Mining the Airline Schedule Data: Strategic View on Fleet Deployment and Mission Diversification

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Bio

Ahmed Abdelghany, Ph.D. (speaker) is a professor and associate dean in the David O'Maley College of Business, Embry-Riddle Aeronautical University, Daytona Beach, Florida. Prior to his academic career, Dr. Abdelghany worked for several years within the information services division of United Airlines, Chicago. Dr. Abdelghany has a doctorate degree from the University of Texas at Austin in Civil Engineering; Transportation Systems (2001). He is the author of the books titled Airlines Network Planning and Scheduling, Wiley (2018) and Modeling Applications in the Airline Industry by Ashgate/Routledge publishing (2010).

Vitaly S. Guzhva, Ph.D., CFA is a Professor in the College of Business of Embry-Riddle Aeronautical University where he teaches Finance, Economics, and Safety courses and participates in applied research projects that require cost-benefit and/or advanced statistical analyses, including Benefits of 4D Trajectory Based Operations; Aircraft Arrival Management System; Key Spaceport Planning and Design Requirement Study; Airborne Execution of Flow Strategies; and others. As a military and corporate pilot, Dr. Guzhva has logged more than 5,000 flight hours primarily in high performance jet aircraft.

Agenda

- Concentration Measures (HHI vs DPCI)
- Mining the Airline Schedule (Timetable) Data
  - Diversification of Fleet Deployment
  - Diversification of Mission (route mileage)
- Example Airlines
- Summary

➢ Herfindahl-Hirschman Index (HHI):

- A common measure of market concentration and is used to determine market competitiveness.

$$HHI = S_1^2 + S_2^2 + S_3^2 + \ldots + S_n^2$$

- S_n the market share percentage of firm n
- The closer a market is to a monopoly, the higher the market's concentration (and the lower its competition).
- Advantage: Very simple
- Extend to other applications other than market competition

➢ Application to Airline Fleet Deployment

- Assume an airline that has three fleet types 319, 32A, and 32B
- We find the share of each fleet in the schedule (measured in terms of scheduled capacity)

n	Sn
319	19.0%
32A	55.6%
32B	25.4%

- $HHI = 0.19^2 + 0.556^2 + 0.254^2 = 0.41$

- One of the main limitations of the HHI is that it does not consider similarity or (differentiation) between alternatives

n	Sn
A320	50%
A321	50%

$$HHI = 0.5^2 + 0.5^2 = 0.5$$

n	Sn
A220	50%
A380	50%

$$HHI = 0.5^2 + 0.5^2 = 0.5$$

$Variable$	Definition
F	Firms, denoted by f
N	Submarkets, denoted by $m\ or\ n$ (Submarket is a grouping of products that have a very high degree of substitutability between each other, relative to the substitutability of products outside the market.)
σ_n	Submarket share
S_{nf}	The fraction that a given firm's products have of the relevant submarket (firm share)
$\sigma_n S_{nf}$	The market share that firm-f's products in submarket-n have as a fraction of the overall market
b_{mn}	The substitutability of products between submarkets $m\ and\ n$
B_m	The fraction of the overall market in which submarket m products effectively compete

➢ Differentiated Product Concentration Index (DPCI):

- Bailey, C., & Raisanen, S. (2015). A General Concentration Index for Multiproduct Firms with Differentiated Products. Journal of Economic Insight, 41(2), 19-34.

- $HHI = \sum_{f=1}^{F}\left[\sum_{m=1}^{N}\left[\left(\sigma_m S_{mf}\right).\sum_{n=1}^{N}\left(\sigma_n S_{nf}\right)\right]\right]$

- $DPCI = \sum_{f=1}^{F}\left[\sum_{m=1}^{N}\left[\left(\sigma_m S_{mf}\right).\sum_{n=1}^{N}\frac{\sigma_n S_{nf} b_{mn}}{B_m}\right]\right]$

- $B_m = \sum_{n=1}^{N}\left(\sigma_n b_{mn}\right)$

Note, DPCI = HHI when

b_{mn} *= 1 &* B_m *= 1*

E	F	G	H	I	J	K	L	M	N
					S_{nf}				
	n	σ_n		319	32A	32B			
	319	0.18986		1	0	0			
	32A	0.55587		0	1	0			
	32B	0.25428		0	0	1			
		$\sigma_n S_{nf}$	n=1	0.18986	0	0			
			n=2	0	0.55587	0			
			n=3	0	0	0.25428			
		S(f)		0.18986	0.55587	0.25428			
		$\sigma_m S_{mf}$	m=1	0.18986	0	0			
			m=2	0	0.55587	0			
			m=3	0	0	0.25428			
			m=1	0.036047	0	0			
			m=2	0	0.308991	0			
			m=3	0	0	0.064658			
				0.036047	0.308991	0.064658	0.409697	HHI	
				C1	C2	C3			
				f1	f2	f3			

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	b_{mn}									S_{nf}				m=1	m=2	m=3				b_{mn}/B_m	
2	Fleet	319	32A	32B		n	σ_n		319	32A	32B			B1	B2	B3		Fleet	319	32A	32B
3	319	1	0.92204	0.89498		319	0.18986		1	0	0			0.92997	0.973557	0.954601		320	1.075304	0.947083	0.937544
4	32A	0.92204	1	0.95418		32A	0.55587		0	1	0			319	32A	32B		321	0.991473	1.027161	0.999559
5	32B	0.89498	0.95418	1		32B	0.25428		0	0	1							319	0.962375	0.980096	1.047558
6																					
7							$\sigma_n S_{nf}$	n=1	0.18986	0	0										
8								n=2	0	0.55587	0										
9								n=3	0	0	0.25428										
10							S(f)		0.18986	0.55587	0.25428										
11																					
12									$\sigma_m S_{mf} b_{mn}/B_m$												
13								n=1	0.204157	0	0										
14								n=2	0	0.570968	0										
15								n=3	0	0	0.266373										
16							S(f)		0.204157	0.570968	0.266373										
17																					
18							$\sigma_n S_{nf}$	m=1	0.18986	0	0										
19								m=2	0	0.55587	0										
20								m=3	0	0	0.25428										
21																					
22																					
23								m=1	0.038761	0	0										
24								m=2	0	0.317384	0										
25								m=3	0	0	0.067733										
26																					
27									0.038761	0.317384	0.067733	0.423879	DPCI								
28																					

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
	b_{mn}									S_{nf}				m=1	m=2	m=3				b_{mn}/B_m	
	Fleet	319	32A	32B		n	σ_n		319	32A	32B			B1	B2	B3		Fleet	319	32A	32B
	319	1	0.5	0.25		319	0.18986		1	0	0			0.531365	0.676228	0.357332		320	1.881946	0.739396	0.699629
	32A	0.5	1	0.1		32A	0.55587		0	1	0			319	32A	32B		321	0.940973	1.478791	0.279852
	32B	0.25	0.1	1		32B	0.25428		0	0	1							319	0.470486	0.147879	2.798518
							$\sigma_n S_{nf}$	n=1	0.18986	0	0										
								n=2	0	0.55587	0										
								n=3	0	0	0.25428										
0							S(f)		0.18986	0.55587	0.25428										
1																					
2									$\sigma_m S_{mf} b_{mn}/B_m$												
3								n=1	0.357306	0	0										
4								n=2	0	0.822016	0										
5								n=3	0	0	0.711607										
6							S(f)		0.357306	0.822016	0.711607										
7																					
8							$\sigma_n S_{nf}$	m=1	0.18986	0	0										
9								m=2	0	0.55587	0										
0								m=3	0	0	0.25428										
1																					
2																					
3								m=1	0.067838	0	0										
4								m=2	0	0.456934	0										
5								m=3	0	0	0.180947										
6																					
7									0.067838	0.456934	0.180947	0.705719	DPCI								
8																					

