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Analyzing air cargo flows of international routes: an empirical study of Taiwan Taoyuan International Airport

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ABSTRACT

Air cargo demand is an important aspect of the operation and planning of private and public agencies responsible for airports. While most existing studies in this field include only geo-economic characteristics of airports and their hinterlands as explanatory variables, this study develops a gravity model of air cargo flows by trying to incorporate more factors that might influence international air cargo flows of an airport. The model is developed based on the panel data of air cargo services on scheduled routes at Taiwan Taoyuan International Airport during the years 2004–2007. The results indicate that population, air freight rate and three dummy variables, including the regional economic bloc of the "Chinese Circle"(an informal partnership between Hong Kong, Macao, Taiwan and mainland China), the Open Sky Agreements and long established colonial links, are key determinants of international air cargo flows from/to Taiwan. These results suggest a wider array of factors needs to be considered in policy.

1. Background

The analysis of international air freight movement helps airlines evaluate their operating strategies and aviation authorities improve infrastructure facilities and allocate resources. Many researchers have studied commodity flow over space. However, relatively few studies have been conducted on international air freight demand through modeling, due to lack of data. Data gathering and tracking is often difficult and costly. Previously published studies (Matsumoto, 2004, 2007; Yamaguchi, 2008) reveal that only a few macroeconomic and hinterland-derived factors, such as GDP per capita, population and distance, have been used to develop gravity type of air cargo demand models. In other approaches, researchers have shown that two groups of factors might affect international air cargo flow. The first group of factors includes the supply-related aspects of air service markets. In a competitive environment, deregulations in the airline industry contributed to radical re-structuring that changed the behavior of both consumers and suppliers (Graham, 1999). According to Graham, ignoring major supply-side factors may result in inaccurate forecasts of the air market traffic growth.

The second group is the factors affecting international trade flows between countries. At a practical level the demand of air cargo transport is generated from bilateral trade between two countries. Research into this aspect by Regan and Gariddo (2002) indicated that freight demand models can be divided into international, intercity, and urban approaches based on their geographical scope. However, increasing globalization of supply chains has blurred these distinctions. Certain historical and cultural contiguities and institutional facts including regional trading blocs, exchange-rate mechanisms, ethnic ties, linguistic identities, colonial links and international borders, influence international trade barriers and flows (Anderson and van Wincoop, 2003). In this broader set of concerns in the field of the international air cargo demand, only Open Sky Agreements (OSAs) have been studied recently (Micco and Serebrisky, 2005; Yamaguchi, 2008).

This paper aims at exploring this wider array of factors which affect international air cargo flows of Taiwan Taoyuan International Airport through development of a panel gravity type of model. Factors cited in the existing literature concerning air transportation demand and international trade, as well as other unique features of Taiwan are both considered in this empirical study.

Section 2 of this article contains a literature review of air cargo demand modeling and international air cargo demand factors. Section 3 analyzes some characteristics of Taiwan's international air cargo flows. Section 4 explains the model specification and describes the variables selected and data sources. Section 5 discusses econometric issues and presents the empirical results. The final section concludes major findings of this study.

2. The driving forces of air cargo: a literature review

The determinant factors of air transport can be categorized into two groups: geo-economic and service-related (Jorge-Calderón, 1997). The first group includes the economic activities and

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geographical characteristics of the areas surrounding the airports and routes. The second group includes the characteristics of the air transport system, which is under the control of the airlines.

Geo-economic factors involve the activities and geographical characteristics of the areas where air cargo transport takes place. Income and population around the areas close to the airports are widely used as mesures of activity related factors (Matsumoto, 2007). Some studies (Russon and Riley, 1993) are more detailed in considering other economical and social variables such as the percentage of university degree holders and employment composition. Recent studies (Micco and Serebrisky, 2005; Khadaroo and Seetanah, 2008; Hazledine, 2009) include factors that explain bilateral international trade flows, including common borders, common languages, and OSA. These factors also affect cross-boundary flows of air transport traffic. International economists have successfully examined some of these factors using gravity models and have explored as the influence of ethnic ties (Frankel et al., 1995), linguistic identity (Frankel et al., 1995), international borders (McCallum, 1995; Frankel et al., 1995), and trading blocs (Eichengreen and Irwin, 1995). These determinants of international trade should be considered in international air cargo demand models.

