Price Competition and Endogenous Product Choice in Networks: Evidence from the U.S. Airline Industry

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Motivation: Repositioning in markets

- Mergers may lead to higher prices and lower consumer surplus
  - main concern of antitrust authorities in merger review
- Network industries: merger can lead to entry/exit
  - here: airline mergers (from 9 to 4 major firms in < 10 years)
- Entry/exit can attenuate or exacerbate consumer harm:
  - (+) network expansion of merged entity
  - (+) post-merger entry of rivals
  - (−) merged entity reduces network
  - (−) rivals exit, can no longer compete with merged entity
- Need a model of entry, supply, and demand for the airline industry

Challenge: Spillovers

- Endogenizing entry in supply/demand for airline industry is challenging
- Airlines can serve markets by connecting cities via common hub
- Hub-and-spoke operations generate synergies across markets
  - increase demand
  - generate marginal cost savings
  - increase coordination costs
  - increase fixed costs
- Due to these synergies, the presence of an airline in a market creates spillovers:
  - affects demand and marginal + fixed costs of products in other markets
  - affects the airline's decision to operate in neighbor markets

This paper

- Two-stage model:
    1. Airlines choose their network
    2. Firms compete in prices, consumers choose flights (nested logit)

- Application: US airline industry, American Airlines/US Airways merger

Main takeaways

- Significant spillovers on demand and supply side
  - Larger network increases willingness to pay, decreases marginal costs and increases fixed costs

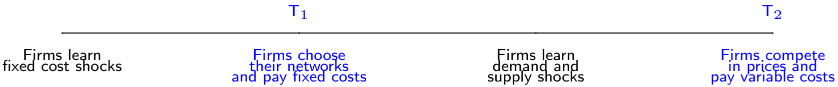
- American Airlines/US Airways merger raised consumer surplus by 4.44% but created tension between

  1. "old" and "new" markets
     - consumer surplus fell by 3.34% in markets served pre-merger
     - expansion of American/US led to overall increase in CS
  2. hub cities
     - consumers gained in Dallas, LA, Charlotte, DC, Philadelphia
     - consumers suffered in Chicago, Miami, New York, Phoenix

Model

Model: Overview

- N firms play a two-stage game



- Solve the game by working backward from 2nd stage

- Use Subgame Perfect pure strategy Nash Equilibrium

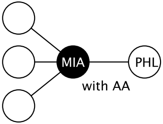
Model 2nd stage: Demand

- Nested Logit demand with 2 nests (airline products, outside option)
- Utility that individual gets from buying in market m

$$\text{product } j{:}U_{i,j,m} = X_{j,m}^{\top}\beta - \alpha P_{j,m} + \xi_{j,m} + \nu_{i,m}(\lambda) + \lambda\epsilon_{i,j,m} \quad (1)$$

$$\text{outside option } 0{:}U_{i,0,m} = \epsilon_{i,0,m} \quad (2)$$

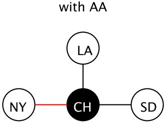
- $X_{j,m}$ includes # direct flights operated at origin by airline offering itinerary j



- Spillovers: demand in market m depends on entry in neighbour markets

Model: 2nd stage - supply - spillover effects

- Constant and linear marginal costs: $\text{MC}_{j,t} = W_{j,t}{}^{\top}\psi + \omega_{j,t}$
- **Spillovers in marginal costs**: $W_{j,t}$ can depend on entry decisions in other markets
- Include in $W_{j,t}$ # of destinations reachable from endpoints and intermediate stops



product 1 in market NY–SD: NY–CH–SD by AA
product 2 in market NY–LA: NY–CH–LA by AA

- economies of density
- NY-CH-SD by AA shares leg with NY-CH-LA by AA, where CH is hub
- traffic in NY-CH leg is higher because it pools passengers of both itineraries
- this reduces marginal costs of both itineraries due to economies of density
- the denser AA's hub, the lower the marginal costs of offering flights at the hub

