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Responses of air cargo carriers to industrial changes

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ABSTRACT

This study examines how product characteristics, values, inventory cost, shipping charges, shipping distance, and time affect an international firm's choice of air carrier. An individual choice model is constructed by assuming that the shipper in a specific industry chooses the optimal air cargo carrier with the minimal logistics cost. The study further aggregates air cargo demands on different routes for the carriers by considering the spatial distribution of the origin-destination pattern and any temporal changes in the industrial structure. A case study is used to illustrate the application of the proposed model using data from Taiwan Taoyuan International Airport and the industrial economics database in Taiwan. The results show that shippers with high product value and short delivery distance focus on the shipping charge and prefer choosing the air cargo carrier that offers more flights. Further a carrier may achieve a larger market share if its supply attributes match the industrial structure and the product characteristics of the market on the route. Finally, because dynamic changes in the industrial structure and product value have been captured, the results are more accurate than that from the Grey model.

1. Introduction

The growth of air cargo demand depends on international trade due to the specialization and evolution of industrial structures all over the world. The air cargo industry is subject to ups and downs, because the trade flow between countries fluctuates with their individual economic status. For example, the slowdown in world trade from a 13% growth in 2000 to a 3% growth in 2001 due to the events of September 11 2001 resulted in a major setback for global air traffic. The recession in the air cargo industry was quite obvious between Taiwan and North American market where the majority of the trade flows were high-tech and high-value products.

The industrial structure in Taiwan has been shifting from being labor to technology intensive. The share from the textile industry in export volume decreased from 15% in 1990 to 7% in 2004, while that from the machinery industry rose from 34% to over 50%. In addition to domestic changes in the industrial structure, there is also significant change in foreign trade partners, with export to the US decreasing from 25.4% in 1990 to 16.2% in 2004, while that to the Asian Area increased from 48.7% to 62% in 2004. Since air cargo is derived from world trade, which in turn is related to economic activity, any efforts to forecast the air cargo traffic must include the influences of the economic fluctuation and trade between countries. Forecasts of demand for the services of route markets for air cargo carriers also need to allow for dynamic industrial changes and product characteristics in different industries.

There are a number of approaches to forecasting air transportation demand. A traditional econometric approach argues that air cargo volumes are correlated with independent variables such as employment, per capital income and gross domestic product (GDP) (Chin and Tay, 2001). Ippolito (1981) discussed the relationship between the demand and the supply sides of air transportation and found that passenger demand is positively related to flight frequency and negatively related to utilizatation Graham (1999) concluded there are two categories of forecast analysis: one applies gravity models using nation macroeconomic data and distances between OD pair while the second investigates how the airport traffic is affected by the gross national product (GNP), the price index and geographic location characteristics.

A variety of forecasting methods are available to for air cargo forecasting, ranging from subjective judgment to sophisticated mathematical modeling (Horonjeff and McKelvey, 1994). The disadvantages of the former involve the absence of statistical measures and quantitative results. Mathematical forecasting models, i.e. regression analysis and logit-based models are performed to examine the relationships between the explanatory and the independent variables, where the abundance of historical data is crucial to the forecasted results. There is usually a considerable

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amount of time and cost required to perform the traditional mathematical forecast methods. Moreover, few of them are focused on forecasting air cargo demand in response to any recent dynamic industrial change. Unlike the traditional methods, we use an analytical model of the choices available to air cargo shippers for estimating carrier route market shares by considering dynamic industrial changes and product values of different industries.

2. Model formulation

The export of goods for producing firms (i.e. shippers) involves not only the determination of the optimal transportation mode but also the optimal carrier to deliver the goods to customers. The logistics cost of the shipper is influenced by not only the charge, flight frequency and transit time of the carrier but also by product characteristics. Regardless of the service attributes of an air carrier, products with high pricing and/or perishable characteristics have a high inventory loss, considerably increasing the cost of the logistics. The decision criterion applied to the optimal carrier choice assumes a rational decision maker who pursues a minimized logistics cost for each shipment. The logistics cost includes the transportation cost, in-transit inventory cost and stationary inventory cost, where the transportation cost is positively related to the base shipping charge and shipping volume. The in-transit inventory cost reflects the inventory loss due to the transit and is related to flight duration and route distance between an OD pair, while the stationary inventory cost represents the loss from goods waiting in the airport or warehouse for shipping and is negatively related to the flight frequency. Furthermore, under a given in-transit time and a stationary time, products of high value or with perishable characteristics will result in an increased inventory cost.

