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Canada-U.S. transborder airline fuel-efficiency ranking

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This study assesses and compares the fuel efficiency of airlines serving 10 transborder routes between Canada and the United States for the 12 months between March 2016 and February 2017. The fuel efficiency of nine airlines flying these routes—five based in Canada and four in the United States—are ranked based on the Piano 5 aircraft modeling software and U.S. Bureau of Transportation Statistics flight data.

Among the 10 selected routes, the smallest gap between best and worst performance was 6% on the Montreal-New York route, and the largest was 36% on the Montreal-Miami route. On certain routes, the gap was driven by aircraft choice, as larger planes are generally more fuel-efficient than smaller ones and turboprops are more fuel-efficient than jet planes of comparable size.

Short-distance flights in general are more fuel-intensive per passenger kilometer than longer ones. In this study, we found that flying about 200 km between Seattle and Vancouver is on average 2.6 times as fuel-intensive per passenger kilometer as flying 2,200 km between Montreal and Miami. However, the effect of stage length on fuel efficiency decreases as stage length increases.

This study corroborates that aircraft are the most carbon-intensive means of travel compared with cars, buses, and trains (Kwan, 2013; Rutherford & Kwan, 2015) based on passenger miles per gallon of gasoline equivalent (MPGge). The working paper ends with a discussion of conclusions, policy implications, and recommendations for future work.

1. INTRODUCTION

The expanding commercial air transport industry affects the global climate. According to the International Air Transport Association (IATA), worldwide revenue passenger kilometers rose 7.4% in 2015, the fastest annual growth since 2010 (IATA, 2016). According to the International Energy Agency (IEA), carbon dioxide (CO_2) emissions from international aviation doubled in the past 25 years, the fastest growth among all transportation modes (IEA, 2017). If current trends persist, aviation emissions will triple by 2050.

To mitigate the rise in CO_2 emissions from aviation, the International Civil Aviation Organization (ICAO) established two aspirational goals for international flights: improving fuel efficiency by 2% annually and zero net growth of aviation CO_2 emissions after 2020 (ICAO, 2010). In March 2017, ICAO formally adopted new global aircraft CO_2 emission standards which member states are expected to implement starting in 2020. In addition, ICAO's Carbon Offsetting Reduction Scheme for International Aviation is expected to come into effect around the same time.

Some ICAO member states established their own fuel-efficiency improvement goals, including Canada, the host country of ICAO headquarters. Canada set a target of at least 2% annual improvements in fuel efficiency until 2020 (Government of Canada, 2015). Canadian airlines' fuel efficiency has been improving by about 1% a year in terms of revenue passenger kilometers per liter, similar to the rate of improvement shown by airlines in the United States for domestic operations (Government of Canada, 2015; Kwan & Rutherford, 2014). More than 27 million passengers flew between the United States and Canada in 2016, accounting for about 1.9% of total international

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aviation passengers (ICAO, 2016). This number is projected to double to 56 million by 2037 (Federal Aviation Administration, 2017).

Despite regulatory efforts to curb aviation emissions, policymakers and consumers often lack access to information that would help them choose less-polluting carriers and flights. To close this gap, the ICCT has produced a series of airline fuel-efficiency rankings for U.S. domestic and transatlantic routes.[1]

In this report, we analyze and compare the fuel efficiency of air carriers serving 10 select routes between Canada and the United States. We also identify contributing factors and explain the gap between the best and worst performers for each route by assessing the role of technology level and operational parameters in airline fuel efficiency. Finally, we compare the fuel efficiency of aircraft to ground transport on shorter routes where a traveler may choose between different modes.

2. METHODOLOGY

This study follows the methodology of previous ICCT route-based analyses (Zeinali et al., 2013; Kwan & Rutherford, 2015). Aircraft fuel burn was computed based on a simple metric of passenger kilometers per liter of jet fuel (pax-km/L).

The scope of this study was limited to direct transborder flights between the United States and Canada using publicly available data from the U.S. Bureau of Transportation Statistics (BTS). The most recent data available at the time of study was used, encompassing a 12-month period between March 2016 and February 2017.

1 For more information, see http://www.theicct.org/spotlight/airline-fuel-efficiency

Table 1. Selected routes and corresponding airports

Route	Airports*	Passengers** (Thousands)
Calgary-Houston	YYC - IAH, HOU	431
Calgary-San Francisco	YYC - SFO	181
Montreal-Miami	YUL - MIA, FLL, PBI	707
Montreal-New York	YUL - LGA, EWR, JFL	882
Toronto-Chicago	YYZ, YTZ - ORD, MDW	1,066
Toronto-Los Angeles	YYZ - LAX	714
Toronto-New York	YYZ, YTZ - LGA, EWR, JFK	2,476
Toronto- Orlando	YYZ - MCO	683
Vancouver-Los Angeles	YVR - LAX, SNA	949
Vancouver-Seattle	YVR - SEA	626

* Airport names corresponding to each code are presented in Appendix A
** Within the analysis period (March 2016 – February 2017)

2.1 ROUTE SELECTION

To identify the most suitable origin-destination city pairs, we analyzed BTS T-100 International Segments data, taking into account geographic coverage, scheduled traffic volume, number of airlines serving the route, and stage length.

To avoid potential bias from ranking a single airport pair between two major cities, we identified major metropolitan areas in Canada based on methodology developed by Brueckner, Lee, and Singer (2013) to cover a wider range of competing airports in a region where people choose to travel. Then, we listed the busiest transborder routes between these Canadian cities and those in the United States. Finally, we eliminated city pairs served by fewer than three airlines, and selected 10 routes under the principle of maximizing the variation of stage length and coverage (north-south, east-west). The selected routes are presented in Table 1.

