Symbiotic Strategies in Enterprise Ecology: Modeling Commercial Aviation as an Enterprise of Enterprises

Sgouris Sgouridis

LAI ANNUAL CONFERENCE
LEAN ENTERPRISE TRANSFORMATION 2008

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Agenda

Overview, Motivation, and Methodology

Research Questions

Modeling Commercial Aviation as an Enterprise of Enterprise

Results and Conclusions

Contributions

Future Work
Motivation

- Cyclicality exists in Commercial Aviation
- Cyclicality has repercussions across the enterprise ecosystem
- Lack of centralized control makes coordinated action to moderate cyclicality difficult
- Symbiotic strategies that can moderate cyclicality in a way beneficial to multiple stakeholders are not readily identifiable
Overview & Methodology

Understanding key aspects of:
- Commercial Aviation
- Business cycles in economics and supply chains
- Enterprise modeling

Representing Commercial Aviation as *Enterprise of Enterprises* (CA EoE) to identify leverage points, strategic alternatives and interests

Modeling of the CA EoE using System Dynamics

Testing strategic alternatives for effectiveness and implementability
Key Finding

• If Boeing follows the Airbus aircraft delivery model then
  – BOTH the manufacturers (Boeing: +87%, Airbus: +55% total op. profit)
  – AND the airline industry as a whole (Airline NPV: +20%) will enjoy increased profitability
  – WHILE passenger surplus will not be affected substantially (total passenger welfare may actually increase)

(Until 2025, one scenario, assuming no new entrants in the large commercial aircraft (>100 seats) category)

• More combinations of strategic alternatives (policies) improve on this performance!
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• How is cyclicality manifested in commercial aviation? What are the impacts from cyclicality in commercial aviation?

• What are the salient causal mechanisms that induce the cyclical behavior in commercial aviation?

• What are implementable strategic alternatives for dampening that cyclicality and what are their benefits?
How is cyclicality manifested in commercial aviation? (I)

- **Cyclical profitability for airlines**
- **Increasing amplitude post-deregulation**

Global Data – Data Sources: ATA (2006)
How is cyclicality manifested in commercial aviation? (II)

→ Correlation between GDP growth and travel demand
→ Bullwhip effect in aircraft orders

Global Data – Data Sources: ATA (2006), Boeing and Airbus Databases
How is cyclicality manifested in commercial aviation? (III)

Aircraft seats ('000)

Boeing ORDERS

Boeing DELIVERIES

Airbus ORDERS

Airbus DELIVERIES

Different Aircraft Production Strategies: Boeing and Airbus

Global Data – Data Sources: Boeing and Airbus Databases

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What are the impacts from cyclicality in commercial aviation?

- Low industry-wide return on invested capital

- Periodic overcapacity and constrained capacity of aircraft:
  - Hire/fire cycles. Airport and ATC planning. Inconsistent LOS and fares.

- Periodic overcapacity and constrained capacity of manufacturing resources:

  $2.6B write-off and 8% overnight stock value loss (Boeing) (Newhouse 2006)

  $3.7B requested assistance

Source: Pope and Nyhan 2002
What are the salient causal mechanisms that induce the cyclical behavior? From business cycle literature

- **Triggers:**
  - *Macroeconomic cycle*
  - *Input variability*

- **Psychological Factors**

- **Industry Structure**
  - *Investment irreversibility and intertemporal substitution* (Timbergen 1931, Einarsen 1938)
  - *Underutilized capacity and labor ‘hoarding’* (Petersen and Strongin 1996)
  - *Technological change* (Schumpeter 1911, 1939)
  - *Low barriers to entry, high barriers to exit, commoditization* (Weil 1996)

  - Order batching
  - Inventories.
  - Long lead times.
  - Order gaming due to constrained supply
  - Price fluctuations (promotions, bulk discounts)
  - Strong seasonality or network effects

✔: applicable to commercial aviation
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Future Work
Modeling an Enterprise of Enterprises (EoE)

1. Define EoE Study Objectives:

2. Qualitatively Represent the EoE:
   - Identify:
     - Primary constituent enterprises,
     - Interests and objectives of constituents (value functions),
     - Interfaces between constituents

3.1. Define the Plausible Futures
3.2. Define the Solution Space

4. Model the EoE

5. Experiment Using the EoE Model

6. Consider implementability of strategic alternatives

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CA as an EoE (I)