Let r and s denote the origin and destination, respectively. Any given OD pair r-s is connected by a set of routes P_{rs} and is served by the carriers for a shipping charge per unit weight, f_{rs}^{x}, with a weekly flight frequency, h_{rs}^{x}, and a shipping time in day, t_{rs}^{x}, where superscript x represents a specific carrier. Stationary time in a day is usually estimated as one half of the reciprocal of the flight frequency assuming flights and shipping demands uniformly distributed over time and can be represented as $7/2h_{rs}^{x}$. Let l represent a specific industry in the market in which the average generalized product value and inventory carrying rate of the products of industry l are denoted as $\overline{\tau}^{l}$ and v^{l}, respectively, and where the inventory carrying rate represents the daily inventory loss for holding the product. The inventory carrying rate is directly related to the characteristics of the product. For time-sensitive products, the inventory loss for carrying the product per unit time is considerable. Agricultural products and electronics can be classified as having a high inventory carrying rate.

We assume that all shippers in the industry are well informed about the services provided by different carriers. The logistics cost of a shipper with shipping volume in weight V in industry l served by carrier x can be expressed as

$$G_{rs}^{x,l} = \left(f_{rs}^{x} + \overline{\tau}^{l} v^{l} t_{rs}^{x} + \frac{7\overline{\tau}^{l} v^{l}}{2h_{rs}^{x}}\right)V \tag{1}$$

In practice, the shipment is carried via either an all-cargo or a belly cargo aircraft. Although the belly cargo aircraft may result in a decreased inventory cost due to its frequent flights, the capacity during a specific period could be limited. On the other hand, the all-cargo aircraft may provide sufficient capacity but less frequency, i.e. an increased stationary time.

Although products of an industry may be valued relatively low or high across the industry, there are an enormous amount of products valued diversely in the same industry. In other words, the value of a product in industry l, τ^{l}, can be viewed as a random variable by considering the industry of interest as a whole. Let $f(\tau^{l})$ represent the probability distribution function (pdf) of τ^{l}. The data details the product values in different industries. The chi-square goodness of fit test is applied to see how well the data follows a specific distribution[1].

The probability of the product value in industry l being equal to τ_{i}^{l} is given by $\Pr\{\tau^{l} = \tau_{i}^{l}\} = p(i)$. The logistics cost of a shipper associated with carrier x and product value τ^{l} on a given OD pair r-s is given by Eq. (1). Accordingly, the probability with which a shipper in industry l chooses object carrier m for carrying products valued as τ_{i}^{l} between OD pair r-s on route p_{rs} can be expressed as follows.

$$\Pr\left\{G_{rsp}^{m,l} \le G_{rsp}^{x,l},\ \forall x \ne m,\ \forall i\right\} = \sum_{\forall i} \Pr\left\{G_{rsp}^{m,l} \le \min_{x \ne m}\left(G_{rsp(i)}^{x,l}\right)\right\} p(i) \tag{2}$$

where $\Pr\{G_{rsp}^{m,l} \le \min_{x \ne m}(G_{rsp(i)}^{x,l})\}$ represents the probability of the minimized logistics cost from object carrier m for a shipper in industry l with the product value as τ_{i}^{l}. The probability in Eq. (2) also represents the percentage of the export from r to s of shippers in industry l being carried by carrier m. The probability of carrier m on route p_{rs} being selected can be derived by summing the probabilities of carrier m being selected by shippers with τ_{i}^{l} valued products in industry l.

If the object carrier provides two or more routes between OD pair r-s, and the logistics cost of the object carrier's route g ($\forall g \ne p$) is denoted as $G_{rsg}^{m,l}$, then the object carrier's route p will be selected if and only if $G_{rsp}^{m,l} \le G_{rsg}^{m,l}$, $\forall g \ne p$, and $G_{rsp}^{m,l} \le G_{rsp}^{x,l}$, $\forall x \ne m$. The market share of the object carrier in industry l on route p between OD pair r-s, $S_{rsp}^{m,l}$ can then be defined as

$$\begin{aligned} S_{rsp}^{m,l} &= \Pr\left\{G_{rsp}^{m,l} \le G_{rsg}^{m,l},\ \forall g \ne p\right\} \cdot \Pr\left\{G_{rsp}^{m,l} \le G_{rsp}^{x,l},\ \forall x \ne m\right\} \\ &= \prod_{\substack{g \\ \forall g \ne p}} \Pr\left\{G_{rsp}^{m,l} \le G_{rsg}^{m,l}\right\} \cdot \left[\sum_{\forall i} \Pr\left\{G_{rsp}^{m,l} \right.\right. \\ &\left.\left. \le \min_{\forall x \ne m} G_{rsp(i)}^{x,l}\right\} p(i)\right] \end{aligned} \tag{3}$$

