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U.S. DOMESTIC AIRLINE FUEL EFFICIENCY RANKING, 2017-2018

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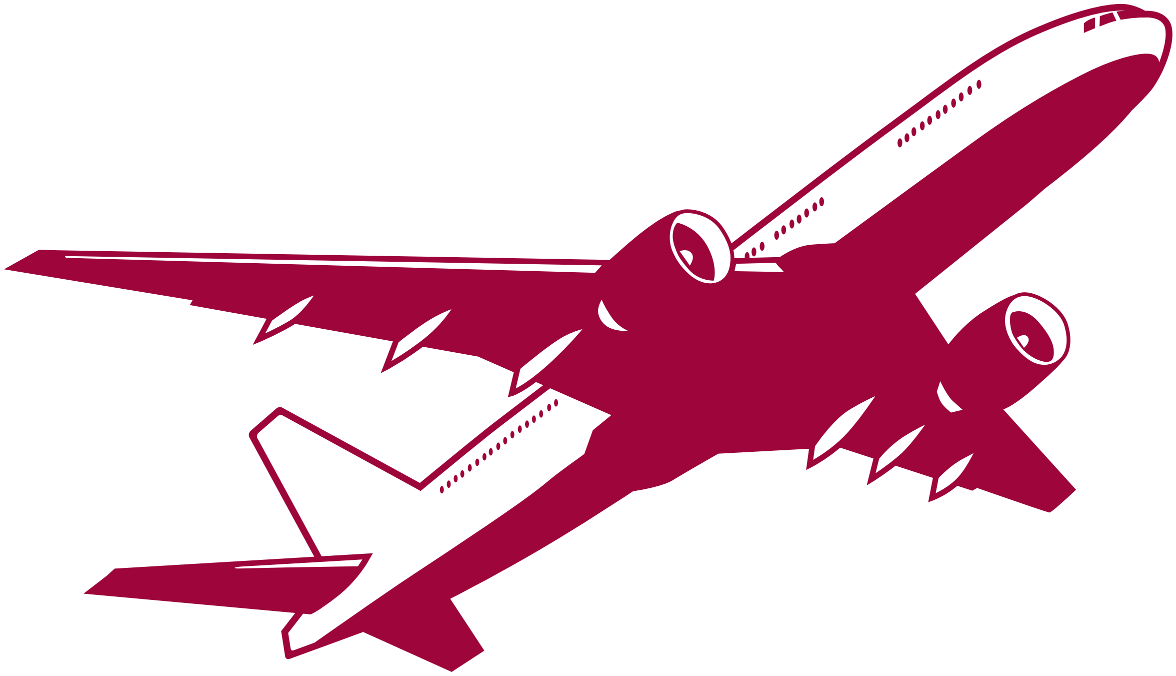

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INTRODUCTION

Aviation is an important part of the global economy, and demand for aviation services is growing. Passenger miles traveled on U.S. airlines are expected to increase 2.2% annually through 2039 (FAA, 2019a). In 2018, commercial aircraft emitted about 900 million tonnes of CO_2 globally (IATA, 2019), which is 2.4% of the worldwide total and more than the entire German economy. Commercial aviation in the United States, which accounts for 30% of global aviation emissions (U.S. EPA, 2016), has been meeting its self-imposed goal to improve fleetwide fuel efficiency by 1.5% annually (Graver, 2018). However, total fuel burn increased by 16% from 2009 to 2017 due to growing demand (Graver and Rutherford, 2018).

Recognizing the importance of reducing aviation emissions, the U.S. government set a goal of capping CO_2 emissions from U.S. commercial carriers at 2005 levels from 2020 (FAA, 2015). In support of this goal, the Federal Aviation Administration (FAA) implemented a voluntary system to collect CO_2 emissions data from airlines (FAA, 2019b). This data will be used to support the International Civil Aviation Organization (ICAO) Carbon Offsetting and Reduction Scheme for International Aviation, or CORSIA, starting in 2021 (Olmer & Rutherford, 2017a). The U.S. Environmental Protection Agency, which is obligated to set an aircraft greenhouse gas emissions standard under the Clean Air Act, is expected to propose a rule that, at a minimum, conforms with ICAO's recommended standard (U.S. EPA, 2016) in fall of 2019 (Office of Management and Budget, 2019).

Individuals, companies, and organizations are increasingly interested in taking action to reduce the carbon footprint of their air travel. Ideally, airlines would provide fuel efficiency data directly to consumers to help them choose more fuel-efficient flights. However, assessments of which carriers are more and less fuel-efficient can also provide value. In 2013, the ICCT began to publish annual fuel efficiency rankings of major U.S. domestic airlines, beginning with data from 2010.[1] This update ranks the fuel efficiency of U.S. airlines in 2017 and 2018.

