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A Decade of Change in Fuel Prices and U.S. Domestic Passenger Aviation Operations

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Over the past decade, significant events have impacted U.S. domestic passenger aviation operations. These events include, but are not limited to the following:

- March to November 2001 and December 2007 to June 2009 economic recessions;
- September 11, 2001 terrorist acts;
- Severe Acute Respiratory Syndrome (SARS) outbreak in 2002;
- Airline mergers, including: American with Trans World (TWA) in 2001, US Airways with America West in 2005, Delta with Northwest in 2008, United with Continental in 2010, and Southwest with AirTran in 2011;
- Adoption of new technologies such as the Required Navigation Performance (RNP) flight guidance technology to fly more direct routes and thereby reduce fuel requirements;
- Streamlining of operations, including but not limited to the replacement of older aircraft with newer, more fuel efficient aircraft; and
- Upward trend in the cost of fuel.

This report looks at changes in U.S. domestic passenger aviation operations that have occurred during the same time frame as the events listed above, with particular focus on those related to fuel price increases. Major findings include:

- Fuel price increases over the past decade coincided with reduced profits and, in many cases, operating losses among carriers. Operating costs include, but are not limited to, flying operations, maintenance, and passenger service.
- Airfares trended downward despite an upward trend in fuel costs. The downward trend in airfares coincided with increased decoupling of airfares with services,

such as baggage check, reservation changes, and food and drink purchases, all of which accounted for a larger portion of total revenue in 2010 than in 2000.

- Carriers reduced capacity on many routes when the cost of fuel was high.
- Carriers improved the number of available seat miles (ASMs)¹ flown per gallon of fuel (fuel productivity) and the number of gallons consumed per block hour (fuel efficiency).² This improvement coincides with airlines using newer and more fuel efficient jets.

Fuel Cost and Operating Expenses

In June 2011, U.S. air carriers with an annual revenue of \$20 million or more paid on average \$2.94 per gallon of fuel for scheduled and nonscheduled domestic service—5 percent more than what they paid in June 2010 and 51 percent more than what they paid in June 2000 after adjusting for inflation³ (see figure 1).

The rise in the cost of fuel since 2000 has resulted in fuel becoming one of aviation's largest operating expenses. In 2000, the cost of labor was 2.5 times that of fuel, but in 2010, the cost of labor and fuel were nearly identical with each accounting for about 25 percent of all operating expenses (see figure 2).⁴

¹ Available seat miles (ASMs) are airline specific. As such, the number of ASMs may differ from carrier to carrier even when operating the same aircraft due to carrier specific configurations of seats (e.g., first class options do not exist with all carriers).

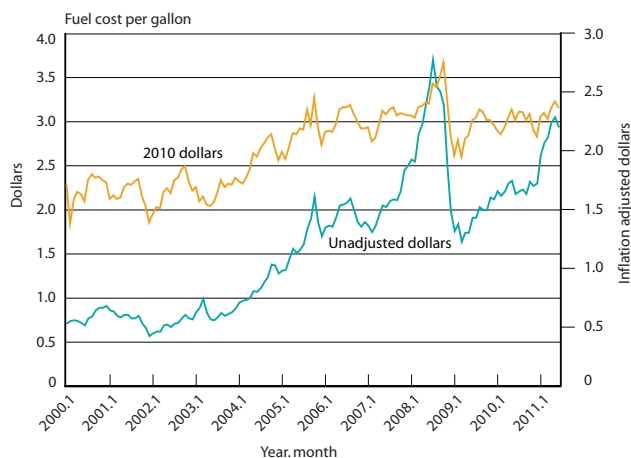
² Block hours are defined as the time elapsed from the moment an aircraft pushes back from the departure gate until the moment of engine shutoff at the arrival gate following its landing.

³ Fuel cost per gallon adjusted for inflation using the Consumer Price Index (CPI) for fuel oil and other fuels, base year 2010 = 275.132.

⁴ In 2000, airlines paid \$14.1 billion for fuel and \$34.5 billion for labor. On average, airlines paid \$3.5 billion for fuel and \$8.6 billion for labor in a quarter. In the third quarter of 2010, airlines paid \$8.4 billion for fuel and \$8.2 billion for labor.

Figure 1: Cost of Fuel for Scheduled and Nonscheduled Domestic Operations – 2000 to 2011

(Monthly data for scheduled and nonscheduled domestic operations by U.S. carriers with annual revenue of \$20 million or more)



NOTE: Fuel cost per gallon adjusted for inflation using the Consumer Price Index (CPI) for fuel oil and other fuels, base year 2010 = 275.132.

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, Form 41 Financial Data Schedule P12a (fuel data) as of Aug. 25, 2011.

Profit/Loss

Over the past decade, real fuel prices have trended upward after remaining relatively stable throughout the 1990s. The following sections of this report examine changes in domestic passenger aviation operations concurrent with real fuel prices using selected legacy and low cost carriers.⁵ Legacy carriers, in this report, refer to the five U.S. airlines with the most enplanements in 2010 that were established before airline deregulation in 1978 (American⁶, Continental, Delta⁷, United, and US Airways⁸). Low cost carriers refer to the five U.S. airlines with the most enplanements in 2010 that utilize a business model emphasizing high aircraft utilization with relatively streamlined passenger and aircraft operations (JetBlue, Frontier, AirTran, Spirit, and Southwest).

Both legacy and low cost carriers have experienced declines in operating profits since the mid 1990s. Unlike low cost carriers, legacy carriers experienced substantial losses immediately after 9/11 and from the first through the fourth quarter of 2008 when the real fuel price rose beyond

⁵ By U.S. definition, a legacy carrier is an airline carrier, with the exception of low cost Southwest Airlines, that established airline routes prior to the Airline Deregulation Act of 1978. Carriers in the United States that formed after the Airline Deregulation Act plus Southwest Airlines, established in 1967, are generally considered to be low cost carriers.