2.2 FUEL BURN MODELING

U.S. airlines report quarterly fuel burn by aircraft type to BTS, but no data is currently collected at the level of city-city pairs. Furthermore, the fuel consumption of Canadian airlines is not available in the BTS database, so the fuel burn for each flight was modeled in Piano 5.[2] The Ascend Fleets online database (Ascend Flightglobal Consultancy, 2017) provided additional data on the aircraft operated by each airline.

We calculated the payload for each flight. Because BTS data is recorded monthly, "Onboard Passengers" is the sum of the onboard passengers of each flight in one month. The number of passengers for each flight was then estimated by dividing the number of onboard passengers by the number of departures. Each passenger is estimated to weigh 100 kg, an industry-wide standard, including their luggage.

To model fuel burn, Piano 5 requires the variants of each aircraft type, such as engine types, winglets, maximum takeoff weight (MTOW), and number of seats. The Ascend fleet database provides detailed specifications for each individual aircraft possessed by air carriers globally. Since air carriers often deploy many variants the same aircraft type, the most common variants according to Ascend were used in Piano 5 modeling. At times, we found data conflicts between BTS and Ascend. For

2 For more information see http://www.lissys.demon.co.uk/Piano5.html

example, one BTS flight record contains an aircraft type that the corresponding airline does not operate, according to Ascend. To resolve the conflict, the respective airline's fleet website was consulted to determine which aircraft type to use in Piano 5. The modeling variables and sources used in this study are presented in Table 2.

More details on the precise fuel burn modeling methodology applied can be found in reports by Zeinali et al. (2013) and Kwan and Rutherford (2015). A list of mainline carriers and their affiliates along with their RPK distribution is presented in Appendix B.

2.3 FUEL-EFFICIENCY CALCULATIONS

To compare the fuel efficiency of each route *r* across all operations, we calculated the average of aggregated data from all flight records *i,* each pertaining to a unique airline-aircraft combination, according to Equation 1:

$$pax\text{-}km/L_r = \frac{\sum_i NP_{r,i} \times SL_{r,i}}{\sum_i FB_{r,i} \times ND_{r,i}} \qquad \text{(Eq. 1)}$$

where NP = number of passengers
SL = stage length in kilometers
FB = flight fuel burn in liters
ND = number of departures

Similarly, the fuel efficiency of airline *a* serving route *r* was calculated by summing the fuel burn, RPKs, and departures for the *i* number of aircraft types it uses on each route:

$$pax\text{-}km/L_{r,a} = \frac{\sum_i NP_{r,a,i} \times SL_{r,a,i}}{\sum_i FB_{r,a,i} \times ND_{r,a,i}} \qquad \text{(Eq.2)}$$

where NP = number of passengers
SL = stage length in kilometers
FB = flight fuel burn in liters
ND = number of departures

Finally, airlines were ranked from lowest to highest on the metric of passenger kilometers per liter of fuel for each city-city pair.

Table 2. Key modeling variables

Types	Variables	Sources
Aircraft used	Aircraft type	BTS T-100 International Segments
	Engines	Ascend Fleets; Piano 5
	Winglets	
	MTOW	
	Seats	
Mission performed	Stage length	BTS T-100 International Segments
	Payload	BTS T-100 International Segments
Operational parameters	Taxi time	Zeinali et al. (2013)
	Fuel reserve	FAA Part 121; Piano 5
	Flight level	Piano 5 default values*
	Speed	Piano 5 default values

* Except for YVR-SEA route where a cruise flight level value of 180 (18,000 ft) was used to allow sufficient cruise time in Piano modeling.

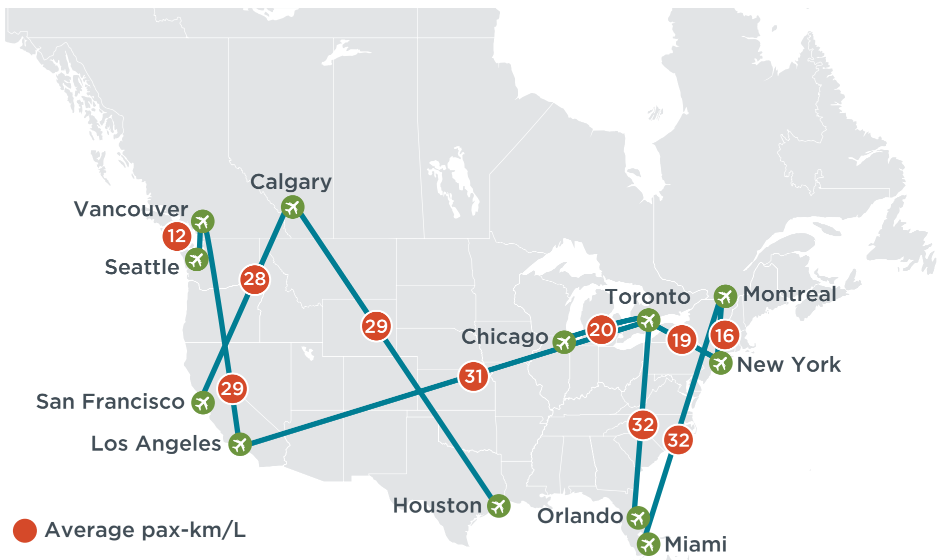

Figure 1. Average fuel efficiency of flights between the 10 Canada-U.S. transborder routes.

