Optimal demand for operating lease of aircraft

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Abstract

Operating lease of the aircraft gives the airlines flexibility in capacity management. However, airlines pay a risk premium to the leasing companies for bearing part of the risks. Therefore, the airlines face a trade-off between flexibility of capacity and higher costs. This paper develops a model for the airlines to determine their optimal mix of leased and owned capacity, taking into consideration that the demand for air transportation is uncertain and cyclical. Empirical results based on the model suggested that the optimal demand by 23 major airlines in the world would range between 40% and 60% of their total fleet, for the reasonable range of premiums of operating lease. For the leasing companies, this indicates huge potential of the market given strong forecast for the growth of air transportation in the next decade. © 1999 Elsevier Science Ltd. All rights reserved.

1. Introduction

Lease of aircraft has become an increasingly important tool for the airline industry. According to recent estimates, approximately one-half of the world’s aircraft fleet is operating under some kind of lease. Within the lease option, there is an increasing trend in favour of short-term operating lease. For example, Gritta et al. (1994) reported that, for a sample of major US carriers, percentage of planes leased increased from 19% in 1969 to 54% in 1991 and the percentage of aircraft under operating leases to total leased aircraft increased from 13% in 1969 to 82% in 1991.

The benefits of lease were traditionally viewed as financial. Gritta et al. (1994) examined the role of lease as sources of off-balance-sheet financing. As operating lease is not capitalized, air carriers can substantially lower their debt/equity ratio on their balance sheet if they finance their
aircraft fleet by leasing rather than by traditional debt. Another well-known financial benefit is that leasing separates the ownership of an aircraft from the aircraft's user. Therefore, it is the lenders (lessors) who own the aircraft while the airlines (lessees) operate the aircraft. This separation of ownership enables valuable depreciation allowances to be used more effectively by the lessors for tax purposes. Indeed, in certain international leasing arrangements, when the lessors and the airlines belong to different tax regimes, it was reported that depreciation allowances were claimed by both parties in the leasing contract, a practice commonly referred to as “double dip”.

It may be argued that the effects of off-balance-sheet financing is largely cosmetic because financial analysts would not be fooled when it is publicly known that an airline has taken up a substantial lease obligation. Indeed, Marston and Harris (1988) demonstrated, using a large sample of US firms, that lease and debt are substitutes as it would under efficient financial markets. Results from a survey study by Bayliss and Diltz (1986) also showed that bank loan officers reduce their willingness to lend when a firm takes up lease obligations. Therefore, lease as source of off-balance-sheet financing does not appear to be able to significantly increase firms' debt capacity. Furthermore, with increasingly stringent accounting and tax rules, the tax effects of lease are also limited. Now, the major attractions of operating lease of aircraft are viewed as more operational than financial in nature. First, while the aircraft manufacturers currently have substantial order backlogs, major aircraft leasing companies have inventories for immediate delivery. Hence, airlines desiring a quick expansion need not wait for the production backlogs. Second, short-term operating lease provides the flexibility to the airlines so that they can manage fleet size and composition as closely as possible, expanding and contracting to match demand.

While significant use of operating lease affords the airlines the flexibility to change aircraft fleet size as demand for air transport changes, it created a burden to the leasing companies to maintain efficient utilization of their inventory of aircraft. In a recession, when demand for aircraft is low, the leasing companies will also suffer from excess capacity. Indeed, the last recession was devastating to dozens of leasing companies when demand and aircraft values dropped. In essence, through the flexibility of operating leases, the airlines shifted part of their business risks to the leasing companies. However, although short-term operating lease reduces the risks of excess capacity for the airlines, it does not eliminate uncertainties in the financial costs. During recession, when costs of short-term leasing are low, airlines have little incentive to expand their fleet. On the other hand, during the booming period, when the airlines need the capacity most, the costs of leasing will also be highest. Thus the operating lease provides a vehicle which enables the airlines and the leasing companies to share the risks of uncertain demand. For the airline industry which faces a cyclical demand, this risk-sharing aspect of operating lease is highly desirable.