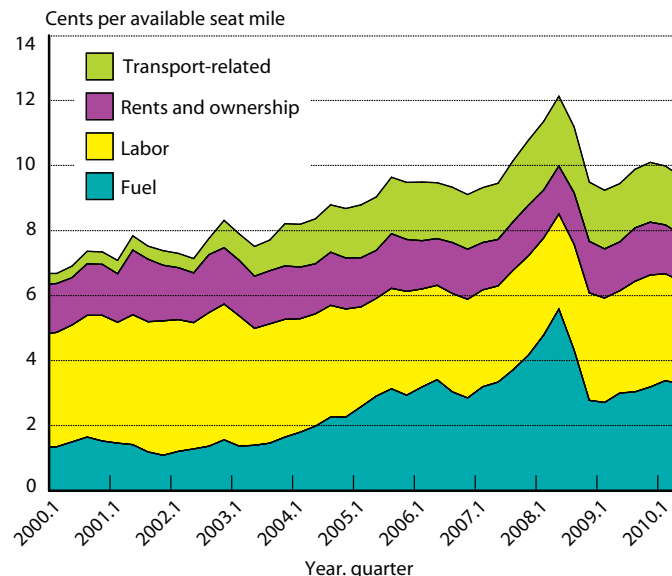
⁶ American Airlines merged with Trans World Airlines (TWA) in 2001. American Airlines and TWA data are combined and referred to as American.

⁷ Delta merged with Northwest in 2008. In this report, Delta and Northwest data are combined and referred to as Delta.

⁸ US Airways merged with America West in 2005. In this report, US Airways and America West data are combined and referred to as US Airways.

Figure 2: Most Costly Operating Expenses – 2000 to Q3 2010

(Data are quarterly)



NOTE: Most costly = any item accounting for 10 percent or more of total operating expenses in Q3 2010. **Fuel** = cost of aviation fuel used in flight operations, excluding taxes, transportation, storage, and fueling expenses. **Labor** = wages, employee benefits (e.g., annuity payments, educational, medical, recreational, and retirement programs) and payroll taxes (e.g., FICA, State and Federal unemployment insurance) paid to or on behalf of general management, flight personnel, maintenance labor, and aircraft and traffic handling personnel. **Rents and ownership** = the cost of aircraft rentals; depreciation and amortization of flight equipment, including airframes and parts, aircraft engine and parts, capital leases and other flight equipment; airport terminal rents, hangars, ground service and support equipment (GSE), storage and distribution equipment, and communication and meteorological equipment. **Transport-related** = expenses incurred for providing air transportation facilities associated with the performance of service that emanate from and are incidental to air transportation services performed by the carrier, including expenses related to regional jet contract agreements.

SOURCE: ATA Quarterly Cost Index: U.S. Passenger Airlines, <http://www.airlines.org/Economics/DataAnalysis/Pages/QuarterlyCostIndex.aspx> as of April 2011.

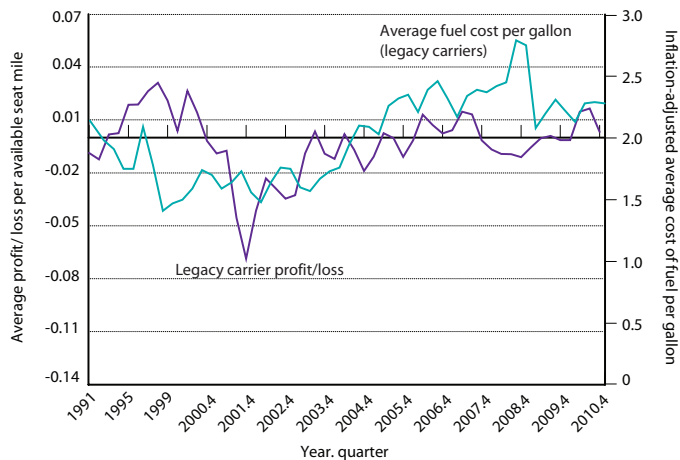
all previous levels (see figure 3 and 4). During the first through the fourth quarter of 2008, legacy carriers posted an operating loss of \$6.4 billion; low cost carriers posted an operating profit of \$0.40 million.

During 2008, the difference in profits between low cost and legacy carriers can be associated with substantial differences in the average price of fuel purchased by the two carrier groups. The average cost among low cost carriers peaked at a lower price than it did among legacy carriers. This was partially a result of individual airline fuel purchasing strategies. Low cost carriers, particularly Southwest, anticipating that the cost of fuel would go up and not down, locked in the price of fuel (termed hedging) for a large portion of the fuel they consumed and thereby avoided price increases by guaranteeing fuel in bulk at a lower price. Legacy carriers engaged in a similar practice but to a lesser extent. The effect of hedging can be seen in the following:

- lower real price of fuel paid by low cost carriers in nearly all quarters over the past decade,

Figure 3: Average Operating Profit/Loss Among Legacy Carriers (2010 dollars) – 1991 to Q4 2010

(Data are yearly from 1991-1999 and quarterly from Q1 2000, adjusted for inflation)



NOTE: Legacy carriers include American Airlines, Continental Airlines, Delta Air Lines, United Airlines, and US Airways. TWA, Northwest, and America West are included as these carriers merged with American Airlines, Delta, and US Airways respectively. From 1991-1999, fuel price is the average for all major, national, and large regional airlines. From Q1 2000, fuel price is the average of all fuel used for scheduled and nonscheduled domestic and international flights for the selected carriers shown in each graph. Average fuel cost per gallon adjusted for inflation using the Consumer Price Index (CPI) for fuel oil and other fuels, base year 2010 = 275.132. Profit/loss adjusted for inflation using the CPI for all urban consumers, base year 2010 = 218.056.

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, Form 41 Financial Data Schedule P1.2 (profit/loss data); Form 41 Financial Data Schedule P12a (fuel data); and Form 41 Traffic Data T2 (ASM) as of July 6, 2011.

- relatively moderate rise of fuel prices paid by low cost carriers in 2008, and
- lack of a relationship between the cost of fuel and profits among low cost carriers.

Both carrier groups reduced hedging practices beginning in 2008, when the tactic faltered as the price of fuel dramatically rose and then dropped to an amount less than that locked in by most carriers.⁹ In the first quarter of 2011, United hedged roughly 63 percent of its fuel needs, American and Delta roughly half, and Southwest approximately 64 percent (down from more than 70 percent in mid 2008¹⁰); US Airways has not engaged in hedging since August 2008.¹¹ As hedging lessened, the real price of fuel paid by low cost carriers approached that of legacy carriers in 2010.