Model 1st stage: Fixed costs

- Firms form networks to maximize expected 2nd stage profits minus fixed costs
- Airlines pay fixed costs to maintain physical, technological, human infrastructures
- Hub-and-spoke network may increase fixed costs
  - risk of congestion at hubs: many flights have to be coordinated
- Fixed costs of firm f are given by

$$\mathsf{FC}_f = \sum_{\{a,b\}} G_{ab,f} \underbrace{(\gamma_{1,f} + \eta_{ab,f})}_{\substack{\text{baseline fixed cost} \\ \text{from serving } ab}} + \sum_{h \in \mathcal{H}_f} \underbrace{\gamma_{2,f} \left(\sum_{\substack{a \in \mathcal{C} \\ a \neq h}} G_{ha,f} \right)^2}_{\substack{\text{congestion cost} \\ \text{at hub } h}},$$

  - $G_{ab,f} = 1$ if f offers direct service between a and b
  - $\eta_{ab,f}$: mean-zero fixed cost shock
  - Spillovers: fixed costs in market m depends on entry in other markets

Identification and estimation

- Second stage
  - Timing of choices allows to follow standard supply/demand model techniques
  - Estimation by GMM
- First stage
  - Possibility of multiple equilibria
  - Impossibility of detailing all the alternative solutions
  - Problem of selection because the firms observe their FC shocks but not the econometrician

Identification of the first stage

- Necessary conditions for PSNE to bound γ (Pakes 2010; Pakes & al. 2015)
- Idea: firm f offers ab if and only if it is profitable to do so:

$$\Pi_f(G_f, G_{-f}) - \Pi_f(G_{f,-ab}, G_{-f}) - \left[FC_f(G_f) - FC_f(G_{f,-ab})\right] \geqslant 0$$

- Selection issue: fixed cost shock known by firms when choosing networks
- Get rid of selection issue by introducing selectors (Wollmann 2018)
  - Large hub markets: almost always served
  - "Legacy routes": served since pre-deregulation
  - Connections to far away hub: almost never served

Empirical application

Empirical application: Data

- Airline Origin and Destination Survey
- 10% random sample of all tickets issued in U.S. during 2nd quarter of 2011
- 85 largest MSAs
- United, Delta, American, US Airways, Southwest
- Other competitors in Low Cost Carriers, Others [details]
    - fringe competitors, exogenous networks

[statistics]

Empirical application: 2nd stage results

Utility			Marginal Cost		
	Coefficient	SE		Coefficient	SE
Mean utility			**Short-haul flights**		
Intercept	-5.598	(0.262)	Intercept	3.118	(0.09)
Price	-0.587	(0.066)	Stops	0.031	(0.028)
Stops	-1.794	(0.066)	Distance	0.474	(0.037)
Connections	0.868	(0.032)	Presence	-1.245	(0.136)
Distance	0.289	(0.084)	**Long-haul flights**		
Squared distance	-0.093	(0.095)	Intercept	3.703	(0.114)
Nesting parameter (λ)	0.623	(0.025)	Stops	-0.189	(0.041)
			Distance	0.667	(0.032)
			Presence	-2.016	(0.145)
Statistics					
J-statistic	15.627				
Number of products	17,481				

Prices are divided by $100. Connections and Presence are divided by 100. City fixed effects are included. The number of over-identifying restrictions is 11.

Empirical application: 1st stage results

Table 1: Projection of identified set

	Estimated set		95% CR	
Variable	Lower Bound	Upper Bound	Lower Bound	Upper Bound
Intercept	655,320	1,029,767	579,159	1,266,119
Congestion costs				
American	8,373	28,278	6,758	31,359
Delta	6,187	22,133	6,187	24,472
United	5,451	13,147	4,804	13,147
US Airways	23,527	34,482	23,527	36,634
Southwest	20,641	31,374	20,641	34,476

Note: Entry costs are in $

Counterfactuals

Overview

- AA and US expressed intention to merge in January 2012 (after sample period)
- DoJ sought to block the merger and a settlement was reached in November 2013
- One remedy: do not reduce level of operations at several hubs
  - CLT, JFK, LAX, MIA, ORD, PHL, PHX
- Procedure: take 50 draws from identified set, consider different market and firm orderings (400 runs in total)
- Scenarios: Merger without remedies, with remedies, with PHX dehubbed

The merger increased consumer surplus, but...