Needless to say, the aircraft leasing companies are in the business for profits. They purchase aircrafts from the manufacturers by means of long-term financing, and then lease the aircraft to the airlines. For short-term operating lease, it would take at least two or more lease transactions on an aircraft for the leasing companies to recover the costs. Therefore, the expected revenues from operating lease must not only cover the long-term financing costs of the aircraft, but also provide the leasing company with a profit (premium) adequate to compensate for the risks involved with aircraft release and residual value.

To the airlines, optimal use of operating lease then presents the problem of a trade-off between operational flexibility and higher financial costs inherent in the short-term lease. The historical trend has been an ever-increasing use of operating lease, in tandem with the development of an
active aircraft leasing market. Now, with the market becoming mature, whether airlines should continue to increase reliance on operating leases has become a strategic question to the fleet management of the airlines.

This paper examines the lease/own decision from the airlines’ standpoint. However, the results will also be valuable to the leasing companies because the airlines’ decisions on the aircraft lease directly affect the profitability of the leasing companies. In Section 2, we derive optimality conditions, relating owned capacity, leased capacity, expected traffic demand to premiums of operating lease. In Section 3, we examine empirically the world’s major airlines’ optimal demand for operating lease of the aircraft. Section 4 concludes.

2. Model

Consider an airline. The airline faces an uncertain demand \( y = y(\tau) \), where \( \tau \) represents the future state of nature. The capacity of the airline is \( Z = K + S \), where \( K \) is the capital stock owned or leased for the long term, \( S \) is the capital stock leased for the short term. \( K \) is inflexible in the sense that once acquired, it cannot be easily disposed of, whereas \( S \) is flexible in the sense that it can be obtained any time as needed. For simplicity, we will call long-term leasing as capital leasing and short-term leasing as operating leasing. ¹

The airline’s profits can be expressed as

\[
\pi = R[y(\tau), Z] - V[y(\tau), Z] - w_k K - w_s(\tau) S,
\]

where \( R \) is the revenue, \( V \) the variable cost, \( w_k \) and \( w_s \) the costs of long-term capital and short-term capital, respectively. Note that \( w_k \) is known at the beginning while \( w_s \) depends on the future uncertain state. The airline's capacity decision is made in two stages. In the first stage, the airline acquires the long-term capital through either purchasing or capital leasing. Then, in the second stage, after the state of nature is revealed, the airline acquires additional capacity, if necessary, through operating leasing.

In the first stage, the airline determines \( K \) to maximize its expected profits, i.e.,

\[
\max_k \mathbb{E} \{ R[y, Z] - V[y, Z] - w_k K - w_s S \} = \max_k \int [R(y, Z) - V(y, Z) - w_k K - w_s S] f(\tau) d\tau.
\]

(1)

where \( K \) and \( S \) are nonnegative. Then, in the second stage, when \( K \) is fixed and the uncertain state, \( J \), is revealed, the airline chooses the amount of operating lease, \( S \), to maximize profits conditional on \( K \) and \( J \). We assume that the following second order condition is satisfied over all the states:

\[
\frac{\partial^2 R}{\partial Z^2} - \frac{\partial^2 V}{\partial Z^2} < 0.
\]

(2)

¹ By textbook definition, if the term of a lease covers a major portion (e.g. 75%) of the economic life of the equipment under the lease, the lease is a capital lease; anything shorter is an operating lease. However, in the aircraft leasing market, although the economic lives of aircraft may be as long as 20–30 years, typical operating leases are short-term (e.g. 5 years or under). In this paper, we focus on short-term leases only.
This condition states that the marginal effects of capacity on revenue and variable costs are diminishing as capacity increases.

In the second stage, given the capacity $K$ and the state $J$, the airline’s problem is

$$\max_{S} R(y, Z) - V(y, Z) - w_{K}K - w_{s}S.$$ 

Let

$$T_{1} = \left\{ \tau \left| \left[ \frac{\partial R}{\partial Z} - \frac{\partial V}{\partial Z} - w_{s} \right]_{S=0} \geq 0 \right. \right\},$$

$$T_{2} = \left\{ \tau \left| \left[ \frac{\partial R}{\partial Z} - \frac{\partial V}{\partial Z} - w_{s} \right]_{S=0} < 0 \right. \right\}.$$ 

Then, the optimal solution $S^{*}$ is zero, if $\tau \in T_{2}$.