Let Q_{rs}^{l} denote the cargo volume forecasted in weight from industry l for air freight on OD pair r-s during a specific period. Hsu and Wen (1998) applied the Grey theory to forecast airline passenger traffic. They use an improved GM(1,1) time-series model and showed that the forecasted result from the Grey model is more accurate than those predicted by the regression model or the ARIMA model. Herein, OD pair air cargo flows forecasts are predicted by using Hsu and Wen models. The forecasted cargo volume in weight from industry l carried by the object carrier m on route p between OD pair r-s can then be estimated as $q_{rsp}^{m,l} = Q_{rs}^{l} S_{rsp}^{m,l}$. Furthermore, considering all industries in the market and the

[1] The chi-square test is defined by the following hypothesis: H_0: The data follow the specified distribution. H_1: The data do not follow the specified distribution. For the chi-square goodness of fit, the collected data is divided into k class and the test statistic is defined as follows $\chi^2 = \sum_{i=1}^{k} (f_i - e_i)^2/e_i$ where f_i and e_i represent the observed and expected frequency in class i, respectively. Furthermore, the expected frequency is calculated by $e_i = N(F((Y_u) - F(Y_l)))$, where N is the sample size and Y_u and Y_l are the upper and lower limit for class k, respectively. The hypothesis that the data follows the specified distribution is rejected if $\chi^2 > \chi^2_{(\alpha,c)}$, where $\chi^2_{(\alpha,c)}$ is the chi-square percent point function with c degrees of freedom and a significance level of α. In the present study, the product value in the industry is calibrated based on the gamma distribution.

routes provided by the carrier, the cargo volume carried by the object carrier m between OD pair r-s is $q_{rs}^{m} = \sum_{\forall l}\sum_{\forall p} q_{rsp}^{m,l}$.

3. Example

The origin market in the example is taken as Taiwan with the main international airport as Taiwan Taoyuan International Airport. Taiwan's air freight export consists mainly of information and communication products made in Taiwan. According to the statistics released by the Bureau of Foreign Trade (BOFT), the monthly exports from Taiwan to mainland China via Hong Kong in 2007 hit an annual growth of 19.1%, reaching $ 6.45 billion. Taiwan's exports to mainland China are mainly goods related to high-tech industries, such as machinery equipment, optical items and related parts, which together account for $ 3.7 billion or 57.4% of the export value during the month.

For the sake of simplicity, three major market regions were selected from regions served by Taiwan, including Hong Kong, Japan and the US The concept of OD pairs is represented as airport-pair. The three OD pairs are Taipei (TPE) –Hong Kong (HKG), –Narita (NRT) and –Anchorage (ANC). The industries are identified in accordance with the Taiwan Institute of Economic Research (TIER). They are agriculture, food and textile, wood products and pulp & paper, chemicals, machinery and electronics industries.

Table 1 summarizes the data about the percentage of products exported from different industries as well as their value distribution. As seen, products from the electronics industry have the largest export percentage among all industries as well as the highest average product value. Exports of the food and textile, wood and pulp & paper, and the chemical and rubber industry are relatively limited. Although the products of the electronics industry account for the highest export percentage among all industries, the industrial structure of the export is changing from year to year. In addition to changes in the industrial structure, as shown in the table there are also dynamic changes in the average and standard deviation of product value distribution within the industries. The products of the electronics industry show an increased average value.

There are many carriers providing air freight services on all routes. This study selected three main carriers for each of the routes. The market shares of these carriers are the highest among all carries and account for the majority of the markets. The carriers on TPE–HKG are China Airline (CI), Eva Air (BR) and Cathay Pacific (CX), where CI and BR of Taiwan are characterized as carrying the highest and the second highest amount of export volume in Taiwan among all carriers. CI and BR are also identified as the carriers on TPE–TYO and TPE–ANC. In addition to CI and BR, shippers may choose Japan Asia Airways (EG) on TPE–TYO and Northwest Airlines (NW) on TPE–ANC. To comprehensively compare the impact of the services provided by different carriers on shippers' choice behavior, the other carriers, excluding the three main carriers discussed above, are grouped as "other carriers" in the example. Table 2 lists the initial values of the base service parameters of these carriers, respectively.

The export percentages without capacity constraint, i.e. potential market, were obtained by applying Eq. (3), where shipping charge, shipping time, and frequency are treated as input parameters. In addition, this study examined how aircraft size as well as limited capacity on the routes impacted the markets of the carriers. In the study, the capacity constraint represents the maximal volume in weight can be supplied by the carrier. The upper bound of the weekly capacity of the carriers on the route is estimated by flight frequency and the capacity of aircraft type. The export percentages with capacity constraint, i.e. realistic market, were also obtained by Eq. (3) where the values of input parameter are the same with those in model without capacity constraint.