The distance between two airports is an important geographical factor affecting air cargo transport demand. Greater distances decrease social and commercial interactions, and also increase air transport competition with other types of transport (Jorge-Calderón, 1997). Another aspect of the geographical characteristic incorporated in modeling air passenger travel demand is that competitive airports in close proximity can offer better schedules (Grosche et al., 2007). However, not all airports provide scheduled international air freight services due to the service arrangements of airlines. For example, some airlines concentrate air freight in a hub and only supply passenger services to other nearby airports. This factor is rarely included in air cargo demand research.

Service-related factors focus on the quality and expenses of air freight service. The factors which determine airline service quality have been studied (McGinnis and Kohn, 1993; Graham, 1999; Hsu et al., 2005). Service frequency, which related to delay occurring from the differences between desired departure time of the customer and the nearest departure time available, is an important factor. The more departure flights, the lower expected frequency delay. The frequency of services has been repeatedly proven to be a significant determinant of air passenger traffic patterns. The evidence of its impact on air freight traffic remains ambiguous. Other relevant factors of service quality include market presence, reputation, and equipment. Finally, freight rates are a very important factor in air transport demand. In general, air transport demand decreases as the freight rates increase.

The above literature review indicates that although many studies discuss possible factors that might affect air transport demand, relatively few studies that attempt to model the international air cargo flows take these factors into account. This gap in the literature is one of the motivations for this study.

3. Analysis of Taiwan's international air cargo flows

Taiwan is located in the Pacific Ocean about 160 km from the southern coast of the Asian continent, about midway between Korea and Japan to the north and Hong Kong and the Philippines to the south. Taoyuan International Airport, the major airport in Taiwan, was ranked as the 15th largest among the world's top 30 airports and 6th largest among airports in the Asia-Pacific region in 2008 by Airport Council International based on total freight tonnage. There was 1.49 million tons of air cargo transported in 2007, which represents over 95% of Taiwan's international cargo shipments by air.

Table 1 lists the major items of Taiwan's export and import air cargo in 2007. Taiwan's exports by air in volume are about 30% larger than that of its imports. At the aggregate level, the major items of Taiwan's international air cargo are electrical machineries and apparatus, fishery products, farm products, precision instruments and equipments, as well as textile products. Japan, the USA, Hong Kong, China and European countries are the main markets of Taiwan's air cargo, which represented a high share (75.6%) of the total trade of Taiwan by air in 2007.

As indicated in Table 1, electrical machineries and apparatus are the major cargo item of Taiwan's export and import merchandise by air, which in total accounts for almost 54% of the total international air cargo in 2007. This situation reflects Taiwan's global leadership in information technology industry where it accounts for more than 50% of all chips, nearly 70% of computer displays and more than 90% of all portable computers produced in the world. With the production bases now set up in mainland China and parts of Southeast Asia, Taiwan's companies use elaborate air cargo service to connect these production locations with markets in the USA and Europe. As shown in Tables 2 and 3, for Taiwan's electrical machineries and apparatus moved by air, it appears that the USA, Japan, Hong Kong, and mainland China are the main markets.

The farm and fisheries sectors are the next two main categories of Taiwan's international air cargo. Taiwan imported a large share of fishery products from Philippine, Thailand and Indonesia and exports mainly to Japan. As for farm and agriculture products, such as wood products, tropical fruits and vegetables, Taiwan largely imported from the USA and Thailand, and exported to Japan and the USA. Precision instruments and equipment and wearing apparel and textile articles are the 4th and 5th largest items of Taiwan's imported air cargo in volume. As shown in Table 2, Taiwan imported precision instruments and equipments largely from Japan, the USA and Hong Kong as well as wearing apparel and textile articles from Macao and Hong Kong.

4. Model specification and data description

The international trade gravity model was originally developed independently by Tinbergen (1962) and Pöyhönen (1963). In its basic form, the amount of trade between two countries or regions is assumed to be directly proportionate to their size and inversely proportionate to the distance between them. Linnemmann (1966) identified population as a measure of country or region size. Gravity type models were empirically successful in explaining various interregional and international flows including migration, commuting, international trade and air passenger service. Because air cargo transport is a form of international trade, it is well suited to estimation by a gravity model.

