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Effects of a Carbon Emissions Trading System on Aviation Financial Decisions

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Abstract

The cost of providing air transportation for passengers and cargo to, from, and within the European Union was scheduled to increase in 2012 due to the EU Emission Trading Scheme. The European Union (EU) has legislated that aircraft landing or taking off from EU airports are subjected to the Emission Trading System (ETS) and are levied a charge for the estimated amount of carbon dioxide (CO_2) generated during the entire flight. Since direct measurement of CO_2 emitted during flight is not practical, the EU carbon emissions are estimated using the amount of fuel consumed. CO_2 is a greenhouse gas associated with detrimental environmental impacts. Transportation in the US contributed 31% of CO_2 emissions and 26% of greenhouse gas emissions in 2010. According to the International Air Transport Association (IATA), aviation is responsible for 2% of global CO_2 emissions, and currently represents a growing percentage. Reducing fuel consumption is the most effective way to reduce CO_2 emissions, but operational changes, design changes, and use of alternative fuels are also effective. While ETS charges are controversial, the purpose of this paper is to discuss ETS and illustrate its inclusion in aviation financial considerations. This paper introduces aviation carbon ETS, discusses the impact of ETS on airlines, and presents a methodology to quantify the cost differences in fuel and EU ETS charges incurred by introducing a stop for flights into and out of the EU.

Keywords: aviation emissions, EU ETS, carbon credit

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Introduction

Carbon emissions are a global concern in today's world. The aviation industry is now part of the policy changes instituted by the European Union (EU) seeking to limit carbon emissions. As aviation is a global industry, nations outside of the EU are also affected by the changes. Due to a decision to extend the EU Emissions Trading Scheme (EU ETS) to aviation beginning in January 2012, the cost of providing air transportation for passengers and cargo to, from, and within the European Union was increased. The EU has legislated that aircraft landing or taking off from EU airports are subjected to the ETS and are levied a charge for the estimated amount of carbon dioxide (CO_2) generated during the entire flight (European Commission, 2011). For instance, flights from Rome to Tokyo or from Chicago to Athens are charged for the entire flight, not just the portion of the flight over the EU. Other industries are already being levied ETS charges by the EU. The EU announced that airlines would be charged with EU ETS beginning in January 2012. The EU ETS is considered controversial by at least 30 countries, including the United who have contested ETS as a unilateral tax on fuel (Ghost at the feast, 2012) and resulting cost implications (International Centre for Trade and Sustainable Development, 2012). If airlines are not in ETS compliance, then EU countries may levy fines and seize aircraft. Actions such as fines or seizures may lead to a trade war. For example, China has threatened to block $14 billion in orders from European aircraft manufacturer Airbus in response to the ETS (Reuters, 2012). Due to controversy over the EU ETS, the European Commission decided in November 2012 to temporarily delay implementation for flights in to and out of the EU for one year to allow ICAO time to develop a multi-national approach to emissions limitations as opposed to the unilateral EU ETS (Laing, 2012). The EU ETS is still in effect for flights within the EU. In this paper, the discussion of the EU ETS refers to the existing emission trading scheme as it was in effect prior to November 2012, as no changes to the EU ETS have been announced other than the implementation delay.

Carbon dioxide, or CO_2, is a greenhouse gas that United States and European Union agencies have both associated with detrimental environmental impacts (Environmental Protection Agency, 2012a; European Environment Agency, 2012). All forms of transportation in the US contributed 31% of CO_2 emissions and 26% of greenhouse gas emissions in 2010 (Environmental Protection Agency, 2012b). Aviation is responsible for 2% of global CO_2 emissions, and that percentage is increasing (International Air Transport Association [IATA], 2012b). In addition to the EU, reducing aviation carbon emissions is also important in the United States. Using 2005 commercial aviation emissions as a baseline, the U.S. Government has a goal of reducing carbon emissions by 115 million metric tons to achieve carbon-neutral growth for US commercial aviation by 2020 (Federal Aviation Administration, 2012). However, direct measurement of CO_2 emitted during flight is not practical, so an estimate is needed. In the EU ETS, CO_2 emissions from flight are estimated by multiplying the amount of fuel consumed during the flight by a factor specific to the type of fuel used (The Commission of the European Communities, 2009).