Table 3 shows the initial results as export percentages of products in different industries carried by the carriers on TPE–HKG, –NRT and –ANC from year 2000 to 2003. The results on the routes without capacity constraint in year 2003 are as follows. The major products exported on the routes are those from electronics industries on TPE–HKG and TPE–ANC, and those from agriculture and electronics industries on TPE–NRT, respectively. Any carrier providing the service meeting the customer needs earns the market. For example, TPE–HKG is only a short distance, 932 kilometers, it has less shipping hours compared to those of TPE–ANC and TPE–NRT. Shippers may focus more on the shipping charges and flight frequency than on the shipping time when they choose the optimal carrier. The advantage of frequent flights from BR ensures the shipper of a decreased stationary inventory cost when they choose BR. For industries with a high product value, such as the electronics industry, the savings are apparent. As Table 3 shows, the intentions toward choosing BR are high for shippers in the electronics industry, resulting in a choice probability of 60.8%. In

Table 1
Data about product values and export percentages of industries.

Industry year	Agriculture	Food and textile	Wood, pulp & paper	Chemical and rubber	Machinery	Electronics
2000						
Product value distribution						
Average ($/kg)	33.5	10.8	1.8	0.6	53.4	277.3
Standard deviation ($/kg)	38.5	14.3	1.6	0.4	66.1	796.4
Export percentage (%)	5.7	2.8	0.4	0.2	6.4	84.6
2001						
Product value distribution						
Average ($/kg)	35.1	12.3	1.8	0.6	59.2	327.2
Standard deviation ($/kg)	44.1	19.3	0.4	1.7	71.4	768.2
Export percentage (%)	7.0	2.5	0.4	0.2	8.3	81.7
2002						
Product value distribution						
Average ($/kg)	24.7	9.4	1.9	0.6	67.4	344.9
Standard deviation ($/kg)	24.1	11.9	0.5	1.9	73.3	751.9
Export percentage (%)	7.4	1.4	0.2	0.1	3.3	87.6
2003						
Product value distribution						
Average ($/kg)	23.6	10.1	2.6	2.2	70.1	514.2
Standard deviation ($/kg)	32.5	15.1	4.4	3.8	85.2	1146.6
Export percentage (%)	6.2	0.8	0.2	0.1	2.2	90.6

Table 2
The initial values of base service parameters of carriers.

Carrier	Shipping charge per unit weight ($/kg)	Shipping time (Hour)	Frequency (Flights/week)	Aircraft type
TPE-HKG				
CI	0.7664	1.75	6	B747-400F
BR	0.7668	1.83	8	B747-400F MD–11F
CX	0.7716	2	7	B747
Others	0.7948	2	6	B747
TPE-–NRT				
CI	0.7763	2.75	2	B747-400F
BR	0.7676	2.33	3	B747-400F MD-11F
EG	0.7965	3	5	B747
Others	0.8025	3	6	B747
TPE–ANC				
CI	1.4376	8.5	37	B747-400F
BR	1.4414	8.66	43	B747-400F MD-11F
NW	1.4183	8.5	6	B747
Others	1.4329	8.5	8	B747

Source: China Airline, 2000–2004; Cathay Pacific, 2000–2004; Eva Air, 2000–2004; Japan Airline, 2000–2004; and Northwest Airline, 2000–2004.

addition, due to the disadvantages of an increased shipping charges and infrequent flights, CX and other carriers cannot survive well on this route.

As shown in Table 3, the other carriers accounted for the majority of the market on TPE–NRT, i.e. 58.8% of the export, while there was no market for CI due to its disadvantage of increased shipping time and infrequent flight. Of the 58.8%, 32.9% and 25.9% were products from the electronics and the agriculture industries, respectively, and account for almost all that was shipped by those carriers. On the other hand, TPE–ANC is characterized as the most distant route of all routes, and the inventory cost resulting from the long shipping hours is apparent. As shown in Table 3, CI attracts the majority of shippers on this route, amounting to 75.4% of the export volume due to its relatively fast shipping time combined with frequent flights. Of the 75.4%, 73.1% are electronics products. NW also carries the remaining 24.5% of products on this route. As shown in Table 2, NW is characterized as having the lowest shipping charge among all. Although their flights are infrequent, shippers with low-value products, i.e. those in food, wood and pulp & paper and chemical industries, are more likely to choose NW. However, since products of the electronics industry account for the majority of the export on this route, the increased export of products in food, wood and pulp & paper and chemical industries, which account for a relatively small share, cannot improve the market share of NW.