The dependent variable in this study is the total cargo volume between airports. The transferred traffic is excluded due to the limitation of data availability. The shipping journeys of transferred goods depend on the number of available flights, empirically reaching the destination airport sometimes via several legs.

Annual air cargo volume shipped from Taiwan Taoyuan International Airport by routes from 2004 to 2007 was collected from the Taiwan Directorate General of Customs. Following Matsumoto (2007), who suggested that one thousand tons can be used as the minimum criteria for the selection of major routes in air cargo networks in Asia, 36 routes were chosen for inclusion in the analysis. These are shown in Table 4. Those flights connect major airports of Taiwan's 21 trading partners, and in aggregate accounted for 91.5% of Taiwan Taoyuan International Airport cargo shipments in 2007.

This study uses four proxy variables for the activities of the origins and destinations of air cargo. Two of the variables, population and regional per capita income, represent the economic and

Table 1
Taiwan's major items of international air cargo in 2007. *Source*: Civil Aeronautics Administration, Taiwan Ministry of Communication and Transportation.

Rank	Export		Import		Total	
	Items	Ton (%)	Items	Ton (%)	Items	Ton (%)
1	Electrical machineries and apparatus	320,089 (59.03%)	Electrical machineries and apparatus	197,214 (47.29%)	Electrical machineries and apparatus	517,303 (53.93%)
2	Fishery products	16,817 (3.10%)	Farm products	23,461 (5.63%)	Fishery products	40,037 (4.17%)
3	Farm products	7381 (1.36%)	Fishery products	23,219 (5.57%)	Farm products	30,843 (3.22%)
4	Pulp paper allied products and printed matter	725 (0.13%)	Precision instruments and equipments	19,338 (4.64%)	Precision instruments and equipments	19,342 (2.02%)
5	Textile products	629 (0.12%)	Wearing apparel and textile articles	18,158 (4.35%)	Wearing apparel and textile articles	18,174 (1.89%)
6	Rubber and plastic products	119 (0.02%)	Machineries	17,542 (4.21%)	Machineries	17,655 (1.84%)
7	Machineries	113 (0.02%)	Chemicals products	14,328 (3.44%)	Chemicals products	14,367 (1.50%)
8	Livestock and poultry products	43 (0.01%)	Non-metallic mineral products	5377 (1.29%)	Non-metallic mineral products	5381 (0.56%)
9	Chemicals products	39 (0.01%)	Pulp paper allied products and printed matter	3453 (0.83%)	Pulp paper allied products and printed matter	4178 (0.44%)
10	Transportation equipments	25 (0.01%)	Transportation equipments	3284 (0.79%)	Transportation equipments	3309 (0.34%)
	Others	196,230 (36.19%)	Others	91,669 (21.98%)	Others	288,666 (30.09%)
	Total	*542,211 (100%)*	Total	*417,042 (100%)*	Total	959,253 (100%)

demographical characteristics of the areas surrounding the airports. It is difficult to assess the actual hinterland/catchment area of the airports so that region-wide measures have to be used. Once again following Matsumoto's (2007) approach, GDP per capita of the country in which an airport located is used as a proximate estimate for the income of the areas surrounding the airport due to lack of regional income data. The data was obtained from the Trade Indicators Database of the Chung Hua Institution for Economic Research and converted to constant US dollars (2004 prices). For population, it was possible to get data on urban agglomerations surrounding the individual airport. The population data was gathered from the UN website and the official websites of related city governments.

This study includes three dummy variables to identify the trade activity relationships between two countries or regions where origins and destinations are located. For various historical and political reasons, Taiwan is not a member of any regional trading bloc. Taiwan signs preferential trade agreements with certain countries, but there are no direct scheduled flights between Taiwan and those countries. However, a development of economic interdependence has characterized the emerging pattern of relations across the Taiwan Strait. Economic interactions between Taiwan and mainland China have grown at an astounding speed since the late 1980s (Huang and Huang, 2006). A growing flood of cross-border investment and trade has created economic interdependence. The emergence of a new regional economic grouping, known as 'Chinese Economic Area' or 'Chinese Circle', an informal partnership between Hong Kong, Macao, Taiwan and mainland China, has been recognized widely. A dummy variable (DM) controls pairs of countries or regions that share membership in this economic bloc. The dummy variable, OSA, captures the effect of an open sky agreement between countries on air transport. Taiwan signed an open sky agreement with the USA in 1997. The agreement allows the USA and Taiwan carriers to determine matters such as the number of flights, routes and fares according to market demand. More than 10 scheduled air freight routes are operated by airlines, including combination and all-cargo carriers. Finally, COL is a dummy variable for the country had colonial links with Taiwan in last century. Japan colonized Taiwan for half a century, so is included under this factor.