Note: larger substitutability parameter values cause the effective market size to rise.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	b_{mn}									S_{nf}				m=1	m=2	m=3				b_{mn}/B_m	
2	Fleet	319	32A	32B		n	σ_n		319	32A	32B			B1	B2	B3		Fleet	319	32A	32B
3	319	1	0.92204	0.89498		319	0.18986		1	0	0			0.92997	0.973557	0.954601		320	1.075304	0.947083	0.937544
4	32A	0.92204	1	0.95418		32A	0.55587		0	1	0			319	32A	32B		321	0.991473	1.027161	0.999559
5	32B	0.89498	0.95418	1		32B	0.25428		0	0	1							319	0.962375	0.980096	1.047558
6																					
7							$\sigma_n S_{nf}$	n=1	0.18986	0	0										
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11																					
12									$\sigma_m S_{mf} b_{mn}/B_m$												
13								n=1	0.204157	0	0										
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22																					
23								m=1	0.038761	0	0										
24								m=2	0	0.317384	0										
25								m=3	0	0	0.067733										
26																					
27									0.038761	0.317384	0.067733	0.423879	DPCI								
28																					

Similarity of fleet is estimated based on seat capacity and mileage

➢ Measuring Fleet Similarities

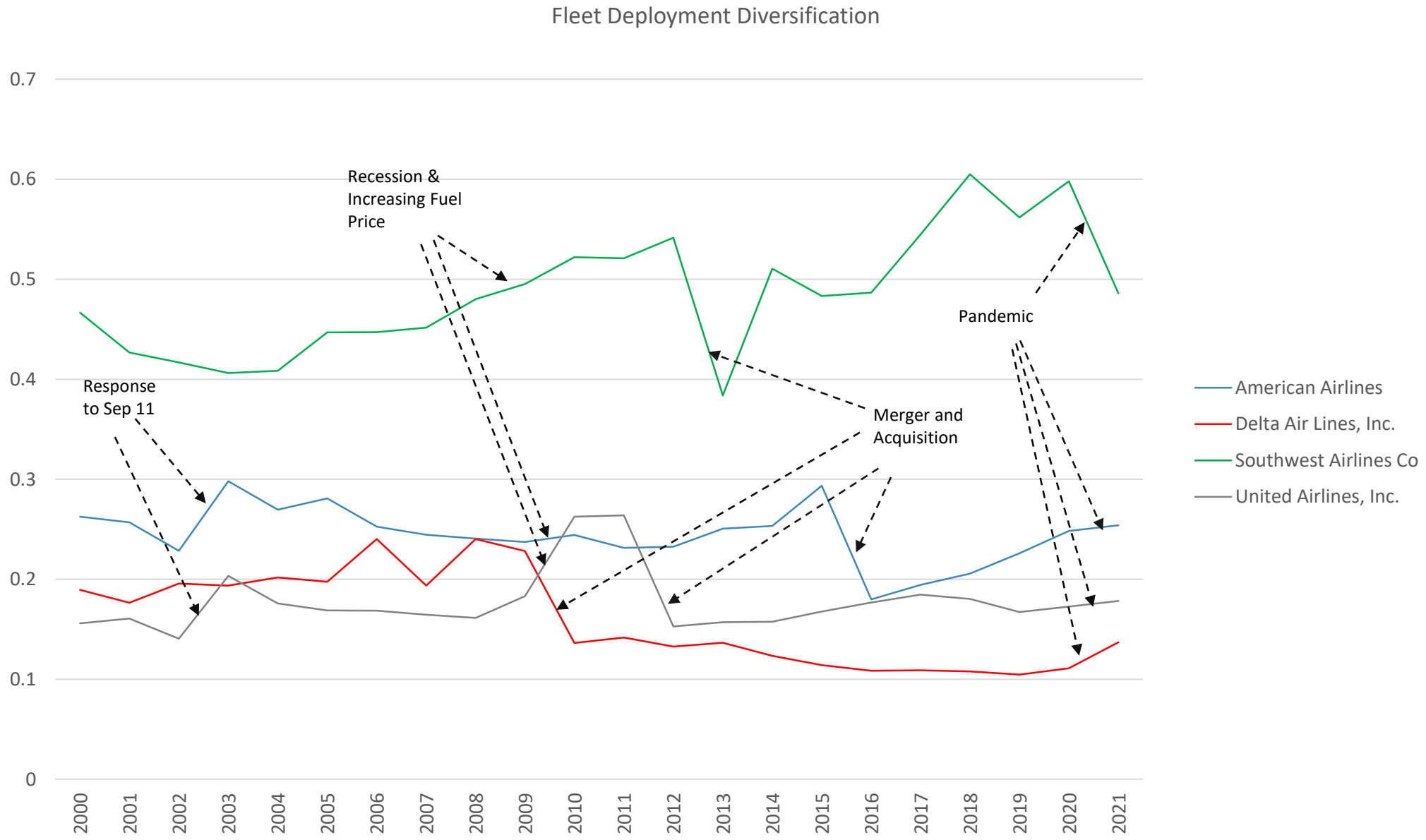
- $$Sim_{mn} = 1 - \frac{\sum_{v=1}^{V} |var_m^v - var_n^v|}{V}$$

- *About 290 fleet types identified in the weekly schedule*
- *A similarity matrix of 290 X 290*
- *Based on seat capacity and average fleet mileage in the schedule (we could use max range)*

e.g.

- *var 1 = Normalized fleet mileage on a 0-1 scale*
- *Var 2 = Normalized seat capacity on a 0-1 scale*

➢ Applying DPCI on Fleet Deployment Diversification



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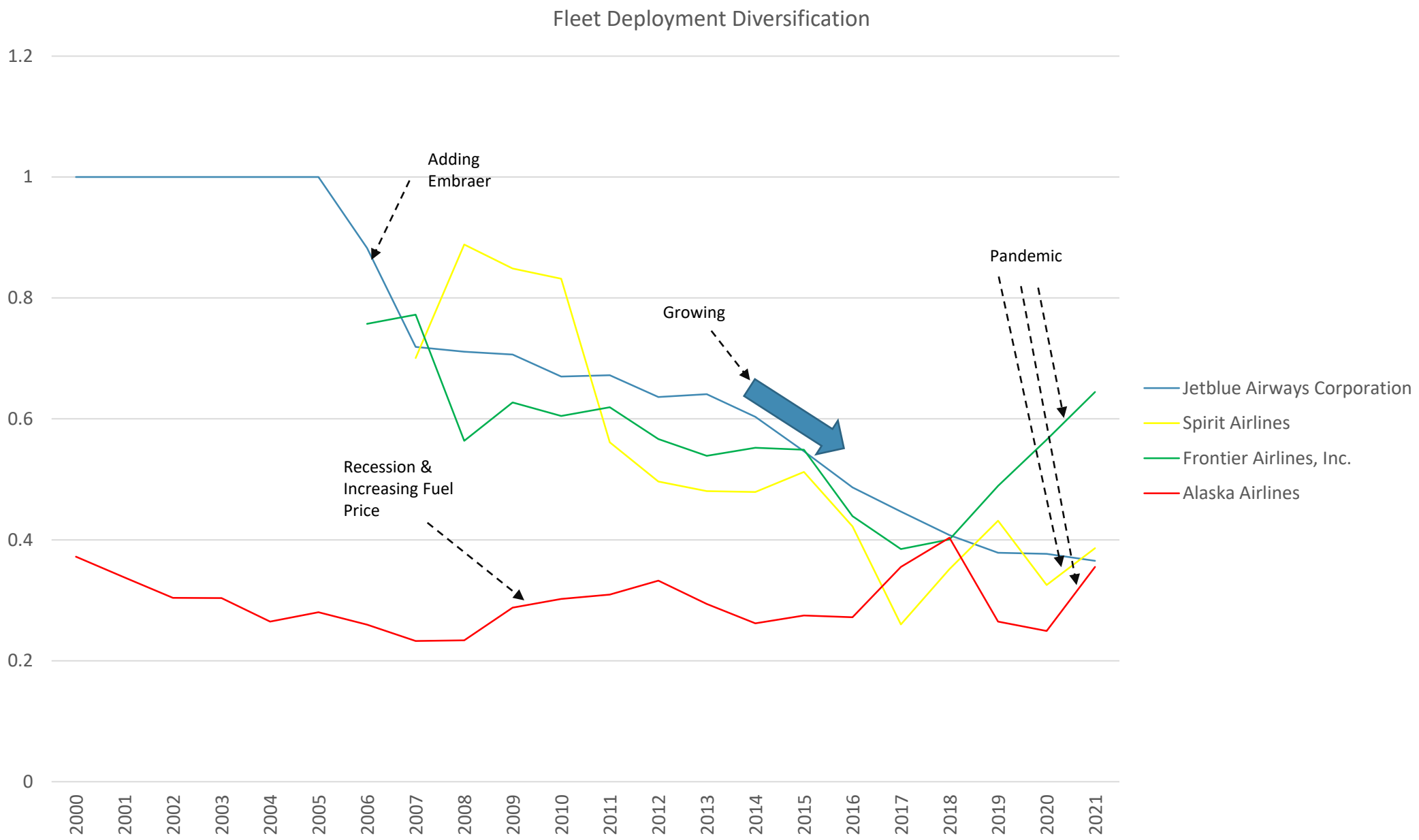