Table 3
The export percentages of industries carried on the routes.

	Agriculture			Food and textile			Wood, pulp & paper			Chemical and rubber			Machinery			Electronics			Total		
Route (TPE—)	HKG	NRT	ANC	HKG	NRT	ANC	HKG	NRT	ANC	HKG	NRT	ANC	HKG	NRT	ANC	HKG	NRT	ANC	HKG	NRT	ANC
Without capacity constraint Year 2003																					
CI	0.0	–	0.0	0.1	–	0.0	0.3	–	0.0	0.1	–	0.0	0.9	–	1.5	25.2	–	73.1	26.5	–	75.4
BR	0.6	8.7	–	0.5	0.0	–	0.2	0.0	–	0.0	0.0	–	11.3	0.2	–	60.8	19.9	–	73.5	28.8	–
CX	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
EG	–	3.6	–	–	0.0	–	–	0.0	–	–	0.0	–	–	1.0	–	–	7.8	–	–	12.4	–
NW	–	–	0.0	–	–	0.0	–	–	0.0	–	–	0.0	–	–	0.2	–	–	23.9	–	–	24.5
Others	–	25.9	–	–	0.0	–	–	–	–	–	0.0	–	–	–	–	–	32.9	–	–	58.8	–
With capacity constraint Year 2000																					
Total	3.0	33.3	5.2	6.7	0.5	0.6	2.5	0.1	0.0	0.3	0.2	0.1	9.7	4.8	4.0	77.9	61.2	94.7	100	100	100
CI	1.1	4.5	1.8	2.3	0.1	0.2	0.9	0.0	0.0	0.1	0.0	0.0	3.3	0.6	1.3	28.0	11.0	30.5	35.7	16.2	33.8
BR	0.7	5.2	2.8	1.7	0.1	0.3	0.5	0.0	0.0	0.1	0.0	0.0	2.0	0.9	1.8	18.4	7.5	39.2	23.4	13.7	44.0
CX	0.7	–	–	1.4	–	–	0.6	–	–	0.1	–	–	2.4	–	–	17.0	–	–	22.2	–	–
EG	–	3.9	–	–	0.2	–	–	0.0	–	–	0.1	–	–	1.9	–	–	27.7	–	–	33.7	–
NW	–	–	0.4	–	–	0.1	–	–	0.0	–	–	0.0	–	–	0.4	–	–	6.4	–	–	7.2
Others	0.6	19.6	0.2	1.3	0.2	0.1	0.5	0.0	0.0	0.1	0.1	0.0	2.0	1.4	0.6	14.5	15.1	14.0	18.8	36.4	14.8
Year 2001																					
Total	2.2	37.6	0.9	5.7	0.2	0.6	1.6	0.0	0.1	0.2	0.1	0.1	13.0	5.6	6.3	77.3	56.5	91.7	100	100	100
CI	0.7	5.0	0.3	1.8	0.0	0.2	0.5	0.0	0.0	0.1	0.0	0.0	3.1	0.8	2.3	24.8	7.5	34.1	31.0	13.3	36.9
BR	0.6	6.4	0.5	1.4	0.0	0.3	0.4	0.0	0.1	0.1	0.0	0.0	4.4	0.9	2.6	18.7	9.8	38.2	25.6	17.1	41.6
CX	0.5	–	–	1.4	–	–	0.4	–	–	0.1	–	–	2.8	–	–	18.8	–	–	22.2	–	–
EG	–	4.3	–	–	0.1	–	–	0.0	–	–	0.0	–	–	2.0	–	–	15.8	–	–	22.2	–
NW	–	–	0.1	–	–	0.1	–	–	0.0	–	–	0.0	–	–	0.5	–	–	8.6	–	–	9.2
Others	0.4	21.9	0.0	1.0	0.1	0.1	0.3	0.0	0.0	0.0	0.0	0.0	2.7	2.0	0.9	15.0	23.5	10.9	19.6	47.5	11.9
Year 2002																					
Total	1.0	42.1	0.9	2.2	0.1	0.3	0.8	0.0	0.0	0.2	0.0	0.1	5.0	2.0	2.4	90.9	55.9	96.1	100	100	100
CI	0.3	5.6	0.3	0.7	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	1.4	0.3	0.4	24.7	7.4	32.8	27.3	13.3	33.7
BR	0.3	6.6	0.4	0.6	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.0	1.3	0.3	0.9	26.1	10.0	42.0	28.5	16.9	43.5
CX	0.2	–	–	0.5	–	–	0.2	–	–	0.0	–	–	1.3	–	–	22.6	–	–	24.8	–	–
EG	–	14.8	–	–	0.0	–	–	0.0	–	–	0.0	–	–	0.7	–	–	20.8	–	–	36.4	–
NW	–	–	0.1	–	–	0.0	–	–	0.0	–	–	0.0	–	–	0.2	–	–	8.4	–	–	8.7
Others	0.2	15.1	0.1	0.4	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	1.0	0.7	0.8	17.6	17.6	14.0	19.4	33.5	14.0
Year 2003																					
Total	0.6	38.3	0.0	0.6	0.0	0.0	0.5	0.0	0.0	0.1	0.0	0.0	3.0	1.1	1.7	95.1	60.6	97.0	100	100	100
CI	0.2	4.6	0.0	0.2	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.7	0.2	0.6	26.1	8.7	33.7	27.3	13.5	34.7
BR	0.2	7.3	0.0	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	1.0	0.2	0.8	28.6	11.2	39.4	30.1	18.7	40.7
CX	0.2	–	–	0.1	–	–	0.1	–	–	0.0	–	–	0.7	–	–	22.0	–	–	23.1	–	–
EG	–	12.6	–	–	0.0	–	–	0.0	–	–	0.0	–	–	0.4	–	–	19.3	–	–	32.3	–
NW	–	–	0.0	–	–	0.0	–	–	0.0	–	–	0.0	–	–	0.2	–	–	10.4	–	–	10.7
Others	0.1	13.7	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.6	0.4	0.2	18.5	21.4	13.5	19.5	35.6	13.9