The distance between two destinations has an influence upon the impact of alternative transport modes by determining the time needed for delivery. The distances used in this study were obtained from the US Bureau of Transportation Statistics website.

This study includes two service-related variables, flight frequency and freight rate, to determine service quality and shipping charge. Flight frequency data was calculated from the scheduled flight timetable of Taiwan Taoyuan International Airport, which included total departures of passenger and dedicated freighter aircrafts. The total number of return flights per week between origins and destinations measured frequency of service. The freight rate was calculated using the transportation cost at the route level. An empirical method was used to calculate air freight costs using data obtained from the free-alongside-ship (FAS) value, cost-insurance-freight (CIF) value, and the insurance cost. This study estimates the airfreight costs as follows:

$$\text{Air freight costs} = \text{CIF value} - \text{FAS value} - \text{insurance cost} \qquad (1)$$

FAS, CIF and insurance cost microdata were made available by the Taiwan Directorate General of Customs through the export and import declaration database. The freight rate measurements are defined as the total freight costs divided by the total shipping weight on each route.

The gravity function is specified as follows:

$$T_{ijt} = f(Y_{it}, Y_{jt}, N_{it}, N_{jt}, D_{ij}, F_{ijt}, R_{ijt}, \mathrm{DM}_j, \mathrm{OSA}_j, \mathrm{COL}_j) \qquad (2)$$

Table 2
Originations of Taiwan's major items of imported air cargo in 2007. *Source*: Civil Aeronautics Administration, Taiwan Ministry of Communication and Transportation.

Rank	Electrical machineries and apparatus	Farm products	Fishery product	Precision instruments and equipments	Wearing apparel and textile articles	Others
1	Japan (28.9%)	USA (54.7%)	Indonesia (25.3%)	Japan (42.9%)	Macao (41.5%)	Japan (25.6%)
2	Hong Kong (20.8%)	Thailand (26.2%)	Norway (14.4%)	USA (20.1%)	Hong Kong (28.8%)	USA (16.8%)
3	USA (12.8%)	Japan (5.9%)	Philippine (13.8%)	Hong Kong (9.4%)	S. Korea (9.1%)	Hong Kong (10.7%)
4	Macao (6.7%)	Canada (1.9%)	Thailand (12.8%)	Macao (6.6%)	Japan (7.3%)	Macao (5.0%)
5	Luxemburg (4.7%)	Australia (1.6%)	USA (4.5%)	Luxemburg (5.5%)	China (2.8%)	Thailand (5.0%)
6	S. Korea (4.4%)	Hong Kong (1.0%)	Hong Kong (3.1%)	Netherlands (3.0%)	USA (2.3%)	S. Korea (4.2%)
7	Singapore (4.2%)	Philippine (0.8%)	Japan (2.8%)	S. Korea (3.0%)	Thailand (2.2%)	Singapore (3.5%)
8	China (3.0%)	Malaysia (0.6%)	Australia (2.8%)	China (1.6%)	Vietnam (0.7%)	Philippine (3.2%)
9	Germany (2.8%)	Indonesia (0.6%)	Canada (2.6%)	Germany (1.2%)	Luxemburg (0.6%)	Germany (3.2%)
10	Malaysia (2.5%)	New Zealand (0.6%)	Vietnam (1.8%)	UK (1.1%)	Singapore (0.5%)	Luxemburg (3.1%)
	Others (9.3%)	Others (6.0%)	Others (16.1%)	Others (5.6%)	Others (4.2%)	Others (19.6%)

Table 3
Destinations of Taiwan's major items of exported air cargo and in 2007. *Source*: Civil Aeronautics Administration, Taiwan Ministry of Communication and Transportation.

