Simulating the Dynamic Effects of Horizontal Mergers: U.S. Airlines

John Lazarev

New York University

May 19, 2016
Research Question
Background:

- Deregulated in 1978
- Several “distressed firm” mergers in mid-1980s
- No mergers for a long while
- Distressed firm mergers: ValuJet-AirTran 97; AA-TWA 01
- United-USAir, 2000 (blocked)
- Recent merger wave
  - USAir-America West 2005
  - Delta-Northwest 2008
  - United-Continental 2010
  - Southwest-Air Tran 2011
  - American-USAir 2013
Introduction

**Static merger evaluation:** Hold industry structure fixed and estimate short run price effect

- DOJ/FTC Merger guidelines: HHI’s, Diversion Ratios
- Differentiated Products Models
  - Berry and Pakes (1993), Berry, Levinson, and Pakes (1995), Nevo (2000), Hausman (various), etc
Conclusions from static analysis: by most historical standards these mergers would look pretty bad
### Table: Top 5 Routes by HHI Increase, Passengers Enplaned, 2008

#### DL-NW

<table>
<thead>
<tr>
<th>CSA1</th>
<th>CSA2</th>
<th># Top 10 Carriers Pre-Merger</th>
<th>HHI Passengers</th>
<th>Pre</th>
<th>Post</th>
<th>Chng</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVG</td>
<td>MSP</td>
<td>2</td>
<td>5066</td>
<td>9996</td>
<td>4930</td>
<td></td>
</tr>
<tr>
<td>CVG</td>
<td>DTW</td>
<td>2</td>
<td>4918</td>
<td>9830</td>
<td>4912</td>
<td></td>
</tr>
<tr>
<td>ATL</td>
<td>FLL, MIA</td>
<td>2</td>
<td>5230</td>
<td>9993</td>
<td>4763</td>
<td></td>
</tr>
<tr>
<td>MSP</td>
<td>SLC</td>
<td>2</td>
<td>3526</td>
<td>6558</td>
<td>3032</td>
<td></td>
</tr>
<tr>
<td>BUR, LAX, ONT, SNA</td>
<td>HNL</td>
<td>5</td>
<td>3520</td>
<td>6292</td>
<td>2772</td>
<td></td>
</tr>
</tbody>
</table>

#### UA-US

<table>
<thead>
<tr>
<th>CSA1</th>
<th>CSA2</th>
<th># Top 10 Carriers Pre-Merger</th>
<th>HHI Passengers</th>
<th>Pre</th>
<th>Post</th>
<th>Chng</th>
</tr>
</thead>
<tbody>
<tr>
<td>OAK, SFO, SJC</td>
<td>PHL</td>
<td>2</td>
<td>5348</td>
<td>9999</td>
<td>4651</td>
<td></td>
</tr>
<tr>
<td>CLT</td>
<td>DEN</td>
<td>2</td>
<td>5893</td>
<td>10000</td>
<td>4107</td>
<td></td>
</tr>
<tr>
<td>BUR, LAX, ONT, SNA</td>
<td>PHL</td>
<td>2</td>
<td>6155</td>
<td>9989</td>
<td>3834</td>
<td></td>
</tr>
<tr>
<td>CLT</td>
<td>MDW, ORD</td>
<td>3</td>
<td>4250</td>
<td>7690</td>
<td>3440</td>
<td></td>
</tr>
<tr>
<td>BWI, DCA, IAD</td>
<td>MSY</td>
<td>3</td>
<td>3617</td>
<td>6876</td>
<td>3259</td>
<td></td>
</tr>
</tbody>
</table>

#### UA-CO

<table>
<thead>
<tr>
<th>CSA1</th>
<th>CSA2</th>
<th># Top 10 Carriers Pre-Merger</th>
<th>HHI Passengers</th>
<th>Pre</th>
<th>Post</th>
<th>Chng</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLE</td>
<td>DEN</td>
<td>2</td>
<td>5414</td>
<td>9988</td>
<td>4574</td>
<td></td>
</tr>
<tr>
<td>DEN</td>
<td>HOU,IAH</td>
<td>3</td>
<td>3500</td>
<td>5889</td>
<td>2389</td>
<td></td>
</tr>
<tr>
<td>DEN</td>
<td>EWR, JFK, LGA</td>
<td>4</td>
<td>3443</td>
<td>5223</td>
<td>1780</td>
<td></td>
</tr>
<tr>
<td>BWI, DCA, IAD</td>
<td>CLE</td>
<td>3</td>
<td>3784</td>
<td>5058</td>
<td>1274</td>
<td></td>
</tr>
<tr>
<td>HOU,IAH</td>
<td>MDW,ORD</td>
<td>4</td>
<td>3053</td>
<td>4296</td>
<td>1243</td>
<td></td>
</tr>
</tbody>
</table>
Introduction

What about dynamics?