If $\tau \in T_{1}$, the optimal solution $S^{*}$ is implicitly determined by the following first order condition:

$$\frac{\partial R}{\partial Z} - \frac{\partial V}{\partial Z} - w_{s} = 0. \quad (4)$$

Differentiating the above equation with respect to $K$ gives:

$$\left( \frac{\partial^{2} R}{\partial Z^{2}} - \frac{\partial^{2} V}{\partial Z^{2}} \right) \left( 1 + \frac{\partial S^{*}}{\partial K} \right) = 0.$$ 

Thus, in sum, we have

$$\frac{\partial S^{*}}{\partial K} = \begin{cases} -1, & \tau \in T_{1}, \\ 0, & \tau \in T_{2}. \end{cases}$$

In the first stage, the first order condition to determine $K$ is

$$\int \left[ \left( \frac{\partial R}{\partial Z} - \frac{\partial V}{\partial Z} \right) \left( 1 + \frac{\partial S^{*}}{\partial K} \right) - w_{K} - w_{s} \frac{\partial S^{*}}{\partial K} \right] f(\tau) \ d\tau = 0. \quad (5)$$

Substituting and rearranging gives:

$$\int_{T_{1}} (w_{s} - w_{K}) f(\tau) d\tau + \int_{T_{2}} \left( \frac{\partial R}{\partial Z} - \frac{\partial V}{\partial Z} - w_{K} \right) f(\tau) d\tau = 0,$$

or,

$$\int (w_{s} - w_{K}) f(\tau) d\tau = - \int_{T_{2}} \left( \frac{\partial R}{\partial Z} - \frac{\partial V}{\partial Z} - w_{s} \right) f(\tau) d\tau. \quad (6)$$

From Eq. (3), the right-hand side of Eq. (6) is positive. Hence,

$$\int (w_{s} - w_{K}) f(\tau) d\tau = E(w_{s}) - w_{K} > 0.$$ 

This inequality has an intuitive interpretation. From the standpoint of the leasing companies (lessors) which own capital stock and then lease to airlines, short-term operating lease is riskier than long-term capital lease due to uncertainties in the future terms of lease. Therefore, the above
inequality shows that leasing companies should expect to earn a positive risk premium on operating lease.

Overall, Eq. (6) shows the trade-off between owning and leasing capacity from the standpoint of the airline. On the one hand, a marginal increase of owned capacity reduces expected capital cost; on the other, since owned capacity cannot be disposed of when demand is low, a marginal increase of owned capacity increases the expected costs of excess capacity. The optimal mix of owned and leased capacity then constitutes a balance between these two costs.

3. An empirical examination

The optimality condition (6) determines the airlines’ optimal mix of owned and leased capacity, thereby the condition can be used to forecast airlines’ demand for operating lease of the aircraft. Needless to say, the ability to forecast such demand is highly valuable to the leasing companies as well.

In this section, we illustrate the use of condition (6) by considering the optimal demand for leased capacity from twenty three of the world’s major airlines.

3.1. Methodology

We start with estimating a variable cost function for the airlines. The cost function may be written as follows:

\[ V = V(Y, W, Z, D), \]

where \( Y \) is output, \( W \) the vector of the prices of variable inputs, \( Z \) total capacity and \( D \) a vector of operating characteristics. Based on the estimated cost function, we take the expectation of the right-hand side of Eq. (6) conditional on \( Z \) to obtain

\[ G(Z) = -E \left\{ \frac{\partial R}{\partial Z} - \frac{\partial V}{\partial Z} - w_s | \tau \in T_2 \right\}. \] (7)

For given expected premiums on operating lease, \( E(w_s) - w_k \), the optimal owned capacity for each airline, \( K^* \), can be solved by equating \( G(Z) \) with \( E(w_s) - w_k \). Then, comparing \( K^* \) with the total capacity gives the optimal demand for leased capacity.