Rank	Electrical machineries and apparatus	Fishery products	Farm products	Pulp paper allied products and print matters	Textile products	Others
1	USA (21.2%)	Japan (93.2%)	Japan (51.7%)	Hong Kong (37.5%)	Vietnam (21.0%)	China (25.9%)
2	China (13.5%)	USA (4.38%)	USA (11.4%)	China (31.8%)	China (9.4%)	USA (14.9%)
3	Hong Kong (10.3%)	S. Korea (0.79%)	S. Korea (10.6%)	Vietnam (14.3%)	Thailand (7.9%)	Hong Kong (13.8%)
4	Japan (10.1%)	Hong Kong (0.69%)	Hong Kong (6.8%)	Macao (7.0%)	Hong Kong (6.5%)	Japan (7.3%)
5	S. Korea (3.9%)	Singapore (0.44%)	Netherlands (5.2%)	Malaysia (3.1%)	Indonesia (6.5%)	Germany (4.5%)
6	Germany (3.8%)	Malaysia (0.11%)	Singapore (2.6%)	Thailand (1.9%)	Philippine (3.7%)	UK (3.8%)
7	Singapore (3.4%)	Thailand (0.07%)	UK (1.9%)	Philippine (1.5%)	Germany (3.0%)	Luxemburg (3.1%)
8	Thailand (3.4%)	Indonesia (0.06%)	France (1.1%)	Japan (0.9%)	USA (2.9%)	Netherlands (3.0%)
9	UK (2.3%)	Canada (0.02%)	Canada (1.0%)	USA (0.8%)	S. Korea (2.5%)	Singapore (2.7%)
10	Malaysia (2.1%)	France (0.02%)	Australia (1.0%)	Australia (0.6%)	Malaysia (2.2%)	Macao (1.8%)
	Others (26.0%)	Others (0.2%)	Others (6.8%)	Others (0.5%)	Others (34.3%)	Others (19.2%)

Table 4
List of the selected air routes.

Continent	Country(airport code)
Asia (14)	Japan (NRT, NGO, FUK, KIX), Hong Kong (HKG), Thailand (BKK), Singapore (SIN), S. Korea (ICN, PUS), Macao (MFM), Malaysia (KUL), Indonesia (CGK), Philippines (MNL), Vietnam (SGN)
North America (11)	USA(LAX, JFK, ORD, DFW, ATL, IAH, BNA, SFO, SEA, ANC), Canada (YVR)
Europe (9)	Germany (FRA, CGN), Luxembourg (LUX), Netherlands (AMS), United Kingdom (LHR, MAN), France (CDG), Italy (MXP), Belgium(BRU)
Oceania (2)	Australia (SYD, BNE)

where i represents Taiwan Taoyuan International Airport, j represents a foreign airport on the route and t represents year. T_{ijt} is the total volume of international cargo shipped between airport$_i$ and airport$_j$ in year t. Y_{it} and Y_{jt} are the GDP per capita of the countries where airport$_i$ and airport$_j$ are located, expressed in US dollars in year t. N_{it} and N_{jt} are the population (in thousands) of two urban agglomerations at both airport$_i$ and airport$_j$ in year t. D_{ij} is the distance between two airports. R_{ijt} corresponds to the average freight cost of goods on the route connecting airport$_i$ and airport$_j$ in year t. F_{ijt} is the scheduled flight frequency of air cargo service between airport$_i$ and airport$_j$ in year t. Dummy variables DM_j are valued at 1 if one side of the route, airport$_j$, is Hong Kong or Macao. OSA_j variables are valued at 1 if the country in which the airport$_j$ is located has an Open Skies Agreement with Taiwan. COL_j variables are valued at 1 if airport$_j$ is located in Japan, representing colonial links with Taiwan.

The corresponding econometric model (reduced-form augmented gravity model) is displayed below:

$$T_{ijt} = \alpha + \beta_1 \ln Y_{it} Y_{jt} + \beta_2 \ln N_{it} N_{jt} + \beta_3 \ln D_{ij} + \beta_4 \ln F_{ijt} + \beta_5 \times \ln R_{ijt} + \beta_6 \mathrm{DM}_j + \beta_7 \mathrm{OSA}_j + \beta_8 \mathrm{COL}_j + \mu_{ijt} \quad (3)$$

The specification is log linear and the variables are in a natural logarithm; α is a constant. Beta (β) is a vector of parameters. μ_{itj} is an individual error term distributed i.i.d. across a route over time. The coefficients associated with other variables are expected to be positive in the estimation, except distance and freight rate.