1 The previous rankings include: Zeinali, et al. 2013; Kwan, Rutherford & Zeinali, 2014; Kwan & Rutherford, 2014; Li, Kwan & Rutherford, 2015; and Olmer & Rutherford, 2017b

METHODOLOGY

This update, as in the previous studies, evaluates the fuel efficiency of U.S. airlines' domestic operations using a deterministic frontier model. The frontier approach benchmarks carriers using a fuel per transport service metric based on data reported by airlines to the U.S. Department of Transportation's Bureau of Transportation Statistics (BTS) (Airline Data, Inc. 2019).[2]

Transport service accounts for both mobility, measured by revenue passenger miles (RPMs), and access, measured by the number of airports served or flight frequency. This ensures the model equitably compares airlines operating under various business models (e.g. point-to-point vs. hub-and-spoke, predominately short haul vs. longer coast-to-coast flights, etc.). The fuel consumed per unit of transport service is compared to that of the average airline, by quarter, in order to generate a Fuel Efficiency Score (FES), which is discussed below.

Quarterly data on RPMs, departures, and fuel burn data for 2017 and 2018 either extracted from BTS database or provided by Airline Data, Inc (2019) are used to develop the statistical frontier model, which relates the fuel consumed by an airline *i* at time *t* to its revenue passenger miles (RPM) and departures (dep):

$$fuel_{it} = f(RPM_{it}, dep_{it}) + \eta_{it} \qquad \text{[Eq. 1]}$$

where η_{it} represents the airline's true inefficiency.

Assuming a log-linear function best describes the relationship between the input and output variables, Equation 1 is transformed into the following functional form:

$$\ln (fuel)_{it} = \beta_0 + \beta_1 \ln (RPM)_{it} + \beta_2 \ln (dep)_{it} + \xi_{it} \qquad \text{[Eq. 2]}$$

where β_0, β_1, and β_2 are the coefficients estimated from a single year's quarterly dataset of fuel consumption, RPMs, and departures. Some air carriers operate a significant portion of their flights through the use of regional affiliates. To account for this, the RPMs, departures, and fuel use of regional affiliates are apportioned to their respective mainline carriers using BTS T100 data (U.S. DOT, 2019). The function also takes into account circuity, measured as the degree to which air carriers' flight paths deviate from direct origin-destination distance as a result of layovers (Zeinali, Rutherford, Kwan, & Kharina, 2013).

In some cases, air carriers misreport their fuel burn, RPMs, or departures to BTS. When possible, we corrected the data using revised data supplied by the air carrier itself. When not possible, erroneous data was backfilled using the relationship between fuel burn and RPMs for that aircraft type. For example, if an airline's Quarter 1 2018 fuel burn value for a specific aircraft type was determined to be an outlier, the fuel burn was backfilled based on a linear regression for that specific air carrier and aircraft type from other quarters in 2017 and 2018.

2 For an in-depth discussion on the Frontier model methodology, see Zou et al. (2012).

The resulting frontier model representing 2017 airline fuel consumption, with standard error in parentheses, is:

$$\ln(\mathit{fuel}) = \underset{(1.006)}{0.599} + \underset{(0.073)}{0.611} \times \ln(\mathit{RPM}) + \underset{(0.060)}{0.373} \times \ln(\mathit{dep}) \quad \text{[Eq. 3]}$$

Number of observations: 48 *R^2: 0.997*

Similarly, the resulting frontier model representing 2018 airline fuel consumption, with standard error in parentheses, is:

$$\ln(\mathit{fuel}) = \underset{(1.194)}{0.857} + \underset{(0.087)}{0.580} \times \ln(\mathit{RPM}) + \underset{(0.071)}{0.411} \times \ln(\mathit{dep}) \quad \text{[Eq. 4]}$$

Number of observations[3]*: 48* *R^2: 0.997*

To compare the efficiency of airlines irrespective of business model, a unitless Fuel Efficiency Score (FES) was developed. The FES measures the transport service (including both mobility and access) per unit of fuel consumed and is calculated by normalizing each airline's inefficiency value by the simple average across all airlines. Thus, a higher FES (>1) indicates relatively higher fuel efficiency, while a lower FES (<1) indicates relatively lower fuel efficiency. See Zeinali, Rutherford, Kwan, & Kharina (2013) for further details.

3 In January 2018, Alaska Airlines and Virgin America received their common operating license (Alaska Airlines, 2019) and began submitting data jointly to DoT in February 2018. Fuel Efficiency Scores for the combined airline in 2018 are presented below. For the purposes of generating the 2018 efficiency frontier, Alaska's and Virgin America's fuel, RPMs, and departures were estimated separately for Q1 to Q4 2019. This is possible because Alaska operated an all Boeing fleet and Virgin America operated only Airbus A320 aircraft before their merger. After the frontier was generated, Alaska and Virgin data were aggregated for the calculation of Alaska's FES. This approach improved the statistical significance of the model by providing four additional observations for the regression analysis.