3. RESULTS

3.1 COMPARISONS BETWEEN ROUTES

Figure 1 presents the average fuel efficiency in pax-km/L serving the 10 Canada-U.S. transborder routes. Table 3 summarizes the stage length as well as the average fuel efficiency and load factor by route. As the figure and table indicate, the average fuel efficiency for different routes varies from as low as 12 pax-km/L to as high as 32 pax-km/L. On average, flying between Vancouver and Seattle is estimated to be more than 2.6 times as fuel intensive as flying between Montreal and Miami on a passenger-kilometer basis. The average load factor among the 10 routes varies from a high of 89% to a low of 75%.

3.2 RANKINGS FOR EACH ROUTE

Table 4 shows the airline fuel efficiency rankings of the 10 transborder routes. In general, airlines that mainly operate narrow-body or turboprop aircraft—Alaska, Air Transat, Porter, and WestJet—were more efficient than legacy carriers such as American, Delta, and Air Canada. Those carriers usually ranked at or below average because they typically outsource transborder flights to affiliates that mainly fly less fuel-efficient regional jets. More detailed information regarding operational parameters for each airline by route is available in Appendix C.

Table 5 presents the fuel efficiency scores for airlines serving the Montreal-Miami route, the most fuel-efficient route in this study, where on average one liter of jet fuel is enough to transport one passenger as far as 32 km.

Air Transat was the most fuel-efficient of the five airlines that flew directly between Montreal and Miami between March 2016 and February 2017. The low-cost leisure airline based in Montreal scored 38 pax-km/L by flying "all economy" 189-seat Boeing 737-800s on most of their flights. Sunwing Airlines, also a low-cost carrier based in Canada, was the second-most fuel-efficient airline on this route. Similar to Air Transat, Sunwing exclusively flew 189-seat Boeing 737-800s between Montreal and Miami but burned 3% more fuel than Air Transat, reflecting a lower load factor. American Airlines also flew 737-800s exclusively on this route, although its lower seating density of 160 seats per aircraft reflecting premium-class seating resulted in lower fuel efficiency and 19% more fuel burned per passenger kilometer.

Table 3. Route comparisons

Routes	Stage length (km)	Average fuel efficiency (pax-km/L)	Load factor
Toronto-Los Angeles	3,501	31	83%
Calgary-Houston	2,813	29	81%
Montreal-Miami	2,236	32	84%
Vancouver-Los Angeles	1,742	29	86%
Toronto-Orlando	1,698	32	85%
Calgary-San Francisco	1,640	28	89%
Toronto-Chicago	704	20	80%
Toronto-New York	566	19	80%
Montreal-New York	527	16	78%
Vancouver-Seattle	204	12	75%

Table 4. Fuel-efficiency rankings on 10 routes between Canada and the United States

Route	Fuel efficiency					
	1st	2nd	3rd	4th	5th	6th
Montreal-Miami	Air Transat	Sunwing Airlines	Air Canada	American Airlines	WestJet	–
Toronto-Orlando	Air Transat	WestJet	Sunwing Airlines	Air Canada	–	–
Toronto-Los Angeles	WestJet	Air Canada	American Airlines	–	–	–
Calgary-Houston	United Airlines	WestJet	Air Canada	–	–	–
Vancouver-Los Angeles	WestJet	Air Canada	United Airlines	American Airlines	Delta Airlines	–
Calgary-San Francisco	WestJet	Air Canada	United Airlines	–	–	–
Toronto-Chicago	United Airlines	Porter Airlines	American Airlines	Air Canada	–	–
Toronto-New York	Porter Airlines	Air Canada	Delta Airlines	United Airlines	American Airlines	WestJet
Montreal-New York	United Airlines	Delta Airlines	American Airlines	Air Canada	–	–
Vancouver-Seattle	Alaska Airlines	Air Canada	Delta Airlines	–	–	–

Unlike the four other airlines which operate their own fleets, Air Canada relied on its subsidiary, Air Canada Rouge, to carry the majority of its passengers on this route. Flying Boeing 767-300ERs, Airbus 319s and Airbus 321s, Air Canada Rouge transported 94% of Air Canada's customers between Montreal and Miami, putting Air Canada in third position with 33 pax-km/L.

Of all the routes analyzed in this study, the largest gap between the best and worst performer was found on the Montreal-Miami route. The worst performer, WestJet, burned 36% more fuel than Air Transat. This large gap could be explained by a combination of aircraft selection and load factor. WestJet mainly flew Boeing 737-700s fitted with 130 seats, compared with 160-189 seats on competitors' larger Boeing 737-800 variants. In addition, it had the lowest load factor, 78% compared with the average of 84% on this route.

While the effect of aircraft type selection is not very clear on the Montreal-Miami route, it becomes more apparent on shorter routes within the range limits of regional jets. An example is the Calgary-San Francisco route presented in Table 6. On this route, WestJet used its own Boeing 737-800s for 99% of the flights, providing the highest fuel efficiency at 33 pax-km/L despite having the lowest load factor.

Air Canada, which outsourced its operations to Jazz Aviation's Bombardier CRJ 705, ranked second with 27 pax-km/L, burning 22% more fuel per passenger mile than WestJet. Similarly, United Airlines outsourced most of its operations on this route to Skywest Airlines. The regional affiliate flew an all-regional jet fleet on this route with 32% more fuel consumed on average than WestJet. If United were to serve this route using its own single-aisle aircraft, used on only 3% of operations on this route, it would have ranked second. This phenomenon of regional affiliates dragging down the fuel-efficiency scores of mainline carriers is also apparent on the Toronto-Chicago and Toronto-New York routes.