Many possibilities:

➤ Offsetting entry by other existing carriers
➤ Or smaller carriers get crowded out by more powerful merged carrier
➤ How will merged carrier behave?
  ➤ More efficient: might enter formerly unserved routes, prices could fall
  ➤ Alternatively, merger might create redundancies/cause exit
➤ Secondary concerns:
  ➤ Quality of service
  ➤ On-time performance

Can we use past data to inform us about which of these might happen?
Introduction

Question of paper: Dynamic merger evaluation

At the time merger is proposed, what can we learn from the data about potential longer term effects?

Specifically, how will the world look different in 10 years?

- Empirical literature sparse on longer run effects
- Hope to generate methods useful in other markets too
- Potentially very complex problem
Method
General Framework

Notation/Framework: Imagine a dynamic game with Markov properties: (EP(1995)/BBL)

- **States:** \( s_t \in S \subset R^G \), commonly known
- **Actions:** \( a_{it} \in A_i \), simultaneously chosen
- **Private Information:** \( \nu_{it} \sim iid \ G(\cdot | s_t) \)

MPE strategies: \( a_i = \sigma_i(s, \nu_i) \)

Note: iid assumption not great.
**Airline Model**

**E.g., Model of airline route segment presence:**

- Air transport network with $K$ cities.
- Nonstop flight “segment”: $j \in \{1, \ldots, J\}$ where $J = K(K - 1)/2$
- Fixed number, $A$, of airlines (no new airline entry)
- Network for airline $i$: $n_{it} \in \{0, 1\}^J$
  (no extent/quality of service)
- “Route Network”: $N_t$, $J \times A$ matrix
- List of profit shifters for every route segment: $Z_t$
- Shocks to cost ($\omega_{it}$) and demand ($\epsilon_{it}$)
In the airline model:

- Commonly known state variable ($s_t$) is current route network for everyone, and vector of profit shifters: $(N_t, Z_t)$
- Action $a_{it}$ for airline $i$ is 1770-vector of route segment entry decisions: $n_{it}$
- Private shocks are $(\omega_{it}, \epsilon_{it})$
- MPE strategy functions:
  \[
  n_{i}^{t+1} = \sigma_i(N_t, Z_t, \omega_{it}, \epsilon_{it}).
  \]
- Underlying is potentially rich dynamic model with primitives for static demand/costs (whole network), and entry/exit.
Methodology

Main alternative:

- Completely specify dynamic oligopoly model (entry, exit, investment, etc)
- Estimate all parameters of this model imposing eq conditions
- Compute MPE under alt. policy regimes

May be useful, but difficult/impossible
Proposed method: Using data on past outcomes,

1. Estimate the “reduced form” choice distributions,
\[ Pr(a_i|s_t) \]

2. Estimate state transition function,
\[ P(s_{t+1}|a_t, s_t) \]

- Not necessarily the same as estimating strategy functions
- Underlying model could be very complex and have multidimensional unobserved shocks
Methodology

The main assumption:

Assumption 1  The same Markov perfect equilibrium profile, $\sigma$, is played for all $t$, whether or not the merger of interest takes place.

Need to hold policy environment fixed:

- If merger approval/nonapproval signals a change in anti-trust policy, then MPE strategies could change
- Any other contemporaneous policy changes will also be problematic

Recall: Industry structure is endogenous, and equilibrium strategy profile is defined for any number of firms
Methodology

As long as this assumption holds:

- the first stage estimates completely determine the future distribution of states and actions:

\[ P((a_{t+1}, s_{t+1}), \ldots, (a_{t+r}, s_{t+r})|a_t, s_t), \text{ for all } r \]

whether or not merger occurs.