FINDINGS

This paper identifies four key findings from the research: the rankings of the relative fuel efficiency of airlines in 2018; trends in the fuel efficiency of airlines over time; operational variables that explain these trends; and industrywide changes in demand, fuel efficiency, and fuel use.

HIGH LEVEL FINDINGS

The 2018 Fuel Efficiency Scores for U.S. domestic air carriers are presented in Figure 1. Carriers with an efficiency score greater than 1.00 are more fuel efficient than the industry average, while carriers with a score less than 1.00 are less efficient than average. Excess fuel burn per unit transport service[4], calculated by passenger miles and departures weighted by the coefficients in Equation 4, relative to the most fuel-efficient carrier are shown at the right of the diagram. The analysis of fuel efficiency from 2017 operations are summarized in the Appendix.

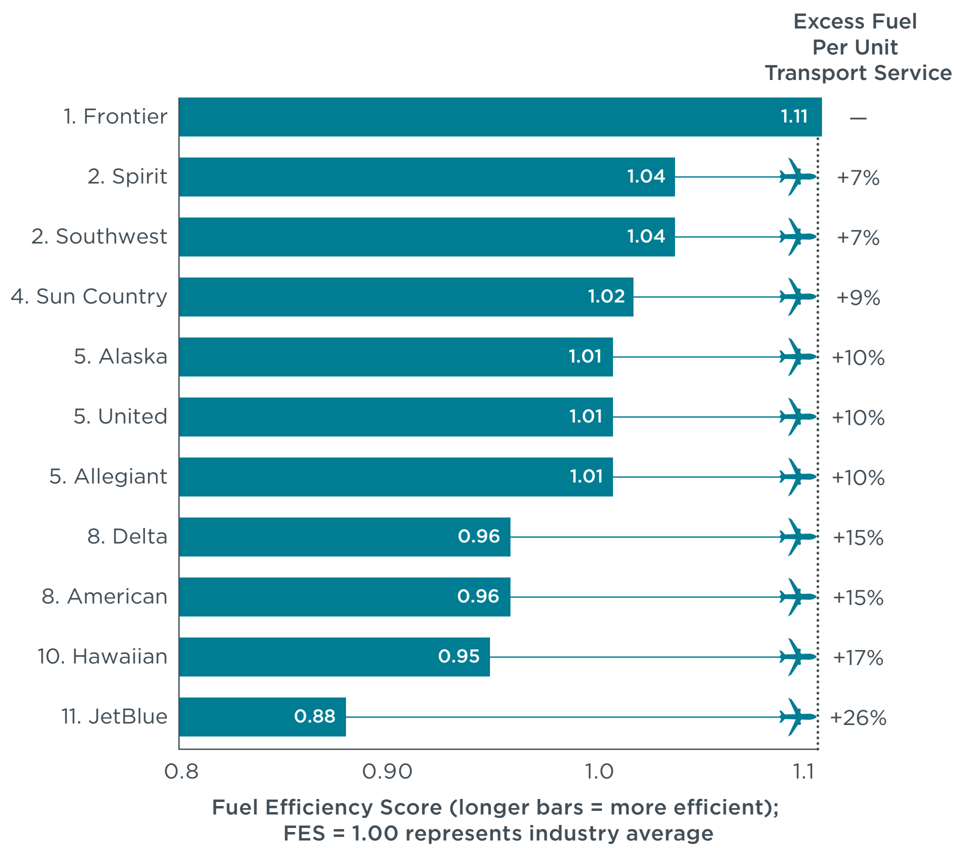

Figure 1. Fuel Efficiency Scores and excess fuel per unit transport service by airline for U.S. domestic operations, 2018.

As shown in Figure 1, Frontier operated the most fuel-efficient domestic operations in 2018 by a significant margin. Spirit and Southwest tied for second in terms of fuel

4 Transport service denotes the combination of RPMs and departures provided by each airline, weighted by their relative importance as a driver of fuel consumption under a deterministic frontier regression. See the methodology section above. For 2018, each airline's transport service can be calculated as (RPM)^0.580*(dep)^0.411.

efficiency on domestic flights, burning 7% more fuel to provide the same amount of transport service as Frontier. Sun Country, which began restructuring to an ultra-low-cost carrier in 2017 (Moseley, 2017), placed fourth in terms of fuel efficiency. Alaska, United, and Allegiant rounded out the carriers with above average fuel efficiency in 2018. United has consistently operated the most fuel-efficient domestic operations of the largest hub-and-spoke legacy carriers since merging with Continental Airlines in 2012.