Abstraction of the CA EoE interfaces, primary constituent enterprises and non-enterprise stakeholders


<table>
<thead>
<tr>
<th>Constituent Enterprise/Stakeholder</th>
<th>Values</th>
<th>Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Passengers/Shippers</strong></td>
<td>Availability of air travel</td>
<td>ASK/year</td>
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<td></td>
<td>Affordability of air travel</td>
<td>Average fares</td>
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<td>Level of Service</td>
<td>Frequency, reliability, amenities (load factors as proxy)</td>
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<td>Stability of Return</td>
<td>Coefficient of variation (CV)</td>
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<td>Downtime</td>
<td>Average time with negative returns</td>
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<td></td>
<td>Stability of Aircraft Deliveries</td>
<td>Coefficient of variation (CV)</td>
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<td>Downtime</td>
<td>Average time with negative returns</td>
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<td><strong>Capital Markets</strong></td>
<td>Return on investment</td>
<td>Combination of airlines and airframe manufacturers returns</td>
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<td>Defaults avoidance</td>
<td>Economic losses due to defaults</td>
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<tr>
<td><strong>Governments</strong></td>
<td>Availability of air travel</td>
<td>ASK/year</td>
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<td>Returns of domestic industries</td>
<td>EVA</td>
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<td></td>
<td>Min. subsidies</td>
<td>Amount of assistance in support of airlines and aircraft manufacturers</td>
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<td></td>
<td>Employment stability</td>
<td>Employment numbers</td>
</tr>
</tbody>
</table>

→ Representation of constituent enterprise and stakeholder *value functions*

→ Used to evaluate and compare effects of strategic alternatives
Modeling EoEs

1. Define EoE Study Objectives:

2. Qualitatively Describe the EoE

3.1. Define Plausible Futures:
Create scenarios that represent realistic outcomes

3.2. Define the Solution Space:
Identify strategic alternatives towards the desired EoE state

4. Model the EoE

5. Experiment Using the EoE Model

6. Consider implementability of strategic alternatives
Strategic areas for reducing cyclicality

• **Flexibility in airline operations:**
  – *Fixed vs. variable costs*
    • Profit sharing and outsourcing
    • Leasing
  – *Aircraft fleet management*
    • Flexibility in Aircraft Fleet Utilization
    • Aircraft retirement
    • Aircraft ordering
      – Supply chain visibility
      – Demand Forecasting
      – Effect of Profitability on Orders

• **Airline competitive environment**
  – Yield management
  – Effect of Airline Entry and Exit on Pricing

• **Aircraft manufacturers competitive environment**
  – Aircraft pricing
  – Manufacturing
    • Production rate adjustments
    • Production costs
Modeling EoEs

1. Define EoE Study Objectives:

2. Qualitatively Describe the EoE

3. Define the Plausible Futures

4. Model the EoE:
   - Identify appropriate modeling method(s)
   - Quantify the value functions of constituent enterprises,
   - Quantify and model the interfaces between constituents,
   - Calibrate, validate and verify the resulting model

5. Experiment Using the EoE Model

6. Consider implementability of strategic alternatives
CA EoE Modeling

→ SD Model: captures critical aspects of the EoE
→ Integration of scenarios, strategies and value functions
CA EoE SD Model Validation: Airlines

Airline Capacity and Demand

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<th>Historical Values</th>
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Airline Costs

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Airline Profit Margins

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Airline Revenues

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Visual inspection and statistical analysis indicate matching
CA EoE SD Model Validation: Manufacturers

Visual inspection and statistical analysis indicate matching
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Modeling EoEs

1. Define EoE Study Objectives:

2. Qualitatively Describe the EoE

3.1. Define the Plausible Futures

3.2. Define the Solution Space

4. Model the EoE

5. Experiment Using the EoE Model:
   - Quantify strategic alternatives (SA)
   - Design experiments that cover interactions across (SA)
     - Run experiments across scenarios
     - Compare and identify the promising SA

6. Consider implementability of strategic alternatives:
   - Design implementation strategy based on institutional/regulatory aspects of the EoE
   - Game theory and compensation schemes for non-Pareto optimal strategic alternatives
There is cyclical behavior even in the absence of exogenous factors