For empirical specification, we use the conventional translog functional form for the variable cost function, namely,

\[
\ln V = a_0 + \sum a_i G_i + \sum a_T T_i + \sum a_{D_i} \ln D_i + a_Y \ln Y + a_Z \ln Z \\
+ \sum b_{Yi} \ln Y \ln W_i + 0.5b_Y \ln Y \ln Y + 0.5b_Z \ln Z \ln Z + 0.5 \sum b_{ij} \ln W_i \ln W_j \\
+ \sum b_{Yi} \ln Y \ln W_i + \sum b_{Zi} \ln Z \ln W_i + 0.5 \sum c_{ij} \ln D_i \ln D_j \\
+ \sum c_Y \ln Y \ln D_i + \sum c_Z \ln Z \ln D_i + \sum e_{ij} \ln W_i \ln D_j,
\] (8)

where the vector of operating characteristics \( D_i \) consists of load factor and the average stage length, \( T_i \) is the time dummy capturing effects of technical change and \( G_i \) the regional dummy differentiating airlines headquartered in different continents (North America, Europe, and Asia.
and Oceania). There are three variable inputs: labour, fuel and materials. As standard practice, two of the three variable cost share equations are estimated jointly with Eq. (8).

Taking into account the flexibility of the short-term capacity expansion afforded by operating lease, Eqs. (3) and (5) give the following optimality condition for the total capacity of an airline:

\[ \frac{\partial R}{\partial Z} - \frac{\partial V}{\partial Z} - w_s \leq 0 \]  

where inequality holds if capacity is rigid and excessive. Rewrite Eq. (9) as

\[ w_s \geq \frac{R}{Z} \frac{\partial \ln R}{\partial \ln Z} - \frac{V}{Z} \frac{\partial \ln V}{\partial \ln Z} \]

or

\[ w_s \frac{Z}{V} = \frac{R}{V} \eta - \frac{\partial \ln V}{\partial \ln Z} + u, \]  

where \( \eta \) is the elasticity of revenue with respect to capacity and \( u \) a nonnegative error. Note that \( \eta \) is related to the elasticity of travel demand with respect to airline’s scheduled frequency (see, for example, Morrison and Winston, 1986; Oum et al., 1995, for further discussion). Since \( u \) is caused by rigid capacity which cannot be adjusted downward in short-run, we assume

\[ u = e_1 \text{rig} + e_2 \text{rig}^2, \]

where rig is the share of owned capacity out of total capacity (owned plus leased) which reflects the rigidity of the capacity. \( e_1 \) and \( e_2 \) are coefficients to be estimated.

Following standard procedure, all variables in the cost function except the dummies are normalized at the respective sample means. Eqs. (8) and (10) and two of the three variable cost share equations are then jointly estimated by a maximum likelihood method after standard normal disturbance terms are appended to each of the equations. The parameters of the cost function are then used to forecast the optimal demand for operating lease by the airlines.

3.2. Data

Our data sample consists of annual observations on 23 major international airlines over the 1986–93 period. \(^2\) The airlines in our sample are chosen mainly on the basis of availability of consistent time-series data. The data is compiled mainly from the Digest of Statistics series published by the International Civil Aviation Organization (ICAO). Some additional data are obtained directly from the airline companies. The annual reports of carriers were used to supplement, cross-check with and correct errors in the ICAO (various years) data. We contacted the airline companies for clarification when the two sources of data could not be reconciled.

\(^2\) For Cathay Pacific and ANA we were able to compile the data only from 1988, and for KLM and Swissair, only to 1992.
The estimation of the variable cost function requires detailed data on outputs, input prices and operating characteristics. Five categories of output data are collected from ICAO’s annual publication series, Commercial Traffic and Financial Data: scheduled passenger service, scheduled freight service, mail service, non-scheduled passenger and freight services, and incidental services. A multilateral output index is formed by aggregating the five categories of outputs using the multilateral index procedure proposed by Caves et al. (1982).

Five categories of inputs are considered: labour, fuel, material, flight equipment, and ground property and equipment. The price of labour input is measured by the average compensation (including benefits) per employee. Both the total labour compensation and the number of employees are collected from ICAO’s annual series, Fleet and Personnel, and supplemented by data obtained directly from airline companies and from their annual reports. It was not possible to compute average hourly compensation per employee because labour hour data were not available for many of the airlines in our sample. Total fuel cost is obtained from ICAO’s annual series, Financial Data, and fuel price is obtained by dividing total fuel cost by gallons of fuel consumed.