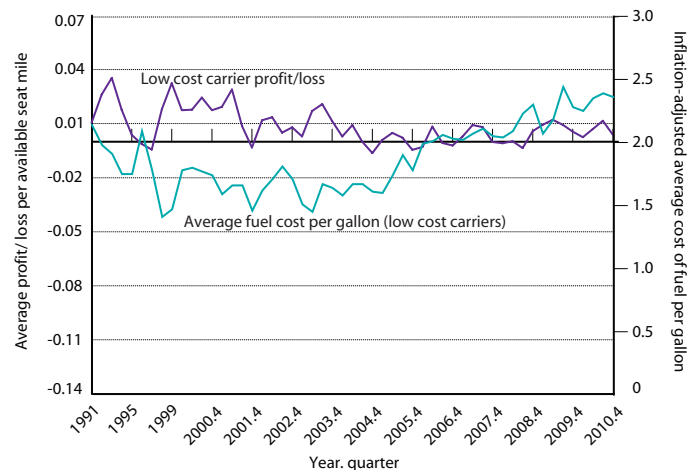
⁹ Allen McAllister. "U.S. airlines more cautious on '10 fuel hedges," Feb. 25, 2010. Retrieved June 7, 2011 from: <http://www.reuters.com/article/2010/02/25/us-travel-leisure-summit-fuel-hedging-idUSTR61059Z20100225>

¹⁰ Peter Pae. "Hedge on fuel prices pays off," May 30, 2008. Retrieved June 7, 2011 from: <http://articles.latimes.com/2008/may/30/business/fi-southwest30>

¹¹ Brett Snyder. "Fuel hedging no guarantee for airlines," Mar. 21, 2011. Retrieved June 7, 2011 from: http://articles.cnn.com/2011-03-21/travel/airlines.fuel.hedging_1_oil-prices-increases-airlines-lower-price?_s=PM:TRAVEL

Figure 4: Average Operating Profit/Loss Among Low Cost Carriers (2010 dollars) – 1991 to Q4 2010

(Data are yearly from 1991-1999 and quarterly from Q1 2000, adjusted for inflation)



NOTE: Legacy carriers include American Airlines, Continental Airlines, Delta Air Lines, United Airlines, and US Airways. TWA, Northwest, and America West are included as these carriers merged with American Airlines, Delta, and US Airways respectively. From 1991-1999, fuel price is the average for all major, national, and large regional airlines. From Q1 2000, fuel price is the average of all fuel used for scheduled and nonscheduled domestic and international flights for the selected carriers shown in each graph. Average fuel cost per gallon adjusted for inflation using the Consumer Price Index (CPI) for fuel oil and other fuels, base year 2010 = 275.132. Profit/loss adjusted for inflation using the CPI for all urban consumers, base year 2010 = 218.056.

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, Form 41 Financial Data Schedule P1.2 (profit/loss data); Form 41 Financial Data Schedule P12a (fuel data); and Form 41 Traffic Data T2 (ASM) as of July 6, 2011.

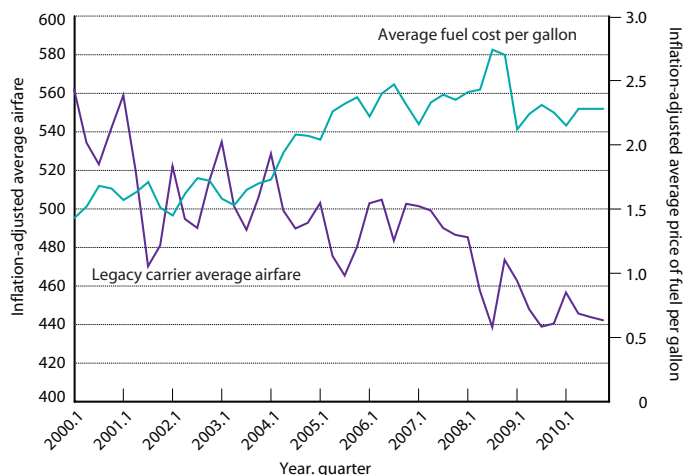
Raising Revenue

Historically, airlines have passed along increased costs to consumers by raising airfares; consequently, airfares have tended to rise and fall with the price of fuel. Figures 5 and 6 show the relationship between airfare and fuel prices (adjusted to 2010 dollars) for both legacy and low cost carriers, respectively. For both airline groups, the average airfare price has trended downward and appears to be related inversely to fuel costs in a few quarters. For example, when fuel costs reached their highest level (since 2000) in the third quarter of 2008, airfares declined through the fourth quarter of 2008. Since then, airfares have continued to rise and fall with fuel prices, yet airfares have trended downward while fuel prices have trended upwards.

The downward trend in airfares also coincides with increased decoupling of ticket prices with air services, such as baggage check, reservation changes, and food and drink purchases. In the first quarter of 2000, legacy and low cost carriers raised a majority of their revenue from passenger airfares (88 and 95 percent respectively). Reservation fees, baggage fees, and other transport revenue accounted for 7 percent of legacy carriers' total revenue and less than 1 percent of low cost carriers' total revenue. By the fourth quarter of 2010, both legacy and low cost carriers collected a larger portion of their total revenue from ancillary fees (27

Figure 5: Average Cost of Airfare for Domestic Flights Operated by Legacy Carriers (2010 dollars) – Q1 2000 to Q4 2010

(Data are quarterly, adjusted for inflation)

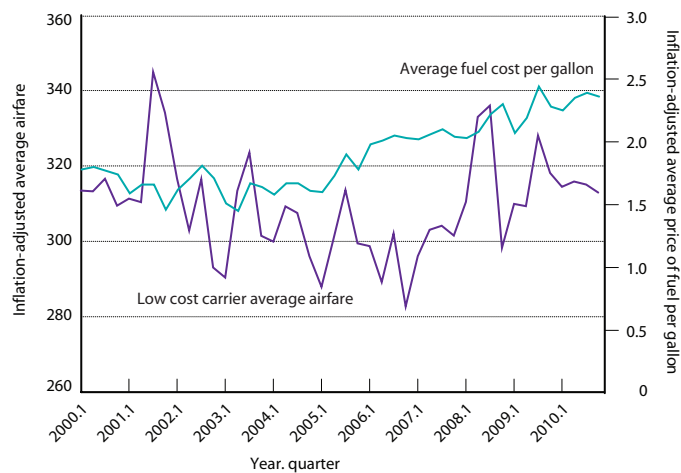


NOTE: Fuel price is the average of all fuel used for scheduled and nonscheduled domestic flights for the selected carriers shown in each graph. Average airfare adjusted for inflation using the Consumer Price Index (CPI) for airline fare, base year 2010 = 278.186. Average fuel cost per gallon adjusted for inflation using the CPI for fuel oil and other fuels, base year 2010 = 275.132. Legacy carriers include American Airlines, Continental Airlines, Delta Air Lines, United Airlines, and US Airways. TWA, Northwest, and America West are included as these carriers merged with American Airlines, Delta, and US Airways, respectively.

