Tracing the Woes

An Empirical Analysis of the Airline Industry

Steven Berry & Panle Jia
(AER 2010)

Park Sinchaisri
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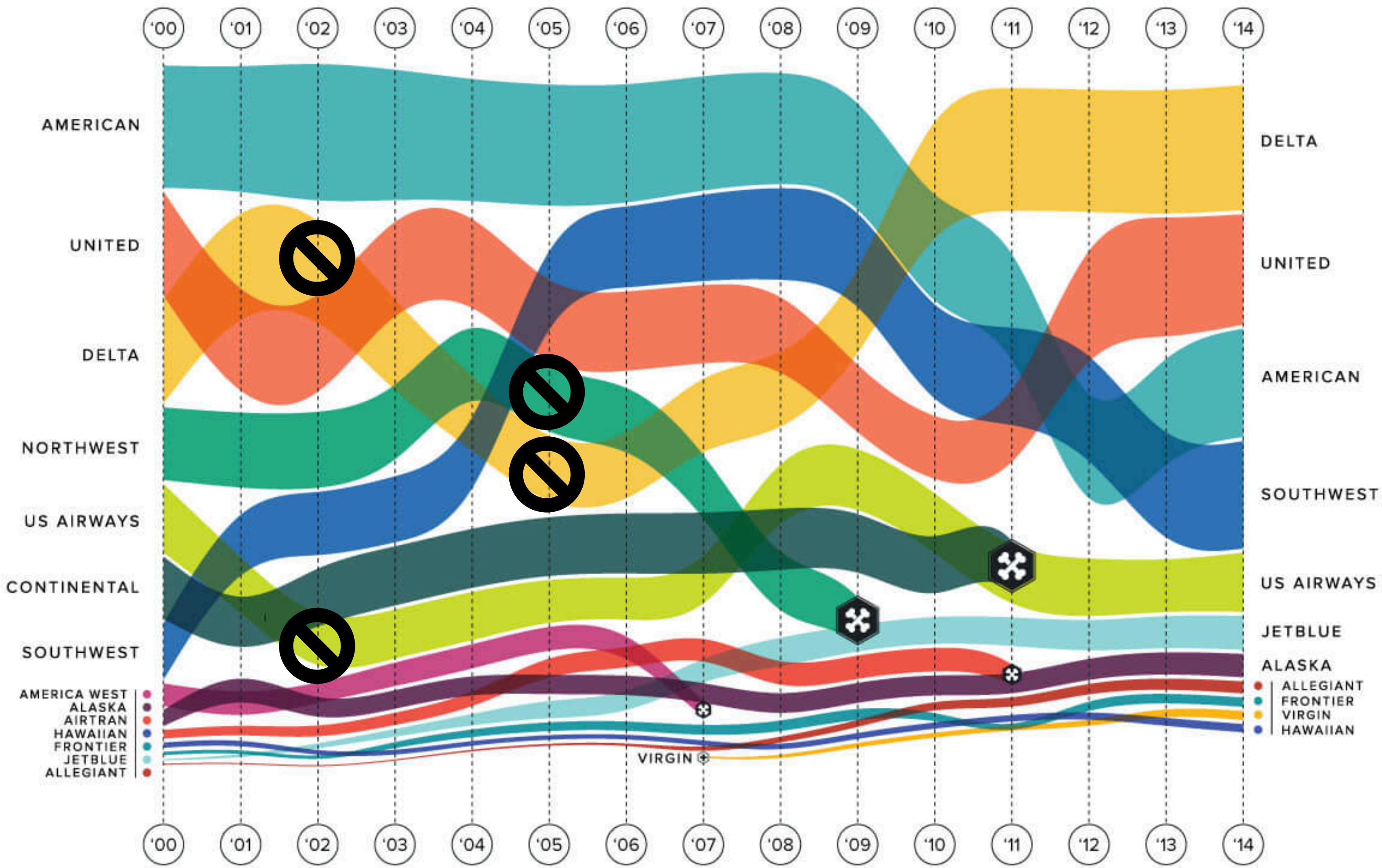
Airline industry in early 2000’s