Table 5 presents the summary statistics for the data used in this study.

5. Model development and results analysis

5.1. Model estimation

The parameters of the proposed model specified in Eq. (3) can be estimated in several ways. The appropriate estimation method depends upon the structure of the error terms, μ_{itj}, and the correlation between the observed determinants of air cargo volume and the different components of the error term. The third to sixth column of Table 6 gives four estimations of the equation, including ordinary least square (OLS) estimation, Fixed Effects Model estimation with route effects only (RFE), Fixed Effect Model estimation with time effects only (TFE) and Random Effects Model estimation

Table 5
Summary statistics.

Variable	Obs.	Mean	SD	Maximum	Minimum
Total weight (ln), T_{itj}	144	8.865	1.143	11.862	6.932
Product of GDPs per Capita of airport$_i$ and airport$_j$ in US$ (ln), Y_{it} (Y_{jt})	144	19.723	1.131	21.078	15.888
Product of populations of airport$_i$ and airport$_j$, (ln), N_i (N_j)	144	17.168	1.139	19.621	14.447
Distance (ln), D_{ij}	144	8.090	0.882	8.994	6.234
Flight frequency annually (ln), F_{ijt}	144	7.521	1.214	10.476	3.951
Freight rate, price per unit of weight (ln), R_{ijt}	144	6.935	0.397	8.213	6.028
Trade bloc dummy, DM$_j$	144	0.056	0.230	1	0
Open sky agreement dummy, OSA$_j$	144	0.278	0.449	1	0
Colonial links dummy, COL$_j$	144	0.111	0.315	1	0

Table 6
Regression coefficients for pooled OLS and panel data.

Variable		Regression 1 (pooled OLS)	Regression 2 (RFE)	Regression 3 (TFE)	Regression 4 (RRE)
C	α	−0.780(2.028) [−0.385]	13.675(0.603) [22.672***]	−0.776(2.000) [−0.388]	5.063(2.758) [1.836*]
GDPP (*Y*)	β_1	0.186(0.053) [3.484***]	−0.219(0.018) [−12.262***]	0.180(0.054) [3.365***]	0.068(0.104) [0.654]
Population (*N*)	β_2	0.229(0.052) [4.393***]	0.046(0.023) [2.000**]	0.231(0.051) [4.547***]	0.289(0.082) [3.537***]
Distance (*D*)	β_3	−0.038(0.128) [−0.297]	–	−0.027(0.122) [−0.221]	−0.414(0.237) [−1.750*]
Frequency(*F*)	β_4	0.735(0.080) [9.172***]	0.023(0.028) [0.813]	0.736(0.076) [9.626***]	0.261(0.070) [3.737***]
Freight rate (*R*)	β_5	−0.441(0.148) [−2.977***]	−0.209(0.032) [−6.486***]	−0.445(0.144) [−3.091***]	−0.166(0.117) [−1.417]
Trade bloc dummy (DM)	β_6	−0.269(0.307) [−0.877]	–	−0.250(0.300) [−0.832]	0.598(0.641) [0.933]
OSA dummy (OSA)	β_7	−0.093(0.152) [−0.610]	–	−0.100(0.145) [−0.658]	0.264(0.268) [0.987]
Colonial links dummy (COL)	β_8	−0.677(0.275) [−2.463**]	–	−0.662(0.251) [−2.635***]	−0.601(0.465) [−1.291]
Tests of effects					
F statistics		–	144.615***	0.120	–
Hausman χ^2		–	–	–	29.94***
Observations		144	144	144	144
Adj. R^2		0.737	0.995	0.732	0.306

Note: Figures in parentheses are standard errors. Figures in brackets are *t*-values.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

with route effects only (RRE), to consider the possibility of a cross-sectional or a time specific heterogeneity. Random effects model with time effects only was not estimated due to lack of sufficient data.

The two *F*-tests indicate the importance of considering the unobservable route heterogeneity but not time heterogeneity. It was then necessary to decide whether a fixed or random effect specification is more appropriate. For the unobservable route effects, the assumption that the route-specific effects are uncorrelated with the independent variables was tested. A Hausman test was conducted based on Baltagi (2001) and the result of the Hausman test reported in Table 6 significantly rejected the random effects model in favor of the fixed effects model (RFE). The variance inflation factors, which ranged from 1.2 to 2.5, indicate no effects of multicollinearity between any two independent variables.