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, OND (U.S. Carriers, average airfare) and Form 41 Financial Data Schedule P12a (fuel data) as of July 6, 2011.

Figure 6: Average Cost of Airfare for Domestic Flights Operated by Low Cost Carriers (2010 dollars) – Q1 2000 to Q4 2010

(Data are quarterly, adjusted for inflation)



NOTE: Fuel price is the average of all fuel used for scheduled and nonscheduled domestic flights for the selected carriers shown in each graph. Average airfare adjusted for inflation using the Consumer Price Index (CPI) for airline fare, base year 2010 = 278.186. Average fuel cost per gallon adjusted for inflation using the CPI for fuel oil and other fuels, base year 2010 = 275.132. Low cost carriers include JetBlue Airways, Frontier Airlines, AirTran Airways, Spirit Airlines, and Southwest Airlines.

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, OND (U.S. Carriers, average airfare) and Form 41 Financial Data Schedule P12a (fuel data) as of July 6, 2011.

and 4 percent respectively) and a smaller percent from passenger airfares (69 and 90 percent respectively).¹²

Changes in Airline Operations

Rising fuel costs can coincide with changes in airline operations. These changes include reductions in capacity and in the fuel burned by aircraft.

Changes in Capacity

The relationship between the cost of fuel and airline capacity, as measured by available seat miles (ASMs), can be seen in figure 7, which shows the cost of fuel per gallon and domestic passenger capacity on routes operated by both legacy and low cost carriers. ASMs are a commonly used measure of airline capacity and are defined as the number of available seats multiplied by miles flown. This metric measures capacity changes resulting from both adjustments in flight schedules and the size of the aircraft used on a flight segment. A reduction in the number of flights and/or the substitution of smaller aircraft reduces capacity as measured in ASMs.

Both legacy and low cost carriers reduced capacity in recent years (see figure 7). Legacy carriers began reducing

capacity in the face of post-9/11 challenges and competition from expanding low cost carriers. These capacity reductions accelerated after fuel prices began to rise in 2008. Low cost airlines expanded capacity during the early years of the decade. Reductions occurred during the 2008 rise in fuel prices and while expansions have since occurred, capacity has not returned to the pre-2008 level.

Changes in Fuel Burn

Airline productivity and efficiency has changed over the past decade. Productivity most commonly is measured by the number of ASMs per gallon of fuel consumed (ASM/g) and fuel efficiency by the number of gallons consumed per block hour.¹³ The productivity and efficiency of a particular aircraft varies from one flight to another because of differences in distance, payload, weather, cruising speed, altitude, and other factors. For example, shorter flights spend a greater percentage of flight time climbing and descending.

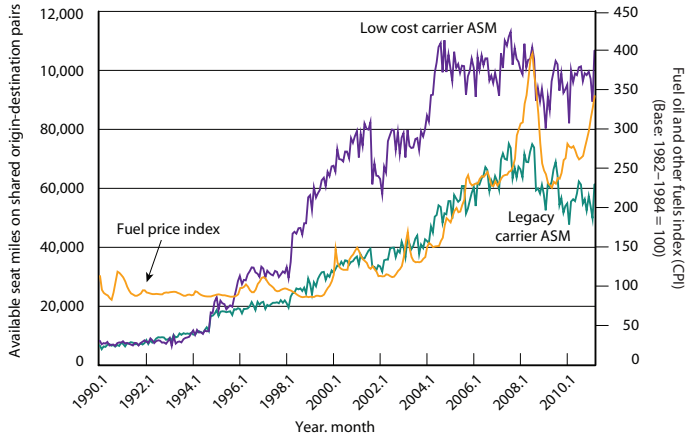
As seen in figure 8, productivity improvements achieved by legacy carriers have coincided with rising fuel prices. On average, productivity has risen 14.5 percent from the first quarter of 2000 to the fourth quarter of 2010, from 55.4 to 64.8 ASM/g. Of the legacy carriers examined, Continental

¹² U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, Form 41 Financial Data P1.2 as of July 6, 2011.

¹³ Block hours are defined as the elapsed time from the moment an aircraft pushes back from the departure gate until the moment of engine shutoff at the arrival gate following its landing.

Figure 7: Cost per Gallon of Fuel and Available Seat Miles on Domestic Flight Segments Operated by Both Legacy and Low Cost Carriers – January 1990 to March 2011

(Data are monthly)

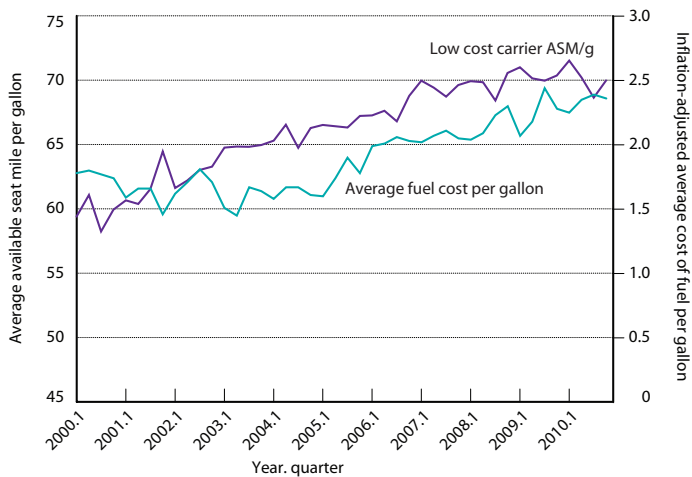


NOTE: Legacy carriers include American Airlines, Continental Airlines, Delta Air Lines, United Airlines, and US Airways. TWA, Northwest, and America West were included as these carriers merged with American Airlines, Delta, and US Airways respectively. Low cost carriers include JetBlue Airways, Frontier Airlines, AirTran Airways, Spirit Airlines, and Southwest Airlines.

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, Form 41 Traffic Data T100 Domestic Segment (U.S. carriers) as of July 6, 2011; Consumer Price Index, U.S. City Average, Fuel Oil and Other Fuels (Series ID CUUR0000SEHE), not seasonally adjusted (Base period 1982-84=100).