Reducing fuel consumption is the most effective way to reduce CO_2 emissions (Environmental Protection Agency, 2012a). The EPA highlights four suggestions for reducing transportation emissions: changing fuels, improving designs, improving operating practices and reducing demand (Environmental Protection Agency, 2012b). Reducing demand for flight is unattractive to airlines, but reducing demand for fuel for each flight is attractive because it could lead to cost reductions without reducing revenue. By 2020, IATA airlines are aiming to reduce fuel consumption and CO_2 emissions by 25% by implementing technology and operational improvements (IATA, 2012b). Alternative fuels are being studied for their effects on CO_2 emissions (IATA, 2012d).

While EU ETS charges are not globally accepted, the purpose of this paper is to discuss EU ETS and illustrate its use in aviation financial considerations. This paper introduces aviation carbon ETS, discusses the impact of ETS on airlines, and presents a methodology to quantify the cost differences in fuel and EU ETS charges incurred by introducing a stop for flights into and out of the EU.

Aviation Carbon Trading Emissions System

Aviation activities produce carbon dioxide emissions. As a way to implement a policy to limit greenhouse gases, the European Union EU has imposed a cap on CO_2 that affects many industries, including aviation (European Commission, 2012a). Aviation is now included in the EU ETS after the UN's International Civil Aviation Organization (ICAO) did not implement the mandated global scheme for aviation (Duffy, 2011). Air transportation emissions are not subjected to the Kyoto Protocol because it was argued that ICAO would develop its own emission reduction system (Van Hasselt, Van der Zwan, Ghijs, & Santema, 2009). Due to the slow pace of ICAO progress toward a global aviation emissions agreement, the EU passed its own carbon emissions plan in 2009 (Clark, 2011).

Beginning in January 2012, all domestic and international flights originating from or landing at EU airports were subject to the EU ETS. In November 2012, the implementation date has been delayed by one year for flights in to or out of the EU as a way of supporting the efforts planned for the ICAO General Assembly meeting in fall 2013 to find a global solution for emissions (European Commission, 2012a). The EU ETS still applies to flights within the EU. The EU plans to reinstate international flights in the EU ETS if a global solution is not found (European Commission, 2012a). In this paper, the EU ETS is discussed as it existed prior to November 2012.

Under EU ETS, airlines will be given a certain amount of tradable carbon allowances, and must surrender a number of allowances equal to their actual emissions in that year. Each carbon allowance represents one metric ton of carbon dioxide emissions (CO_2). If actual emissions are lower than an airline's given allowances, the allowances may be either sold or held for future years. If actual emissions are higher than given allowances, the airline may purchase additional allowances or take measures to reduce emissions (European Commission, 2012a). Emissions estimates may be higher or lower based upon the amount of fuel consumed by the airline. In EU ETS, the more fuel consumed, the more emissions; the less fuel consumed, the less emissions. Possible ways to lower emissions are discussed in a later section.

To determine the emissions cap, or total number of allowances to be allocated, for the airlines, the European Environment Agency estimated the average annual aviation sector emissions in the EU for the years 2004, 2005, and 2006 as 221,420,279 metric tons of CO_2. In 2012, there are enough aviation tradable carbon allowances to cover 97% of the estimated annual aviation emissions from 2004-2006, and this amount reduces to 95% in 2013. Airlines that cooperated with the EU ETS rules and reported their fuel usage and distance data for 2010 are to be given 85 percent aviation allowances for free in 2012. The remaining 15 percent of the allowances will be auctioned. In 2013–2020, 82% of the allowances will be free, 15% of the CO_2 allowances will be auctioned, and the remaining 3% will remain in a special reserve for later distribution to fast growing airlines and new entrants into the market (European Commission, 2012b).