Relative effect on cyclicality of exogenous factors:
1. Fuel (CV: 1.12)
2. GDP (CV: 0.87)
3. External shocks (CV: 0.46)
From Strategic areas to Strategic Alternatives: 2 examples

• **Flexibility in airline operations:**
  – *Fixed vs. variable costs*
    • Profit sharing and outsourcing
    • Leasing
  – *Aircraft fleet management*
    • Flexibility in Aircraft Fleet Utilization
    • Aircraft retirement
    • Aircraft ordering
      – *Supply chain visibility*
      – *Demand Forecasting*
      – *Effect of Profitability on Orders*

• **Airline competitive environment**
  – *Yield management*
  – *Effect of Airline Entry and Exit on Pricing*

• **Aircraft manufacturers competitive environment**
  – *Aircraft pricing*
  – *Manufacturing*
    • *Production rate adjustments*
    • Production costs

- 25% SC Visibility
- 50% SC Visibility
- 75% SC Visibility

- Slow production rate adjustment
- Faster production rate adjustment
  • Just-in-time (JIT) delivery
  • Fixed schedule production rate
## Results: Individual Strategic Alternatives

Performance (average across scenarios)

<table>
<thead>
<tr>
<th>Airline/Scenario</th>
<th>Airline NPV Change</th>
<th>Airline CV Change</th>
<th>Manufacturers NPV Change</th>
<th>Manufacturers Order CV Change</th>
<th>Passengers Fare Change</th>
<th>Passengers LF change</th>
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</thead>
<tbody>
<tr>
<td>75% SC visibility</td>
<td>256.4%</td>
<td>54.0%</td>
<td>-45.6%</td>
<td>41.8%</td>
<td>2.6%</td>
<td>13.8%</td>
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<tr>
<td>50% SC visibility</td>
<td>168.7%</td>
<td>47.3%</td>
<td>-38.9%</td>
<td>31.5%</td>
<td>2.7%</td>
<td>9.5%</td>
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<tr>
<td>MF fixed prod. Rate</td>
<td>49.6%</td>
<td>-23.4%</td>
<td>123.3%</td>
<td>N/A</td>
<td>-0.3%</td>
<td>2.8%</td>
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<tr>
<td>Slow prod rate change</td>
<td>25.6%</td>
<td>-2.6%</td>
<td>63.7%</td>
<td>-43.5%</td>
<td>-0.8%</td>
<td>1.3%</td>
</tr>
<tr>
<td>Slow prod rate change + 25% SC visibility</td>
<td>142.2%</td>
<td>50.5%</td>
<td>4.3%</td>
<td>5.3%</td>
<td>2.2%</td>
<td>7.4%</td>
</tr>
<tr>
<td>MF JIT+ lean + 25% SC visibility</td>
<td>90.6%</td>
<td>41.9%</td>
<td>-40.2%</td>
<td>25.4%</td>
<td>3.6%</td>
<td>5.2%</td>
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</table>

> Control of Capacity is key
Symbiotic Quadrant – Optimization search for strategic alternative bundles

Control of capacity leads to symbiotic strategies close to the Pareto front
There are benefits to be gained from bundling strategic alternatives
Conclusions

→ Strong endogenous dynamics in commercial aviation structure that fuel cyclicality

→ Non-collusive slowing of production rate adjustment provides strong symbiotic benefits to both manufacturers and airlines while passengers are not negatively impacted

→ No synergistic advantage found if MF.A pursues JIT and MF.B maintains its slow-to-adapt production strategy (*)

→ Other interesting strategic alternatives were shown:
  • Airline industry consolidation
    – In pricing (*)
    – In ordering (reducing ‘supply chain discounting’)
  • Increasing fleet flexibility (higher level of short term op. leases) (*)

→ Bundling of alternatives can provide improvements but production control (in the extreme) is on the Pareto front

→ Commercial Aviation as an EoE: a useful perspective
Thank you for your attention!