Figure 9: Average Available Seat Miles per Gallon (ASM/g) of Fuel Among Low Cost Carriers – Q1 2000 to Q4 2010

(Data are quarterly)

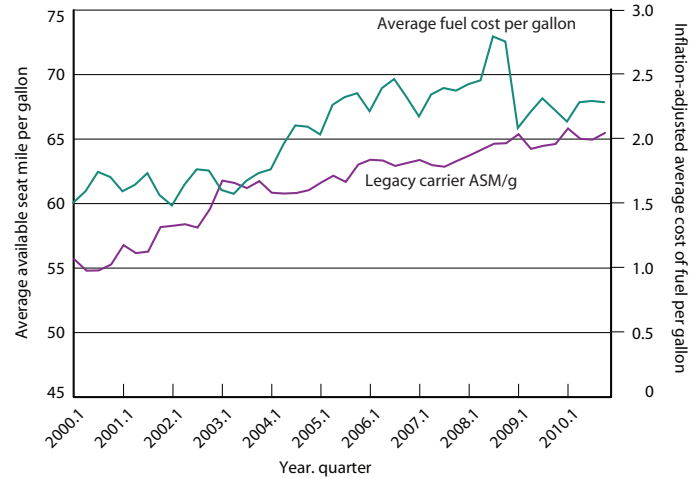


NOTE: Low cost carriers include JetBlue Airways, Frontier Airlines, AirTran Airways, Spirit Airlines, and Southwest Airlines. Frontier's data in Q3 2000, Q1 2002, Q2 2010, and Q4 2010 and Spirit's data in Q3 2010 excluded because of suspected misreporting (data significantly different from that in other quarters and that of other carriers). P5.2 data is used for 4th Quarter 2010 fuel use data.

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, Form 41 Traffic Data T2 (U.S. carriers) as of July 11, 2011.

Figure 8: Average Available Seat Miles per Gallon (ASM/g) of Fuel Among Legacy Carriers – Q1 2000 to Q4 2010

(Data are quarterly)



NOTE: Legacy carriers include American Airlines, Continental Airlines, Delta Air Lines, United Airlines, and US Airways. TWA, Northwest, and America West included as these carriers merged with American Airlines, Delta, and US Airways respectively. US Airways' data in Q4 of 2000 and Q3 of 2002 excluded because of suspected misreporting (data significantly different from that in other quarters and that of other carriers). P5.2 data is used for 4th Quarter 2010 fuel use data.

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, Form 41 Traffic Data T2 (U.S. Carriers) as of July 11, 2011.

reported the highest productivity in 2010 and increased its productivity the most, with about a 21 percent increase.¹⁴

The overall productivity of the low cost carriers appears to have been equally impacted (see figure 9). On average, low cost carrier ASM/g increased from 57.8 in the first quarter of 2000 to 68.9 in the fourth quarter of 2010, an increase of 11.1 ASM/g (or 16.0 percent).¹⁵ JetBlue maintained its high productivity while AirTran, Southwest, and Spirit reported a large increase that brought their productivity number closer to that of JetBlue.

Average aircraft age also affects carrier efficiency. The marginally greater improvement in ASM/g among legacy carriers follows, in part, from the carriers' greater need to replace older aircraft. In 2009, the legacy carriers' fleet was twice as old as those of the low cost carriers (see figure 10). Low cost carriers have newer aircraft than legacy carriers as all low cost airlines, with the exception of Southwest, began operation in the mid to the late 1990s. Omitting Southwest, the average age of aircraft flown by the low cost carriers is 5.9 years compared to 13.8 years for legacy carriers.

¹⁴ Observations with available seat miles per gallon in the top 1 percent or bottom 1 percent of all values (in Q1 2000 through Q3 2010) are excluded from these statistics as they are suspected outliers. Data from: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, Form 41 Traffic Data T2 (U.S. carriers) as of July 11, 2011.

¹⁵ ASMs per gallon for Frontier Airlines is excluded from the average for both 2000 and 2010 because data reported by Frontier for the fourth quarter of 2010 appears to be misreported as it is notably lower than in all other quarters (see figure 4).

Table 1: Available Seat Miles Per Gallon – Q1 2000 and Q4 2010

(Data are quarterly)

Carrier	Q1 2000	Q4 2010	% change
Legacy	55.4	64.8	14.51
American	55.1	62.4	11.59
Continental	55.6	70.7	21.30
Delta	53.6	65.0	17.49
United Airlines	58.3	62.8	7.26
US Airways	55.9	66.6	16.06
Low cost	57.8	68.9	16.03
Jet Blue	73.5	71.2	-3.20
Frontier	64.9	48.7	-33.09
AirTran	43.3	64.8	33.14
Spirit	56.0	75.4	25.77
Southwest	59.4	68.6	13.38

NOTE: Data from TWA, Northwest, and America West are included as these carriers merged with American Airlines, Delta, and US Airways respectively. The large change in available seat miles per gallon for Frontier appears to be due to suspected misreporting of data in Q4 2010. P5.2 data is used for Q4 2010 fuel use data.

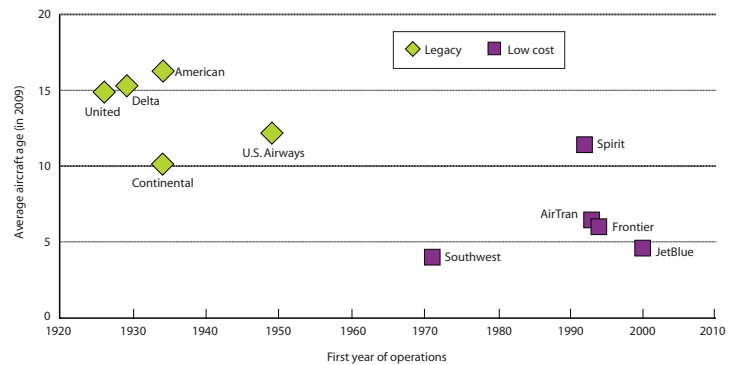
SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, Form 41 Traffic Data T2 (U.S. Carriers) and Form 41 Financial Data Schedule P5.2 as of July 11, 2011.