To simplify the collection of allowances, the EU has assigned each airline to be administered by either the EU country where the airline is based or the EU country where the airline emissions were the greatest for the base year (European Commission, 2011). In this way, each airline reports ETS information to a single country. For instance, US-based Airborne Express is assigned to Belgium and US-based American Airlines is assigned to the United Kingdom (European Commission, 2011). If an airline chooses to not comply with ETS, the EU ETS imposes a penalty of €100 (approximately $135) per ton of carbon dioxide emissions (Reals, 2011). Failure to comply or pay penalties can result in aircraft being seized and sold to recover any owed carbon emissions charges and penalties.

The EU was in the process of drafting new ETS regulations to be effective in January 2013 (Duffy, 2011). In November 2012, the European Commission temporarily delayed implementation of the ETS for one year to allow ICAO time to develop a multi-national aviation carbon emissions agreement (Laing, 2012). The EU has delayed ETS for flights in and out of the EU; however, the ETS is still in effect for flights within the EU (European Commission, 2012a). If an ICAO agreement on global emissions is reached at a later date, the EU may modify the ETS (Clark, 2011). "The EU is committed to finding a comprehensive and non-discriminatory multilateral agreement within ICAO, and the EU legislation is designed to be amended in the light of such an agreement" (European Commission, 2012a).

Airlines and over 30 governments across the globe are contesting the inclusion of aviation in the EU ETS, primarily based on viewing the ETS as a unilateral tax on fuel for the entire flight, possible violation of national sovereignty, and violation of existing international agreements (Anonymous, 2012; Wall and Madhu, 2011). On December 21, 2011, the European Court of Justice upheld the 2009 ETS legislation in a legal suit filed by some US airlines and their trade association (European Commission, 2012a). The court asserted that the EU ETS does not constitute an illegal charge, tax or fee on fuel. Such a charge on fuel could be in breach of the EU-US Air Transport Agreement. The Court concluded that the uniform application of the EU ETS to all flights which depart or arrive from the EU is consistent with provisions designed to prohibit discriminatory treatment between aircraft operators, on nationality grounds also covered by this agreement (European Commission, 2012a). Airlines also contest the EU ETS on the grounds that the charges apply to the entire flight, not just over EU airspace, and are therefore in violation of international agreements and national sovereignty of the airline's home nation and nations along the flight path (Laing, 2012). Both the US Senate and the US House of Representatives have passed different resolutions asking for the US to ban the US-based airlines from participating in the EU ETS (Laing, 2012). President Obama of the United States signed a bill into law on November 27, 2012 making it possible for the US Transportation Secretary to ban airlines from participating in the EU ETS (Airlines for America, 2012). Now that ICAO has agreed to relook at a global agreement for aviation emissions, the EU has issued a temporary delay in implementing the EU ETS for international flights in to and out of the EU.

Ways to Reduce Emissions Charges

The most effective way to reduce EU ETS charges is to reduce fuel consumption, as the charges are based on the amount of fuel consumed when flying to and from EU airports. Changing fuels, improving designs, and improving operating practices are suggested ways to reduce emissions (Environmental Protection Agency, 2012b). There are two types of alternative jet fuels that have been approved by ASTM standards (ASTM, 2011) and used in flight; however, these fuels are not widely available in sufficient quantities for extensive use in airlines. Reducing demand for fuel is attractive to airlines only if the reduction in demand is due to improvements in designs or operations and not due to a reduction in passenger and cargo demand as these may result in reduced revenue. IATA member airlines have developed a goal of reducing fuel consumption and CO_2 emissions by 25% by implementing technology and operational improvements (IATA, 2012b). Capital investments, expense changes, or both may be required to implement technology or operational improvements to cover the costs of items such as new equipment, training, and procedure development. Modifications to the airframe or engines may include changes such as coatings, cleaning procedures, wing modifications, combustor upgrades, or even fleet replacement. Boeing and Airbus both offer aircraft with wing tip modifications that are presented as reducing fuel consumption by 3–5% (Airbus, 2012; Aviation Partners Boeing, 2011). Examples of changing operational rules to reduce emissions include: route navigation rules for ascent and descent, power settings rules, and ground control rules for dispatching aircraft that reduces hold time on runways. IATA has worked with key aviation participants for ten years on the iFlex project, to change long haul flight routes so that carriers reduce flight time, fuel consumption by 2% and CO_2 emissions (IATA, 2012c).