The results without and with the capacity constraints are also shown in Table 3 to further explore and compare the potential and realistic markets for the carriers in year 2003. In reality, the capacity of an international carrier is somewhat constrained because of bilateral agreement restrictions, limited flight frequency and available aircraft type in light of a carrier's fleet constraint. This may restrict the market potential of the carrier. As shown in Table 3, when the capacity constraint is considered, the market share distribution changes. The market share of BR on TPE–HKG declined markedly from 73.5 to 23.4% when its capacity was constrained. Although BR attracted shippers with its frequent flights and its decreased shipping charge, their limited capacity prevented the carrier from reaching its potentially high market share. To gain this high market share and satisfy potential shippers, this study suggests that BR employs only aircraft types with a large capacity, such as B747–400F instead of MD–11F. Although there may be an increased stationary time for consolidating shipments for large aircraft, the short haul distance of TPE–HKG, high demand, frequent flights and the low shipping charge of BR can offset the negative effects of the increased stationary inventory loss. BR's shipping capacity on TPE–NRT is also restricted by a bilateral agreement, and is also limited due to the fact that they share their quota with CI. The market for BR was significantly decreased compared to that without a capacity constraint, 18.7% versus 28.8% in 2003. On the contrary, EG gained a larger share of the market due to its higher flight frequency and due to the fact that they have less restriction regarding the bilateral agreement, as shown in Table 3.

In addition to the service attributes, the market share of the air freight carriers are also affected by a changing market structure as indicated by the industrial structure in this study. This includes the product value distribution and the export shares of various industries, and results in a dynamic market share of carriers. The results of the percentage of export carried by the carriers between year 2000 to 2003, when the capacity was constrained, are also shown in Table 3 and illustrated as follows. As shown in Table 3, CI and BR carried the largest volume of export from Taiwan to Hong Kong. The reason for this can be explained as follows. There is a continuous outward flow of Taiwan's industries, including electronic equipment and machinery industries, to mainland China. Taiwan's trade with mainland China must be carried out indirectly via a third party, Hong Kong. As a result there is a lot of export volume to Hong Kong from Taiwan doing trade with mainland China. Because they offer the lowest shipping charge and the shortest shipping hours, CI and BR have a high shipping demand from the electronics and machinery industries, and so they have a high market share on this route.

As shown in Table 3, the market shares of BR and CX on TPE–HKG increased while those of CI and other carriers decreased in 2002. Table 1 shows that in 2002 there was a larger volume of more valuable electronic products exported from Taiwan to Hong Kong compared to 2001. Therefore, the frequent flight services of BR and CX attracted more shippers with urgent and valuable freight. The major products exported from Taiwan to Japan are those from the agricultural and electronics industries, and are characterized as having a high inventory carrying rate. CI achieved the least market share on this route due to its low flight frequency and high shipping charges. As the export volume of the agriculture industry increased, the market share of CI dropped significantly. On the other hand, EG and other carriers serve shippers with more frequent flights, which resulted in lower logistics costs for shippers through a reduced inventory loss. Consequently, EG and other carriers attracted most of the shippers in the agricultural and electronics industries, resulting in high market shares on this route.