The number of gallons of fuel consumed during aircraft operation (measured in terms of block hours) also can be used to examine changes in fuel burn. Table 2 shows the change in the number of gallons of fuel consumed per block hour from the fourth quarter of 2000 to the fourth quarter 2010 (the most recent data point). In table 2, it can be seen that:

- All low cost carriers, with the exception of Frontier (which reported significantly below average fuel consumption in the fourth quarter of 2010), required fewer gallons of fuel per block hour in 2010.
- Spirit demonstrated the greatest improvement, requiring 14 percent less fuel per block hour. The improvement was due, in part, to Spirit replacing its McDonnell Douglas DC-9 aircraft with more fuel efficient aircraft.¹⁶
- With the exception of Delta, improvements in efficiency among legacy carriers were small or nonexistent. In 2010, Delta used 7 percent fewer gallons per block hour than in 2000. Delta's improvement resulted partially from the airline abandoning large passenger jets

¹⁶ Spirit first began scheduled domestic operations using the McDonnell Douglas DC-9-30 in 1992. From 1992-1997, 99.9 percent or more of scheduled domestic ASMs were provided on this aircraft. ASMs on the McDonnell Douglas DC-9-30 gradually declined and by 2004, this aircraft was no longer used for scheduled domestic flights. In 2010, 11.7 percent of all scheduled domestic ASMs were offered on the Airbus Industries A320, 78.7 percent on the Airbus Industries A319, and 9.6 percent on the Airbus Industries A321. (SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, Form 41 Traffic Data T100 Domestic Data as of April 29, 2011)

Figure 10: Average Aircraft Age (in 2009) by Year of First Operations



SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, Form 41 Financial Data Schedule B43 Inventory as of Apr. 29, 2011.

Table 2: Gallons of Fuel per Block Hour by Carrier – Q1 2000 and Q4 2010

(Data are quarterly)

Carrier	Q1 2000	Q4 2010	% change
Legacy	1,140.1	1,132.3	-0.69
American	1,122.4	1,149.2	2.39
Continental	1,081.4	1,057.7	-2.19
Delta	1,240.1	1,149.5	-7.30
United Airlines	1,296.3	1,341.8	3.51
US Airways	829.7	888.8	7.12
Low Cost	768.5	734.9	-4.37
Jet Blue	777.2	745.4	-4.08
Frontier	749.6	1,074.1	43.28
AirTran	768.3	683.7	-11.01
Spirit	894.2	766.6	-14.27
Southwest	761.8	709.5	-6.87

NOTE: Data from TWA, Northwest, and America West are included as these carriers merged with American Airlines, Delta, and US Airways respectively. The large change in available seat miles per gallon for Frontier appears to be due to suspected misreporting of data in Q4 2010. P5.2 data is used for Q4 2010 fuel use data.

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, Form 41 Traffic Data T2 (U.S. Carriers) and Form 41 Financial Data Schedule P5.2 as of July 11, 2011.

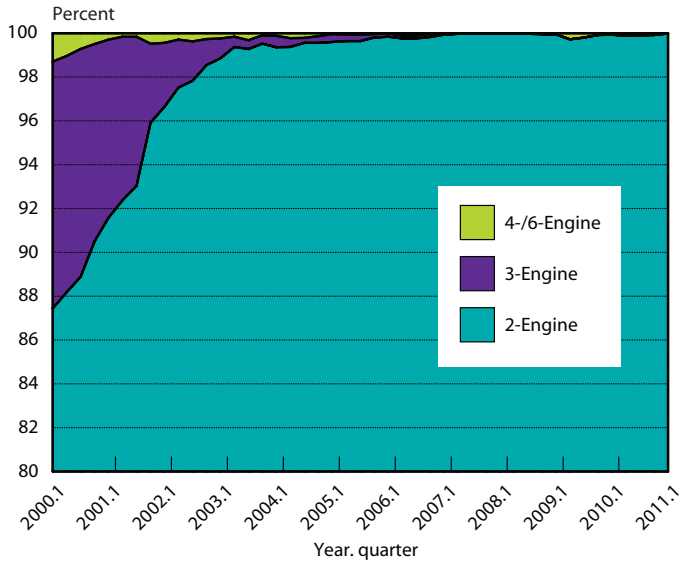
(three or more engines) in favor of smaller, more fuel efficient aircraft.¹⁷

The changes in productivity and efficiency reflect changes in carrier fleets. As noted above, carriers have turned away from using three- to six-engine jets for domestic flights and toward using two-engine passenger jets. The two-engine

¹⁷ In 2000, 22 percent of Delta's ASMs were on aircraft with three or more engines compared to 0.02 percent in 2010 (Source: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, Form 41 Traffic Data T100 Domestic Segment (U.S. Carriers) as of July 6, 2011).

Figure 11: Percent of Available Seat Miles on Domestic Flight Segments for Passenger Aircraft by Jet Type – Legacy and Low Cost Carriers – Q1 2000 to Q1 2011

(Data are quarterly)



NOTE: Legacy carriers include American Airlines, Continental Airlines, Delta Air Lines, United Airlines, and US Airways. TWA, Northwest, and America West are included as these carriers merged with American Airlines, Delta, and US Airways respectively. Low cost carriers include JetBlue Airways, Frontier Airlines, AirTran Airways, Spirit Airlines, and Southwest Airlines.

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, Form 41 Financial Data Schedule B43 Inventory as of Apr. 29, 2011.

jets, such as the Airbus Industrie A321, require less fuel than aircraft with more engines, such as the Boeing 747 (four engine) and the McDonnell Douglas MD-11 (three engine) (see figure 11 and table 3). In 2000, 65.2 billion ASMs (10.4 percent of domestic ASMs) were offered on three-engine passenger jets making a scheduled domestic flight; by 2010, ASMs on these same aircraft fell to zero as three-engine jets were phased out from use for domestic flights. ASMs on four- and six-engine passenger jets also declined, dropping from 5.6 billion ASMs (0.89 percent) in 2000 to 505.4 million ASMs (0.09 percent) in 2010.