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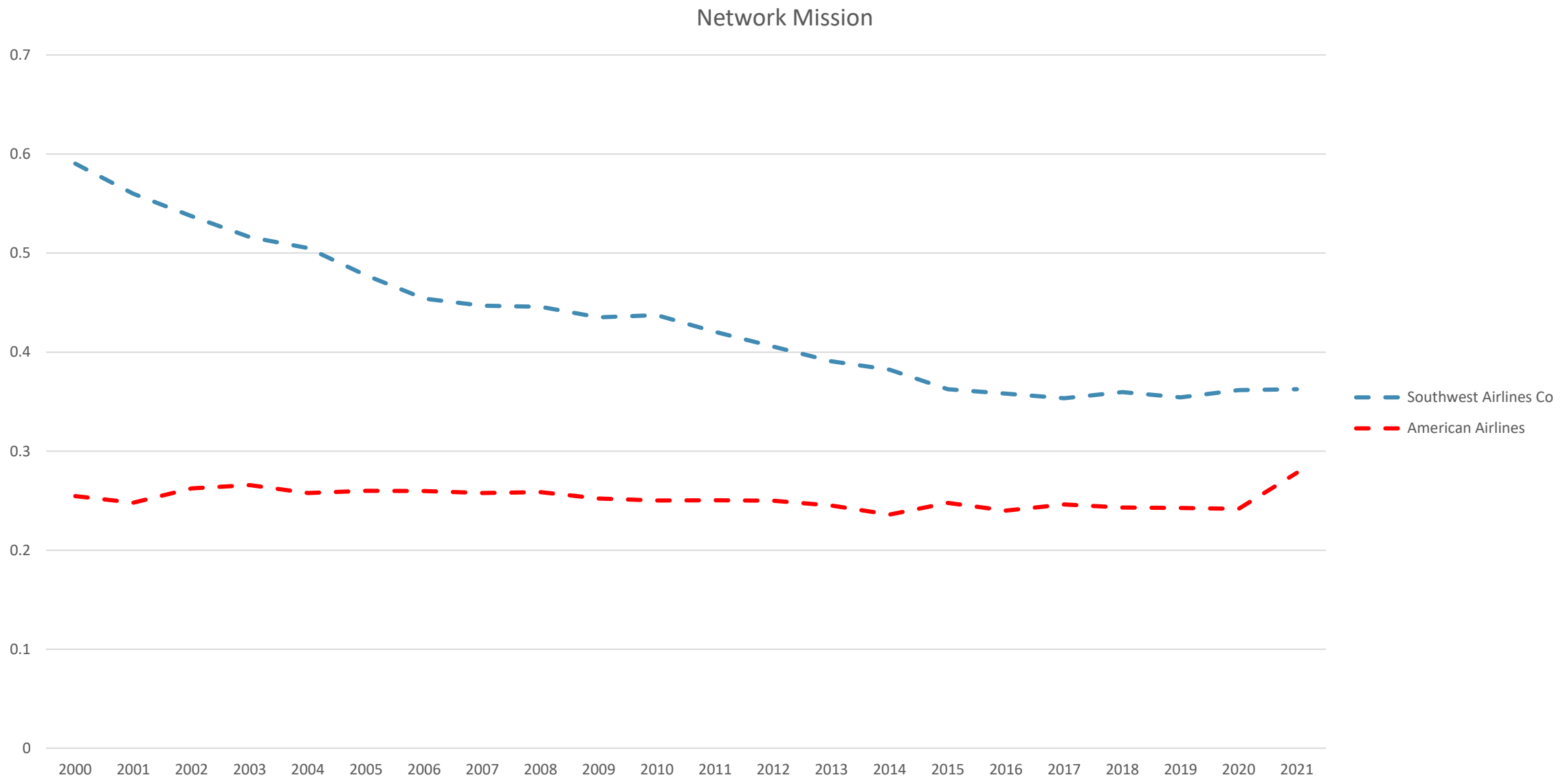
➢ Diversification of Mission

- Assume an airline that its routes are in the range of 0-500 nm, 500-1000, 1000-1500, and 1500-2000.
- We find the share of each range in the schedule (measured in terms of scheduled capacity)

k	Sk
0-500	20%
500-1000	30%
1000-1500	45%
1500-2000	5%

- $HHI = 0.2^2 + 0.3^2 + 0.45^2 + 0.05^2 = 0.335$


Network Mission
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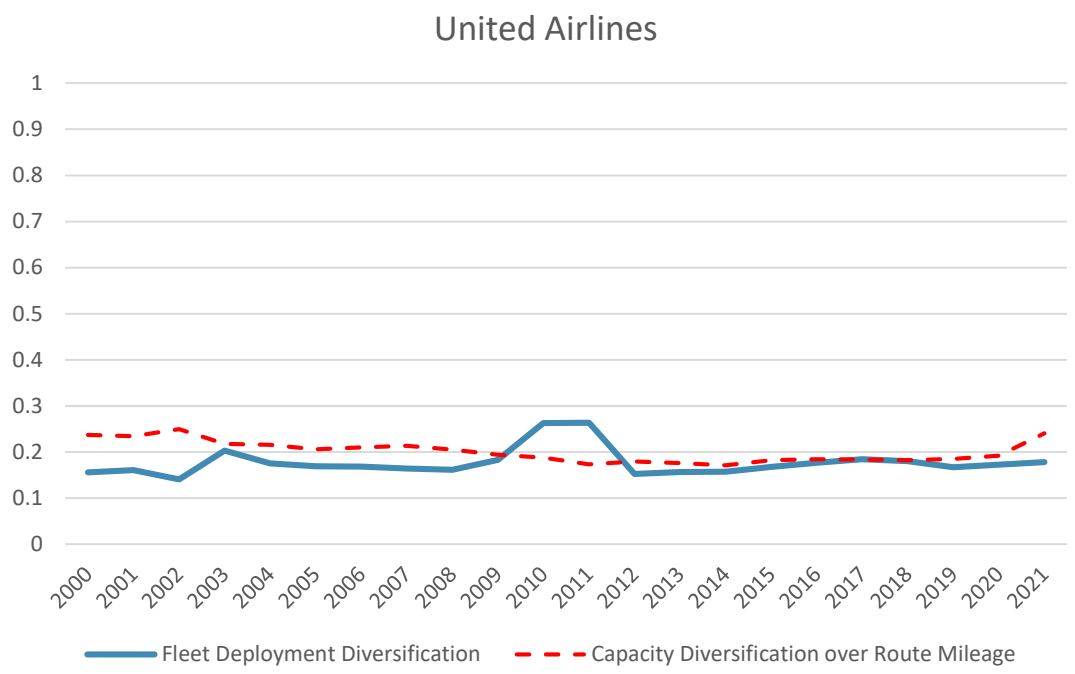
Southwest Airlines Co
American Airlines