Since products in the electronics industry account for the majority of the export on TPE–ANC, shippers in this industry as well as their choices are key influences on the market share of the carriers. Shippers in the electronics industry emphasize more on fast delivery rather than shipping charge, so they tend to choose carriers with more frequent flights, i.e. BR and CI. As a result, BR and CI are featured as the top two carriers on this route, i.e. 40.7% and 34.7% of the export in year 2003, respectively. Although shippers have to pay a relatively high shipping charge to BR, such as $ 1.42 per kg, the advantage of a reduced inventory cost offsets the disadvantage of the increased transportation cost. NW and other carriers mainly attract shippers with low-value products, such as those in food and wood products industries, by offering the lowest shipping charge among all carriers. However, their small share of the export volume from the food and wood products industries cannot improve the market share of NW and other carriers.

As shown in Table 3, the results of the export percentages carried by the carriers are different depending on whether capacity constraints are considered. BR, other carriers and CI have the larger market shares on routes TPE–HKG, TPE–NRT and TPE–ANC, respectively, when the capacity is sufficient. However, the market shares of these above carriers decrease significantly when the capacity is constrained. Due to the small capacity of aircraft employed on these routes, the shippers have to deal with an excessive amount of waiting time for a flight, resulting in an increased logistics cost. Table 4 shows the differences of the average logistics cost per kg on the routes when capacity constraint is considered and when it is not.

As shown in Table 4, the shippers in these industries can gain benefits in terms of cost saving if there is sufficient capacity. These cost savings differ between routes, such as $ 0.66 and 0.05 per kg on route TPE–HKG and route TPE–NRT, respectively. The magnitude of benefits on these routes depends on the composition of the shippers in the industries, their product value distribution as well as their export volumes. Most of the export on route TPE–HKG is products from the mechanical and the electronics industries, which are high-value products. The choice of the shippers in these industries is focused on one or two carriers. Therefore, the limited capacity of these carriers causes the shippers a lot of stationary inventory cost due to the extra waiting time for flights as well as insufficient capacity because of the too small type of aircraft. Conversely, the cost savings would be apparent if the demand was satisfied and the carriers employed aircraft with a larger capacity in case there is no capacity constraint. On the other hand, the benefit that can be gained by the shippers on route TPE–NRT is smaller than on any other route because the demand for export on this route is not high and the choice of optimal carrier is not substantially affected by the capacity constraint.

The export demand from various industries towards the carriers can be estimated by the market shares of the carriers and the

Table 4
The average logistics cost savings between models without and with a capacity constraint ($/k).

	Agriculture	Food and textile	Wood, pulp & paper	Chemical and rubber	Machinery	Electronics	Total
TPE-HKG	0.03418	0.02643	0.0069	0.00792	0.0919	0.4894	0.6567
TPE-NRT	0.00249	0.0111	0.0196	0.01766	0	0	0.0508
TPE-ANC	0.0044	0.0097	0.0155	0.0124	0.0713	0.0149	0.1282

Table 5
Estimated export volume carried by the carrier (10^3 kg).

Route	Carriers	Year						Difference value
		2000	2001	2002	2003	2004 (Estimated)	2004 (Actual)	
TPE-HKG	CI	16868	19226	26579	32572	42066	15581	170.0%
	BR	15167	17044	27714	35627	50164	15299	227.9%
TPE-NRT	CI	10852	11723	11359	11282	12012	13413	−10.4%
	BR	13943	12581	13792	14314	15368	10997	39.7%
TPE-ANC	CI	61309	43310	45175	50508	54074	53722	0.7%
	BR	81994	58346	61810	59205	60636	35521	70.7%

Table 6
Comparison results of the carriers between the proposed, the Grey models and the actual data (10^3 kg).

Route	Carriers	Forecasted results		Actual data	Difference value	
		Developed model	Grey model		Developed model	Grey model
TPE-HKG	CI	42066	41548	15581	170.0%	166.7%
	BR	50164	28126	15299	227.9%	83.8%
TPE-NRT	CI	12012	16422	13413	−10.4%	22.4%
	BR	15368	16787	10997	39.7%	52.6%
TPE-ANC	CI	54074	38114	53722	0.7%	−29.1%
	BR	60636	55534	35521	70.7%	56.3%

export volumes of the industries. Table 5 shows the estimated export volume carried by CI and BR from 2000 to 2004, in which the actual data of the export volume carried by CI and BR in 2004 is also presented.