Another way to reduce the EU ETS charges is to change the route so that the last leg of the flight into or out of the EU is shorter than the current non-stop route. Changing routes to include an additional stop reduces the amount of fuel used for flight segments into and out of the EU, and therefore reduces EU ETS charges because the charges are based on fuel consumption during the entire flight, not just the portion over EU. A major US-based cargo carrier, UPS Airlines, considered adding stops to reduce the EU ETS charges (Cameron & Michaels, 2011). Instead of flying non-stop from between hubs in Hong Kong and Cologne, Germany, the route would be changed by adding a stop in Mumbai, India. While UPS estimates that the route change reduces the ETS charge by 25%, UPS also estimates that the emissions are increased by 33% due to the longer route and added takeoff and landing. This option is especially applicable to cargo carriers, as many passengers prefer non-stop flights, where the potential for lost revenue may negate any cost savings by adding stops on passenger routes (Cameron & Michaels, 2011). This paper presents a methodology for comparing airline costs that includes fuel costs and EU ETS emissions charges. In this methodology, fuel costs and emissions charges on long haul non-stop routes are compared to flights with an added stop prior to landing at an EU airport as a way to reduce EU ETS charges.

Methodology For Cost Comparision of Non-Stop and Alternative Routes

This methodology compares fuel costs and emissions charges for two flights with the same origin and destination; one flight is non-stop and the other flight has a single stop. Both flights have the same destination and origination city, with one of the cities in the EU. The non-stop flight will have EU ETS charges for fuel consumption for the entire flight. The single stop flight has the same origination and destination cities, but the flight is routed through a non-EU city before entering the EU. The single stop flight will have EU ETS charges only for the flight segment that starts or ends in an EU city. The methodology compares the fuel costs and emissions costs for the two routes.

The first step is to estimate the fuel consumption and fuel costs for each route. The fuel consumption data for each route is obtained using the ICAO carbon calculator on the ICAO website. Table 1 shows the fuel requirements for two different long haul routes. The first route compares the non-stop flight from Hong Kong to Paris and a single stop flight between Hong Kong and Paris in Mumbai. To estimate flight distance and fuel requirements, the ICAO Carbon Emissions Calculator was used to retrieve kilometers traveled and kilograms of fuel for the three segments of the trips (Hong Kong-Paris, Hong Kong-Mumbai, and Mumbai- Paris). The second route compares the non-stop flight from Los Angeles to London and a single stop flight between Los Angeles and London in Boston. The amount of fuel consumed estimated by the ICAO calculator considers the type of aircraft typically used on specific routes and the distance travelled. It is important to note that the ICAO calculation of fuel consumption is based on distance travelled and a composite of the variety of aircraft used on those flights. Actual fuel consumed on these flights may vary from these estimates.

Distance and fuel consumption data from both the ICAO website calculator and the ICAO app are shown as both of

Table 1
ICAO Carbon Calculator Data Comparison

Routes			ICAO Website		ICAO App	
From	To	Stop	Round Trip Distance	Round Trip Fuel Consumption	Round Trip Distance	Round Trip Fuel Consumption
Hong Kong (HKG)	Paris (CDG)	None	19,164	77,295	19,164	89,438
		Mumbai (BOM)	22,516	85,927	22,516	85,118
Los Angeles (LAX)	London (LHR)	None	17,510	80,505	17,510	79,909
		Boston (BOS)	18,856	50,809	18,856	50,130

Note. Distances in kilometers and fuel in kilograms. All numbers were obtained from the ICAO Carbon Emissions Calculator (ICAO, 2012a).