For flight equipment, a fleet quantity index is constructed by aggregating 14 types of aircrafts using the multilateral index procedure. The number of aircrafts by type is collected from ICAO’s annual series, Fleet and Personnel. The leasing price series for these aircraft types were kindly supplied to us by Avmark, Inc. and are used as the weights in the aggregation. The stock of ground properties and equipment (GPE) is estimated using the perpetual inventory method. Data on the 1986 benchmark capital stock and the net investment series are compiled from ICAO’s annual series, Financial Data. The annual cost of the GPE input is computed by multiplying the GPE service price to the GPE stock. The GPE service price is constructed using the method proposed by Christensen and Jorgenson (1969) which reflects the interest rate, depreciation and effects of taxes.

The last category of input is materials. The materials input is the residual input which is not included in any of the input categories discussed above. As such, materials cost is the catch-all cost. We compute materials cost by subtracting the labour, fuel and capital related costs from the total operating costs. The price index for the materials input is constructed using the US GDP deflator and the intercountry purchasing power parity index for GDP from the Penn World Table (Summers and Heston, 1991). The purchasing power parity indices for GDP and GDP deflators together reflect a country’s general price level, and are appropriate to be used as a proxy for materials price since the materials costs include numerous items. Since the GPE costs are small relative to other categories of costs, GPE costs are further aggregated into the materials costs.

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3 Note that ICAO reports traffic data by the calendar year while reporting the financial data by the carrier’s fiscal year. In the cases where fiscal year does not fall on calendar year, monthly data are used to construct the traffic data consistent with the fiscal year.

4 Although the ICAO Financial Data reports fuel expense data, it does not report fuel price or quantity. Many airlines have provided the data on quantity series of fuel consumption upon our request. Fuel consumption for some US carriers is also collected from the Airline Monitor. The fuel quantity data for Canadian carriers are collected from Statistics Canada publications. As was done in Windle (1991), a fuel quantity regression model was used to estimate fuel consumption for those airlines whose fuel consumption data are not available to us.

5 GPE is often aggregated with flight equipment to form capital stock. However, since the purpose of this paper is to examine the optimal lease of aircraft, we decided to keep flight equipment separate from the rest of the inputs.
The variation of operating characteristics of the airlines is reflected by average load factor and average stage length of each airline in each year. The average load factor is computed as the ratio of total passenger mile to total seat mile flown. The average stage length is the average distance between take-off and landing. 6

The 23 major air carriers used in the study and the key descriptive statistics of our sample are listed in Tables 1 and 2. The variable costs are the sum of labour, fuel and materials costs. The stock of flight equipment is used to represent capacity.

3.3. Results

The coefficients of the estimated cost function are reported in Table 3. Based on the coefficient on output, economies of density appear to be present at the sample mean point. According to Caves et al. (1984), returns to density at sample mean is \((1 - a_K)/a_Y = (1 - 0.224)/0.586 = 1.32\). However, this does not imply the presence of economies of scale which require consideration of the size of the network of the airlines (see, for example, Caves et al., 1984; Xu et al., 1994; Jara-Díaz and Cortés, 1996; Oum and Zhang, 1997, for more discussion). Since we do not have consistent data on the measurement of the size of the network of the airlines, we are unable to estimate returns to scale.

The estimated elasticity of revenue with respect to capacity, \(\eta\), is about 0.05. \(\eta\) is related to the elasticity of travel demand with respect to scheduled flight frequency and is identical to the latter if output price is fixed and if scheduled frequency increases in proportion to the increase in total capacity. Morrison and Winston (1986) estimated that the elasticity of passenger travel demand with respect to scheduled flight frequency was about 0.05 for leisure travellers and 0.21 for business travellers.

Regarding the operating characteristics, the first-order coefficient on average stage length is negative, as expected, indicating that long-haul flight is economically more efficient than short-haul flight. On the other hand, the sign of the first-order coefficient of average load factor is positive, which at first glance seems to suggest that increasing load factor while keeping all other variables unchanged would increase variables costs at the sample mean point. However, we believe that the coefficients on load factor should be interpreted with caution. Essentially, average load factor depends on output to capacity ratio; increasing load factor with both output and capacity fixed is counterfactual. Therefore, a clear interpretation of the coefficients on load factor is difficult.

