ABATING CARBON EMISSIONS IN THE AVIATION SECTOR: POLICY ANALYSIS AND RECOMMENDATIONS FOR THE FEDERAL GOVERNMENT

by

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Abstract

The top U.S. airlines by passenger volume move a little more than half a billion passengers annually, both domestically and internationally, burning millions of gallons of fuel and releasing millions of tons of the GHG carbon dioxide in the process. After building a case for action, this paper assumes that the United States Federal Government cannot sit idly by and is considering a carbon mitigation strategy for the aviation sector. Using publicly available data from MIT, the paper measured the carbon emission intensity of the major U.S. airlines to determine how efficiently airlines allocate carbon emissions, with the results providing insight into areas for emissions efficiency improvements. After determining that modernizing U.S. airline fleets is the most realistic opportunity to curb emissions, the paper developed a standard policy criterion to determine the best mix of regulatory policies to do so. It found that an emissions trading system, economic safeguards against foreign carriers and financial incentives for innovation can promote fleet modernization, decreasing carbon emissions across all airlines. Combining this modernization with new FAA air traffic management strategies, carbon emissions can be appreciably curbed despite projected growth.
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Introduction

Commercial aviation connects people, cultures, commerce, and continents in a way that no other mode of transportation can. Long gone are the days of where traveling from New York City to London took upwards of a week by ship. Since the advent of jet aircraft and the start of commercial air service, the same voyage now takes just under 7 hours; there is simply no substitute for this service that has truly revolutionized what it means to travel the globe. Like many modes of transportation, commercial aircraft combust hydrocarbon-based fuel for energy, thus powering them through the sky. In the United States, thousands of commercial aircraft take to the skies each day, burning millions of gallons of jet fuel annually, releasing seemingly innumerable amounts of carbon dioxide and additional pollutants into the air. Both ground level and high altitude pollution from aircraft come with negative environmental externalities that are not yet being adequately addressed by either the federal government or the industry itself. The most pressing concern, however, is aviation’s contribution to climate change and how best to abate the industry’s carbon emissions. From the industry’s perspective, commercial aircraft are not going to stop burning hydrocarbon-based fuel in the foreseeable future, and demand for this service won’t be abating as the economy continues to recover and the industry predicts steady growth domestically and internationally in the coming years. In the long run, this international problem of carbon emissions from aviation demands an international solution. Though in the interim, there is clearly a need for an effective policy response from the U.S. federal government.

Assuming the role of a consultant to the federal government, this paper will primarily serve as a decision support tool to help the federal government choose the best
combination of regulatory mechanisms to combat carbon emissions from the air transport sector as much as is realistic. It will begin with background information about the industry, economic projections, and carbon emissions data in an effort to build the case for urgency that some action must be taken. It will then conduct a carbon intensity analysis of the major U.S. airlines to inform the federal government of the efficiency disparities that exist and identify areas with potential for improvement. Finally a policy analysis is carried out to evaluate the major regulatory mechanisms for carbon emissions abatement for aviation in the United States, to identify which policy (or a combination thereof) would suit the U.S. aviation industry the best, given the standard criterion laid forth by the paper.

Background

Commercial Aviation Market Indicators

While demand for air travel took a pronounced dip during the global financial crisis of 2008 and subsequent years, it is recovering and burgeoning international markets are further buoying up demand projections for the sector, including for U.S. airlines. In table 1, the International Air Transport Association’s (IATA) econometric analysis of air travel markets shows that at domestic or national level, short-haul and long-haul demand for the service is relatively inelastic (IATA 2007). For international travel, both long-haul and short haul, demand is decidedly inelastic and speaks to the market for the service of international air travel; a commodity that limited substitutes (IATA 2007).

<table>
<thead>
<tr>
<th>Route/Market Level</th>
<th>National Level</th>
<th>Supra-national Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Short-haul</td>
<td>Long-haul</td>
</tr>
<tr>
<td>Intra North America</td>
<td>-1.5</td>
<td>-1.4</td>
</tr>
<tr>
<td>Trans-Atlantic</td>
<td>-1.9</td>
<td>-1.7</td>
</tr>
<tr>
<td>Trans-Pacific</td>
<td>-0.9</td>
<td>-0.8</td>
</tr>
</tbody>
</table>

Table 1: IATA 2007 Econometric Analysis of Market-level Demand Elasticity associated with U.S.
Also from the perspective of the U.S. market, the Federal Aviation Administration (FAA) released its projections for passenger growth from 2010-2031 in four major international markets (See Figure 1). It projected upwards of 5% annual growth in both Latin America and the Asia/Pacific markets, on the assumption that stable and robust economic growth would continue to drive demand (FAA 2010). As the world economy continues to recover from the global financial crisis and the Eurozone begins to stabilize further, solid growth will follow in both the transatlantic market and the trans-border North American market as well.

**Figure 1**: FAA Projected annual percentage growth of passengers (FAA 2010)

### The Economics of Oil and Jet Fuel

World oil supplies are becoming more constrained by the day. The majority of conventional, easily recoverable oil has already been discovered, and production is tightly controlled. As conventional oil deposits have begun to near depletion, oil companies have moved into unconventional oil recovery which is not only more technologically challenging to recover more costly, relying on oil prices to remain relatively high to be economically
viable. As oil powers all modern economies, “countries experiencing rapid economic growth are the ones most likely to dramatically increase their demand for oil. In particular, countries like China and India are experiencing rapid growth in GDP” (Basher 2006). Thus constrained supply and growing GDPs from large economies leads to higher prices per barrel of oil, translating directly into higher jet fuel or Jet A prices in the marketplace.