Four carriers—Delta, American, Hawaiian, and JetBlue—all had fuel efficiencies worse than the industry average. Delta and American operated the eighth most fuel-efficient domestic flights in 2018 with efficiency scores of 0.96. Hawaiian, whose fuel efficiency has dropped five spots since 2016, ranked 10th in 2018. JetBlue operated the least fuel-efficient U.S. domestic operations by a wide margin in 2018. The gap between best-performing Frontier and worst-performing JetBlue was 26% in 2018, equal to that observed in 2016 (Olmer & Rutherford, 2017), although slightly narrower than the 27% gap seen in 2017 (see Appendix).

KEY AIRLINE FINDINGS

The airline fuel efficiency rankings from 2014 to 2018 are presented in Table 1.[5] The table highlights the shift in ranking over time as well as mergers (arrows) and fuel-efficiency rank ties (asterisks). As a result of the American-U.S. Airways and Alaska-Virgin America mergers, the total number of airlines in this series dropped from 13 in 2014 to 11 in 2018.

Table 1. Airline fuel efficiency rankings for U.S. domestic operations, 2014 to 2018.

Rank	2014	2015	2016	2017	2018	Rank
1	Alaska	Alaska	Alaska	Frontier	Frontier	1
2	Spirit	Spirit	Frontier	Alaska*	Spirit*	2
3	Frontier	Frontier	Spirit	Spirit*	Southwest*	3
4	Southwest	Southwest	Southwest	Southwest	Sun Country	4
5	United	Hawaiian*	Hawaiian	Sun Country	Alaska*	5
6	Hawaiian	United*	Sun Country*	United*	United*	6
7	U.S. Airways	Sun Country	United*	Hawaiian*	Allegiant*	7
8	Allegiant	Delta	American	American	Delta*	8
9	JetBlue	Allegiant*	Allegiant*	Allegiant*	American*	9
10	Sun Country	American*	Delta*	Delta*	Hawaiian	10
11	Delta	JetBlue*	JetBlue	JetBlue	JetBlue	11
12	Virgin America	Virgin America	Virgin America	Virgin America	—	
13	American	—	—	—	—	

* Denotes ties between airlines in a given year

Beginning in 2017 (see Appendix), Frontier took over the top spot in the ranking from Alaska, which held the distinction of being the most fuel-efficient U.S. domestic airline from 2010 to 2016. In October 2016, Frontier began receiving new Airbus A320neo aircraft with more efficient Leap-1A engines and wingtip devices (Airbus, 2016). As of July 2019, Frontier has 43 A320neo aircraft in service (Z. Kramer, personal communication, August 2019), more than any other U.S. carrier. It ordered an additional 134 aircraft from the A320neo family in December 2017 through its parent company (eTurboNews, 2017), pointing to further improvements in future rankings.

5 See Olmer and Rutherford (2017) for the equivalent rankings for 2010 to 2013.

Spirit Airlines, an ultra-low-cost carrier with operating bases in Detroit, Fort Lauderdale, Las Vegas, and five other cities, has consistently ranked second or third in fuel efficiency since 2010. Southwest Airlines, which flies an all-Boeing 737 fleet throughout the U.S., moved from fourth place for fuel efficiency in 2016 to a tie with Spirit for second place in 2018. Southwest's improving fuel efficiency has been tied to fleet modernization, as the company is retiring its older and smaller 737-300 aircraft in favor of larger and more fuel-efficient 737 Next Generation and 737 MAX aircraft (Ewing, 2017).

Alaska slipped four ranks in fuel efficiency from 2016 to 2018 due in large part to its merger with Virgin America, which operated the least fuel-efficient U.S. domestic flights from 2015 to 2017. The merger resulted in a percentage point drop in load factor from 85% to 84% and a 2% reduction in seating density from 2016 to 2018. The fuel efficiency of Alaska's regional operations also fell due to the greater use of regional jets instead of more efficient turboprop aircraft. In 2016, Alaska's affiliate Horizon Air flew 132,000 turboprop flights, or one half of all such flights in the United States. By 2018, Alaska's regional turboprop flights fell by about one-quarter, from 82% of regional flights in 2016 to 55% in 2018 (Figure 2).[6] Over the same period, Alaska's use of less fuel-efficient regional jets increased from 18% to 45% of regional operations. The share of regional flights completed by turboprops for all airlines, including Alaska, fell from 8% in 2016 to 4% in 2018.

