Impact of Aircraft Size and Service Frequency on Airlines’ Demand and Market Share

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Presentation Outline

• Motivation and objective
• A framework of demand and market share analysis
• Data source and estimation results
• Implications and applications
• Summary
Motivation (1)

- Airlines’ using larger aircraft can alleviate airport congestion
  - Building new runways or ATC systems is expensive
  - Increase of air travel demand can be accommodated through increase of service frequency or aircraft size or both
  - Airport throughput will be increased if airlines use larger aircraft
  - Major airports have large proportion of operations of small aircraft, especially in short-haul markets
  - Future aircraft size: small (Boeing’s opinion) or large (Airbus’ opinion)?
Motivation (2)

• What’s the impact of airport expansion and government regulation on airlines’ decisions on service?
  – Airport capacity expansion, through either building new runways or ATC systems, influences airlines’ choice of aircraft size, service frequency and routing network
  – Government regulation, such as landing fee policy, also influence airlines’ choices
Motivation (3)

• Aircraft fleet simplification in airlines’ reconstruction process after September 11th, 2001
  – Only the most profitable aircraft are retained in the fleet
  – In practice, there is no model capturing the role of aircraft size specifically
Objective and Goals

• Study the role of aircraft size and service frequency in airlines’ demand and market share
  – In duopoly markets
  – At the market level
  – To account for “seat availability”: proportion of seats available to local passengers
“Aircraft Size”

- Focus on jet aircraft
- Not including small regional aircraft (with fewer than 60 seats)
- Ranging from 100 seats to 400+ seats
- Seat capacity is based on actual seat configurations by each carrier

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Seat Capacity</th>
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<tbody>
<tr>
<td>B737-1/2</td>
<td>110</td>
</tr>
<tr>
<td>B737-5/6</td>
<td>111</td>
</tr>
<tr>
<td>B737-3/7</td>
<td>130</td>
</tr>
<tr>
<td>B737-4</td>
<td>143</td>
</tr>
<tr>
<td>B727-2</td>
<td>148</td>
</tr>
<tr>
<td>B757</td>
<td>185</td>
</tr>
<tr>
<td>B767-2</td>
<td>188</td>
</tr>
<tr>
<td>B767-3</td>
<td>234</td>
</tr>
<tr>
<td>B747-2/3</td>
<td>401</td>
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<tr>
<td>B747-4</td>
<td>432</td>
</tr>
</tbody>
</table>

Source: Form 41
Analysis Framework

• Study the role of aircraft size and service frequency, together with other service attributes, in demand and market share
• Focus on duopoly (i.e. two airlines) non-stop markets (at the market level)
• Traveler choice-based two-level nested-logit model

Not air travel

Air travel

Airline 1

Airline 2
Market Share and Demand Models

• Low-level result (for market share)

\[ S_{im} = \frac{\exp(V_{im})}{\sum_j \exp(V_{jm})} \]

\( V_{im} \) : deterministic utility if choosing airline \( i \) in market \( m \)

• High-level result (for total air travel demand)

\[ Q_m = D_m \frac{\left( \sum_j \exp(V_{jm}) \right)^\theta}{\exp(V_{om}) + \left( \sum_j \exp(V_{jm}) \right)^\theta} \]

\( D_m \) : saturation demand
\( \theta \) : “nested coefficient”
\( V_{om} \) : deterministic utility for “not air travel”
Passenger Utility Function

\[ V_{jm} = \alpha \ln(Freq_{jm}) + \beta \ln(Size_{jm}) + \eta \ln(Aval_{jm}) + \gamma \text{Fare}_{jm} \]

- For non-stop markets with connecting passengers in flight
- Availability: percentage of seats available in local market
  - \((\text{total seats}-\text{connecting passengers})/\text{total seats}\)
- Effects captured by the specified airline service variables
  - Capacity effect: total seats = frequency*size*availability
  - Schedule delay: frequency
  - Safety, speed and amenity effect: size
  - RM effect (likelihood to get a seat): seats per flight = size* availability
  - Traffic mix effect: availability
  - Price effect: fare

- Two reasons to use “log” form
  - Diminishing returns from increasing flights or seats
  - Passengers’ choice of airlines is an aggregation of choice of flights or seats
- Different coefficients reveal different contributions or roles
Coefficient Estimation Results

- Log-linear models for market share and total demand
  - Data sample: 13 non-stop duopoly markets from 1989 to 1999
- Different contributions of service attributes in airlines’ demand and market share
  - Trade-off between aircraft size and frequency
  - S-curve effect from increase of frequency in market share
  - Higher returns from frequency
  - Coefficient for availability is higher than that for aircraft size

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Estimates</th>
<th>T statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$ (Frequency)</td>
<td>1.287</td>
<td>41.43</td>
</tr>
<tr>
<td>$\beta$ (Size)</td>
<td>0.185</td>
<td>2.45</td>
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<tr>
<td>$\eta$ (Availability)</td>
<td>0.849</td>
<td>15.92</td>
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<tr>
<td>$\gamma$ (Fare)</td>
<td>-0.002</td>
<td>-2.79</td>
</tr>
<tr>
<td>$\theta$ (Nested Coefficient)</td>
<td>0.333</td>
<td>10.21</td>
</tr>
</tbody>
</table>

\[
\ln \left( \frac{S_{im}}{S_{jm}} \right) = \alpha \ln \left( \frac{freq_{im}}{freq_{jm}} \right) + \beta \ln \left( \frac{Size_{im}}{Size_{jm}} \right) + \\
\eta \ln \left( \frac{Aval_{im}}{Aval_{jm}} \right) + \gamma (fare_{im} - fare_{jm})
\]
First Implication

- Passengers prefer increase of frequency rather than increase of aircraft size
  - Coefficient for service frequency is higher
- Airlines have no economic incentives to use aircraft larger than the least-cost aircraft
  - Market share ratio increases much faster with the increase of frequency than with the increase of aircraft size
Second Implication

• Passengers prefer smaller aircraft with higher availability rather than larger aircraft with lower availability
  – Convenience is more important than amenity

• Airlines’ economies of scope realized by serving both connecting and local passengers are offset by reduction in service quality in hub-and-spoke network
  – Importance of traffic mix
Applications of Research Results (1)

• To predict and facilitate airlines’ choice of aircraft size
  – For monopoly case: profit maximization problem
    • Extending duopoly demand model to monopoly case
  – For fixed utility (non-demand competition) case: constrained cost minimization problem
    • Airlines’ trade-off between service frequency and aircraft size
  – Game-theoretical analysis in a general competitive environment

• Decision support on whether hub-and-spoke or direct service should be provided
  – Tradeoff between cost reduction and service quality reduction
Applications of Research Results (2)

- Social welfare and benefit analysis for airport capacity expansion and government regulations such as landing-fee policies
  - Airlines’ choice of aircraft size, service frequency and routing network are affected by airport capacity and government policies
  - Impact can be quantified and monetized through the tradeoff between “fare” and other service variables in the demand model
Summary

• Impact of aircraft size and service frequency on airlines’ demand and market share in non-stop duopoly markets

• A two-level nested-logit model framework

• Main findings:
  – Passengers prefer smaller aircraft size with higher service frequency and higher seat availability
  – Trade-off between size and service frequency; higher returns from increase of frequency
  – Importance of traffic mix effect; service quality reduction in hub-and-spoke network

• Applications and further studies