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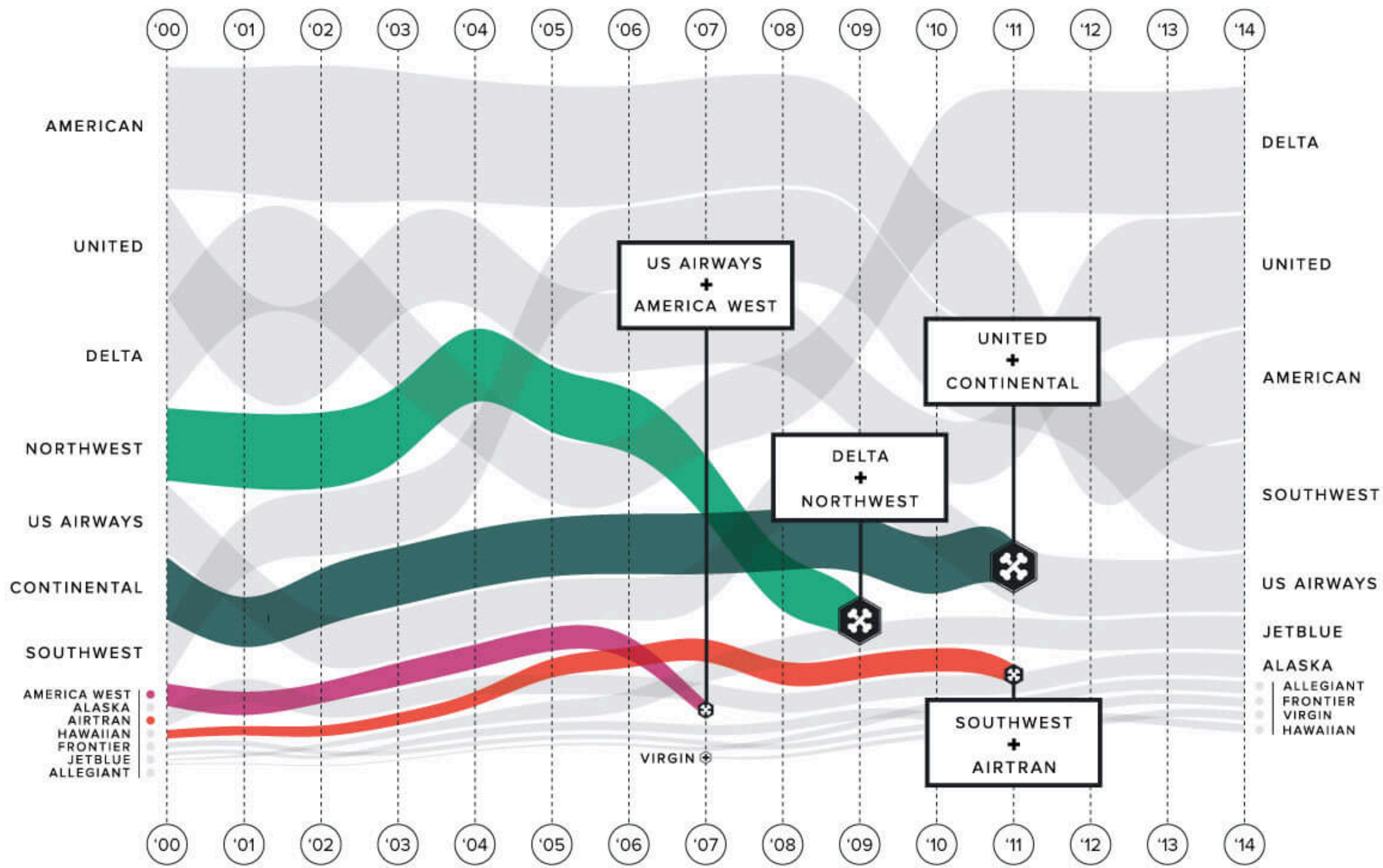

What caused financial stress?

Despite more passengers traveling and fuller planes...