United Airlines
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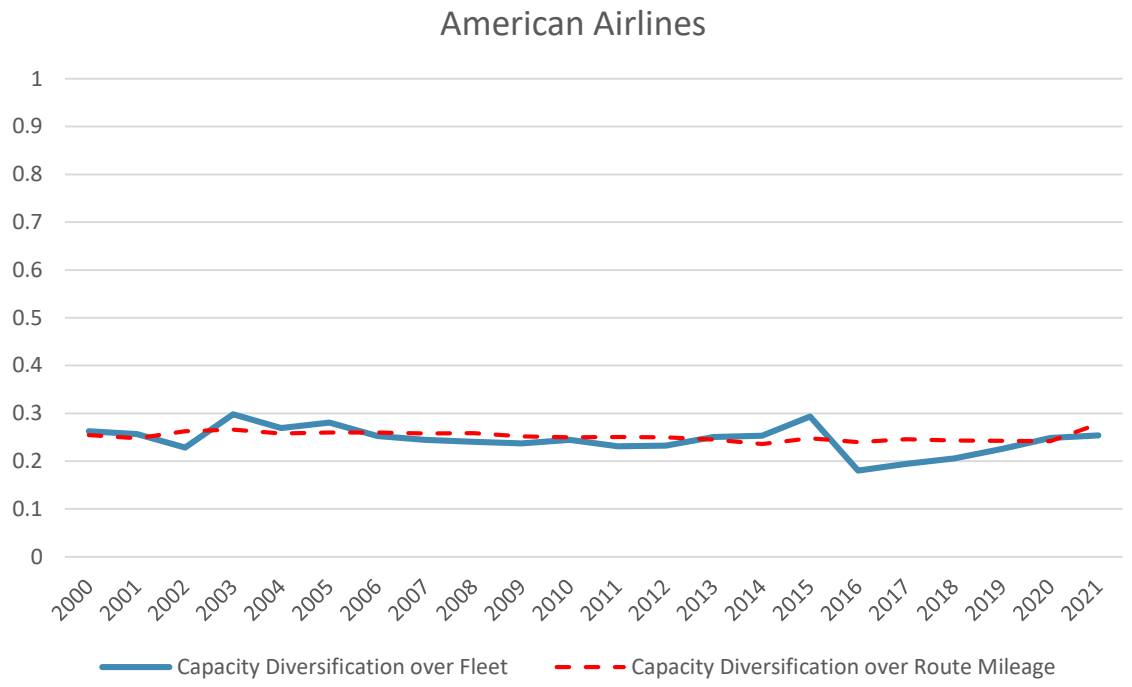
Fleet Deployment Diversification
Capacity Diversification over Route Mileage


American Airlines
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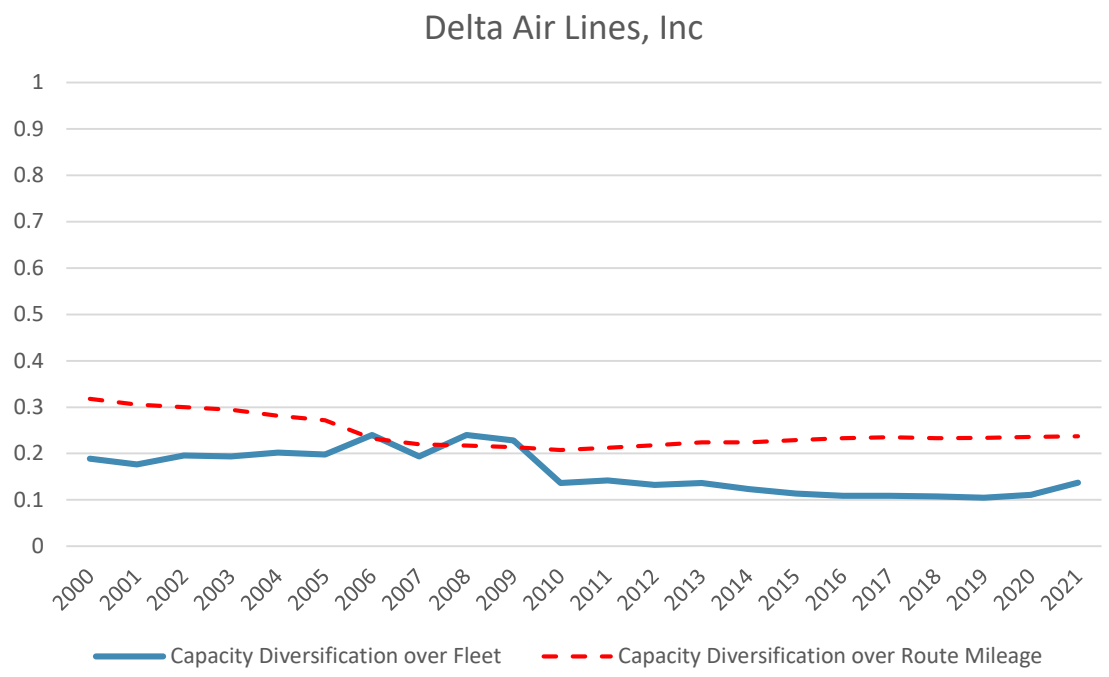
Capacity Diversification over Fleet
Capacity Diversification over Route Mileage


Delta Air Lines, Inc
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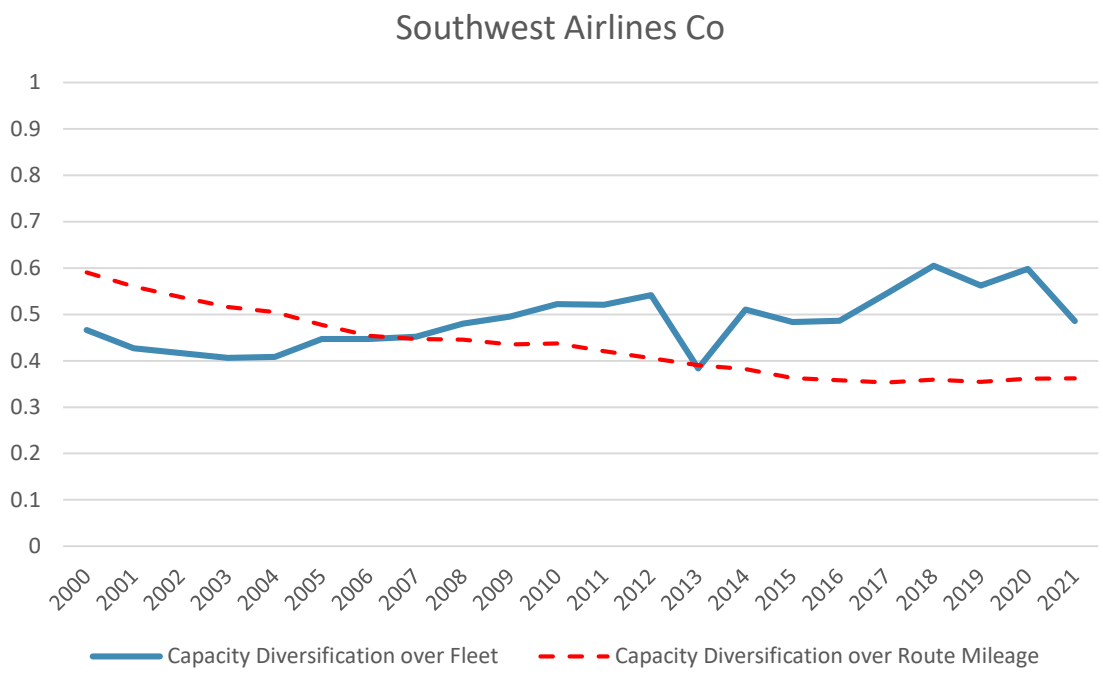
Capacity Diversification over Fleet
Capacity Diversification over Route Mileage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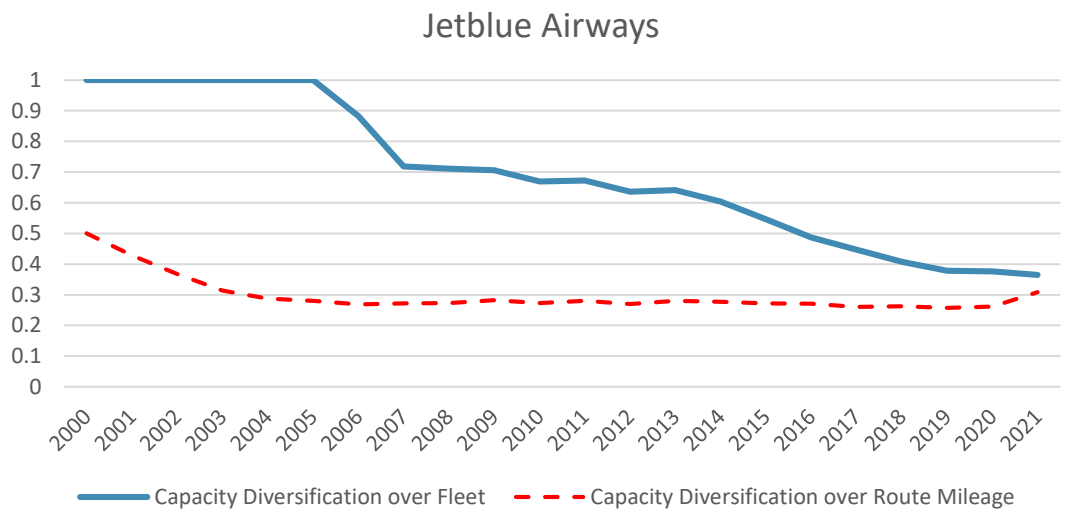
Capacity Diversification over Fleet
Capacity Diversification over Route Mileage