Table 2
Fuel Consumption and Distance Analysis

Distance (nm)	Fuel Consumption Estimates by Aircraft		
	340	777	744
6,000	83,691.99	90,693.23	128,170.81
3,000	39,114.82	43,143.25	59,576.88
2*3,000	78,229.64	86,286.50	119,153.76
Difference	5,462.35	4,406.73	9,017.05
5,000	67,669.69	73,655.15	103,611.40
2,500	32,695.54	36,026.67	49,480.22
2*2,500	65,391.08	72,053.34	98,960.44
Difference	2,278.61	1,601.81	4,650.96

Note. ICAO, 2012a, p. 14.

these sources may be available to the reader. It is important to show data from both sources as there are differences between the fuel requirements shown by the ICAO website and ICAO app carbon emission calculators. For instance, while the roundtrip distance is the same for both the ICAO website and the app for the Hong Kong to Paris trip, the fuel consumption amounts are different as reported in Table 1. No explanation for discrepancies such as these was found in the ICAO documentation. For this reason, in this research the fuel consumption data is used from one source, the ICAO Carbon Calculator website. While the numbers reported in Table 1 reflect the values retrieved in November 2012, it should also be noted that ICAO may update the fuel consumption estimates at any time, and therefore, future analyses should use updated numbers.

In Table 1, the flight between Los Angeles and London shows that adding one single stop in Boston consumes less fuel than the non-stop flight between the origin and final destination cities. As 14 CFR Part 121 flight operations prescribe, the amount of fuel loaded is sized for each segment of flight so that safety and cost are considered. Consistent with Part 121, Table 2 shows that the CORINAIR fuel data for A340, B777 and B747 aircraft types indicate that flights broken into two equal legs may consume less fuel than a non-stop of the same distance. The CORINAIR data are in nautical miles and gallons. For instance, an A340 type aircraft traveling a non-stop 6,000 nautical mile flight is estimated to consume 83,691.99 gallons of fuel, and only 78,229.64 gallons of fuel on two 3,000 nautical mile trips. Typically, aircraft on a non-stop flight will be heavier because there is more fuel on board compared to the amount of fuel on board for two shorter flights. Once the fuel consumption is estimated using the ICAO carbon calculator website, the fuel cost is estimated for each route and compared.

The second step is to estimate the carbon emissions and carbon costs. The ICAO carbon calculator website also presents an estimate for carbon emissions per passenger that considers factors such as load factor, economy or first class seat, and the ratio of passengers to cargo. In the EU ETS estimates of carbon emissions, the amount of fuel consumed in kilograms is multiplied by the approved factor to estimate carbon emissions for Jet A or Jet A-1 of 3.15 kilograms of carbon dioxide per kilogram of fuel (The Commission of the European Communities, 2009). The EU ETS method estimates carbon emissions for the amount of fuel consumed for the flight. The ICAO carbon calculator website estimates carbon emissions per passenger. The authors chose to use the EU ETS way to calculate aviation emissions because it considers only the amount of fuel consumed, and is not apportioned to each passenger as in the ICAO carbon calculator website. After the carbon emissions are estimated, the aviation carbon allowance costs are estimated. Finally, the fuel and the emissions costs are compared for the two routes.

To illustrate this methodology, the estimated fuel and EU ETS savings are compared when adding a stop outside the EU to a specific non-stop flight into or out of the EU. A non-stop flight from Singapore to Paris and a flight from Singapore to Paris with a stop in Mumbai are compared. These routes were selected because the distances for the non-stop and for the one-stop flights were very similar (21,424 km versus 21,796 km) (ICAO, 2012a).