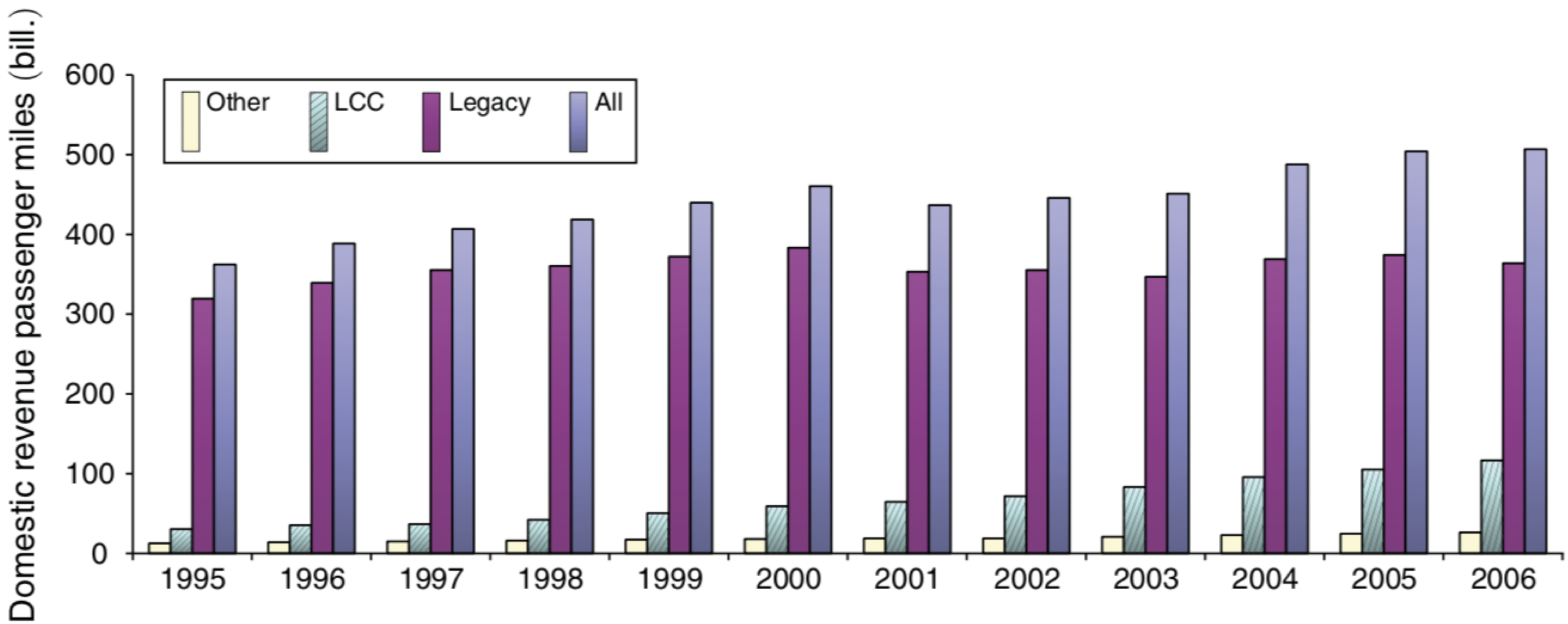

FIGURE 1. DOMESTIC REVENUE PASSENGER MILES (*in billions*)

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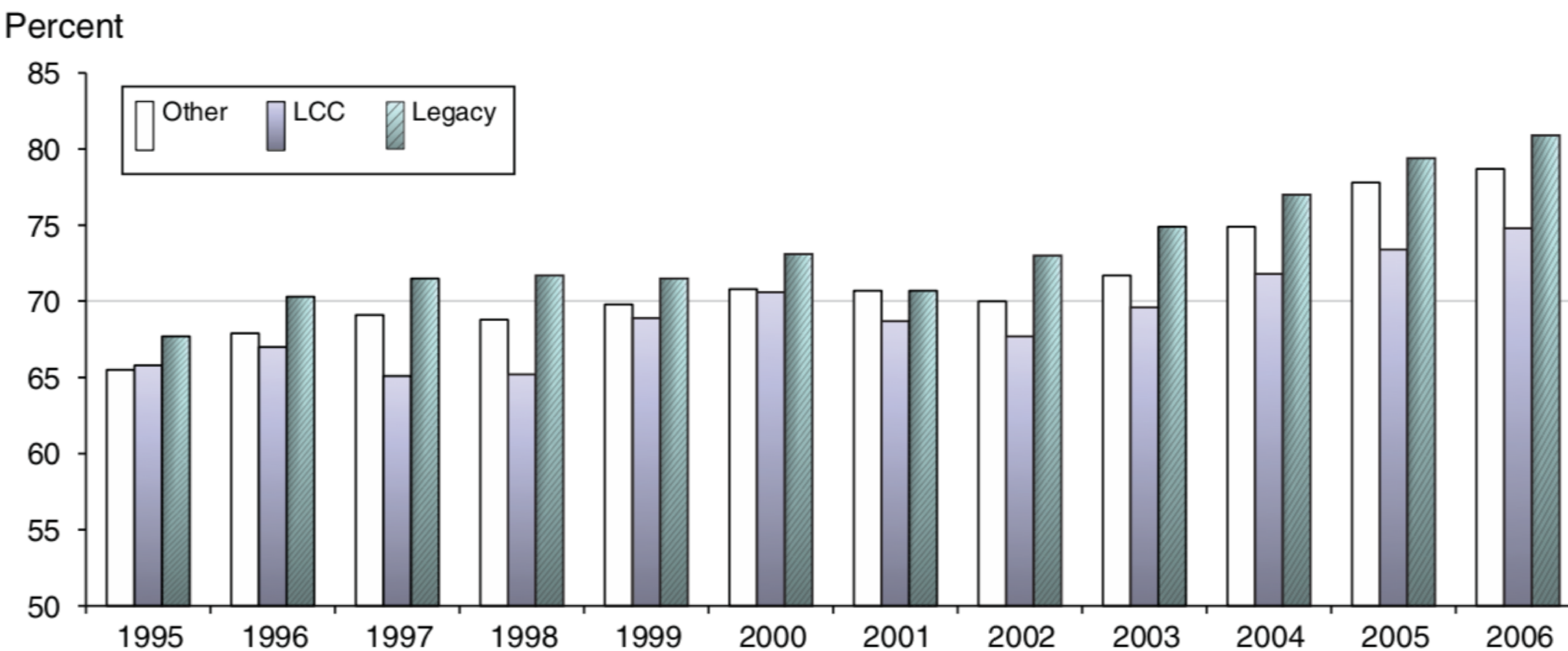