On very short routes, for example the 527 km Montreal-New York route presented in Table 7, only a slight variation in fuel efficiency was observed. Regional affiliates provided the vast majority of all operations on this route except for Air Canada, which flew 12% of its own operations while assigning 88% to Jazz Air and Sky Regional Airlines. Almost all flights on this route were carried out using 50-75 seat regional jets, with a relatively small variation of load factor among airlines.

Table 5. Montreal-Miami fuel efficiency by airline

Rank	Airline	Fuel efficiency (Pax-km/L)	Relative fuel burn	Load Factor	Passenger share
1	**Air Transat**	38	-	86%	5%
2	**Sunwing Airlines***	37	+3%	80%	3%
3	**Air Canada**	33	+15%	85%	62%
4	**American Airlines**	32	+19%	85%	21%
5	**WestJet**	28	+36%	78%	8%

*Sunwing flew only six months of the 12-month analysis period

Table 6. Calgary-San Francisco fuel efficiency by airline

Rank	Airline	Fuel efficiency (Pax-km/L)	Relative fuel burn	Load Factor	Passenger share
1	**WestJet**	33	-	83%	29%
2	**Air Canada**	27	+22%	91%	18%
3	**United Airlines**	25	+32%	91%	53%

Table 7. Montreal-New York fuel efficiency by airline

Rank	Airline	Fuel efficiency (Pax-km/L)	Relative fuel burn	Load Factor	Passenger share
1	**United Airlines**	17	-	82%	10%
2	**Delta Airlines**	17	-	77%	30%
3	**American Airlines**	17	-	81%	17%
4	**Air Canada**	16	+6%	77%	43%

More detailed information about the fuel-efficiency ranking on these routes and others in this study are available in Appendix C.

3.3 STAGE LENGTH AND AIRLINE FUEL EFFICIENCY

Many factors influence airline fuel efficiency, including stage length, aircraft choice, seating density, and load factor, among other variables. One obvious trend observed during this analysis is the relationship between stage length and fuel efficiency.

As shown in Figure 2, there is a good correlation between stage length and fuel efficiency. Overall, flights flown over longer distances are more fuel-efficient. However, the sensitivity of fuel efficiency declines as stage length approaches 4,000 km. For example, the 3,051 km flight between Toronto and Los Angeles is about twice the 1,698 km distance between Toronto and Orlando. However, flying between Toronto and Orlando is on average about as fuel intensive on a passenger mile basis as flying between Toronto and Los Angeles.

In addition, the scatter between airline fuel efficiency on the middle of the chart—for routes roughly between 1,500 km and 3,000 km in distance—is visibly wider than the scatter on either end of the distance spectrum. This may be related to how airlines select the aircraft they fly, which is discussed in more detail in Subsection 3.3.2.

In the following we discuss two aspects that affect the relationship between stage length and airline fuel efficiency: the inherent nature of aircraft fuel efficiency and airline fleet strategies.

3.3.1. Aircraft fuel-efficiency performance on different stage lengths

Figure 3 represents the percentage of block fuel[3] used by a Boeing 737-800 carrying the same payload flying different stage lengths as modeled in Piano 5. In general, the longer the stage length, the smaller the fraction of fuel burned for the most fuel-intensive phases of flight: takeoff and climb to cruise altitude. On a 700 km route, nearly three-quarters of block fuel is used for takeoff and climb, compared with 29% for 2,200 km and 20% for 3,500 km. As a result, the aircraft's fuel efficiency over 2,200 km is 33 pax-km/L and over 3,500 km, 34 pax-km/L. Those compare with 26 pax-km/L over 700 km.

3 Block fuel is the fuel burn required from gate to gate, including taxi, landing and takeoff, climb, cruise, and descent.