- Merger is simply a change in the starting state, \( s_t \)

- Use estimates of choice distributions and transition probabilities to simulate future distribution of states and actions above

Note: Turns computational problem into a data problem. Require enough past data to fully identify choice distributions in all circumstances of interest.
Estimation

For the airline model, the choice distributions are:

\[ Pr(n_{i}^{t+1} \mid N_t, Z_t) \quad \text{for all } i \]

- Complex high dimensional object, many Y’s, X’s
- Handle this using “big data” techniques, LASSO, ANN
- Instead of putting \((N_t, Z_t)\) in explicitly, make informed choices of variables (“features”) to include
- Estimation based on a Probit model
- Also experiment with correlation in Probit errors
Main data source: T100S “segment” data
- All nonstop flights by quarter, airline, plane type, includes seats and enplaned passengers.
- Period: 2003-2008
- Top 75 airports by enplaned passengers
- Aggregated to CSA level: Top 60 CSA’s
- Smallest CSA’s: Anchorage, Albany, Norfolk, Boise
- 1770 segments and markets
- 10 major airlines, plus 2 groups of small carriers
- Entry/exit definitions
- Regional carriers
- Supplement with T100M, DB1B
- American Travel Survey (1995), Census
Table: Examples of “features”

<table>
<thead>
<tr>
<th>Regressor</th>
<th>Avg</th>
<th>SD</th>
<th>Min</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pop1*Pop2 (*1e-12)</td>
<td>8.46</td>
<td>17.6</td>
<td>0.030</td>
<td>1.49</td>
<td>3.40</td>
<td>8.30</td>
<td>350</td>
</tr>
<tr>
<td>Pop1*Pop2 (*1e-12) * 2002 Dens=0</td>
<td>0.82</td>
<td>3.24</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.341</td>
<td>82.0</td>
</tr>
<tr>
<td>Log 2002 Passenger Density</td>
<td>7.62</td>
<td>5.60</td>
<td>0</td>
<td>0</td>
<td>10.7</td>
<td>12.6</td>
<td>16.0</td>
</tr>
<tr>
<td>Percent Tourist</td>
<td>0.37</td>
<td>0.35</td>
<td>0</td>
<td>0</td>
<td>0.33</td>
<td>0.67</td>
<td>1</td>
</tr>
<tr>
<td>Num Big 3 Comps.</td>
<td>2.06</td>
<td>0.92</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Num Other Major Comps.</td>
<td>1.70</td>
<td>1.04</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Southwest Competitor</td>
<td>0.48</td>
<td>0.50</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Num Oth. Low Cost Comps.</td>
<td>0.422</td>
<td>0.58</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Num Oth. Comps.</td>
<td>0.3</td>
<td>0.46</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Number Nonstop Comps</td>
<td>0.78</td>
<td>0.99</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Number One-Stop Comps</td>
<td>3.52</td>
<td>1.97</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Number Other Major Comps</td>
<td>1.70</td>
<td>1.04</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Num Oth. Low Cost Comps.</td>
<td>0.422</td>
<td>0.58</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Num Oth. Comps.</td>
<td>0.3</td>
<td>0.46</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Number Nonstop Comps</td>
<td>0.78</td>
<td>0.99</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Number One-Stop Comps</td>
<td>3.52</td>
<td>1.97</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Number Other Major Comps</td>
<td>1.70</td>
<td>1.04</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Num Oth. Low Cost Comps.</td>
<td>0.422</td>
<td>0.58</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Num Oth. Comps.</td>
<td>0.3</td>
<td>0.46</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>HHI Among Others (Market)</td>
<td>4869</td>
<td>4445</td>
<td>0</td>
<td>0</td>
<td>5085</td>
<td>9993</td>
<td>10000</td>
</tr>
<tr>
<td>HHI Among Others Large (City)</td>
<td>3377</td>
<td>1762</td>
<td>49</td>
<td>2018</td>
<td>3030</td>
<td>4200</td>
<td>8933</td>
</tr>
<tr>
<td>HHI Among Others Small (City)</td>
<td>1695</td>
<td>889</td>
<td>6</td>
<td>1200</td>
<td>1561</td>
<td>2023</td>
<td>7861</td>
</tr>
<tr>
<td>Own Share Large (City)</td>
<td>0.15</td>
<td>0.17</td>
<td>0</td>
<td>0.0367</td>
<td>0.089</td>
<td>0.19</td>
<td>0.94</td>
</tr>
<tr>
<td>Own Share Small (City)</td>
<td>0.05</td>
<td>0.06</td>
<td>0</td>
<td>0.0001</td>
<td>0.027</td>
<td>0.06</td>
<td>0.83</td>
</tr>
<tr>
<td>Present in Segment</td>
<td>0.09</td>
<td>0.29</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Present in Market (not Segment)</td>
<td>0.41</td>
<td>0.49</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Present at One Airport (not Both)</td>
<td>0.23</td>
<td>0.42</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Present at Both Airports (not Market)</td>
<td>0.27</td>
<td>0.44</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>One Hub</td>
<td>0.135</td>
<td>0.34</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Both Hubs</td>
<td>0.004</td>
<td>0.07</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Number of Hubs</td>
<td>0.15</td>
<td>0.37</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Hub Conv (NS dist/OS dist)</td>
<td>0.76</td>
<td>0.28</td>
<td>0.01</td>
<td>0.57</td>
<td>0.89</td>
<td>0.99</td>
<td>1</td>
</tr>
<tr>
<td>Dist Nearest Hub Small</td>
<td>440</td>
<td>489</td>
<td>0</td>
<td>119</td>
<td>286</td>
<td>553</td>
<td>4679</td>
</tr>
<tr>
<td>Dist Nearest Hub Large</td>
<td>1180</td>
<td>932</td>
<td>0</td>
<td>495</td>
<td>857</td>
<td>1797</td>
<td>4756</td>
</tr>
<tr>
<td>Log Pass. Dens. New Markets</td>
<td>2.63</td>
<td>4.46</td>
<td>0</td>
<td>0</td>
<td>5.2</td>
<td>15.8</td>
<td>53</td>
</tr>
<tr>
<td># Nonstops Small (City)</td>
<td>2.28</td>
<td>3.10</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>53</td>
</tr>
<tr>
<td># Nonstops Large (City)</td>
<td>8.38</td>
<td>11.8</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>56</td>
</tr>
</tbody>
</table>
Estimation