FIGURE 2. US AIRLINES' SYSTEM LOAD FACTORS

What caused financial stress?

Despite more passengers traveling and fuller planes...

Changes in...

Demand

- Easier to search
- Lower WTP
- Reimbursement limits
- Tightened security regulations

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Supply

- Expansion of LCCs (lower fares, competing services)
- Regional jets
- Lower labor costs

Berry & Jia 2010

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- Estimates structural model of US airline industry
- Disentangles impact of demand and supply changes on profitability of *legacy carriers*, comparing 1999 and 2006
- Results:
  - Demand for air travel 8% more price sensitive
  - 17% stronger preference for direct flights
  - Marginal costs significantly lower for direct flights
  - Consider the entry of LCCs

Agenda

- Model: demand, market share, marginal cost
- Data
- Empirical model
  - Instruments
- Results: demand, marginal cost
  - Robustness checks, marginal effects
- Counterfactual

Model: Demand

- Simple random-coefficient discrete-choice *(McFadden '81, BLP '95)*
- Discrete-type: *R* types of consumers *(BCS '06)*
- Utility of *i* buying *j* in market *t:*

taste for characteristics

nested logit random taste

$$u_{ijt} = x_{jt}\,\beta_r - \alpha_r\, p_{jt} + \xi_{jt} + \nu_{it}(\lambda) + \lambda \epsilon_{ijt}$$

marginal disutility of price increase

nested logit parameter: [0,1]

unobserved product characteristics

- Utility of outside goods:

$$u_{iot} = \epsilon_{i0t},$$

Model: Demand

- **Error structure** is assumed to follow distributional assumptions for classic nested logit
- **2 nests:** all airline products vs outside option (not flying)

$$u_{ijt} = x_{jt}\beta_r - \alpha_r p_{jt} + \xi_{jt} + \boxed{\nu_{it}(\lambda) + \lambda\epsilon_{ijt}}$$

- $\lambda = 0$: i.i.d. errors have no effect
- $\lambda = 1$: $\nu = 0$, P(buy) = simple MNL
- Else, shares have traditional nested logit form

Model: Market share

% of type ***r*** who purchase ***j*** in ***t***

$$s_{jt}(x_t, p_t, \xi_t, \theta_d) \equiv \sum_r \gamma_r \boxed{\frac{e^{(x_{jt}\beta_r - \alpha_r p_{jt} + \xi_{jt})/\lambda}}{D_{rt}}} s_t^r(x_t, p_t, \xi_t, \theta_d)$$

% type ***r*** in population

share of type ***r*** who make a purchase

$$D_{rt} = \sum_{k=1}^{J} e^{(x_{kt}\beta_r - \alpha_r p_{kt} + \xi_{kt})/\lambda}$$

$$s_t^r(x_t, p_t, \xi_t, \theta_d) \equiv \frac{D_{rt}^{\lambda}}{1 + D_{rt}^{\lambda}}$$