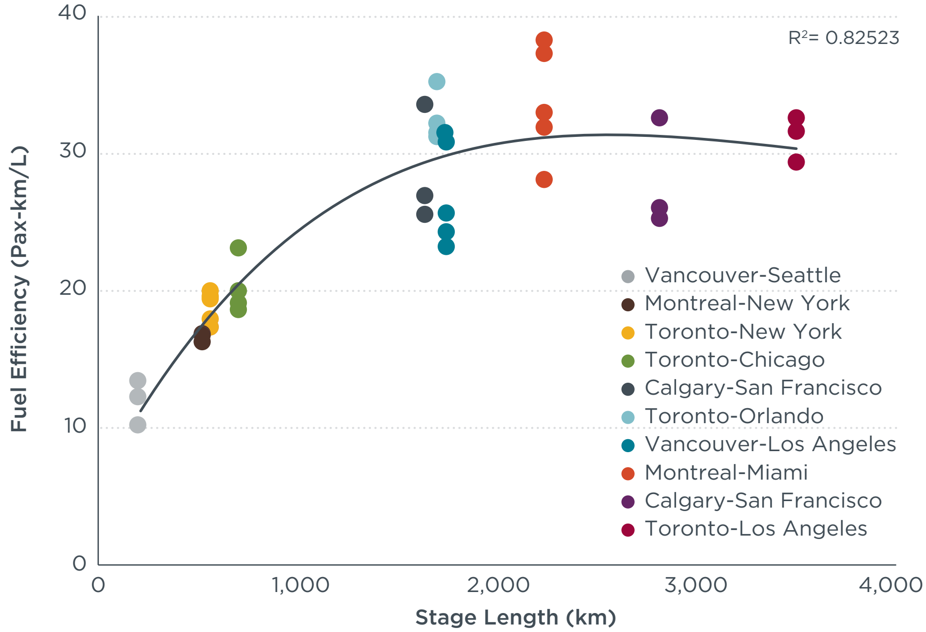

Figure 2. Stage length versus fuel efficiency

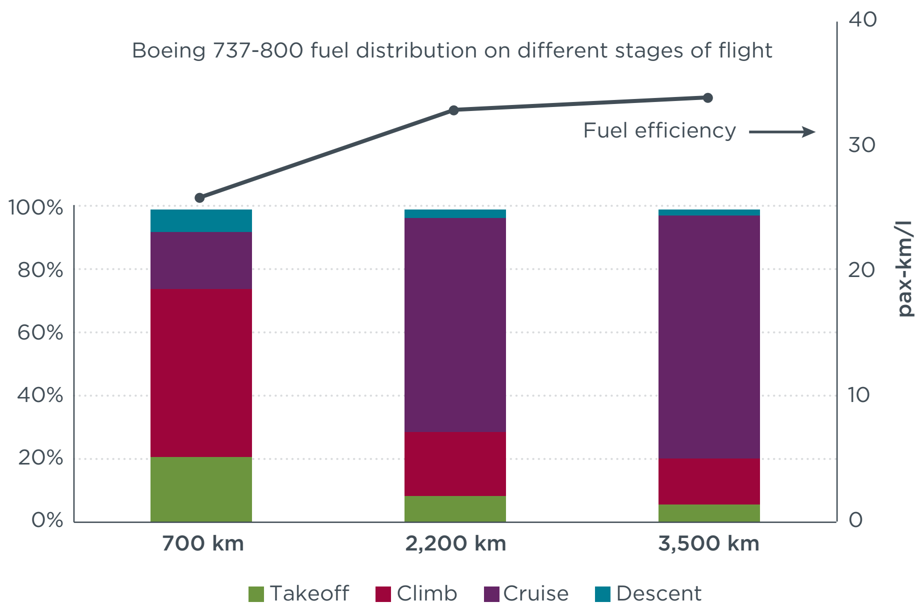

Figure 3. Percentage of fuel used by flight stage and distance.

3.3.2. Stage length and airline fleet strategies

Stage length also has an indirect effect on fuel efficiency by influencing aircraft choice. While low-cost carriers tend to operate all their own flights, mainline carriers have a different strategy. They are more likely to fly single-aisle jets on longer routes and outsource shorter-route operations to regional airlines. These affiliates usually fly smaller regional jets or in some cases turboprops.

Figure 4 maps the fuel efficiency of several aircraft types included in this study over different stage lengths. This graph supports the earlier observation about the relationship between fuel efficiency and stage length for a given aircraft. Larger aircraft tend to be more efficient on a per-seat basis at a given range. Finally, when compared among short-haul aircraft, turboprops are more fuel-efficient than regional jets. At the ranges over which these aircraft directly compete—1,500-2,500 km, the fuel-efficiency gap tends to be the highest.

Given a stable market between Canadian and U.S. cities, airlines have the option of either flying narrow-body planes with fewer departures, or flying regional jets with more departures. Most carriers choose more departures using regional planes, probably because flying narrow-body aircraft would mean lower load factors and increased risk of missing revenue from travelers sensitive to departure times. Flying regional jets with more departures might generate more revenue per unit of time, which may increase profits despite the possibility of higher maintenance costs[4] and overall increased fuel cost caused by low fuel efficiency.

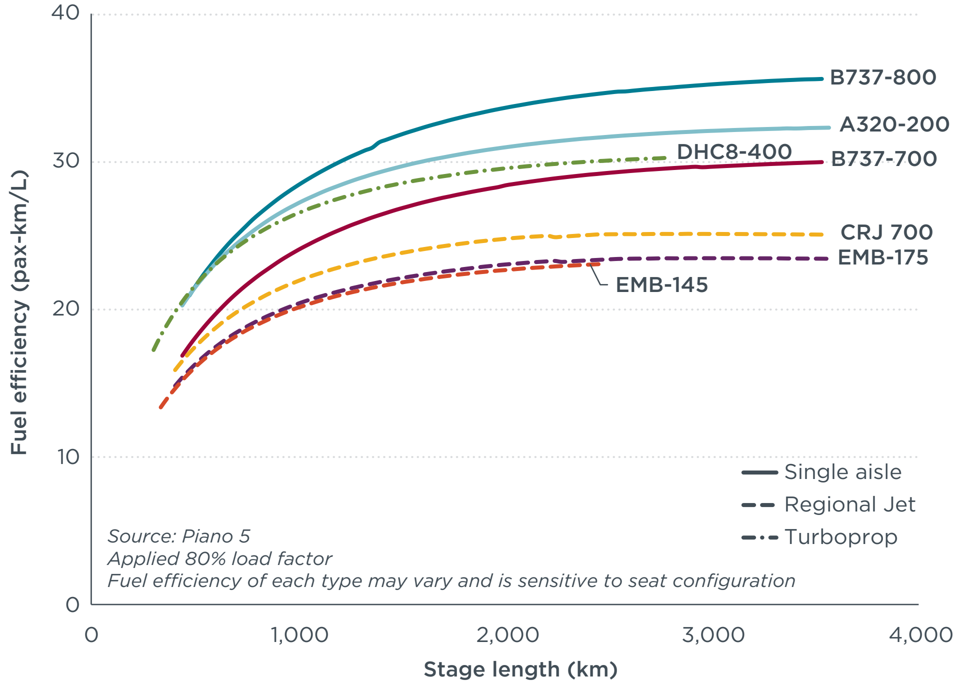

Figure 4. Fuel efficiency on different stage lengths by aircraft type

Table 8. Fuel efficiency of various transportation modes. Source: Kwan (2013), Rutherford & Kwan (2015)

Mode/Route	Average Fuel Efficiency (MPGge)
Plane: Vancouver - Seattle	25
Plane: Montreal - New York	34
Plane: Toronto - New York	40
Plane: Toronto - Chicago	42
Train (Amtrak)	51
SUV car (e.g. Ford Explorer 4WD)	48
Hybrid car (e.g. Honda Civic Hybrid)	93
Bus (Greyhound)	152

3.4 COMPARISON WITH OTHER MODES

When traveling relatively short distances, for example under 800 kilometers, flying may not be the only option and a traveler might reasonably choose between traveling in a car, plane, bus, or train. Four routes in this study fall into this category: Vancouver-Seattle (204 km), Montreal-New York (527 km), Toronto-New York (566 km), and Toronto-Chicago (704 km).