Questions?
Back-up
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Contributions

• Integrating disparate literature strands:
  – Extensive coverage of commercial aviation
  – Synthesis of the literature on business cycles in economics and supply chain
  – Modeling approaches for enterprises (Ch. 8)

• Formalizing the Enterprise of Enterprises concept

• Creating an SD model of the CA EoE with duopolist manufacturer dynamics and separate narrow-, wide- body market segments

• Identifying and comparing CA EoE specific symbiotic strategic alternatives
Future Work

• Use agents to model airline behavior and specifically the evolution of Airline – Manufacturer partnerships

• Model manufacturer new entrants

• Extend competition on aircraft market beyond only price: introduce endogenous dynamic decisions for technological aircraft change

• Calibrate the manufacturer module of the model with proprietary industry data

• Adapt the EoE view and methodology to other cyclical industries and seek generalizations on mechanisms for cyclical dynamics
Based on and extended H. Weil’s airline industry model (1996)
Partly developed in collaboration with J. Lin and J. McConnell.
Implemented using Anylogic
Dampening Mechanism

For the “supply chain visibility” strategic alternative
## Competitive Dynamics for S1 (I)

<table>
<thead>
<tr>
<th>Strategic Alternatives</th>
<th>Exp 1</th>
<th>Exp 2</th>
<th>Exp 3</th>
<th>Exp 4</th>
<th>Exp 5</th>
<th>Exp 6</th>
<th>Exp 7</th>
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<td><strong>Production scheduling</strong></td>
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<tr>
<td>JIT delivery</td>
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<tr>
<td>Slow production rate change</td>
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<td>Fixed production schedule</td>
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<td>Vertical integration (50%)</td>
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<td>Aggressive Competition</td>
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<td>0.6%</td>
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<td><strong>NPV Change</strong></td>
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<td>32.5%</td>
<td>48.1%</td>
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<td>-22.4%</td>
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<td>10.6%</td>
<td>9.7%</td>
<td>13.2%</td>
<td>13.4%</td>
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<td><strong>MF. B</strong></td>
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<td><strong>Total order change</strong></td>
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## Competitive Dynamics for S1 (II)

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<tr>
<td>Slow production rate change</td>
<td>*</td>
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<tr>
<td>Quick production rate change</td>
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<td>*</td>
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<tr>
<td>Fixed production schedule</td>
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<td>*</td>
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<tr>
<td>Production costs</td>
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<tr>
<td>Lean manufacturing</td>
<td>*</td>
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<td>*</td>
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<td>*</td>
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<tr>
<td>Adaptive production (costs)</td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
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<tr>
<td>Industry relations and pricing</td>
<td></td>
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<td></td>
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<tr>
<td>Vertical integration (15%)</td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Aggressive Competition</td>
<td></td>
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</table>

### Airlines

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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>NPV Change</td>
<td>1.2%</td>
<td>12.4%</td>
<td>55.9%</td>
<td>0.7%</td>
<td>11.1%</td>
<td>-0.1%</td>
<td>20.5%</td>
<td>17.7%</td>
</tr>
<tr>
<td>Coef. Var. Change</td>
<td>22.2%</td>
<td>6.4%</td>
<td>-11.4%</td>
<td>3.0%</td>
<td>-2.1%</td>
<td>3.2%</td>
<td>2.5%</td>
<td>5.7%</td>
</tr>
<tr>
<td><strong>Mf. A</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPV Change</td>
<td>32.0%</td>
<td>-51.5%</td>
<td>-26.7%</td>
<td>46.8%</td>
<td>-10.0%</td>
<td>5.3%</td>
<td>87.1%</td>
<td>119.6%</td>
</tr>
<tr>
<td>Total order change</td>
<td>2.4%</td>
<td>-6.8%</td>
<td>-44.1%</td>
<td>-3.0%</td>
<td>-23.0%</td>
<td>-1.8%</td>
<td>15.0%</td>
<td>22.6%</td>
</tr>
<tr>
<td>Order coef. Of Var. change</td>
<td>18.9%</td>
<td>28.7%</td>
<td>-6.1%</td>
<td>1.7%</td>
<td>-6.2%</td>
<td>5.2%</td>
<td>-11.9%</td>
<td>-11.2%</td>
</tr>
<tr>
<td><strong>Mf. B</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPV Change</td>
<td>-13.6%</td>
<td>-18.0%</td>
<td>-21.1%</td>
<td>0.3%</td>
<td>-27.3%</td>
<td>-5.0%</td>
<td>55.8%</td>
<td>35.5%</td>
</tr>
<tr>
<td>Total order change</td>
<td>-1.2%</td>
<td>3.8%</td>
<td>-20.9%</td>
<td>3.2%</td>
<td>-0.6%</td>
<td>0.2%</td>
<td>53.0%</td>
<td>49.3%</td>
</tr>
<tr>
<td>Order coef. Of Var. change</td>
<td>19.7%</td>
<td>21.8%</td>
<td>9.2%</td>
<td>5.5%</td>
<td>13.8%</td>
<td>4.1%</td>
<td>10.3%</td>
<td>10.1%</td>
</tr>
</tbody>
</table>