Table 2: Outcomes across different scenarios

	Before	**Merger**			
		Network fixed	Network varies		
			Without remedies	With remedies	PHX dehubbed
Total	2807.06	+0.08 [-0.47, +3.4]	+5.97 [+4.09, +7.38]	+6.66 [+4.31, +7.99]	+3.85 [+1.81, +5.08]
Mean	4.09	+0.08 [-0.47, +3.4]	+4.44 [+2.45, +5.69]	+5.1 [+2.81, +6.28]	+2.47 [+0.49, +3.63]
Markups: American	119.2	+7.34 [+5.98, +8.64]	+15.49 [+14.07, +16.4]	+15.97 [+13.59, +16.86]	+14.61 [+13.16, +15.6]
Markups: Others	116.22	-0.45 [-0.68, +0.07]	-1.95 [-2.21, -1.59]	-2.15 [-2.39, -1.52]	-1.48 [-1.73, -1.14]
Segments: American	430	430	556 [526, 581]	576 [528, 597]	521 [493, 544]
Segments: Others	736	736	689 [656, 703]	690 [654, 712]	693 [658, 707]

Note: Consumer surplus is computed using the log-sum formula and it is in USD 1 million up to constant of integration. Mean consumer surplus is total consumer surplus divided by the number of markets out of hubs. Percentage differences with respect to Before are reported.

[consumer surplus formula]

…consumer surplus decreased in "old markets"…

Table 3: Percentage changes in consumer surplus

	W/o remedies	**With remedies**	**PHX dehubbed**
New markets	52.57 [45.99, 56.39]	52.41 [46.13, 56.7]	50.78 [44.69, 54.34]
Old markets	-3.34 [-4.97, -2.78]	-3.05 [-4.75, -2.53]	-3 [-4.77, -2.28]

... and the impact differs greatly across hubs.

Table 4: Change in consumer surplus at hub airports of merging firms

	Pre-merger	Post-merger			
		Networks fixed	Networks vary		
			w/o remedies	with remedies	PHX dehubbed
AA hubs					
DFW	341.22	-1.48	+5.85	+5.86	+4.8
LAX	520.29	+0.01	+15.43	+15.14	+12.78
ORD	485.16	+0.46	-7.18	-7.17	-7.52
MIA	314.55	-0.34	-23.48	-16.87	-24.39
JFK	631.27	-0.3	-5.03	-5.02	-8.68
US hubs					
CLT	134.27	-1.52	+13.45	+13.43	+6.31
PHX	237.55	-0.64	-17.98	-17.97	-30.83
DCA	428.19	-0.29	+24.57	+24.57	+20.92
PHL	213.55	-0.91	+15.86	+15.85	+12.75

Note: Consumer surplus is computed using the log-sum formula and it is in USD 1 million up to constant of integration. Mean consumer surplus is total consumer surplus divided by the number of markets out of hubs. Percentage differences with respect to Before are reported.

Conclusion

Conclusion

- Methodological contribution
  - model of network formation, demand, and supply
  - inference
  - applicable to other "network industries" in addition to airlines
- Empirical contribution
  - endogenous networks matter
  - tension between consumer surplus gains due to network expansion and losses due to increased market power
- Future research: dynamics, slot constraints, capacity/frequency

Appendix

Appendix: Identification 1st stage: Instruments

Markets that are served by direct flights
All firms: no hub, served since deregulation, serves both endpoints
AA: hub, size $>$ 6 million, serves both endpoints
DL: hub, size $>$ 6 million, serves both endpoints
UA: hub, size $>$ 6 million, serves both endpoints
US: hub, size $>$ 5 million, serves both endpoints
WN: hub, size $>$ 6 million, serves both endpoints
Markets that are not served by direct flights
All firms: no hub, other firm has hub, serves both endpoints
American: hub, one of three furthest hubs, serves both endpoints
Delta: hub, furthest hub, serves both endpoints
United: hub, one of three furthest hubs, serves both endpoints
US Airways: hub, furthest hub, serves both endpoints
Southwest: hub, furthest hub, serves both endpoints