Based on previous calculations by Kwan (2013), Rutherford and Kwan (2015), and analysis results from this study, Table 8 compares the average aircraft fuel efficiency on the four routes and other transportation modes on a similar interurban trip. To take into account the difference in energy density between different fuels, we use miles per gallon gasoline equivalent as metric. As a reference, a Ford Explorer 4WD has a highway fuel efficiency of 24 miles per (US) gallon, or 9.8 liter/100km.

It is important to note that we assume an occupancy of two in a passenger vehicle. This a conservative approach compared to other studies on vehicle occupancy for longer trips. For example, Santos, McGuckin, Nakamoto, Gray, & Liss (2011) derived a value of 2.2 while Schiffer (2012) concluded

4 Because aircraft maintenance is done on a takeoff-landing cycle basis, planes flown at a higher frequency are inherently more expensive to maintain.

that auto occupancy rates for long-distance trips are 3.1, compared to 1.5 for urban or rural travel.

While a longer stage length means a more fuel-efficient flight, a comparison with other transportation modes shows that on a comparable distance flying is the least fuel-efficient way of traveling. An exception in this case is driving alone in a car with low fuel efficiency, such as a sport utility vehicle (SUV).

4. CONCLUSIONS, POLICY IMPLICATIONS, AND NEXT STEPS

This study compared airline fuel efficiency on operations encompassing 10 transborder routes between Canada and the United States. In general, most of the fuel efficiency gap between the best- and worst-performing airlines can be explained by the use of different aircraft types. On longer routes, airlines flying single-aisle aircraft are more likely to record better fuel efficiency than those flying regional jets. On shorter routes, airlines that fly turboprops are more efficient than airlines that fly regional jets. These gaps indicate that airline fuel efficiency can be significantly improved. While aircraft manufacturers and airlines can narrow the significant gap by improving technology and operations, it would be more likely to happen if supported by government regulations or incentives.

On comparable routes where passengers have the option to take different modes of transportation, flying is more fuel-intensive than any other mode. This could also be considered when designing incentives to reduce greenhouse gases from transportation.

Future updates may be beneficial in a couple of ways. As with the few published U.S. domestic airline fuel efficiency rankings, a year-on-year comparison may provide insights on how the industry evolves. In addition, it would be helpful to evaluate how new aircraft purchases influence airlines' fuel efficiency. Air Canada, for example, plans to replace 45 Embraer E190s with the new Bombardier C-Series airplanes in 2019 (Air Canada, 2016).

The scope of this study may be expanded in the future as data availability improves. Greater transparency in airline fuel efficiency and emissions would be supported if Canada began collecting airline data similar to that summarized in BTS T-100 International Segments data. Primary fuel-use data would allow the analysis of actual, as opposed to modeled, Canadian domestic airline fuel efficiency and provide a more comprehensive snapshot of airline performance in Canada. More transparent data in general can allow researchers to present more accurate results and help policymakers make more evidence-based decisions.

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APPENDIX A: List of Airports

Table A1. Airports on Toronto - Los Angeles route

Airport code	Airport Name
YYC	Calgary International Airport
IAH	George Bush Intercontinental Airport
HOU	William P. Hobby Airport

Table A2. Airports on Vancouver - Los Angeles route

Airport code	Airport Name
YVR	Vancouver International Airport
LAX	Los Angeles International Airport
SNA	John Wayne Airport

Table A3. Airports on Montreal - Miami route

Mainline	Affiliates
YUL	Montréal–Pierre Elliott Trudeau International Airport
MIA	Miami International Airport
FLL	Fort Lauderdale–Hollywood International Airport
PBI	Palm Beach International Airport

Table A4. Airports on Toronto - New York route

Mainlines	Affiliates
YYZ	Toronto Pearson International Airport
YTZ	Billy Bishop Toronto City Airport
LGA	LaGuardia Airport
EWR	Newark Liberty International Airport
JFK	John F. Kennedy International Airport

Table A5. Airports on Calgary - Houston route

Airport code	Airport Name
YYC	Calgary International Airport
IAH	George Bush Intercontinental Airport
HOU	William P. Hobby Airport

Table A6. Airports on Toronto - Orlando route

Mainlines	Affiliates
YYZ	Toronto Pearson International Airport
MCO	Orlando International Airport

Table A7. Airports on Toronto - Chicago route

Mainlines	Affiliates
YYZ	Toronto Pearson International Airport
YTZ	Billy Bishop Toronto City Airport
ORD	Chicago O'Hare International Airport
MDW	Chicago Midway International Airport

Table A8. Airports on Montreal - New York route

Mainlines	Affiliates
YUL	Montréal–Pierre Elliott Trudeau International Airport
LGA	LaGuardia Airport
EWR	Newark Liberty International Airport
JFK	John F. Kennedy International Airport

Table A9. Airports on Calgary - San Francisco route

Mainlines	Affiliates
YYC	Calgary International Airport
SFO	San Francisco International Airport