### Pax

<table>
<thead>
<tr>
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<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fare change</td>
<td>0.0%</td>
<td>-1.2%</td>
<td>-3.1%</td>
<td>0.3%</td>
<td>-1.5%</td>
<td>0.2%</td>
<td>0.4%</td>
<td>-2.6%</td>
</tr>
<tr>
<td>LF change</td>
<td>-0.2%</td>
<td>0.9%</td>
<td>3.9%</td>
<td>0.0%</td>
<td>1.3%</td>
<td>-0.1%</td>
<td>1.6%</td>
<td>1.4%</td>
</tr>
</tbody>
</table>

### Total Return

| Universal owner view | 104 | 90  | 116 | 111 | 96  | 100 | 145  | 146 |
CA Value Chain

- Raw Material Supply
- Subsystem Development and Production
- Aircraft Integration and Assembly
- Aircraft Fleet Ownership and Maintenance
- Aircraft Operations

Capital Provision
- Public/Private Investors
- Govt. (Regulatory)

Infrastructure Provision
- Travel Demand Satisfaction
- Public/Private Partnerships

Travelers/Shippers
- Airlines

Leasing Firms
- Airframe Manufacturers

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Airline Costs

UNIT COST BY CATEGORY
Cents per Available Seat Mile

- Labor: 24.2%
- Fuel: 24.7%
- Ownership: 12.9%
- Professional Services: 6.9%
- Passenger Commissions: 1.2%
- Landing Fees: 1.9%
- Food & Beverage: 1.5%
- Maintenance Materials: 1.3%
- Communication: 1.0%
- Insurance: 0.8%
- Utilities & Office Supplies: 0.6%
- Other: 22.2%
- Ad & Promotion: 0.9%
Based on H.B. Weil's airline industry model (1996)
Developed further in collaboration with Jijun and Josh.
Using Anylogic
## Statistical Tests

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Mean</th>
<th>Sqrt (MSE)</th>
<th>R sq.</th>
<th>Theil statistics</th>
<th>$P(T&lt;=t)$ two-tail</th>
<th>Statistically significant difference at 0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity (in trillion op. ASM)</td>
<td>2.03</td>
<td>2.03</td>
<td>0.077</td>
<td>0.981</td>
<td>0.001</td>
<td>0.153</td>
<td>0.845</td>
</tr>
<tr>
<td>Demand (in trillion RPM)</td>
<td>1.39</td>
<td>1.39</td>
<td>0.061</td>
<td>0.975</td>
<td>0.004</td>
<td>0.007</td>
<td>0.989</td>
</tr>
<tr>
<td>Load factors</td>
<td>0.68</td>
<td>0.68</td>
<td>0.02</td>
<td>0.430</td>
<td>0.019</td>
<td>0.002</td>
<td>0.979</td>
</tr>
<tr>
<td>Airline costs in ($B)</td>
<td>101</td>
<td>98.9</td>
<td>5</td>
<td>0.959</td>
<td>0.172</td>
<td>0.246</td>
<td>0.582</td>
</tr>
<tr>
<td>Airline revenues</td>
<td>103</td>
<td>101.1</td>
<td>5.2</td>
<td>0.949</td>
<td>0.152</td>
<td>0.185</td>
<td>0.663</td>
</tr>
<tr>
<td>Airline profit margins</td>
<td>0.026</td>
<td>0.027</td>
<td>0.018</td>
<td>0.663</td>
<td>0.003</td>
<td>0.000</td>
<td>0.997</td>
</tr>
<tr>
<td>Aircraft orders (in trillion ASM)</td>
<td>0.21</td>
<td>0.19</td>
<td>0.067</td>
<td>0.628</td>
<td>0.081</td>
<td>0.095</td>
<td>0.824</td>
</tr>
<tr>
<td>Aircraft backlog (in trillion ASM)</td>
<td>0.61</td>
<td>0.63</td>
<td>0.164</td>
<td>0.636</td>
<td>0.019</td>
<td>0.111</td>
<td>0.871</td>
</tr>
</tbody>
</table>
Manifestations of Cycles in CA