As shown in Table 5, the estimated export volume carried by CI on TPE–HKG shows an increasing trend, while that of TPE–NRT remains steady. CI experienced a decreased demand on TPE–ANC in 2001 and 2002 due to the export volume from Taiwan to the US being negatively affected by the events of 9/11. As the economic conditions and air freight transportation returned to normal, CI's export volume showed a recovery from the recession as shown in Table 5. Furthermore, the average differences between the estimated export volume from the proposed model and the actual data on TPE–NTR and on TPE–ANC carried by CI in 2004 are 10.4% and 0.7%, respectively. As shown in Table 5, the different values on the above routes carried by BR are 39.7 and 70.7%, respectively. However, the difference between the estimated and the actual export volume on TPE–HKG carried by CI and BR is considerable and is up to 170.0 and 227.9%, respectively. The reason for this is that due to the increased shift of Taiwan's business to mainland China, there is a sharp increase of export volume in weight from 2000 to 2003, i.e. 38.3% average annual growth rate in 2002. This rapidly increasing trend has led to an enormous export volume compared to the actual data.

To further investigate the accuracy of the proposed model, the export volumes of CI on the routes were forecasted directly via the grey forecasting model. The Grey forecasting model was employed since in the literature the model has been shown to be more accurate than traditional models (Hsu and Wen, 1998). Table 6 summarizes the results of the comparison between the proposed model, the Grey model and the actual data.

As shown in Table 6, the differences in the results between the proposed model and the actual data as well as the difference between the Grey model and the actual data on TPE–HKG are both high. The dynamic and rapidly expanding export from Taiwan to mainland China makes the forecasted results inaccurate for both models. On the other hand, there are contrasting results from the two models for TPE–ANC. The difference in value between the result from the Grey model and the actual data on TPE–ANC is quite high, i.e. 29.1%, much higher than the 0.7% difference of the proposed model. Although the US experienced the 9/11 events in 2001, their economy recovered soon. Because the Grey model, which is based on past trends, might be unable to capture the quick economic recovery, the export volume on the route is underestimated. Moreover, the difference in value between the actual data and the estimated result from the Grey model on TPE–NRT also shows a much larger error than that from the proposed model, indicating that the proposed model is more accurate. In sum, because the dynamic changes in industrial structural and product value were captured, the forecasted results from the proposed model are more accurate than those from the Grey model. The export volumes to be carried by CI from 2005 to 2010 are forecasted by the proposed model and presented in Table 7.

Table 7
Forecasted export volume carried by CI from year 2005 to 2010 (10^3 kg).

Route	Year						Average growth rate
	2005	2006	2007	2008	2009	2010	
TPE-HKG	45266	51949	5956	68346	78357	89812	14.7%
TPE-NRT	11796	11878	11961	12044	12128	12212	0.6%
TPE-ANC	58455	63182	68285	73793	79740	86159	8.0%
				Total average growth rate			7.8%

As shown in Table 7, Taiwan's export to Hong Kong and Mainland China is growing substantially with an average annual growth rate that is projected to reach about 15% between 2005 and 2010 in light of the double digit growth rate of China's GDP and the closer trade and industrial relationship between Taiwan and China. Taiwan's export to the U.S is experiencing a steady growth rate of 8%. The export to Japan is estimated to increase by merely 0.8% due to the slow economic growth in Japan and the relatively low market share of CI.

4. Conclusions

This study forecasts the route market for the air cargo carriers by taking into consideration the economic trade between countries and the evolution of the industrial structures. Rather than spending a considerable amount of time and money for collecting data as is common in the forecast methods found in the literature, this study developed an analytical model of the choices of an air cargo carrier shipper for estimating carrier route market shares using the existing database.

A case study on Taiwan Taoyuan International Airport found that for TPE–HKG limited capacity hinders BR from taking a large share of export volume. Larger capacity type aircraft are suggested for this route. Although there may be an increased stationary time for consolidating the shipments for a large aircraft, the short route distance of TPE–HKG, the strong demand, the frequent flights and the low shipping charge of BR can offset the negative effects brought by the increased stationary inventory loss.

The results show that CI and BR carried an increasing volume of export from Taiwan to Hong Kong because of increased trade with China via the latter. The major exports from Taiwan to Japan are in agricultural and electronics industries. There are, however, differences between the outputs of our model and the actual data as well as between the results of the Grey model and actual traffic on TPE–HKG partly because of rapidly expanding exports to mainland. The Grey model's underestimation of exports may be because it does not captured the quick recovery in traffic after September 11 2001.

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