- Most important variables:
  1. Route presence
  2. Competition
  3. Own Share Lg & # Nonstops Lg

- Endogeneity has big impact on comp vars
- Next: fit is outstanding, not much variation left to explain
Merger Simulations

Simulating the U.S. airline route network:
1. Start at state $s_0$ (different for each scenario)
2. Take draws on entry/exit for every segment conditional on $X$’s
3. Update dynamic $X$’s for every market
4. Move to next period and repeat steps 2-3
Merger Simulations

- Simulate industry under four scenarios:
  1. No merger
  2. Delta-Northwest
  3. United-USAir
  4. United-Continental

- (All scenarios assume US Air-America West merger.)
- Difference in scenarios is starting value of state variables
Results
Merger Simulations

Aggregate U.S. market findings:

- Merged carrier expands more than no-merger case
  - Cost efficiency or demand?
- Aggregate response by other carriers is small:
  - SW & AL crowded out by DL-NW
  - AL & JB more entry under UA-US
  - SW & DL crowded out by UA-CO
Aggregate U.S. market findings (cont):

- Base case has market less concentrated in 10 yrs
- DL-NW:
  - Initially: 3 extra monopoly markets but in 10 years: 1
  - Many more duopoly and triopoly markets
- UA-US:
  - Initially: 3 extra monopoly markets but in 10 years: 0
  - More duopoly and triopoly markets
- UA-CO:
  - One less monopoly market initially and long run
  - More duopoly and triopoly markets
Merger Simulations

Worst case cities:

- In many cases entry response to merger is small (DL-NW, UA-CO)
- Sometimes there is an entry response (UA-US)
Merger Simulations

Worst case routes, DL-NW:

- 11 routes flown by both carriers
- Of these, 6 are 2→1
  - None of these have new entry in 10 yrs.
- 2 are 4→3, 2 are 5→4, 1 is 6→5
  - All of these routes have new entry within 10 yrs
- Reason: realistic set of potential entrants
- Five routes (SLC→IND, MEM→RSW, MEM→SLC, MKE→SLC, CVG→HNL) have large increases in prob of gaining nonstop service
Worst case routes, UA-US:

- 38 routes flown by both carriers
- Of these, 5 are 2→1
  - All except one (PHL→DEN) have significant chance (>0.5) of offsetting entry
- Rest: often offsetting entry
- No routes gain service
Merger Simulations

Worst case routes, UA-CO:

- 16 routes flown by both carriers
- 1 is 2→1 (CLE→DEN) and it shows no offsetting entry
- 4 are 3→2 and half of these show significant chance of offsetting entry
- Rest: often offsetting entry, but not always
- No routes gain service
Conclusions

- Simple, data driven, approach
- Big data techniques
- Consistent with rich underlying model, without need to estimate structural parameters of such a model

Main Drawbacks:

- Requires assumption about stability of policy regime and general environment
- Relatively high data requirement
- Difficult to handle serially correlated unobservables
Conclusions

- Empirical findings:
  - Dynamic analysis leads to different conclusions than static analysis
  - All three mergers look better in 10 years than static analysis
  - UA-US (blocked) looks much better after 10 years, perhaps best of three

- Value of new service?

- To do list: AA-US, retrospective analysis