Table A10. Airports on Vancouver - Seattle route

Mainlines	Affiliates
YVR	Vancouver International Airport
SEA	Seattle–Tacoma International Airport

APPENDIX B: Airline RPK Distribution by Route

Table B1. Mainline-affiliate RPK distribution on Toronto - Los Angeles route

Mainlines	Affiliates	Share of RPKs	RPKs (Millions)
Air Canada	Air Canada	81%	2018
American Airlines	American Airlines	12%	309
WestJet	WestJet	7%	170

Table B2. Mainline-affiliate RPK distribution on Vancouver - Los Angeles route

Mainline	Affiliates	Share of RPKs	RPKs (Millions)
Air Canada	Air Canada	37%	615
	Air Canada rouge LP	6%	103
WestJet	WestJet	34%	563
Delta Airlines	Compass Airlines	16%	268
United Airlines	Skywest Airlines	5%	89
	United Air Lines	0.1%	2
American Airlines	Compass Airlines	1%	14

Table B3. Mainline-affiliate RPK distribution on Montreal - Miami route

Mainline	Affiliates	Share of RPKs	RPKs (Millions)
Air Canada	Air Canada rouge LP	58%	924
	Air Canada	4%	58
American Airlines	American Airlines	22%	343
WestJet	WestJet	8%	133
Air Transat	Air Transat	5%	74
Sunwing Airlines	Sunwing Airlines	3%	48

Table B4. Mainline-affiliate RPK distribution on Toronto - New York route

Mainlines	Affiliates	Share of RPKs	RPKs (Millions)
Air Canada	Air Canada	38%	531
	Sky Regional Airlines	9%	126
	Air Canada Regional (Jazz Air)	0.3%	4
WestJet	WestJet	17%	240
Porter Airlines	Porter Airlines	15%	215
American Airlines	Trans States Airlines (New code)	6%	80
	Republic Airlines	3%	37
	Air Wisconsin Airlines Corp	0.3%	4
	American Eagle Airlines (Envoy Air)	0.1%	2
Delta Air Lines	Endeavor Air	4%	63
	Delta Air Lines	2%	23
	GoJet Airlines	1%	10
	Shuttle America Corp.	0.02%	0.3
United Airlines	ExpressJet Airlines (ASA)	4%	51
	Republic Airlines	1%	18
	Shuttle America Corp.	0.20%	2

Table B5. Mainline-affiliate RPK distribution on Calgary - Houston route

Mainlines	Affiliates	Share of RPKs	RPKs (Millions)
United Airlines	United Airlines	60%	727
Air Canada	Air Canada Regional (Jazz Air)	29%	348
WestJet	WestJet	11%	138

Table B6. Mainline-affiliate RPK distribution on Toronto - Orlando route

Mainlines	Affiliates	Share of RPKs	RPKs (Millions)
Air Canada	Air Canada rouge LP	62%	719
WestJet	WestJet	28%	320
Sunwing Airlines	Sunwing Airlines	6%	66
Air Transat	Air Transat	5%	53

Table B7. Mainline-affiliate RPK distribution on Toronto - Chicago route

Mainlines	Affiliates	Share of RPKs	RPKs (Millions)
United Airlines	United Air Lines	24%	177
	Skywest Airlines	4%	28
	ExpressJet Airlines (ASA)	2%	19
	GoJet Airlines	2%	18
	Republic Airlines	2%	13
	Shuttle America Corp.	1%	4
	Trans States Airlines (New code)	0.20%	1
Air Canada	Sky Regional Airlines	19%	142
	Air Canada	13%	101
American Airlines	American Eagle Airlines (Envoy Air)	17%	126
Porter Airlines	Porter Airlines	16%	120

Table B8. Mainline-affiliate RPK distribution on Montreal - New York route

Mainlines	Affiliates	Share of RPKs	RPKs (Millions)
Air Canada	Sky Regional Airlines	27%	125
	Air Canada Regional (Jazz Air)	11%	53
	Air Canada	4%	20
Delta Airlines	Endeavor Air Inc.	17%	77
	GoJet Airlines	8%	35
	ExpressJet Airlines (ASA)	4%	20
	Shuttle America Corp.	1%	4
American Airlines	Trans States Airlines (New code)	17%	77
	Air Wisconsin Airlines Corp	1%	4
	Republic Airlines	0.10%	0
United Airlines	ExpressJet Airlines (ASA)	8%	36
	Republic Airlines	2%	10
	Shuttle America Corp.	0.30%	1

Table B9. Mainline-affiliate RPK distribution on Calgary - San Francisco route

Mainlines	Affiliates	Share of RPKs	RPKs (Millions)
United Airlines	Skywest Airlines	51%	151
	United Airlines	3%	10
WestJet	WestJet	27%	80
Air Canada	Air Canada Regional (Jazz Air)	19%	56

Table B10. Mainline-affiliate RPK distribution on Vancouver - Seattle route

Mainlines	Affiliates	Share of RPKs	RPKs (Millions)
Alaska Airlines	Horizon Air	26%	34
	Alaska Airlines	17%	22
Delta Airlines	Compass Airlines	19%	24
	Skywest Airlines	15%	20
Air Canada	Air Canada Regional (Jazz Air)	23%	29