A fuel cost comparison of two routes is shown in Table 3. The fuel consumption data from the ICAO carbon calculator website are shown for each of the two routes. The ICAO calculator estimates the Singapore to Paris non-stop flight to consume 88,131 kg of fuel each way. The ICAO carbon calculator for the one stop flight estimates 24,618 kg of fuel for a one-way trip between Singapore and Mumbai, and 50,005 kg of fuel for a one-way trip between Mumbai and Paris. Fuel consumption values shown in the

Table 3
Fuel Cost Comparison Using Two Routes from Singapore to Paris

From	To	Stop	Round Trip Distance (km)	Round Trip Fuel Consumption (kg)	Round Trip Fuel (gal)	Single Round Trip Fuel Cost ($3.19/gal)	Annual Fuel Cost on 365 Round Trips
Singapore (SIN)	Paris	None	21,424	176,262	57,146	$182,296	$66,538,018
	(CDG)	Mumbai (BOM)	21,796	149,246	48,387	$154,355	$56,339,614
Fuel Difference with additional stop							$10,198,404

Round Trip Fuel Needed (gal) = Round Trip Fuel Needed (kg) * (1 / 0.45359) * (1 / 6.8), (Butcher, Crown, & Gentry, 2006).
Single Round Trip Fuel Cost = Round Trip Fuel Needed (gal) * Fuel Price/gal.
Annual Fuel Cost (365 Round Trips) = Single Round Trip Fuel Cost * Number of Round Trips.

Table 4
EU ETS Comparison Using Two Routes from Singapore to Paris

From	To	Roundtrip Fuel Needed Kilograms	Round trip EU ETS CO_2 Emissions	Annual Allowance 365 Roundtrips
Singapore	**Paris**	176,262	555	$1,795,543
Mumbai	**Paris**	100,010	315	$1,018,780
	Emissions Allowance Cost Reduction			**$776,763**

Note. Roundtrip EU ETS CO_2 Emissions (Metric Tons) = (Roundtrip Fuel Needed (Kilograms) * Emission Factor (3.15)) / 1,000 (to Metric Tons). Annual Allowance (365 Roundtrips) = Roundtrip EU ETS CO_2 Emissions (Metric Tons) * Allowance Price per Metric Ton ($8.86) * Number of Roundtrips (365).

table are the round-trip amounts in kilograms. The kilograms of fuel are converted to gallons and a cost per round trip for fuel is calculated using a recent fuel price of $3.19 per gallon. Next, the costs are extended to 365 flights per year for an annual estimate of one flight per day. The fuel savings for adding the stop in Mumbai is estimated at 8,759 gallons per roundtrip. At an estimated $3.19/gallon, the savings per roundtrip would be $27,941. If 365 roundtrips per year were flown, the savings would be over $10 million. In addition to specific routes selected and frequency of trips, the estimated savings will vary with the price of fuel and should be changed in future analyses to reflect current or expected fuel prices when using this methodology.

The emissions estimates for the same two routes are shown in Table 4. As mentioned earlier in the paper, the emissions amounts reported in the ICAO carbon calculator are not used in this methodology. Instead, the EU ETS carbon emissions calculations are used. To calculate EU ETS carbon emissions, the kilograms of Jet A fuel are multiplied by the emission factor 3.15 (The Commission of the European Communities, 2009) and then divided by 1,000 to convert kilograms of carbon emissions into metric tons. One carbon credit (allowance) is equivalent to 1,000 kilograms or one metric ton. To calculate the total emissions cost, the emissions metric tons are multiplied by the allowance price. In Table 4, the fuel requirements for the Mumbai to Paris roundtrip are lower than shown in Table 3. Only the fuel consumed on the second portion of the flight, between Mumbai and Paris, the EU city's airport, is considered. The EU ETS charges apply to the entire leg of the flight going to or coming from an EU airport. Table 4 shows a difference of 240 EU ETS emissions allowances on each one-stop roundtrip versus the non-stop roundtrip. If EU ETS aviation allowances were traded at $8.86, then the difference would be over $776,000 for one trip per day for a year. It is valid to consider the total amount of aviation allowances, as the allowances are tradable. The allowances have a monetary value whether they are retained by the airline for their own use, purchased to cover the airline's emissions, or sold to another airline. In addition to specific routes selected and frequency of trips, the estimated savings will vary with the price of carbon emissions allowances and should be changed in future analyses to reflect current or expected prices when using this methodology.