Jetblue Airways
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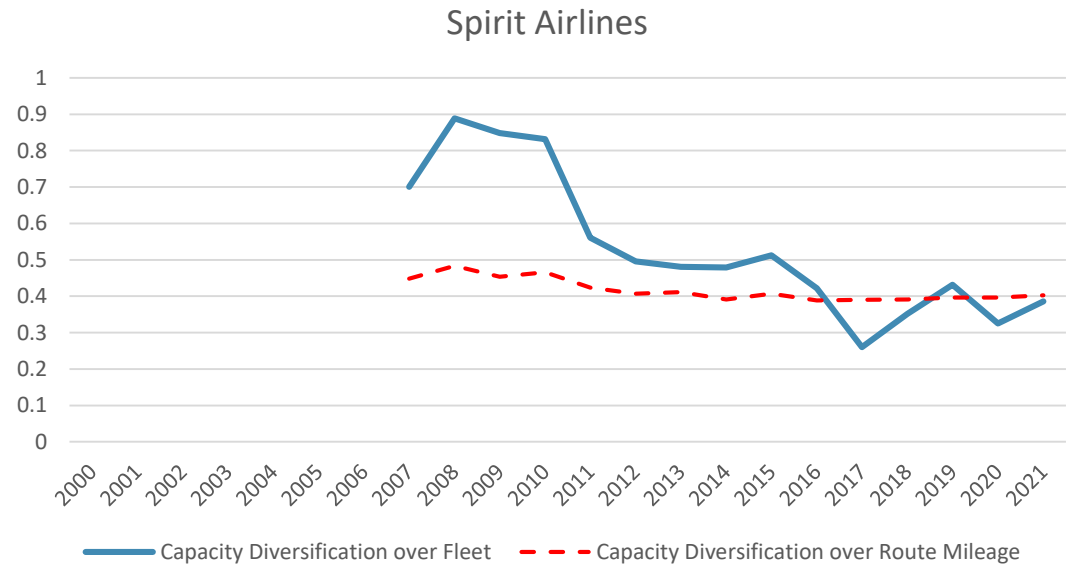
Capacity Diversification over Fleet
Capacity Diversification over Route Mileage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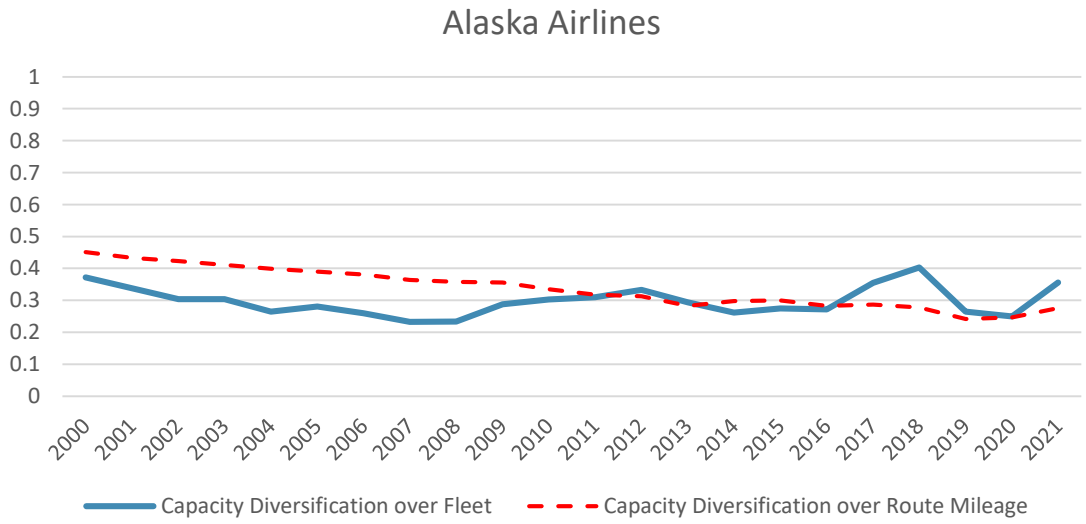
Capacity Diversification over Fleet
Capacity Diversification over Route Mileage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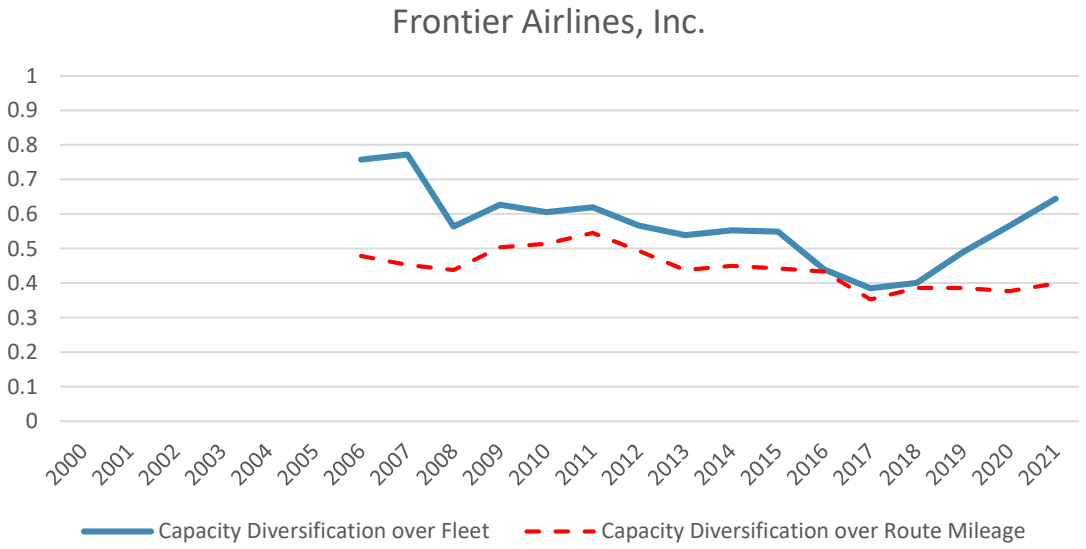
Capacity Diversification over Fleet
Capacity Diversification over Route Mileage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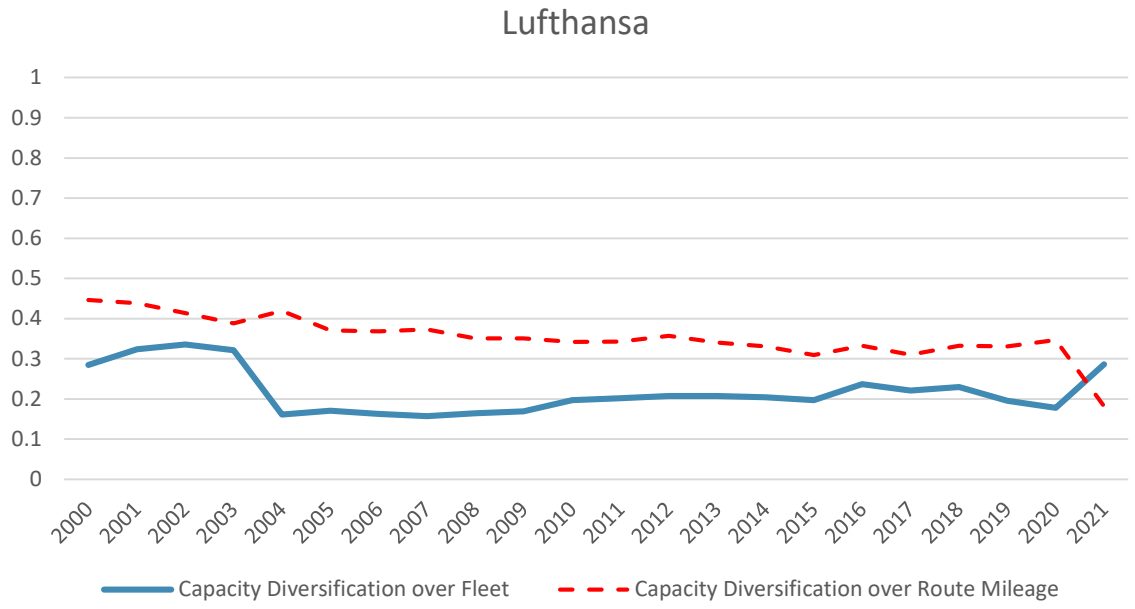
Capacity Diversification over Fleet
Capacity Diversification over Route Mileage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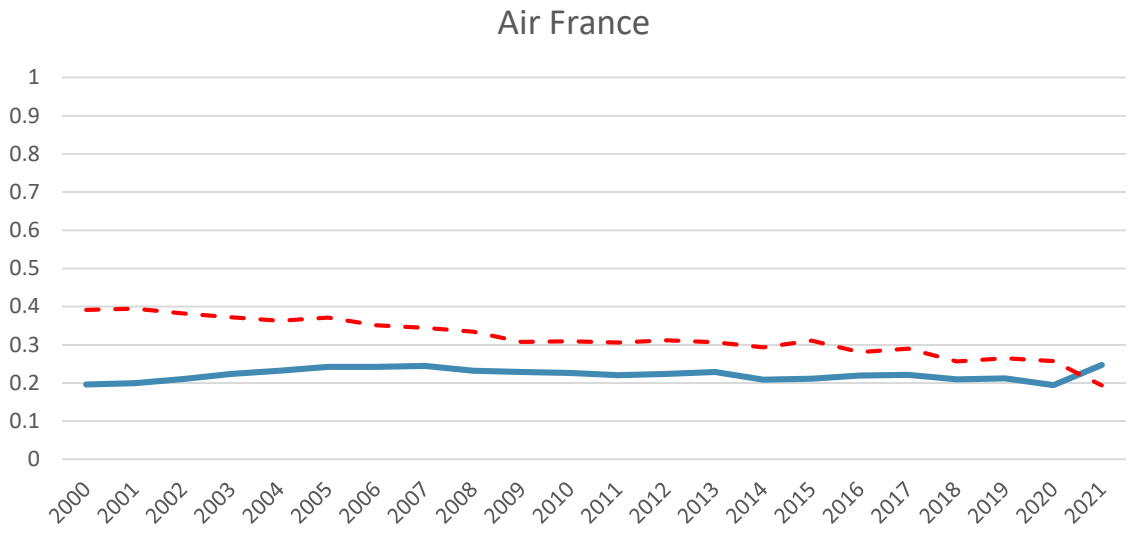