Demand parameters to be estimated ($\boldsymbol{\theta}$): tastes for product characteristics, disutility of price, nested logit λ, type-probability γ

Model: BLP/BCS method

- Form moments that are expectations of unobservable ξ interacted with exogenous instruments
- Invert market share, solve for demand unobservables

$$\xi_t = s^{-1}\left(x_t, p_t, s_t, \theta_d\right)$$

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$$\xi_t = s^{-1}(x_t, p_t, s_t, \theta_d)$$

- Slightly modify contraction mapping

$$\xi_{jt}^{M} = \xi_{jt}^{M-1} + \boxed{\lambda[\ln s_{jt} - \ln s_{jt}(x_t, p_t, \xi_t, \theta_d)]}$$

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- Moment conditions

$$E(\xi(x_t, p_t, s_t, \theta_d) | z_t) = 0 \longrightarrow E(h(z_t)\xi(x_t, p_t, s_t, \theta_d)) = 0$$

- Choose θ to make sample analog as close to zero

Model: Markups/MCs

- Prices are set by a static NE with multi-product firms.
- 2 definitions of MCs

equilibrium markups

$$mc_{jt} = p_{jt} - \underbrace{b_{jt}}_{\text{equilibrium markups}}(s_t, x_t, p_t, \theta_d)$$

unobserved cost shock

observed cost-shifters

$$mc_{jt} = \underbrace{w_{jt}}_{\text{observed cost-shifters}}\psi + \underbrace{\omega_{jt}}_{\text{unobserved cost shock}}$$

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$$mc_{jt} = w_{jt}\psi + \omega_{jt}$$

- BCS '07 model MC as depending on distance, pax flow
- Here, model hub density effect through *hub* variable

$$\omega_{jt} = p_{jt} - b_{jt}(s_t, x_t, p_t, \theta_d) - w_{jt}\psi$$

$$E(h(z_t)\,\omega(x_t, p_t, s_t, \theta_d, \psi)) = 0$$

Data

- 3 sources
  - DOT's Airline Origin & Destination Survey
  - Scheduling data from Back Aviation Solutions, Inc.
  - Flight delays from DOT's Airline On-Time Performance Data
- Sample selection:
  - Continental US, at most 4 segments
  - $P > \$25$
  - No ground traffic, no code shares

Data

- Market = directional pair of origin and destination
- Airports located in metro with >= 850k people
- Group nearby airports in the same market
- Aggregate fares by bins

- Product = combo of **origin, connecting, destination airports, ticketing carrier, binned fare**
- There are 215k in 1999, 227k in 2006

	1999		2006	
Variable	Mean	SD	Mean	SD
Fare (2006 \$100)	4.94	3.17	4.51	2.59
Product share	1.42E-04	6.37E-04	1.42E-04	5.26E-04
No. connections	1.25	0.97	1.14	0.99
No. daily departures	4.42	2.77	4.18	2.40
No. destinations (100 cities)	0.17	0.28	0.19	0.31
Hub	0.17	0.37	0.17	0.37
HubMC	0.87	0.34	0.78	0.41
Distance (1,000 miles)	2.73	1.40	2.78	1.42
Distance^2 (10^6 miles)	9.42	8.44	9.72	8.66
Tourist place (FL/LAS)	0.13	0.33	0.13	0.34
Slot-control	0.36	0.76	0.35	0.75
SlotMC	0.21	0.41	0.20	0.40
Plane size (100)	1.35	0.33	1.23	0.34
Delay >= 30 minutes	0.14	0.07	0.13	0.07
Observations	214,809		226,532	
Market average				
No. products	53.73	38.52	52.68	36.67
No. carriers	3.51	2.00	3.30	1.88
No. direct passengers (1,000)	20.13	40.45	22.75	43.66
No. connecting passengers (1,000)	3.52	4.10	2.71	3.13
No. markets with LCC entry			1,569	
No. markets	3,998		4,300	

Empirical model

- 2 types of consumers: **tourists vs business**
- 3 type-specific parameters:
  - Constant, fare coefficient, # connections coefficient
- Hopefully carriers' choices of flight frequencies, but...
  - Some mix different aircrafts on the same route (peak time)
  - Hard to measure frequencies for connecting flights
  - Need info on type of aircraft, schedule, # passengers on each
- So, instrument frequencies w/o modeling departures