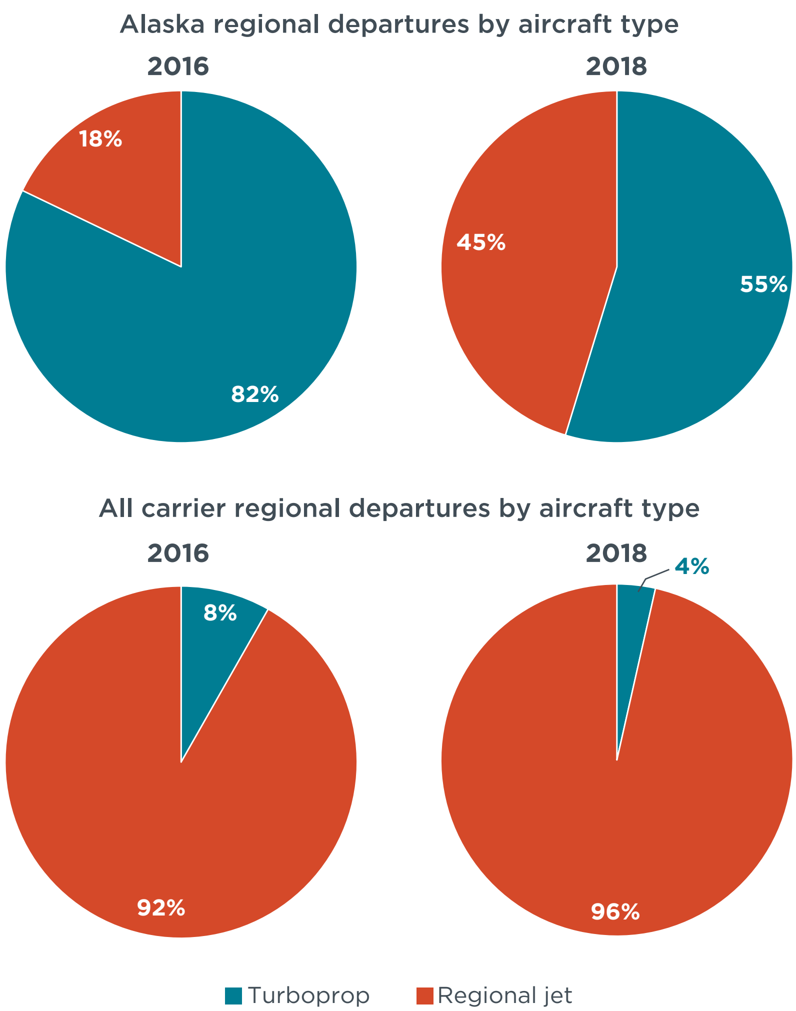

Figure 2. Share of regional departures by aircraft type for Alaska and all carriers, 2016 and 2018.

6 Here, we define regional operations as those flown by turboprop and regional jets only.

This shift in aircraft type reduced the fuel efficiency of Alaska's regional operations and, therefore, the carrier's overall fuel efficiency. Fuel burn per revenue passenger mile for Alaska's affiliates increased by 11%, and fuel burn per departure increased by 35% from 2016 to 2018. Combined with its merger with Virgin America, these changes contributed to Alaska dropping from the most fuel-efficient carrier in 2016 to a tie for fifth in 2018.

A few other shifts are apparent in the ranking. Hawaiian slipped five efficiency ranks from 2016 to 2018 on account of fewer turboprop operations, increased premium economy seating on its A330 aircraft, and an 5% decrease in the average size of aircraft[7] used for domestic operations. Together, these changes led to an 8% decrease in the average number of seats per Hawaiian flight, from 273 in 2016 to 253 in 2018. The least fuel-efficient carrier in 2018, JetBlue, has held steady in 11th place since 2015. JetBlue operates its fleet of Airbus A320, Airbus A321, and Embraer 190 aircraft at a lower load factor and with fewer seats per plane compared to its competitors. JetBlue's order of 60 A220 aircraft, along with options for 60 more in July 2018 (Leeham News, 2018) could improve its fuel efficiency on future rankings.

OPERATIONAL VARIABLES INFLUENCING AIRLINE FUEL EFFICIENCY

Table 2 summarizes key airline operational parameters for the 11 carriers included in this survey, including absolute and share of RPMs, passenger load factor, seating density in seats per m^2 of floor area[8], and the relative fuel burn[9] of each airline's combined mainline and regional fleets. The table also identifies circuity, a ratio of actual distance traveled by passengers to the great circle distance between origin and destination airports. A circuity of 1.00 corresponds to direct flights only, while a value of 1.06 represent 6% excess miles traveled due to less efficient routing.

7 RPM-weighted average of square meters of pressurized floor area using the metric of Reference Geometric Factor, or RGF. RGF was developed by the International Civil Aviation Organization as a means to help assess aircraft fuel efficiency. See Rutherford (2013) for further details.