Global Airline Data – Data Source ATA (2006)
Manifestations of Cycles in CA

Global Data – Data Sources: ATA (2006), Boeing and Airbus order and delivery history
SD Model Basic Assumptions

- Manufacturers produce equivalent models compete on price (can be relaxed)
- There are no manufacturer entrants
Manufacturer Response to Cycles

Backlog in Years

- Boeing Backlog in Years Narrow
- Boeing Backlog in Years Wide
- Airbus Backlog in Years Narrow
- Airbus Backlog in Years Wide

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Business Cycles?

World Airlines Operating Results and Orders

Airline operating results
Narrow body orders
Widebody orders

Shipbuilding in tons for Norwegian Ship Owners (1883-1913) [Source: Einarsen 1938]
Airframe manufacturers due to their central position in the value chain have the potential power to enhance system stability.

**Objective:**

*Symbiotic strategies* that can enhance long term value by supplanting zero-sum games with value adding propositions. They can be cooperative but not necessarily so.
### Value Functions: CA as an EoE

<table>
<thead>
<tr>
<th>Passengers</th>
<th>$P_{VF} = \begin{cases} \max \sum_t \sum_i Q_{it} \ \min \sum_t \sum_i D_{it} F_{it}(1 + r_p)^t, \quad r_p = 0 \ \sum_t D_{it} \quad \forall t \end{cases}</th>
<th>Symbols</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carriers</td>
<td>$Car_{VF} = \begin{cases} \max \left( \sum_t \left( \frac{F_{it} D_{it} - C_{it} Q_{it}}{EVA} \right) \cdot (1 + r_i)^t \right) \ \min \left( \text{std}(EVA) \right) \ \min( t, EVA &lt; 0) \end{cases}$</td>
<td>t: unit of time, i: carrier, j: airframe manufacturer, r: discount rate, $Q_{it}$: Available Seat Kilometers (ASK), $D_{it}$: Realized demand in Revenue, $F_{it}$: Passenger Kilometer (RPK), $C_{it}$: Unit cost (Expenses/ASK), including cost of capital</td>
</tr>
<tr>
<td>Airframe</td>
<td>$Mfg_{VF} = \begin{cases} \max \left( \sum_t (P_{jt} - CP_{jt}) QP_{jt} \cdot (1 + r_j)^t \right) \ \min \left( \text{std}(QP_{jt}) \right) \end{cases}$</td>
<td></td>
</tr>
<tr>
<td>Manuf.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government</td>
<td>$Gov_{VF} = \begin{cases} \sum_i Q_{it} &gt; q_t, \forall \text{ domestic } \ i \ \text{ and } \ \sum_j QP_{jt} &gt; q_P, \forall \text{ domestic } \ j \end{cases}$</td>
<td></td>
</tr>
<tr>
<td>Capital Markets</td>
<td>$Cap_{VF} = \begin{cases} \max \left( \sum_t \left( F_{it} D_{it} - C_{it} Q_{it} \right) \cdot (1 + r_m)^t + \sum_t \left( P_{jt} - CP_{jt} \right) QP_{jt} \cdot (1 + r_m)^t \right) \quad \text{or} \ \max \left( \left( F_{it} D_{it} - C_{it} Q_{it} \right) + \left( P_{jt} - CP_{jt} \right) QP_{jt} \right), \forall t \end{cases}$</td>
<td></td>
</tr>
</tbody>
</table>

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Views of Commercial Aviation

- Passengers: ~0.8 Billion
- Direct O-D Markets: ~40,000
- Major Airlines: ~500
- Airframe manufacturers: 2+
- Engine manufacturers, 1st tier sub-system contractors: ~20
- Direct Output in $B: ~405
- Employees ('000): ~2000
- Air transportation: 154 employees, 691* employees
- Airport services: 18 employees, 121 employees
- Commercial Aircraft manufacturing: 75 employees, 241 employees