Empirical model

- **Demand**
  - Fares *(instrumented)*, # connections, # destinations, average # daily departures *(instrumented)*,
  - Roundtrip distance, distance^2,
  - Tour dummy *(Florida + Vegas)*,
  - # slot-controlled airports *(negative effect of congestion)*,
  - Carrier dummies
- **Marginal Cost**
  - Constant, roundtrip distance, # connections, hub dummy, slot dummy, carrier dummies
  - Allow 2 sets of cost parameters: short ($<$ 1.5k miles) vs long ($>$ 1.5k miles)

Empirical model: instruments

- **Strategy 1:** exploit rival product attributes, competitiveness of market environment *("Closer substitutes have lower prices")*
- Concern: By construction, market w/ wider price dispersion has larger # products
- Use route-level characteristics instead
  - % rival routes that offer direct flights, average distance of rival routes, # rival routes, # all carriers

Empirical model: instruments

- **Strategy 2:** search for variables that affect costs but don't affect demand
- Whether the destination is a hub for the ticketing carrier
  - Affect MC b/c larger and more fuel efficient planes can be used on routes with denser traffic, but is excluded from demand
- # cities that carrier flies direct to from the destination
  - Reflects carrier's size of operation at the destination airport
- Dummy for transferring at the hub
  - Costs are lower if the flight connects at a hub

Empirical model: instruments

- **Strategy 3:** parsimoniously capture price dispersion
- 25^{th} and 75^{th} quantile of fares in a given route
- There is a wide fare dispersion across passengers travelling on the same route (Borenstein & Rose '94, '07)

- **Strategy 4:** Flight frequencies by regressing segment departures on characteristics of the end cities, then include the fitted values
- **Also,** exogenous variables directly entering share equation and interaction terms of all variables when not highly collinear.

Identification

Focus on λ + type-specific parameters

- $\boldsymbol{\lambda}$ identified from changes in aggregate market share when # products varies
- **Type-specific parameters** identified from substitution patterns among similar products when the mix of products varies across markets

Results

	Demand variables	1999	2006
Tourists	Fare 1	−0.78**	−1.05**
		(0.02)	(0.03)
	Connection 1	−0.53**	−0.59**
		(0.02)	(0.03)
	Constant 1	−5.79**	−5.68**
		(0.19)	(0.19)
Business	Fare 2	−0.07**	−0.10**
		(0.00)	(0.00)
	Connection 2	−0.31**	−0.51**
		(0.02)	(0.02)
	Constant 2	−8.56**	−8.60**
		(0.40)	(0.30)
	No. destination	0.38**	0.27**
		(0.03)	(0.02)
	No. departures	0.04**	0.11**
		(0.00)	(0.00)
	Distance	0.30**	0.53**
		(0.04)	(0.04)
	Distance^2	−0.05**	−0.08**
		(0.01)	(0.01)
	Tour	0.30**	0.36**
		(0.03)	(0.03)
	Slot-control	−0.19**	−0.18**
		(0.01)	(0.01)
	λ	0.77**	0.72**
		(0.01)	(0.01)
	γ	0.69**	0.63**
		(0.12)	(0.11)

Cost variables	1999	2006
Constant_short	1.07**	1.16**
	(0.06)	(0.06)
Distance_short	0.26**	0.19**
	(0.01)	(0.01)
Connection_short	−0.06**	0.07*
	(0.03)	(0.04)
Constant_long	1.61**	1.59**
	(0.08)	(0.07)
Distance_long	0.09**	0.04**
	(0.01)	(0.01)
Connection_long	−0.09**	0.06
	(0.03)	(0.04)
HubMC	−0.02	−0.05**
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Demand was more price sensitive in 2006

Aggregate price elasticity jumped from 1.55 to 1.67

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Stronger preference for direct flights in 2006

If all became non-direct, aggregate pax traffic drops 27% in '99 and 34% in '06

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Hub premium declined

Loyalty programs less valuable, narrower difference in service between hub & non-hub

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U-shape for distance, Tourist places attract more consumers, flights through SC airports have fewer passengers

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Products became closer substitutes

Reduced differentiation among flights as they cut down services and competed intensively on price

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	(0.06)	(0.06)
Distance_short	0.26**	0.19**
	(0.01)	(0.01)
Connection_short	−0.06**	0.07*
	(0.03)	(0.04)
Constant_long	1.61**	1.59**
	(0.08)	(0.07)
Distance_long	0.09**	0.04**
	(0.01)	(0.01)
Connection_long	−0.09**	0.06
	(0.03)	(0.04)
HubMC	−0.02	−0.05**
	(0.01)	(0.01)
SlotMC	0.08**	0.03**
	(0.01)	(0.01)