Capacity Diversification over Fleet
Capacity Diversification over Route Mileage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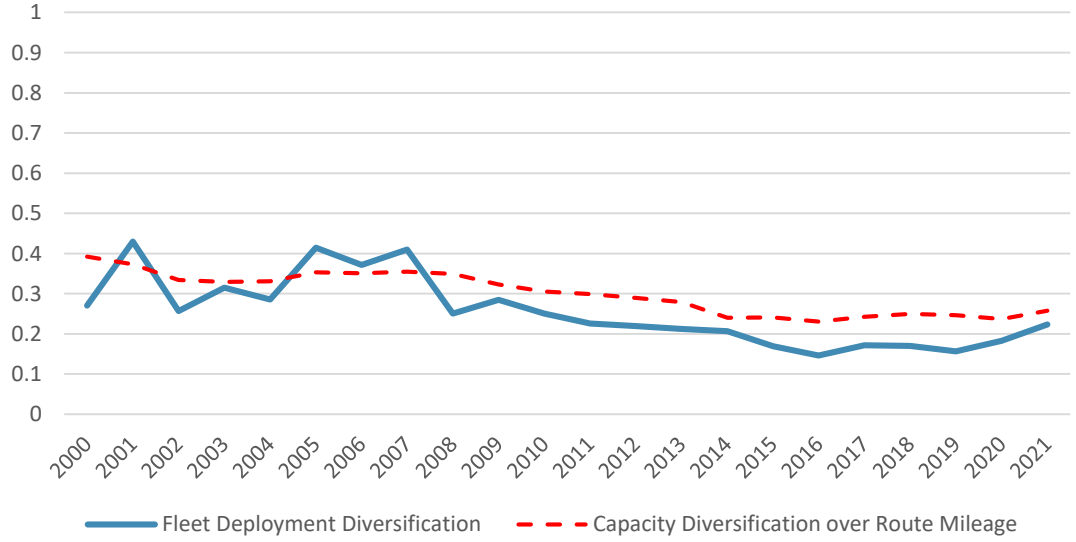
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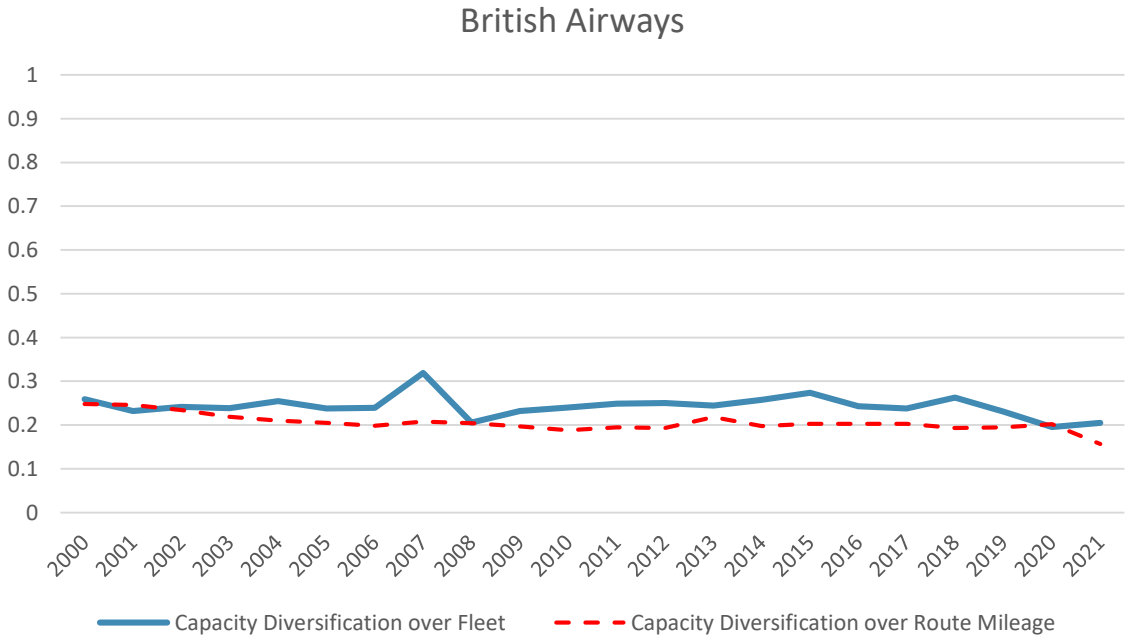
Fleet Deployment Diversification
Capacity Diversification over Route Mileage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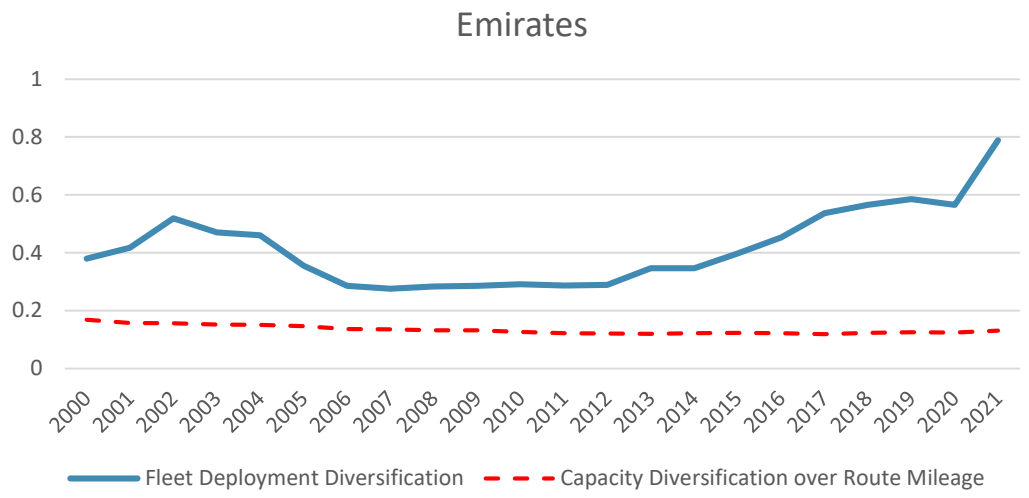
Capacity Diversification over Fleet
Capacity Diversification over Route Mileage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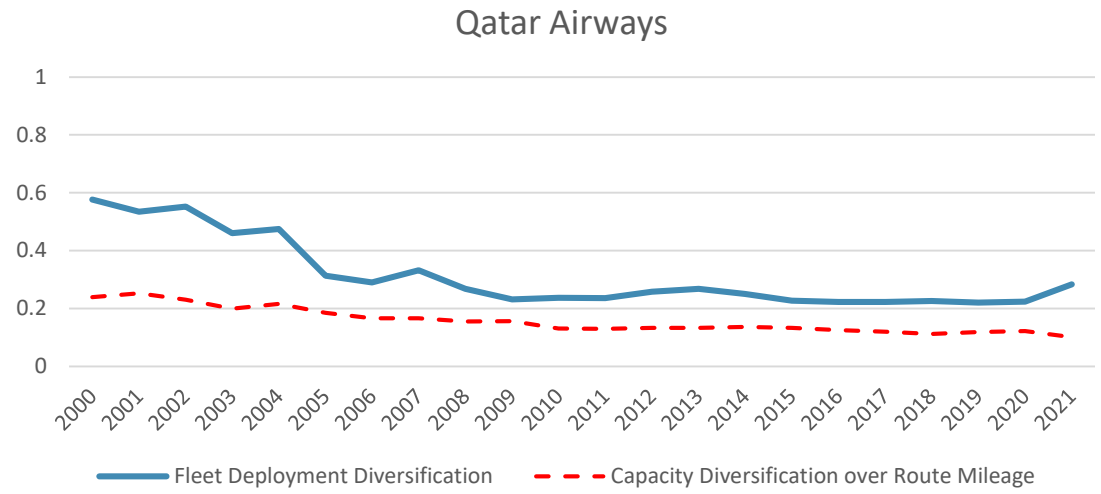
Fleet Deployment Diversification
Capacity Diversification over Route Mileage