8 As measured by seats per square meter of RGF. See footnote 7 for details.

9 As measured by margin from the International Civil Aviation Organization's fuel efficiency (CO_2) standard, which established a means of assessing and comparing aircraft efficiency independent of how it is used in actual operations. Lower values indicate more fuel-efficient fleets, while higher values indicate more fuel-intensive aircraft. See Rutherford & Kharina (2017) for details.

Table 2. Explanatory variables for fuel efficiency, 2018

Rank	Airline	Domestic RPMs		Passenger load factor	Seating density[a] (seats/m²)	Aircraft fuel burn[b]	Circuity[c]
		Billion	%				
1	Frontier	20	3%	86%	1.71	+3.0%	1.01
2	Spirit	28	4%	85%	1.68	+3.7%	1.01
2	Southwest	129	18%	83%	1.71	+4.5%	1.03
4	Sun Country	3	0.4%	81%	1.66	+5.4%	1.00
5	Alaska[d]	52	7%	84%	1.50	+7.2%	1.03
5	United	132	18%	85%	1.39	+4.7%	1.04
5	Allegiant	12	2%	85%	1.69	+11.2%	1.00
8	Delta	141	20%	86%	1.44	+9.2%	1.06
9	American	152	21%	84%	1.36	+4.0%	1.05
10	Hawaiian	12	2%	87%	1.21	+1.5%	1.01
11	JetBlue	40	6%	85%	1.37	+4.3%	1.01
RPM weighted average				**85%**	**1.45**	**+5.5%**	**1.04**

[a] As measured by seats per square meter of RGF. See footnote 7 for details.
[b] As measured by the average margin of aircraft to ICAO's CO_2 standard. See footnote 9 for details.
[c] A circuity of 1.00 corresponds to direct flights only, while a value of 1.06 represent 6% excess miles traveled due to less efficient routing.
[d] Post-merger value including Virgin America flights. 2017 results, summarized in the Appendix, include Virgin America as an independent carrier.

As summarized in Table 2, key operational parameters of U.S. domestic operations varied less compared to previous years, reflecting the move by most U.S. carriers toward a low-cost business model since 2010. For example, carrier load factors varied from 70% (Sun Country) up to 90% (Allegiant) in 2010, compared to the narrower load-factor range of 81% (Sun Country) to 87% (Hawaiian) in 2018. Likewise, the fuel burn of Allegiant's fleet of predominately older A320 family aircraft was about 10 percentage points higher than Hawaiian's fuel burn, which on average operated the most fuel-efficient aircraft in 2018. In 2010, there was 27 percent difference in a comparable metric[10], when Allegiant operated only very inefficient McDonnell Douglas MD-80 aircraft compared to Alaska's much more fuel-efficient Boeing 737 Next Generation aircraft (Zeinali et al., 2013).

The data in Table 2 provides evidence for Frontier's superior fuel-efficiency performance in 2018. In addition to operating the second most fuel-efficient fleet, Frontier operated with an above average load factor (86%) and low circuity (1.01), and tied with Southwest for the highest seating density (1.71 seats/m²). In other words, Frontier operated predominately direct flights on fuel-efficient aircraft with more passengers than most other airlines. Spirit and Southwest were broadly comparable in these measures to Frontier. Carriers with lower, but still above average fuel efficiencies —Alaska, United, and Allegiant—tended to either operate less fuel-efficient fleets with fewer passengers and/or with higher circuity than their better performing peers. Operations of airlines with below-average fuel efficiency tended to compare poorly on multiple variables.

10 Technology Utilization Score (TUS), a metric developed to compare the relative fuel burn of each airline's fleet in the 2010 study, was used by ICCT prior to ICAO's CO_2 standard metric. See Zeinali et al. (2013) for further details.

INDUSTRYWIDE CHANGES IN DEMAND, FUEL EFFICIENCY, AND FUEL USE

From 2016 to 2018, increases in the number of U.S. domestic flights continued to outstrip improvements in fuel efficiency. Overall, RPMs by the ranked carriers increased by 10% from 2016 to 2018, identical to the increase seen from 2014 to 2016 (Olmer & Rutherford, 2017). Fuel efficiency, measured in RPMs per gallon of fuel, improved by 3% from 2016 to 2018. The net result was a 7% increase in overall fuel burn and CO_2 emissions from U.S. domestic operations. Fuel use from domestic operations by U.S. passenger carriers hit 12.5 billion gallons in 2018, a 17% increase since the 2009 minimum during the global financial crisis (Figure 3) and above 2005 levels.[11]