The dollar savings for the routes and frequency of trips illustrated in Tables 3 and 4 are dependent on the price of fuel and the price of aviation emissions allowances. The cost estimates in Tables 3 and 4 include only the fuel and EU ETS emissions charges. There are additional EU ETS rules for calculating emissions charges on flights with stops (The Commission of the European Communities, 2009). Table 5 summarizes the conversion factors, fuel price, and allowance price used to calculate the results shown in Tables 3 and 4. Sources for the prices and factors are listed in the notes for the table.

This methodology addresses fuel and EU ETS emissions costs as a starting point for understanding the effect of the EU ETS on alternative international routes in to and out of the EU. The methodology does not consider additional possible relevant costs for changing flight routing such as airport landing and take-off fees and taxes differences, trip duration differences, crew requirements, and the potential impact of unforeseen delays due to maintenance, weather, or political events. In addition, if other ETS systems are implemented either unilaterally or globally, the specific rules of those systems would need to be reviewed and necessary revisions made to the methodology.

Results

Overall, this analysis indicates that on selected routes, making one stop outside the EU reduces EU ETS emissions costs for aircraft carriers when compared to long-haul non-

Table 5
Summary of Prices and Conversion Factors Used

Fuel Price per Gallon[a]	$3.19
Allowance Price per Metric Ton[b]	$8.86
Emission Factor for Jet Fuel[c]	3.15
gallons to lbs Factor[d]	6.8
lbs to gallons Factor[d]	1/6.8
lbs to kilograms Factor[e]	0.45359
kilograms to lbs Factor[e]	1/.45359
kilometers to statute miles Factor[d]	1/1.609347

Note. [a]International Air Transport Association (2012a). [b]Intercontinental Exchange (2012). [c]The Commission of the European Communities (2009). [d]U.S. Department of Transportation Federal Aviation Administration Flight Standards Service (2009). [e]United States Environmental Protection Agency (2004).

stop flights in and out of the EU. When selecting non-stop and one-stop routes with similar total distances, a flight with one stop may consume less fuel than a non-stop flight. Most of this difference in fuel consumption is because the non-stop flight is expected to carry more fuel compared to the amount of fuel carried on the two shorter flights. This paper used a Singapore to Paris roundtrip as an example and showed both fuel cost savings and EU ETS savings. However, there are many other possible city-pair flights that may be explored. Savings due to fuel and emissions are expected to vary depending on specifics of the routes being compared. In addition, the inclusion of other relevant costs such as airport fees, taxes, crew costs, and the impact of potential weather, maintenance and political events are not included.

Future Research and Conclusion

The number of governing bodies that track and impose carbon emissions regulations is expected to increase in the next decade. Under the EU ETS, commercial aviation carbon emissions add imposed costs to flights in to, out of, and within the European Union. The stated purpose of the EU ETS is to reduce carbon emissions. Air carriers seek to reduce fuel consumption while not lowering revenues. Reducing fuel consumption reduces emissions. These reductions may require investments to make changes to aircraft or procedures that reduce demand for fuel by reducing consumption while still providing the same level of air service. Successfully reducing fuel consumption is not only important to comply with any current or future emission trading scheme, but will also become a major factor for survival in a competitive aviation market. Future research is planned to include other relevant costs such as taxes, depreciation, landing fees, and flight crew requirements in addition to ICAO fuel consumption estimates and EU ETS emissions estimates.

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