U.S. Data (Source: Campbell) Global Data (extrapolation)

- Business Passengers
- Leisure Passengers
- Airports
- ATC
- American
- Southwest
- Lufthansa
- Ryanair
- JAL
- Capital Markets
- Leasing companies
- Unions
- Boeing
- Airbus
- FAA
- DOT
- EPA
- DOC
- US Government
- WTO
- EU Government

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Two enterprise models

<table>
<thead>
<tr>
<th></th>
<th>Shareholder-centric/modular Enterprise</th>
<th>Stakeholder-centric/integral Enterprise</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>View</strong></td>
<td><img src="Diagram.png" alt="Diagram" /></td>
<td><img src="Diagram.png" alt="Diagram" /></td>
</tr>
<tr>
<td><strong>Goals</strong></td>
<td>Maximize shareholder wealth</td>
<td>Pursue multiple objectives of parties with different interests</td>
</tr>
<tr>
<td><strong>Governance</strong></td>
<td>Principal-Agent Model: Managers are agents of stakeholders. Control is the key task.</td>
<td>Team production model: Coordination, cooperation, &amp; conflict resolution are the key tasks.</td>
</tr>
<tr>
<td><strong>Performance metrics</strong></td>
<td>Shareholder value</td>
<td>Fair distribution of value</td>
</tr>
</tbody>
</table>

Results: Endogenous Dynamics

Cyclical behavior in the absence of exogenous factors
Effect of exogenous factors in order of importance:
1. Fuel
2. GDP
3. External shocks
Model Key Assumptions

• Equivalent aircraft
• Freight market represented by passengers
Endogenous dynamics mechanisms
What are the salient causal mechanisms that induce the cyclical behavior? CA-specific factors

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disruptive technologies</td>
<td>Jets, 2-pilot cockpit, fuel efficient designs, product families etc.</td>
</tr>
<tr>
<td>Technical regulations</td>
<td>Noise abatement, stage 2,3,4 aircraft</td>
</tr>
<tr>
<td>Exogenous factors</td>
<td>Macroeconomic cycles, fuel prices, materials, interest rates</td>
</tr>
<tr>
<td>Demand shocks</td>
<td>Iraq war I, 9/11, SARS etc.</td>
</tr>
<tr>
<td>Reinvestment cycle Intertemporal substitution</td>
<td>Aircraft as large capital investment with limited but adjustable lifetime</td>
</tr>
<tr>
<td>Bullwhip in supply chains, labor, and inventory</td>
<td>Long lead times for both labor and capital. Irreversibility.</td>
</tr>
<tr>
<td>Industry characteristics</td>
<td>Scale economies and large investment in upfront R&amp;D incentivize airframe mfg. to promote their wares aggressively in short term</td>
</tr>
<tr>
<td></td>
<td>Low marginal costs for airlines</td>
</tr>
<tr>
<td>Market regulations</td>
<td>Deregulation combined with imperfect financing allows multiple entrants.</td>
</tr>
<tr>
<td></td>
<td>Subsidies, bankruptcy protections, and national pride policies retain players in weak markets</td>
</tr>
<tr>
<td>Decision-making</td>
<td>Bounded rationality and strategic optimism create overreaction by multiple entrants.</td>
</tr>
<tr>
<td></td>
<td>Large number of decision makers.</td>
</tr>
<tr>
<td>Financing volatility</td>
<td>Debt and equity financing available in economic upturns lowers barriers to entry BUT dries quickly in downturns increasing risk of price wars.</td>
</tr>
<tr>
<td></td>
<td>Short-term returns can be overemphasized over long-term stability.</td>
</tr>
</tbody>
</table>
## Airline Strategic Areas