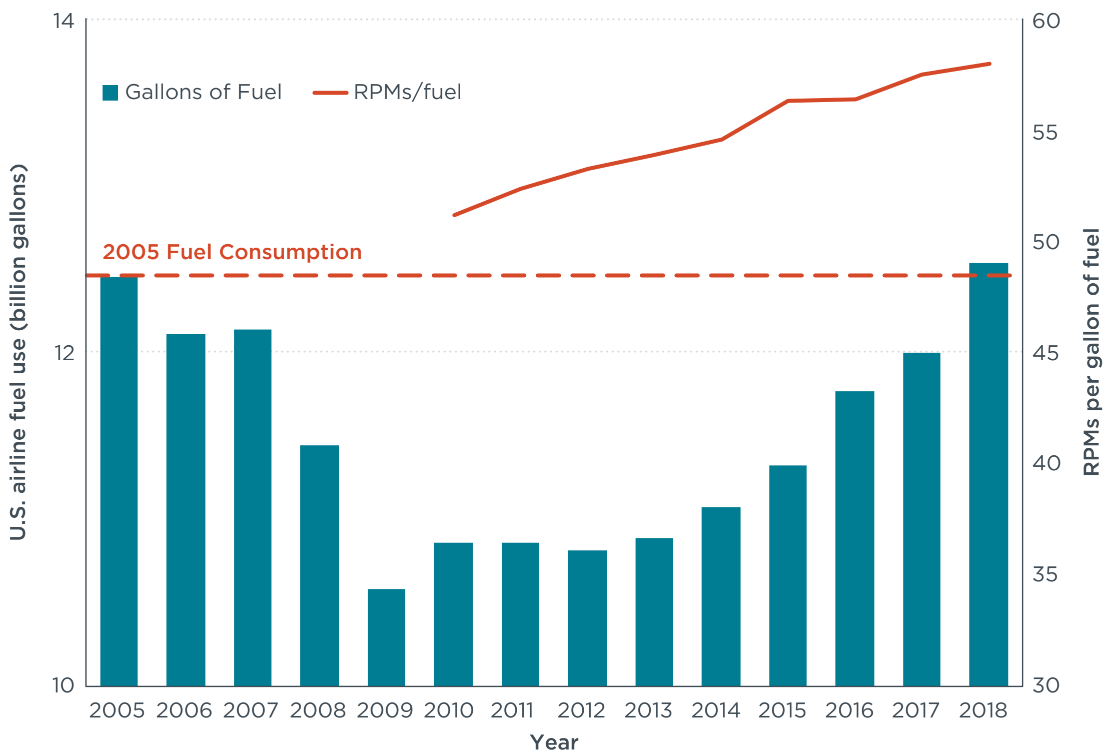

Figure 3. United States domestic passenger airline fuel use and RPMs per gallon of fuel, 2005-2018.

11 Gallons of fuel for 2005 to 2009 shown in Figure 3 are directly from BTS Form-41 data. Fuel use from 2010 is drawn from previous ICCT studies with corrections of erroneously reported data from carriers as described in the methodology section above.

CONCLUSIONS

This study assessed the fuel efficiency of U.S. airlines on domestic operations in the years 2017 and 2018. For the first time, Frontier's fuel efficiency on domestic flights exceeded that of Alaska Airlines, which fell to 5^{th} due to its merger with less efficient Virgin America and its reduced use of highly efficient turboprop aircraft. Spirit and Southwest tied for second place in the ranking, burning 7% more fuel per unit transport service than Frontier. Frontier's widespread use of new, more fuel-efficient Airbus A320neo aircraft, along with its operational practices, accounted for its superior efficiency. Conversely, JetBlue took the lowest spot on the ranking, burning 26% more fuel than Frontier to provide a similar level of transport service.

Domestic airline operations continued to expand, with increases in fuel efficiency outstripped by an overall increase in activity. Revenue passenger miles increased 10% and departures increased by 4% from 2016 to 2018. Fuel efficiency in terms of RPMs per gallon of fuel consumed improved by 3%. The net result was a 7% increase in overall fuel burn and CO_2 emissions from domestic passenger operations. CO_2 emissions from U.S. domestic operations have increased by 15% over the past five years, raising questions about how the U.S. aviation industry can meet its goal of carbon neutral growth from 2020 without further policy interventions.

Future updates to this series will investigate how changes in industry structure, overall aviation activity, and new technologies influence airline efficiency. As industry consolidation solidifies, for example through the full integration of Virgin America's operations by Alaska (Gates, 2019), we may expect corresponding changes in the relative fuel efficiency of the remaining carriers. Likewise, the expanded market share of more efficient single-aisle aircraft types, like the Airbus A320neo, Boeing 737 MAX, and the Airbus A220 (formerly the Bombardier CSeries), should improve the fuel efficiency of more U.S. carriers.