Appendix: Model 1st stage: Hubs

AA	DL	UA	US	WN
Dallas	Atlanta	Washington DC	Charlotte	Washington DC
New York	Cincinnati	Denver	Washington DC	Denver
Los Angeles	Detroit	Houston	Philadelphia	Houston
Miami	New York	New York	Phoenix	Las Vegas
Chicago	Memphis	Los Angeles		Chicago
	Minneapolis-Saint Paul	Chicago		Phoenix
	Salt Lake City	San Francisco		

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Appendix: Empirical application: LCC and Other

LCC	Other
Frontier Airlines	AirTran Airways
Alaska Airlines	USA3000 Airlines
Spirit Airlines	
Jetblue Airlines	
Virgin America	
Sun County Airlines	
Allegiant Air	

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Appendix: Introduction: Mergers

Mergers
American Airlines + Trans World Airlines (2001)
US Airways + American West (2005)
Delta Airlines + Northwest Airlines (2008)
United Airlines + Continental Airlines (2010)
Southwest Airlines + AirTran (2010)
American Airlines + US Airways (2013)
Bankruptcies
US Airways (2002-2003)
United Airlines (2002-2006)
US Airways (2004-2005)
Northwest Airlines (2005-2007)
Delta Airlines (2005-2007)
American Airlines (2011-2013)

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Appendix: Summary statistics

Sizes		
Number of firms	7	
Number of products	17,481	
Number of markets	3,146	
Fraction of direct flights	0.14	
Fraction of hub itineraries	0.83	
Fraction of direct passengers	0.85	
Fraction of passengers in hub markets	0.57	
Fraction of markets served	0.93	
Passengers by airline (1 million)		
Total	25.33	
AA	3.15	
DL	4.85	
UA	3.81	
US	2.21	
WN	6	
LCC	4.1	
Other	1.21	
Network statistics	**Mean**	**St.dev**
Degree (hub)	49.86	13.03
Density (hub)	0.61	0.16
Clustering (hub)	0.24	0.14
Degree (non-hub)	7.21	7.72
Density (non-hub)	0.09	0.09
Clustering (non-hub)	0.8	0.33

Hub itineraries are itineraries where at least one of the endpoints or intermediate stops is a hub. Hub markets are markets where at least one of the endpoints is a hub. The degree of a hub is the number of spokes. The density of a hub is the ratio between the number of spokes and the total number of potential markets out of the hub. The clustering coefficient of a hub is the ratio between the number of triplets of cities including the hub served by direct flights and the total number of potential triplets of cities including the hub. The degree, density, and clustering coefficient of non-hubs are defined similarly.

Appendix: Summary statistics (ctd)

Demand and marginal cost variables	Mean	St.dev
Price ($100)	4.32	1.2
Stops	0.86	0.34
Connections (100)	0.2	0.19
Presence (100)	0.56	0.15
Distance (100 km)	1.44	0.68
Product share	4.6083e-04	1.4784e-03
Market size (1 million)	2.55	1.85
Market-level statistics	**Mean**	**St.dev**
Number of firms	3.59	1.81
Number of products	5.56	4.43
Number of direct flights	0.75	1.2
Number of hub itineraries	4.62	3.43
Number of passengers (1,000)	8.05	24.43
Number of direct passengers (1,000)	6.82	23.98
Number of passengers in hub markets (1,000)	4.6	15.39

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Merger AA and US: consumer surplus formula

- Log-sum formula

- Consumer surplus in market t is given by

$$CS_t = \frac{1}{\alpha} \log \left(1 + \lambda \log \Big(\sum_{j=1}^{J_t} \frac{\exp\left(X_{j,t}^\top \beta - \alpha P_{j,t} + \xi_{j,t}\right)}{\lambda} \Big) \right) M_t$$

- We can average this consumer surplus across markets

- Small & Rosen (1981), Durrmeyer & Samano (2017)

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