<table>
<thead>
<tr>
<th>Strategic Area</th>
<th>Desired effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pr</td>
<td>Flexibility. Reduces fixed capacity costs.</td>
</tr>
<tr>
<td>Profit-sharing programs</td>
<td>Flexibility. Reduces labor costs during hard times.</td>
</tr>
<tr>
<td>Good mix of ages in the fleet</td>
<td>Flexibility. Old amortized aircraft can be retired or parked without penalty on fixed costs.</td>
</tr>
<tr>
<td>Off-cyclical behavior (buy low, sell high)</td>
<td>Bullwhip reduction. Individual airline bottom line boost.</td>
</tr>
<tr>
<td>Steady ordering and flexible retirement</td>
<td>Bullwhip reduction.</td>
</tr>
<tr>
<td>Long-term profit-based planning</td>
<td>Bullwhip reduction. Compared to short-term profit-based vs. market-share based planning.</td>
</tr>
<tr>
<td>Less aggressive revenue management</td>
<td>Bullwhip reduction. Marginal costs of seats are not zero – holding off price wars.</td>
</tr>
<tr>
<td>Mergers</td>
<td>Number of players. Consolidating capacity will increase market power and reduce excessive capacity.</td>
</tr>
<tr>
<td>Tempered expectations</td>
<td>Decision making. Reducing irrational exuberance.</td>
</tr>
</tbody>
</table>
## Airframe Manufacturers Strategic Areas

<table>
<thead>
<tr>
<th>Strategic Area</th>
<th>Desired Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ordering</td>
<td>Flexibility. Allowing family orders with specification of size later in time. Order cancellation policies Order vetting.</td>
</tr>
<tr>
<td>Standardize aircraft design</td>
<td>Flexibility. Stronger second hand and leasing markets. Facilitate quick post-manufacture customization (custom color schemes).</td>
</tr>
<tr>
<td>From aircraft manufacturer to service provider</td>
<td>Fly-by-the-hour aircraft services. Capacity decisions made with a system wide view.</td>
</tr>
<tr>
<td>New aircraft family release timing.</td>
<td>Cycle dampening. Follow the reinvestment cycle.</td>
</tr>
<tr>
<td>Production capacity management.</td>
<td>Cycle dampening. Allow backlogs to build before new production facility is established.</td>
</tr>
<tr>
<td>Production and development costs (lean improvements)</td>
<td>Bullwhip reduction. Lower capacity costs and higher profit margins.</td>
</tr>
</tbody>
</table>
CA EoE Model Structural View
Two conceptual ways to dampen the CA EoE based on Manufacturer Constituents

**JIT Delivery:**
- + No requirement for collusion
- + Increasing barriers to entry
- - Depends on technical feasibility
- - Provides comparatively less ROIC

**Decoupling Capacity:**
- + No requirement for collusion
- + Provides very high ROIC
- - Attracts entrants
- - Depending on implementation, may increase fares
Results: Symbiotic Quadrants

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Definitions

EoE is a conceptual abstraction of an enterprise ecosystem

Strategic alternative is a specified action

Symbiotic strategic alternative is an action that improves total system performance by

(a) increasing the probability of survival for a majority of the EoE constituents; and

(b) without significantly compromising the long-term value delivered to any single constituent
Systems and Enterprises

Layers of systems (based on Hitchins 1994):

Layer 5 - *Socio-economic*. Principal lever of control is regulation.

Layer 4 - *Industry*. Complete and competitive supply chains.


Layer 2 - *Project*. The making of complex artifacts.

Layer 1 - *Product*. The making of tangible artifacts.

---

Socio-technical

<table>
<thead>
<tr>
<th>Complexity</th>
<th>Focus of:</th>
</tr>
</thead>
</table>
| Socio-technical | OR
| | SE
| | SA

<table>
<thead>
<tr>
<th>Technical/Mechanical</th>
<th>Traditional Engineering</th>
<th>SoS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authority</td>
<td>Unitary</td>
<td>Pluralist</td>
</tr>
</tbody>
</table>

Classification based on Jackson and Keys (1984)
From SoS to Enterprise of Enterprises

“organizations are purposeful systems which contain purposeful parts and which are themselves part of larger purposeful systems. Hence organizations have responsibilities to their own purposes, to the purposes of their parts, and to the purposes of the larger systems of which they are part.” (Jackson and Keys 1984)


• Operational Independence of the Constituent enterprises
• Managerial Independence of the Constituent enterprises
• Evolutionary Development
• Emergent Behavior
• Diversity of Interfaces

Distinct value functions of constituents from emergent global value
No obvious architect or point of leverage
Large system inertia
Loose coupling at interfaces

(tighter coupling EoE $\rightarrow$ Extended Enterprise (Nightingale 2004))
Loose coupling vs. Tight coupling
Scenarios

- S1: Global Village
- S2: Islands of Sufficiency
- S3: Growth and overshoot