A Chow test was also conducted to test the poolability of data across heterogeneous time period units and the *F* statistics value is 0.201, which indicates that the null hypothesis, that parameters of interest are assumed to have common values across time periods, is not rejected at the significance level of 10%.

6. Empirical results

The third column of Table 7 presents the route fixed effect model without the frequency variable. This study also applies Arellano's (1987) correction to deal with autocorrelation. In the original panel framework, the variables that did not change over the study

Table 7
Regression coefficients for panel data.

Variable		Regression 2 (RFE model without time-invariant variables)	Regression 2-1 (RFE model with time-invariant variables)
C	α	8.245(0.760)[10.853***]	7.711(0.655)[11.775***]
GDPP (*Y*)	β_1	–	–
Population (*N*)	β_2	0.142(0.035)[4.046***]	0.147(0.017)[8.325***]
Distance(*D*)	β_3	–	–
Frequency (*F*)	β_4	–	–
Freight rate(*R*)	β_5	−0.261(0.045)[−5.855***]	−0.228(0.071)[−3.213***]
Trade bloc dummy (DM)	β_6	–	2.091(0.056)[37.194***]
OSA dummy (OSA)	β_7	–	0.105(0.025)[4.202***]
Colonial links dummy (COL)	β_8	–	0.437(0.092)[4.769***]
Adj. R^2		0.993	0.969
DW value		1.897	2.046

Note: Figures in parentheses are standard errors. Figures in brackets are *t*-values. ***significant at the 10% and 5% levels respectively. Heteroskedastic-consistent standard errors are used to calculate *t*-statistics, shown in parentheses.
*** Significant at the 1% level.

period, i.e. distance, trade bloc dummy, and OSA, should be dropped in the fixed effects models (RFE).

However, the estimated coefficient of the GDP per capita in the fourth column of Table 6 has a negative impact which is an unexpected result. In general, the trade flow between two countries is directly proportionate to the GDP per capita of two countries; that is, the greater GDP per capita of two countries, the larger is the bilateral trade flow. In order to gain more insights about the relationship in the current research, the two data sets were plotted in Fig. 1, and a Pearson's product-moment correlation coefficient of these two variables was calculated to be −0.2, which indicates that there is no significant correlation between these two variables. This outcome may reflect on the type of data used to measure GDP, but also suggests that airline hub operation can be a major factor in air cargo activity, as shown by the position of Hong Kong and Luxembourg (two major air cargo hubs) on Fig. 1. Therefore, GDP per capita was not included in the two models in Table 7.

The population variable has a significant positive effect on air cargo demand. The estimated coefficient of the freight rate is negative; as expected higher freight rates reduce air cargo volume. The air freight rate elasticity is estimated to be −0.261 after omitting the variable GDP per capita, as shown in Table 7. This is much smaller than the rate proposed by Oum et al. (1990), which ranged from −0.82 to −1.6, indicating that the air cargo flows of this case study seem to be less sensitive to freight rate than before. One reasonable explanation is that electronics products, which represent a very large portion of Taiwan's exported and imported air cargo, have higher value-to-weight ratios and thus possess higher capacities to afford the costs of air transport. As global leaders, most of Taiwan's electronics firms, especially PC and Notebook manufactures, use global production networks based on air cargo services to respond more effectively to competitive forces in their global markets. In addition, Taiwan Taoyuan International Airport is adjacent to the Hsinchu Science and Industrial Park, the hub of Taiwan's information technology industry, and its air logistic services are readily available to the manufacturers in the park. Therefore the air freight rate elasticity for Taiwan air cargo is lower that that found in other research.

Despite the good statistical fit, the estimated model in this study did not explain some particular characteristics of air cargo flows of Taiwan Taoyuan International Airport, such as the huge volume on route Taipei–Hong Kong, and the three explanatory variables mentioned above did not contribute to the explanation. That is due to the fact that trade effects of the three dummy variables could not be explored in the estimated RFE model because the route-specific effect actually aggregates, into one term, the effect of other explanatory variables which do not vary across the study period. A technique developed by Plümper and Troeger (2007) was adopted to estimate time-invariant variables, and the fourth column of Table 7 shows these results.