Qatar Airways
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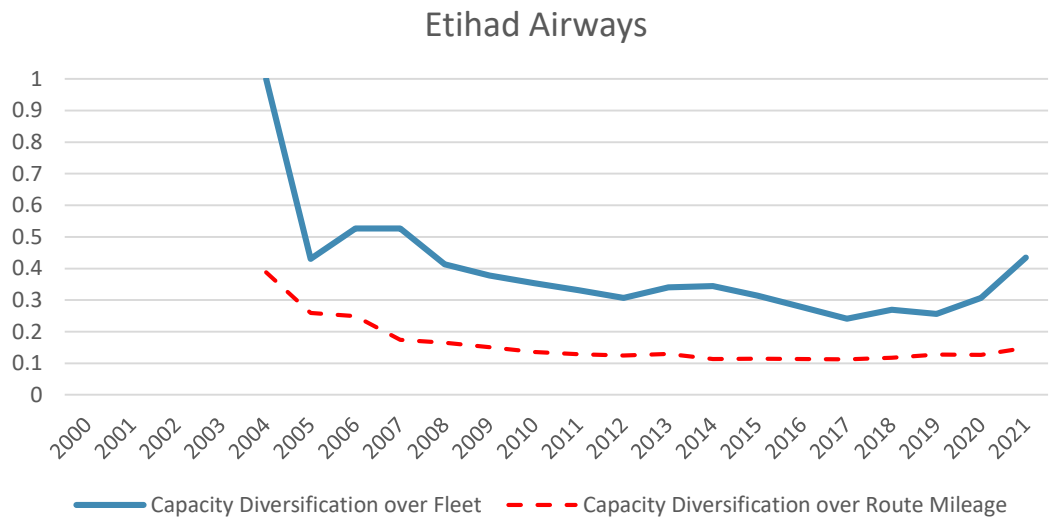
Capacity Diversification over Route Mileage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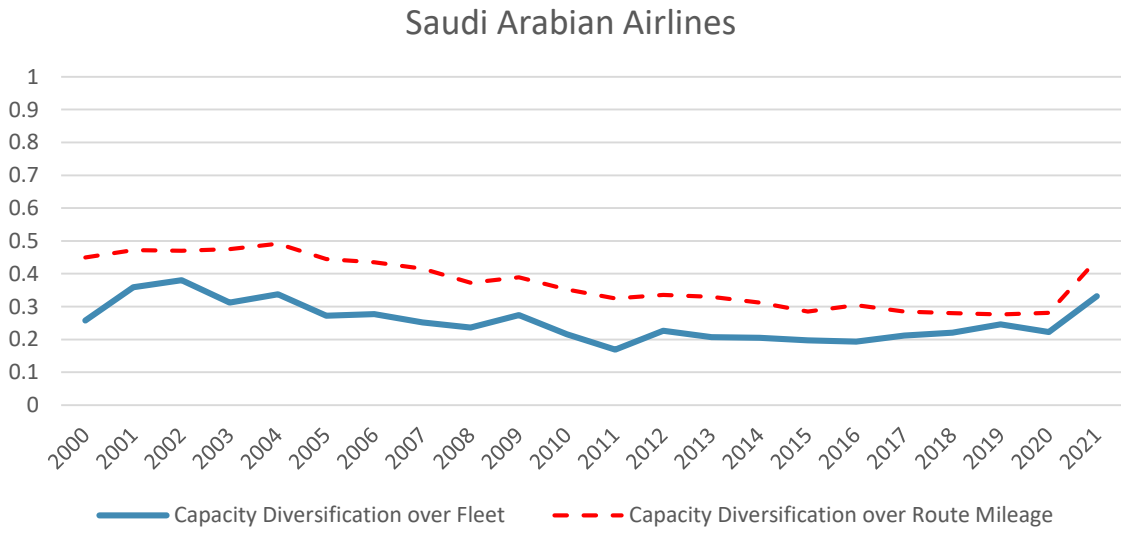
Capacity Diversification over Route Mileage