Cost advantage of connecting flights disappeared in 2006

Increasing fuel costs

Results

Demand variables	1999	2006	Cost variables	1999	2006
Fare 1	−0.78** (0.02)	−1.05** (0.03)	Constant_short	1.07** (0.06)	1.16** (0.06)
Connection 1	−0.53** (0.02)	−0.59** (0.03)	Distance_short	0.26** (0.01)	0.19** (0.01)
Constant 1	−5.79** (0.19)	−5.68** (0.19)	Connection_short	−0.06** (0.03)	0.07* (0.04)
Fare 2	−0.07** (0.00)	−0.10** (0.00)	Constant_long	1.61** (0.08)	1.59** (0.07)
Connection 2	−0.31** (0.02)	−0.51** (0.02)	Distance_long	0.09** (0.01)	0.04** (0.01)
Constant 2	−8.56** (0.40)	−8.60** (0.30)	Connection_long	−0.09** (0.03)	0.06 (0.04)
No. destination	0.38** (0.03)	0.27** (0.02)	HubMC	−0.02 (0.01)	−0.05** (0.01)
No. departures	0.04** (0.00)	0.11** (0.00)	SlotMC	0.08** (0.01)	0.03** (0.01)
Distance	0.30** (0.04)	0.53** (0.04)			
Distance^2	−0.05** (0.01)	−0.08** (0.01)			
Tour	0.30** (0.03)	0.36** (0.03)			
Slot-control	−0.19** (0.01)	−0.18** (0.01)			
λ	0.77** (0.01)	0.72** (0.01)			
γ	0.69** (0.12)	0.63** (0.11)			

MC increases with distance, higher when flying through SC airports, and lower at hubs

Other specifications

- Use only share equation (not pricing)
  – fewer tourists %, larger price sensitivity, else robust
- Add a delay variable (% flights arriving 30+ minutes behind schedule)
  – can't explain increased disutility of connecting flights
- Combining close airports (e.g., Midway + O'Hare as Chicago)
  – smaller lambda as choices become more similar
- Finer/rougher sets of fare bins
  – smaller aggregate price sensitivity
- Add dummies for 25 airports with largest pop
  – demand is less elastic, lower MCs

What drives preference for direct flights?

- Changes in *supply* or *demand*?
  - Low-cost carriers expanded steadily. They offered a higher fraction of direct services.
  - More negative connection coefficient in 2006 might be due to decreasing shares of legacy carriers?
- Re-estimate model using only markets w/o LCC entry

What drives preference for direct flights?

- Changes in *supply* or *demand*?
  - Low-cost carriers expanded steadily. They offered a higher fraction of direct services.
  - More negative connection coefficient in 2006 might be due to decreasing shares of legacy carriers?
- Re-estimate model using only markets w/o LCC entry
- Consumers prefer direct flights even in markets not affected by LCC entry!

	1999	2006
Demand variables		
Fare 1	−0.85**	−1.20**
	(0.03)	(0.04)
Connection 1	−0.48**	−0.53**
	(0.02)	(0.04)
Constant 1	−5.68**	−5.38**
	(0.31)	(0.39)
Fare 2	−0.07**	−0.11**
	(0.00)	(0.00)
Connection 2	−0.36**	−0.48**
	(0.02)	(0.03)
Constant 2	−8.55**	−8.75**
	(0.71)	(0.60)
No. destination	0.38**	0.26**
	(0.03)	(0.03)
No. departures	0.05**	0.12**
	(0.00)	(0.01)
Distance	0.31**	0.51**
	(0.05)	(0.05)
Distance^2	−0.05**	−0.08**
	(0.01)	(0.01)
Tour	0.18**	0.18**
	(0.05)	(0.04)
Slot-control	−0.15**	−0.18**
	(0.01)	(0.01)
λ	0.75**	0.72**
	(0.01)	(0.01)
γ	0.71**	0.63**
	(0.21)	(0.23)

Maybe more direct flights available?

- New regional jets allow carriers to provide more direct services
- Restrict sample to markets longer than 1.5k miles one way (30% of data)

Maybe more direct flights available?

