53)
Adj.R^2		0.71	0.81
D.F.		182	180

Note: ** and * indicate significance at the 1% and 5% levels, respectively.
Figures in parentheses are *e* raised to the power of the coefficients of the dummy variables.

Table 3

Regression coefficients for intra-European traffic (1998)

		Passenger	Cargo
Constant	lnA	4.55	-0.76
GDP	α	0.24**	0.16**
Population	β	0.24**	0.22**
Distance	γ	0.25**	-0.07
London	δ	1.03** (2.81)	0.93** (2.55)
Paris	ε	0.51** (1.67)	0.69** (1.99)
Frankfurt	ζ	0.63** (1.88)	1.19** (3.29)
Zurich	η	0.53** (1.69)	0.76** (2.13)
Amsterdam	θ	1.08** (2.93)	1.22** (3.37)
Bruxelles	ι	0.52** (1.69)	-0.05 (0.95)
Adj.R^2		0.65	0.48
D.F.		394	330

Table 4

Regression coefficients for intra-American traffic (1998)

		Passenger	Cargo
Constant	lnA	7.57	0.13
GDP	α	0.20**	-0.06
Population	β	0.23**	0.46**
Distance	γ	0.50**	-0.02
New York	δ	0.73** (2.08)	0.87** (2.38)
Los Angeles	ε	0.27 (1.31)	0.13 (1.14)
Miami	ζ	1.13** (3.10)	2.41** (11.18)
Adj.R^2		0.39	0.39
D.F.		204	172

Table 5

Regression coefficients for inter continental traffic (1998)

		Passenger	Cargo
Constant	lnA	11.92	2.85
GDP	α	0.19**	0.24**
Population	β	0.16**	0.40**
Distance	γ	0.80**	0.67**
Tokyo	δ	0.38 (1.47)	0.19 (1.21)
Seoul	ε	0.10 (1.10)	0.73** (2.07)
Taipei	ζ	0.87 (2.39)	0.82 (2.28)
Hong Kong	η	0.72** (2.05)	1.23** (3.43)
Bangkok	θ	0.76** (2.14)	0.88** (2.41)
Singapore	ι	0.41 (1.51)	0.90** (2.47)
London	κ	0.91** (2.49)	0.65** (1.91)
Paris	λ	0.42* (1.52)	0.80** (2.22)
Frankfurt	μ	0.77** (2.17)	1.22** (3.39)
Zurich	ν	-0.05 (0.95)	0.61** (1.85)
Amsterdam	ξ	0.70** (2.01)	1.44** (4.23)
Bruxelles	ο	0.09 (1.10)	0.48 (1.61)
New York	π	0.45** (1.56)	0.38 (1.46)
Los Angeles	ρ	0.67** (1.95)	0.31 (1.37)
Miami	σ	0.96* (2.62)	1.04 (2.83)
Adj.R^2		0.45	0.49
D.F.		320	338