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APPENDIX: 2017 RESULTS

The table below (Table A1) shows the Fuel Efficiency Scores and excess fuel use for U.S. domestic carriers in 2017. Carriers with an efficiency score greater than 1.00 are more fuel efficient than the industry average, while carriers with a score less than 1.00 are less efficient than average.

Table A1. Fuel Efficiency Scores and excess fuel per unit transport service by airline for U.S. domestic operations, 2017.

Rank	Airline	FES	Excess Fuel Per Unit Transport Service
1	Frontier	1.11	—
2	Alaska	1.07	+4%
	Spirit	1.07	+4%
4	Southwest	1.04	+7%
5	Sun Country	1.03	+8%
6	United	1.00	+11%
	Hawaiian	1.00	+11%
8	American	0.98	+13%
9	Allegiant	0.96	+15%
	Delta	0.96	+15%
11	JetBlue	0.91	+21%
12	Virgin America	0.87	+27%

Frontier exceeded Alaska in domestic fuel efficiency in 2017. Spirit tied with Alaska in domestic fuel efficiency in 2017, burning 4% more fuel than Frontier on comparable domestic flights. Southwest, ranked 4th, and Sun Country, ranked 5th, rounded out the group of five carriers with better-than-average fuel efficiency. United and Hawaiian tied for sixth with FESs equal to the average industry (1.00). In 2017, United continued to operate the most fuel-efficient domestic operations of the largest hub-and-spoke legacy carriers, a distinction it has held since merging with Continental Airlines in 2012.

Five carriers—American, Allegiant, Delta, JetBlue, and Virgin America—had fuel efficiencies below the industry average. American and Delta continued their positions as more fuel intensive legacy carriers, burning 13 to 15% more fuel than Frontier on comparable flights. JetBlue (0.91) and Virgin America (0.87) were ranked the most inefficient carriers. Virgin America burned 27% more fuel per unit transport service than Frontier in 2017, the largest gap seen in U.S. domestic operations since 2013 (Kwan & Rutherford, 2014).

Table A2 summarizes the key explanatory variables for airline fuel efficiency in 2017.

Table A2. Explanatory variables for fuel efficiency, 2017

Rank	Airline	RPMs		Passenger load factor	Seating density[a] (seats/m²)	Aircraft fuel burn[b]	Circuity[c]
		Billion	% of total				
1	Frontier	18	3%	87%	1.69	6.7%	1.01
2	Alaska	37	5%	85%	1.53	7.4%	1.03
	Spirit	23	3%	83%	1.67	3.9%	1.01
4	Southwest	125	18%	84%	1.72	5.2%	1.03
5	Sun Country	3	0.4%	80%	1.58	5.5%	1.01
6	United	124	18%	85%	1.37	4.8%	1.04
	Hawaiian	11	2%	88%	1.22	2.4%	1.01
8	American	149	22%	84%	1.37	4.4%	1.05
9	Allegiant	11	2%	84%	1.68	18.0%	1.00
	Delta	134	20%	86%	1.43	10.1%	1.06
11	JetBlue	37	5%	85%	1.37	4.3%	1.01
12	Virgin America	13	2%	84%	1.38	7.2%	1.01
RPM weighted average				**85%**	**1.48**	**6.2%**	**1.04**

[a] As measured by seats per square meter or RGF. See footnote 7 in the main body of the report for details.
[b] As measured by the average margin of aircraft to ICAO's CO_2 standard. See footnote 9 in the main body of the report for details.
[c] A circuity of 1.00 corresponds to direct flights only, while a value of 1.06 represent 6% excess miles traveled due to less efficient routing.

A few observations can be made from Table A2. Frontier's fuel efficiency is linked to the large numbers of passengers it carried on its flights owing to high load factors and dense seating configuration, second only to Southwest. It's fleet, however, was slightly less fuel-efficient than the average in 2017 relative to ICAO's international efficiency benchmark. Alaska was less fuel-efficient than Frontier on each of these metrics, but almost matched on overall efficiency due to the widespread use of turboprops for regional flights (see Figure 2 and accompanying text).

Fourth-ranked Southwest had the highest seating density (1.72 seats/m²) in 2017, but was roughly average in terms of load factor, fleet efficiency, and circuity. Hawaiian's high load factor and efficient fleet was largely offset by greater premium seating offerings on flights to the mainland United States. The two least fuel-efficient carriers, JetBlue and Virgin America, demonstrated similar load factors, seating configurations, and circuity, although Virgin America operated a less fuel-efficient fleet. Allegiant, which flew 38% of its RPMs on MD-80 aircraft in 2017, had the most fuel intensive fleet by a wide margin, almost 16 percentage points worse than best-performing Hawaiian.