- New regional jets allow carriers to provide more direct services
- Restrict sample to markets longer than 1.5k miles one way (30% of data)
- Demand more elastic, but stronger preference for direct flights remains

	1999	2006
Demand variables		
Fare 1	−0.88**	−1.60**
	(0.05)	(0.10)
Connection 1	−0.53**	−0.54**
	(0.03)	(0.05)
Constant 1	−3.44**	−1.74**
	(0.95)	(0.75)
Fare 2	−0.06**	−0.12**
	(0.00)	(0.00)
Connection 2	0.00	−0.55**
	(0.11)	(0.04)
Constant 2	−8.88*	−7.36**
	(5.00)	(0.80)
No. destination	0.39**	0.27**
	(0.06)	(0.05)
No. departures	0.02**	0.07**
	(0.01)	(0.01)
Distance	−0.16**	−0.14**
	(0.02)	(0.02)
Distance^2		
Tour	0.51**	0.63**
	(0.05)	(0.05)
Slot-control	−0.16**	−0.17**
	(0.01)	(0.01)
λ	0.75**	0.67**
	(0.02)	(0.01)
γ	0.85	0.57
	(0.76)	(0.35)

Results: Profit/Revenue

- Potential concern: # products change might reflect changing dispersion of price rather than actual # distinct products
- Analyze carrier's average profit and revenue per market instead of average profit per product

TABLE 9—CARRIER PROFIT AND REVENUE PER MARKET

		Profit ($100k)			Revenue ($100k)		
Year		All fares	Bottom 90% fares	Top 10% fares	All fares	Bottom 90% fares	Top 10% fares
1999	All flights	17.80	11.77	6.03	26.38	19.79	6.60
	Direct	14.95	$\boxed{10.17}$	4.77	21.90	$\boxed{16.62}$	5.29
	Connecting	2.86	2.14	0.72	4.48	3.64	0.84
2006	All flights	14.46	12.19	2.27	23.92	20.72	3.19
	Direct	12.53	$\boxed{11.03}$	1.50	20.53	$\boxed{18.31}$	2.23
	Connecting	1.94	1.62	0.32	3.38	2.93	0.45

Counterfactuals

- Compute CF profits and revenues for
  - 2006 products/MCs, 1999 demand
  - 2006 products/MCs, 1999 demand, ξ replicates 1999 distribution
  - 2006 products/demand, 1999 MCs
  - 2006 products/demand/MCs, excluding LCCs
  - 2006 products, 1999 demand/MCs, ξ replicates 1999 distribution, excluding LCCs
- Solve for new vector of optimal prices that satisfy FOCs

Counterfactuals: Results

Connecting flights

Different scenarios	Profit ($100k)			Revenue ($100k)		
	All fares	Bottom 90% fares	Top 10% fares	All fares	Bottom 90% fares	Top 10% fares
1999 base case	2.86	2.14	0.72	4.48	3.64	0.84
2006 base case	1.94	1.62	0.32	3.38	2.93	0.45
1999 demand θ_d	2.47	1.97	0.50	4.05	3.43	0.63
1999 demand θ_d and ξ	2.45	1.91	0.54	3.95	3.27	0.68
1999 MC parameters	2.02	1.64	0.38	3.51	2.99	0.52
No LCC expansion	2.01	1.62	0.39	3.51	2.97	0.54
All factors	2.59	2.04	0.56	4.15	3.45	0.69

Direct flights

Different scenarios	Profit ($100k)			Revenue ($100k)		
	All fares	Bottom 90% fares	Top 10% fares	All fares	Bottom 90% fares	Top 10% fares
1999 base case	14.95	10.17	4.77	21.90	16.62	5.29
2006 base case	12.53	11.03	1.50	20.53	18.31	2.23
1999 demand parameters	10.97	9.62	1.35	18.08	16.28	1.80
1999 demand parameters and ξ	15.06	11.72	3.34	22.11	17.67	4.44
1999 MC parameters	11.99	10.41	1.58	19.85	17.48	2.36
No LCC expansion	12.81	11.20	1.61	20.85	18.49	2.36
All factors	14.80	11.46	3.34	22.03	17.55	4.48

Limitations

- Costs not directly observed; stylized model
  - Change in variable profits, not in net profits
- LCCs found to have modest impact
  - Consumers' search behavior and awareness of fare dispersion might lead to larger effect
- Static model; no dynamic decisions
  - Capacity, network formation, improvements in tech

Conclusions

- Estimates structural model of US airline industry and impact of demand and supply changes on profitability of legacy carriers, comparing 1999 and 2006
- Demand is more price sensitive
- Consumers exhibit stronger preference for direct flights
- Marginal costs become significantly lower for direct flights