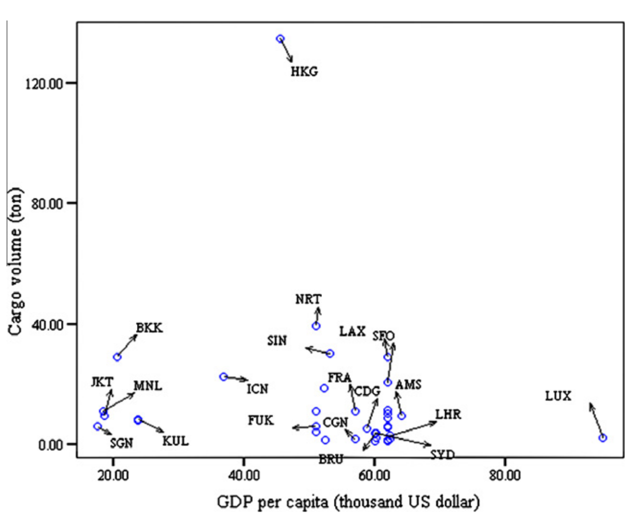

Fig. 1. Air cargo volume and GDP per capita by routes.

The dummy regional economic bloc has a significantly positive sign with a large coefficient, and so explains air cargo flows between Taiwan and Hong Kong as well as Macao. Taiwan is one of the largest investors in mainland China and mainland China has become the important overseas investment area and the largest export market of Taiwan. The roles of Hong Kong and Macao in the Chinese Circle have largely been as connectors between Taiwan and China. Due to the absence of direct air cargo flights between China and Taiwan before 2008, all cross-strait trade had to transship via Hong Kong or Macao. The COL dummy variable has a positive value and is significant at standard level. Taiwan had colonial links with Japan in last century and established friendly cultural ties. Taiwan now has intensive economic links with Japan as many Japanese manufacturers have located plants in Taiwan, predominantly in the electronics industry, which produces demand for air transport. The OSA dummy variable has a positive value and is significant at standard levels, which implies an increase of 10.5% in the air cargo volume. The agreement adds more flexibility in operations and route development. For the air cargo markets between the USA and Taiwan, opening up routes to competition, and allowing more scope for airlines to serve particular routes, drives an increase in bilateral air cargo trade, which in turn improves the productivity of airlines and strengthens the position of an airport in the competitive airport industry.

7. Conclusion

Analyzing air market traffic is necessary practically for planning airline operations and for aviation authorities. Numerous studies have been conducted on air passenger market demand, but few have addressed air cargo. Research on air cargo demand typically uses one or two demographical factors and distance as explanatory variables. By including service-related and market-specific input variables and proxy variables for bilateral trade, this study develops a panel gravity model for international air cargo flows on routes to and from Taiwan Taoyuan International Airport. The main determinants of international air cargo flow found at Taiwan Taoyuan International Airport include population, air freight rate, and three dummy variables for the regional trading bloc, OSAs and colonial links. The proposed model is meaningful in terms of goodness of fit measures and does not suffer from multicollinearity. The estimated air freight rate elasticity is much smaller than the rate proposed by Oum et al. (1990), indicating that the air cargo flows of this case study seem to be less sensitive to freight rate than before. One reasonable explanation is that electronics products, which represent a large portion of Taiwan's exported and imported air cargo, have higher value-to-weight ratios and thus possess higher capacities to afford the costs of air transport.

International commerce has grown exponentially in the last two decades due to multinational firm operations. Further development of our understanding of air cargo will need to utilize knowledge of these multi-national operations. In this study the economic interactions of the Chinese circle contribute to the level of air cargo flows between Taiwan and Hong Kong, as well as Taiwan and Macao, which are in effect gateways to mainland China for Taiwan's firms over this period. Similarly the old colonial link between Taiwan and Japan has a modern expression in close economic relationships as seen in the location of Japanese firms in Taiwan, which create large air cargo demand. The study also found regulation was a relevant factor. OSAs enable an increase in the bilateral air cargo flows. The liberalization of air cargo markets between the USA and Taiwan for example has opened up routes to competition, and led to increase in bilateral air cargo trade, which in turn improves in the productivity of airlines and strengthens the position of an airport in the competitive airport industry. The long term planning of the air cargo operation at Taiwan Taoyuan International Airport will need to take these broader forces into consideration.

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