To derive optimal demand for operating lease based on the estimated cost function, we still need the distribution of firm-specific demand for air transportation facing each carrier. For simplicity, we assume that the annual growth rate of demand for air service follows a normal distribution. Specifically, since the mean and standard deviation of the growth rate of our data

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6 Although the number of points served is another important characteristic of an airline network, it is not included here because we are unable to obtain a consistent time series data especially for the non-US carriers. Some of the previous studies involving non-US carriers, such as Good and Rhodes (1991), Good et al. (1993), Distexhe and Perelman (1993) and Oum and Yu (1995) have not included this variable as well.
Since our focus is on the optimal allocation of capacity between owning and leasing under an uncertain future state, the main factor is the uncertainty in traffic demand. Hence, given the distribution of traffic demand, without loss of generality, we take all other variables as given except load factor which we assume will vary proportionally with the output to capacity ratio.

Substituting Eq. (11) into Eq. (7) gives

$$G(Z) = - \int_{T_2} \left[ \frac{\partial R(\tau)}{\partial Z} - \frac{\partial V(\tau)}{\partial Z} - w_s \right] f(\tau) \, d\tau.$$
Numerical integration on the right-hand side is taken conditional on $Z$ (for numerical integration, the distribution of $s$ is truncated to be between $l^\gamma - 3F$ and $l^\gamma + 3F$). And then the optimal owned capacity $K$ is obtained by solving the following equation:

$$G(K^*) = \frac{E(w_s) - w_k}{w_k}.$$

The difference between the observed total capacity, $Z_{i,t}$, and $K_{i,t}^*$, is the optimal demand for aircraft lease by carrier $I$ in year $t$.

As an illustration, we applied the above procedure to derive the optimal demand for aircraft leasing for the 23 major airlines in 1993. The results are presented in Table 4. It is shown that when the cost premium defined as $[E(w_s) - w_k]/w_k$ is at 5%, the optimal demand for operating

<table>
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<tr>
<th>Variable</th>
<th>Coef.</th>
<th>S.E.</th>
<th>Variable</th>
<th>Coef.</th>
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Variables are as follows: $Y$ is output, $L$ is labour price, $F$ is fuel price, $K$ is capacity, $D$ is load factor, and $S$ is stage length. Labour price and fuel price are normalized by materials price.

Numerical integration on the right-hand side is taken conditional on $Z$ (for numerical integration, the distribution of $\tau$ is truncated to be between $\mu - 3F$ and $\mu + 3F$) and then the optimal owned capacity $K^*$ is obtained by solving the following equation:

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<thead>
<tr>
<th>Cost premium of lease</th>
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<th>10%</th>
<th>15%</th>
<th>20%</th>
<th>25%</th>
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<tbody>
<tr>
<td>Share of lease (%)</td>
<td>66.4</td>
<td>60.2</td>
<td>55.7</td>
<td>53.9</td>
<td>50.1</td>
<td>40.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Demand for lease contributed by the region: (Out of 100%)</th>
<th>North America</th>
<th>Europe</th>
<th>Asia and Oceania</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost premium of lease defined as $[E(w_s) - w_k]/w_k$.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Estimation based on 1993 data.
lease of aircraft would be about 66% of the existing total fleet for the 23 major airlines. The demand for lease decreases as the premium increases. When premium is at 30%, the demand for lease would be about 40% of the total fleet. This reveals that the flexibility of operating lease is highly valuable to the airlines. In 1993, the actual share of leased aircraft, including both operating lease and capital lease, for the 23 airlines was 45.7% of their total fleet. Since long-term capital lease accounted for about 20% of total lease, the actual share of aircraft under operating lease would be around 37%. Thus, it appears that there is still potential for the growth of the demand for operating lease.

Table 4 also lists the breakdown of total demand for operating lease by the 23 major airlines by the regions. It shows that the North American major carriers account for about two thirds of the demand in the leasing market. As the leasing premium is low, the European, and Asian and Oceania major carriers have about the same demand; however, as the leasing premium increases, Asian and Oceania major carriers demand twice as much as the European carriers do.