Data on the operational fuel economy of the above jets are available for all flight segments (scheduled and nonscheduled) provided by the selected carriers originating or ending at a U.S. location. Scheduled and nonscheduled flights operating with three, four, and six-engine passenger jets achieved lower operational fuel productivity in 2010 than two-engine passenger jets (after achieving nearly the same fuel productivity in 2000) and required significantly more gallons of fuel per block hour (see table 4) in both 2000 and 2010. For an hour flight in 2000, two-engine passenger jets required an average of 1,001 gallons of fuel while three-engine passenger jets required 1,755 gallons and four- and six-engine passenger jets required 3,469 gallons. The

Table 3: Available Seat Miles on Domestic Flight Segments for Passenger Aircraft by Number of Jet Engines – Legacy and Low Cost Carriers

		Two-engine	Three-engine	Four-/six-engine
2000	Available seat miles (millions)	559,045.41	65,199.48	5,628.61
	Percent	88.76	10.35	0.89
2010	Available seat miles (millions)	532,821.06	0	505.42
	Percent	99.91	0	0.09

NOTE: Legacy carriers include American Airlines, Continental Airlines, Delta Air Lines, United Airlines, and US Airways. TWA, Northwest, and America West included as these carriers merged with American Airlines, Delta, and US Airways respectively. Low cost carriers include JetBlue Airways, Frontier Airlines, AirTran Airways, Spirit Airlines, and Southwest Airlines. No available seat miles provided on three-engine jets in 2010.

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, Form 41 Traffic Data T100 Domestic Segment (U.S. Carriers) as of July 6, 2011.

gallons required per block hour by each aircraft improved between 2000 and 2010.

The higher fuel requirements of three, four, and six-engine jets result from the inefficiency of their greater number of engines. Per seat mile, the difference may be less as jets with a larger number of engines typically provide more capacity. Year to year, jets will achieve different levels of efficiency and productivity due to variations in the way carriers operate them and in the segments on which they are flown (see table 4).

The above fuel productivity and efficiency averages by number of engines mask significant variation within the engine groups. Table 5 shows this variation for selected two-engine passenger aircraft operated by U.S. carriers in 2010. As shown in the table:

- Low cost carriers achieved the highest level of productivity on the Airbus Industrie A321 at 131.3 ASM/g in 2010. The aircraft was operated only by Spirit. Legacy carriers achieved a lower level of productivity on the same aircraft and a higher level on the Boeing 737-900, which was operated by Continental alone.
- Low cost carriers achieved the best fuel efficiency on the aircraft on which they achieved the best productivity—the Airbus Industrie A321. Legacy carriers achieved the best fuel efficiency on a different aircraft—the Boeing 737-300 (operated, among legacy carriers, by Continental and US Airways). In 2010, the Airbus Industrie A321 required 635 gallons of fuel per block hour and the Boeing 737-300 required 750 gallons of fuel per block hour—115 more gallons of fuel on a 1 hour flight despite it being a somewhat smaller aircraft than the Boeing jet.

Table 4: Fuel Productivity and Efficiency of Passenger Aircraft by Number of Jet Engines - Legacy and Low Cost Carriers

	Two-engine	Three-engine	Four-/six-engine
Fuel productivity (available seat miles per gallon*)			
2000	56.0	43.1	54.1
2010	65.8	N/A	58.7
Fuel efficiency (gallons per block hour*)			
2000	1,001.2	1,755.2	3,469.3
2010	982.8	N/A	3,312.5

KEY: N/A = No three-engine passenger aircraft used by selected carriers.
* Includes all scheduled and nonscheduled flights on passenger aircraft.

NOTE: Data in all quarters of 2000 and 2010 included. Legacy carriers include: American Airlines, Continental Airlines, Delta Air Lines, United Airlines, and US Airways. TWA, Northwest, and America West included as these carriers merged with American Airlines, Delta, and US Airways respectively. Low cost carriers include: JetBlue Airways, Frontier Airlines, AirTran Airways, Spirit Airlines, and Southwest Airlines. P5.2 data is used to for Q4 2010 fuel use data.

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, Form 41 Traffic Data T2 (U.S. Carriers) and Form 41 Financial Data Schedule P5.2 as of July 11, 2011.

The operational differences in productivity across two-engine aircraft generally result from physical variation in the aircraft themselves (e.g., capacity and the weight of the aircraft and its components, such as service carts, body modifications to improve aerodynamics, etc.) and from operational variation, including but not limited to carrier adoption of efficiency improving technologies (e.g., navigation systems); carrier maintenance schedules; and average flight segment distance, time, and weather conditions.¹⁸

The effect of carrier specific factors on aircraft fuel productivity can be seen in tables 6 and 7. Tables 6 and 7 show that not all major legacy and low cost U.S. carriers operate the aircraft shown in table 5 and not all achieve the same ASM/g. In 2010, 2 of the 10 major carriers (US Airways and Spirit) operated the Airbus A321, a high productivity aircraft. The highest productivity (88 ASM/g) of any of the carriers was noted on Delta's Boeing 757-300, an aircraft that averaged a lower productivity than the Airbus A321 when considering the carriers in each group.

The different fuel productivity of the same aircraft across carriers reflects a variety of operational differences, including but not limited to stage length, payload factor, weather conditions on the segments flown, fuel saving technologies adopted, and aircraft retrofits. For example, a few carriers,

¹⁸ See Mayerowitz, Scott. "Airlines positioned for big gains in efficiency," Miami Herald, July 4, 2011. Retrieved July 11, 2011 from: <http://www.miamiherald.com/2011/07/04/2298876/airlines-positioned-for-big-gains.html>

Table 5: Fuel Productivity and Efficiency of Selected Passenger Aircraft, 2010 (Q1 through Q4) – Legacy and Low Cost Carriers

Aircraft Code	Aircraft/Carrier type	Seat miles per gallon		Gallons per block hour	
		Legacy	Low cost	Legacy	Low cost
612	Boeing 737-700/700lr	64.4	72.9	757.2	692.8
614	Boeing 737-800	77.4	N/A	796.7	N/A
619	Boeing 737-300	57.2	61.6	750.0	747.5
622	Boeing 757-200	69.7	N/A	1,054.0	N/A
623	Boeing 757-300	77.3	N/A	1,175.1	N/A
625	Boeing 767-200/Er/Em	56.3	N/A	1,439.4	N/A
626	Boeing 767-300/300er	63.3	N/A	1,592.4	N/A
634	Boeing 737-900	82.4	N/A	861.4	N/A
655	McDonnell Douglas DC-9 Super*	51.7	N/A	942.5	N/A
694	Airbus Industrie A320-100/200	70.7	77.4	793.3	771.3
699	Airbus Industrie A321	78.0	131.3	925.2	634.8

KEY: N/A = No three-engine passenger aircraft used by selected carriers.
*80/Md81/82/83/88

NOTE: Legacy carriers include American Airlines, Continental Airlines, Delta Air Lines, United Airlines, and US Airways. Low cost carriers include JetBlue Airways, Frontier Airlines, AirTran Airways, Spirit Airlines, and Southwest Airlines. Seat miles per gallon for the Airbus Industries A321 appear to be inflated due to suspected misreporting of data by Frontier in Q2 and Q4 of 2010. P5.2 data is used to for Q4 2010 fuel use data.