Saudi Arabian Airlines
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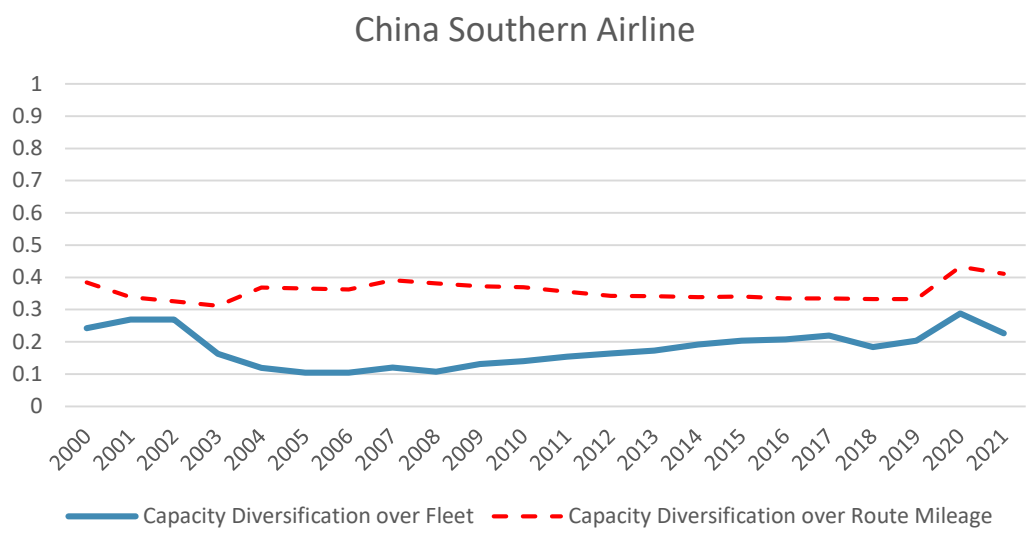
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Capacity Diversification over Fleet
Capacity Diversification over Route Mileage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0.8
0.7
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0.3
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2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
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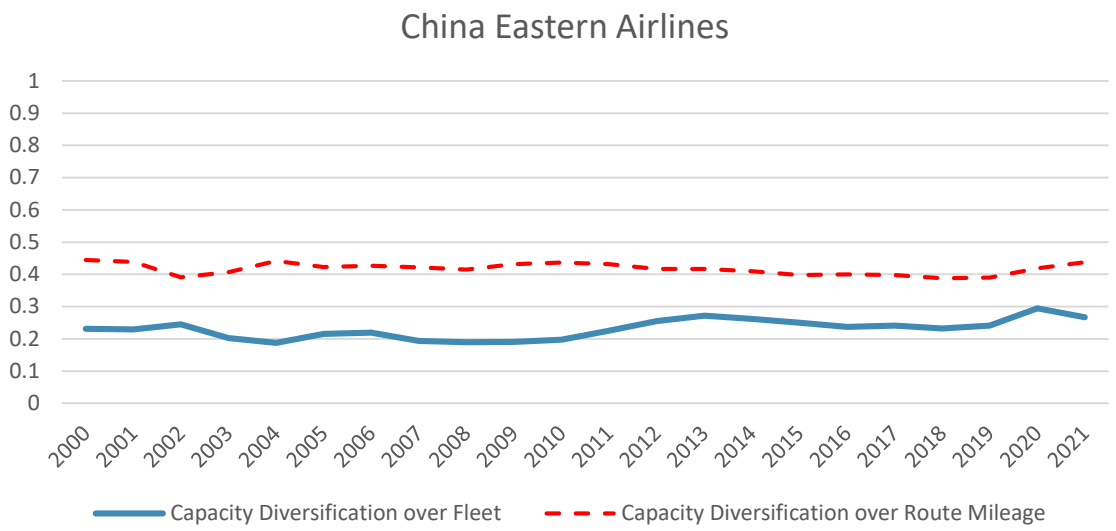
China Eastern Airlines
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0.9
0.8
0.7
0.6
0.5
0.4
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2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
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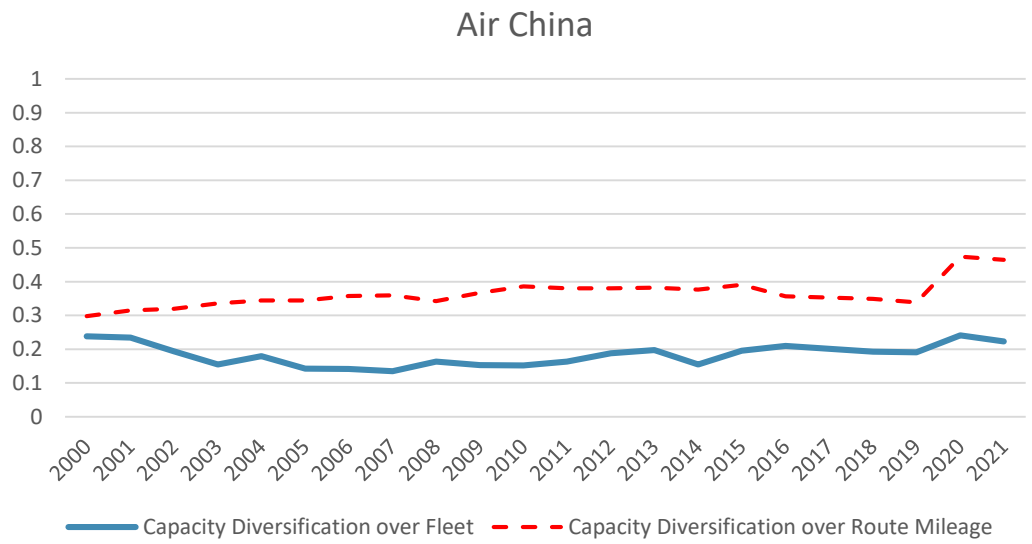
Air China
1
0.9
0.8
0.7
0.6
0.5
0.4
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2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
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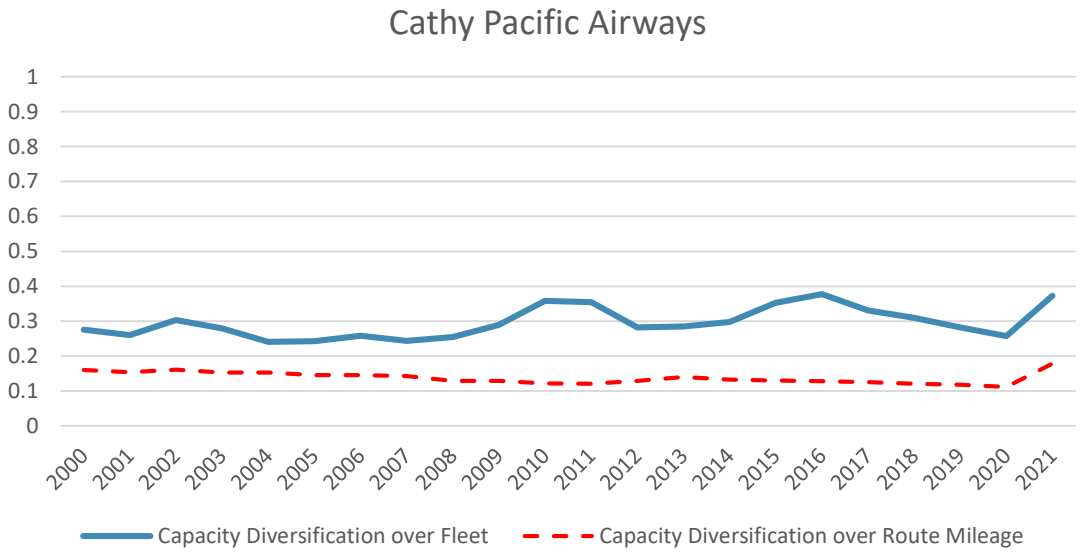
Cathy Pacific Airways
1
0.9
0.8
0.7
0.6
0.5
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2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
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Summary

- More understanding to fleet deployment diversification
- Airlines do change their fleet deployment with major events
- The relationship between fleet deployment diversification and airline (network) mission
- Comparison among airlines and over time can reveal interesting trends
- There are chances to capture important trends and strategies
- Possibly study other relationships with fuel prices, airline performance, etc.
- More data mining exercises are definitely helpful to airline strategists and decision makers

Questions/Comments