APPENDIX C: Airline Fuel Efficiency and Operational Parameters

Table C1. Montreal - Miami fuel efficiency by airline

Rank	Airline	Fuel efficiency (Pax-km/L)	Relative fuel burn	Passenger share	Load factor	Prevalent aircraft type	Prevalent aircraft type share of ASKs
1	**Air Transat**	38	-	5%	86%	Boeing 737-800	85%
2	**Sunwing Airlines**	37	3%	3%	80%	Boeing 737-800	100%
3	**Air Canada**	33	15%	62%	85%	Boeing 767-300ER	46%
4	**American Airlines**	32	19%	21%	85%	Boeing 737-800	100%
5	**WestJet**	28	36%	8%	78%	Boeing 737-700	94%

Table C2. Toronto - Orlando fuel efficiency by airline

Rank	Airline	Fuel efficiency (Pax-km/L)	Relative fuel burn	Passenger share	Load factor	Prevalent aircraft type	Prevalent aircraft type share of ASKs
1	**Air Transat**	35	-	5%	79%	Boeing 737-800	100%
2	**WestJet**	32	9%	28%	85%	Boeing 737-800	67%
3	**Sunwing Airlines**	31	13%	7%	69%	Boeing 737-800	100%
3	**Air Canada**	31	13%	61%	87%	Boeing 767-300ER	65%

Table C3. Toronto-Los Angeles fuel efficiency by airline

Rank	Airline	Fuel efficiency (Pax-km/L)	Relative fuel burn	Passenger share	Load factor	Prevalent aircraft type	Prevalent aircraft type share of ASKs
1	**WestJet**	32	-	7%	84%	Boeing 737-700	75%
2	**Air Canada**	31	3%	80%	83%	A320-100/200	32%
3	**American Airlines**	29	10%	13%	79%	A319	76%

Table C4. Calgary-Houston fuel efficiency by airline

Rank	Airline	Fuel efficiency (Pax-km/L)	Relative fuel burn	Passenger share	Load factor	Prevalent aircraft type	Prevalent aircraft type share of ASKs
1	**United Airlines**	33	-	60%	81%	A320-100/200	35%
2	**WestJet**	26	27%	11%	71%	Boeing 737-700	71%
3	**Air Canada**	25	32%	29%	80%	Bombardier CRJ 705	100%

Table C5. Vancouver-Los Angeles fuel efficiency by airline

Rank	Airline	Fuel efficiency (Pax-km/L)	Relative fuel burn	Passenger share	Load factor	Prevalent aircraft type	Prevalent aircraft type share of ASKs
1	**WestJet**	31	-	35%	84%	Boeing 737-800	55%
1	**Air Canada**	31	-	4%	90%	Airbus 320-100/200	58%
2	**United Airlines**	26	19%	5%	92%	Embraer EMB-175	67%
3	**American Airlines**	24	29%	1%	93%	Embraer EMB-175	100%
4	**Delta Airlines**	23	35%	17%	82%	Embraer EMB-175	100%

Table C6. Calgary-San Francisco fuel efficiency by airline

Rank	Airline	Fuel efficiency (Pax-km/L)	Relative fuel burn	Passenger share	Load factor	Prevalent aircraft type	Prevalent aircraft type share of ASKs
1	**WestJet**	33	-	29%	83%	Boeing 737-800	99%
2	**Air Canada**	27	22%	18%	91%	Bombardier CRJ 705	99%
3	**United Airlines**	25	32%	53%	91%	Embraer EMB-175	66%

Table C7. Toronto-Chicago fuel efficiency by airline

Rank	Airline	Fuel efficiency (Pax-km/L)	Relative fuel burn	Passenger share	Load factor	Prevalent aircraft type	Prevalent aircraft type share of ASKs
1	**United Airlines**	23	-	32%	85%	Boeing 737-900	20%
2	**Porter Airlines**	20	15%	20%	64%	Bombardier Dash 8 400	100%
3	**American Airlines**	19	21%	16%	86%	Embraer EMB-145	54%
3	**Air Canada**	19	21%	32%	80%	Embraer EMB-175	56%

Table C8. Toronto-New York fuel efficiency by airline

Rank	Airline	Fuel efficiency (Pax-km/L)	Relative fuel burn	Passenger share	Load factor	Prevalent aircraft type	Prevalent aircraft type share of ASKs
1	**Porter Airlines**	20	-	17%	71%	Bombardier Dash 8 400	100%
2	**Air Canada**	19	2%	44%	84%	BombardierEMB-190	45%
2	**Delta Airlines**	19	2%	6%	86%	Bombardier CRJ-900	61%
3	**United Airlines**	18	11%	5%	86%	Embraer EMB-145	70%
4	**American Airlines**	17	15%	9%	82%	Embraer EMB-145	62%
4	**WestJet**	17	16%	19%	71%	Boeing 737-600	49%

Table C9. Montreal-New York fuel efficiency by airline

Rank	Airline	Fuel efficiency (Pax-km/L)	Relative fuel burn	Passenger share	Load factor	Prevalent aircraft type	Prevalent aircraft type share of ASKs
1	**United Airlines**	17	-	10%	82%	Embraer EMB-145	75%
1	**Delta Airlines**	17	-	30%	77%	Bombardier CRJ-900	38%
1	**American Airlines**	17	-	17%	81%	Embraer EMB-145	94%
2	**Air Canada**	16	6%	43%	77%	Embraer EMB-175	60%

Table C10. Vancouver-Seattle fuel efficiency by airline

Rank	Airline	Fuel efficiency (Pax-km/L)	Relative fuel burn	Passenger share	Load factor	Prevalent aircraft type	Prevalent aircraft type share of ASKs
1	**Alaska Airlines**	13	-	43%	76%	Bombardier Dash 8 400	60%
2	**Air Canada**	12	8%	25%	68%	Bombardier Dash 8 400	75%
3	**Delta Airlines**	10	30%	33%	78%	Embraer EMB-175	49%