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, Form 41 Traffic Data T2 (U.S. Carriers) and Form 41 Financial Data Schedule P5.2 as of July 11, 2011.

such as Southwest, have begun to use Required Navigation Performance (RNP) flight guidance technology to fly more direct routes and thereby reduce fuel requirements.¹⁹ The adoption of such technologies has coincided with recent increases in the cost of fuel.

Net Impacts

Fuel price increases have coincided with rising ancillary fees and changes in airline operations, including but not limited to reductions in capacity and increases in fuel productivity and efficiency. Such changes already have been

¹⁹ See: "Southwest Airlines' Pilots Begin Flying Required Navigation Performance Efficient Procedures at 11 Airports," Jan. 11, 2011. Retrieved July 11, 2011 from: <http://www.prnewswire.com/news-releases/southwest-airlines-pilots-begin-flying-required-navigation-performance-efficient-procedures-at-11-airports-113275099.html>

noted with the rise of fuel prices in 2011²⁰ and are predicted to persist in 2012. Morgan Stanley, prior to American filing for bankruptcy, estimated available seat miles from Alaska, American, Delta, United, and US Airways would decline

by 0.6 percent in 2012. Conversely, Frontier, Jet Blue, and Southwest are predicted to increase capacity, although by less than 1 percent following a 5 percent growth in 2011.²¹

²⁰ Industry analysts have estimated that if the cost of fuel rises to and carriers purchase fuel at an average of \$3.00 per gallon in 2011, U.S. airlines face an estimated \$15 billion increase in their fuel bill (as compared to 2010). See: John Heimlich. "The Price of Jet Fuel and Its Impact on U.S. Airlines," Mar. 29, 2011. Retrieved Apr. 26, 2011 from: http://www.airlines.org/News/Letters/Pages/Oped_03-09-2011.aspx

²¹ Jay Boehmer. "Analysts Project Lower 2012 U.S. Carrier Capacity," *Business Travel News*, Dec. 7, 2011. Retrieved Jan. 5, 2012 from: <http://www.businesstravelnews.com/Business-Travel/Analysts-Project-Lower-2012-U-S--Carrier-Capacity/?ida=Airlines&a=mgmt>

Table 6: Fuel Productivity (Available Seat Miles per Gallon) on Selected Passenger Aircraft for Legacy Carriers, 2010

	American Airlines	Continental Air Lines	Delta Air Lines	United Air Lines	US Airways
Boeing 767-200/Er/Em	48.67	53.99	N/A	N/A	60.58
McDonnell Douglas DC-9 Super*	54.13	N/A	50.01	N/A	N/A
Boeing 737-700/700lr	N/A	69.42	52.75	N/A	N/A
Boeing 737-300	N/A	59.88	N/A	N/A	60.85
Boeing 767-300/300er	64.51	N/A	63.48	59.91	N/A
Boeing 757-300	N/A	65.7	83.53	N/A	N/A
Boeing 757-200	71.78	67.28	69.32	70.75	74.79
Airbus Industrie A320-100/200	N/A	N/A	71.43	70.49	74.38
Boeing 737-800	74.28	78.65	77.91	N/A	N/A
Boeing 737-900	N/A	74.43	N/A	N/A	N/A
Airbus Industrie A321	N/A	N/A	N/A	N/A	76.29

KEY: *80/Md81/82/83/88
N/A = aircraft not used

NOTE: Bolded value corresponds to aircraft, among the selected, that the carrier flew the most seat miles per gallon. For each carrier, available seat miles per gallon shown only for the selected passenger aircraft operated by the carrier. If available seat miles are not shown, then the selected aircraft was not used by the carrier in 2010.

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, Form 41 Traffic Data T2 as of July 6, 2011.

Table 7: Fuel Productivity (Available Seat Miles per Gallon) on Selected Passenger Aircraft for Low Cost Carriers, 2010

	JetBlue Airways	AirTran Airways	Frontier Airlines	Spirit Airlines	Southwest Airlines
Boeing 767-200/Er/Em	N/A	N/A	N/A	N/A	N/A
McDonnell Douglas DC-9 Super*	N/A	N/A	N/A	N/A	N/A
Boeing 737-700/700lr	N/A	71.31	N/A	N/A	72.43
Boeing 737-300	N/A	N/A	N/A	N/A	61.64
Boeing 767-300/300er	N/A	N/A	N/A	N/A	N/A
Boeing 757-300	N/A	N/A	N/A	N/A	N/A
Boeing 757-200	N/A	N/A	N/A	N/A	N/A
Airbus Industrie A320-100/200	78.51	N/A	68.15	75.36	N/A
Boeing 737-800	N/A	N/A	N/A	N/A	N/A
Boeing 737-900	N/A	N/A	N/A	N/A	N/A
Airbus Industrie A321	N/A	N/A	N/A	80.95	N/A

KEY: *80/Md81/82/83/88
N/A = aircraft not used

NOTE: Bolded value corresponds to aircraft, among the selected, that the carrier flew the most seat miles per gallon. For each carrier, available seat miles per gallon shown only for the selected passenger aircraft operated by the carrier. If available seat miles are not shown, then the selected aircraft was not used by the carrier in 2010.

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, Form 41 Traffic Data T2 as of July 6, 2011.

About This Report

This article was prepared by Theresa Firestine, an Economist in the Bureau of Transportation Statistics (BTS), and Jenny Guarino, a Mathematical Statistician in BTS. BTS is a component of the U.S. Department of Transportation's Research and Innovative Technology Administration (RITA). Both authors contributed equally.

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Data

This special report is based on the following monthly and quarterly data reported to BTS:

- *Air Carrier Financial Reports (Form 41 Financial)*,
- *Air Carrier Statistics (Form 41 Traffic)*,
- *Air Carrier Summary data*, and
- *Airline Origin and Destination Survey data*

For more information on the data used, please visit: <http://www.transtats.bts.gov/>