The results of Table 4 are based on the assumption that all of the major carriers face the same stochastic distribution of traffic growth. This assumption may be unrealistic given that there are substantial differences in growth rates experienced in the different regions of the world in the past. As a further illustration, we divide our data sample into three major regions. Based on the sample statistics of the major carriers in each of the regions, we assume

\[ Y_{i,t} = Y_{i,t-1} (1 + \tau), \quad \tau \sim N(\mu, \sigma), \]

where \( \mu = 0.109, F = 0.164 \) for North American major carriers; \( \mu = 0.072, F = 0.102 \) for European major carriers, and \( \mu = 0.102, F = 0.083 \) for Asian and Oceania major carriers. The same procedure to derive firm-specific demand for operating lease is applied again to each of the 23 major carriers and the aggregate results are reported in Table 5. The results are quite similar to those reported in Table 4. The basic pattern of regional demands in Table 4 remains true in Table 5 that the North American major carriers contribute about two thirds of the total demand and the Asian and Oceania major carriers contribute more relative to the European major carriers as leasing premium increases.

The results in Tables 4 and 5 also illustrated the risks to the leasing companies since the lease premiums seem to be quite sensitive to the swings in demand. In view of this, although the industry has good reason to be optimistic about future growth in aircraft lease, there is considerable uncertainty regarding the profitability to the lessors. During the last recession, many leasing

Table 5
Optimal demand for aircraft lease: differential forecast of traffic growth

<table>
<thead>
<tr>
<th>Cost premium of lease</th>
<th>5%</th>
<th>10%</th>
<th>15%</th>
<th>20%</th>
<th>25%</th>
<th>30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share of lease (%)</td>
<td>66.6</td>
<td>63.2</td>
<td>55.5</td>
<td>53.6</td>
<td>44.2</td>
<td>40.1</td>
</tr>
</tbody>
</table>

Demand for lease contributed by the region: (Out of 100%)

<table>
<thead>
<tr>
<th>Region</th>
<th>North America</th>
<th>Europe</th>
<th>Asia and Oceania</th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
<td>62.1</td>
<td>20.2</td>
<td>17.7</td>
</tr>
<tr>
<td>10%</td>
<td>62.4</td>
<td>19.5</td>
<td>18.1</td>
</tr>
<tr>
<td>15%</td>
<td>68.3</td>
<td>11.5</td>
<td>20.2</td>
</tr>
<tr>
<td>20%</td>
<td>68.0</td>
<td>11.5</td>
<td>20.5</td>
</tr>
<tr>
<td>25%</td>
<td>67.1</td>
<td>8.7</td>
<td>24.2</td>
</tr>
<tr>
<td>30%</td>
<td>67.4</td>
<td>9.4</td>
<td>23.2</td>
</tr>
</tbody>
</table>

Estimation based on 1993 data.

Cost premium of lease is defined as \( |E(w_c) - w_k|/w_k \).
companies failed and the leasing industry is still undergoing consolidation as the airline industry has recovered. The empirical methodology illustrated in this section would also be useful to the leasing companies to forecast demand on the aircraft lease.

4. Summary

The airline industry all over the world has been increasingly relying on aircraft lease. While previous researchers mostly focused on financial aspects of the leasing, this paper emphasized the operational effects of aircraft leasing. It is shown that short-term operating lease provided a vehicle for risk shifting or risk sharing between the airlines and the leasing companies. Operating lease of the aircraft gives the airlines flexibility in capacity management when demand for air transportation service is uncertain and cyclical. As the demand for air service increases, the airlines will be able to quickly expand capacity through aircraft leasing. However, if the demand takes a downturn, the leasing companies which supply the aircraft will suffer from excess capacity. Leasing companies compensate this risk by charging a premium on operating leases. Thus, the airlines are facing a trade-off between flexibility of capacity and higher costs.

This paper developed a model for the airlines to determine their optimal mix of leased and owned capacity. Empirical results based on the data from 23 major airlines in the world suggested that the optimal demand by these airlines would range between 40% and 60% of their total fleet, for the reasonable range of premiums of operating lease. To the leasing companies, this indicated huge potential of the market given strong forecast for the growth of air transportation in the next decade. However, the extent of the risks in this market should not be underestimated. The empirical results revealed the sensitivity of the profitability of the aircraft leasing to the swings in the demand. Therefore, the leasing companies should also be cautious in the management of their inventory. The approach illustrated in this paper is also useful to the leasing companies to forecast demand for operating lease of the aircraft and to assess the extent of risks in the market, and thus to have a better management of the supply side of the market.

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