With regards to the U.S. commercial aviation sector, the Energy Information Administration says that in the U.S., “the transportation sector dominates demand for liquid fuels” at around 72% (EIA 2011). Of this total, the U.S. air transport sector commands 10% of the entire transportation sector’s share of liquid fuels (Gruenspecht 2011) and “energy consumption for aircraft increases from 2.7 quadrillion Btu in 2009 to 3.1 quadrillion Btu in 2035” (EIA 2011). As a result of the oil supply constraints previously mentioned as well as increasing demand, The EIA further projects the market price of jet to remain above $2.50 per gallon, only to surpass $3.00 per gallon around the year 2020 (See Figure 2).

![Figure 2: EIA Jet Fuel Price Projection through 2035 (EIA Data Browser 2012)](image-url)
Still, world economies growing steadily, post-recession, is leading to a sustained increase in demand for air travel, despite higher oil prices. All of this, of course, is occurring with increasing carbon emissions and the prospect of severe consequences from global climate change.

**Aviation, Energy & Environment**

The International Energy Agency reports that in 2009, as a result of energy production from fuel combustion, the world in total produced 29.0 gigatons of carbon dioxide emissions (IEA 2011). Of those 29 gigatons, the air transport sector is responsible for 750 megatons of carbon dioxide emissions and is slated to grow. Figure 3 shows a graphical breakdown of typical engine exhaust from aircraft engines; carbon dioxide comprises 49% of all emissions (GAO 2009).

![Figure 3: Components of Aircraft Engine Emissions (GAO 2009)](image)

Standard and Poor’s reports that “although the airline sector is currently responsible for a relatively small (3%) share of total global emissions, this is set to rise as
the sector experiences rapid growth. According to industry experts, the airlines’ share of total emissions will increase to 5% by 2050” (Clements 2011). Figure 4 shows the distribution of the world’s carbon emissions by sector transportation sector, indicating that aviation is responsible for 13% of all transportation related carbon emissions (GAO 2009). The United States is the world’s largest economy and its major carriers move more than 0.5 billion people annually (BTS 2010), contributing a substantial amount of the aviation emissions total percentage.

![Figure 4: Aviation’s Contributions to Carbon Dioxide Emissions (GAO 2009)](image)

**Carbon Emission Intensity Analysis of the Major U.S. Carriers**

In order to give federal government policymakers and industry leaders a critical snapshot of how various regulatory policies might affect the airlines under their jurisdiction, this paper measured the carbon emission intensity across the commercial aviation industry. Carbon emission intensity is a measure of how efficiently airlines allocate carbon emissions per unit, and this paper chose to look at the carbon intensity per passenger and per aircraft airborne hour. The results provide insight into the nuances of
this allocation based on airline efficiency and operational characteristics, which are directly affected by specific regulatory and management policies that can induce positive change to these characteristics. This analysis evaluates the largest U.S.-based airlines based on passengers carried from 2010. The year 2010 represents the most current operational aviation data that could be sourced. Figure 5 shows the top U.S. airlines ranked by the Bureau of Transportation Statistics (BTS):

![U.S. Airlines by Passenger Volume in 2010](image)

**Figure 5: BTS Airline Rankings (BTS 2010)**

The BTS airline passenger data had to be manipulated to account for recent mergers within the industry within the last two years: Continental merged into United, AirTran merged into Southwest, and Northwest merged into Delta. After this industry consolidation, the U.S. is left with seven major American carriers, carrying 71.8% of all commercial passengers, both domestic and internationally, in 2010 (BTS 2010). The other
28.2% of commercial passenger traffic is accounted for by smaller regional and domestic carriers, as well as international carriers that are outside the scope of this assessment.

Data

Data for the carbon intensity calculations was sourced from the Massachusetts Institute of Technology’s Airline Data Project (MIT ADP), established as part of the MIT Global Airline Industry Program. The MIT ADP compiled data from three reliable government sources: the U.S. Department of Transportation, the Bureau of Transportation Statistics, and the Securities and Exchange Commission. While this data is also concerned with the many business metrics related to the financing and operation of assets like equipment and human capital, it contains valuable data concerning actual flight and fuel consumption metrics that reveal a great deal about the individual carriers operational habits and characteristics.

Methodology

The carbon intensity calculation centers upon four primary MIT ADP components:

1. Passengers carried
2. Miles traveled
3. Airborne hours
4. Fuel burned

The Methodology is as follows:

2. Converting 1 gallon Jet A weight to Pounds, 6.84 lbs
3. Calculating the Pound to Tonne multiplier, 0.00045359

4. Using an International Civil Aviation Authority (ICAO) constant of 3.157
   “representing the number of tonnes of CO2 produced by burning a tonne of aviation fuel” (ICAO 2010)

5. Using the aforementioned primary MIT ADP data components to calculate:
   i. Fuel burn/ Airborne hour
   ii. CO2 emissions/ Passenger

The results from step 5 will serve as the comparison metrics for the top 7 U.S. airlines. The results show which airlines are the most and least carbon emission intensive, relative to the number of passengers carried and airborne hours where the majority of fuel is burned. They will help policymakers and industry leaders identify areas of improvement and realize future efficiency gains across the commercial aviation sector.

**Results**

<table>
<thead>
<tr>
<th>Rank</th>
<th>Airline</th>
<th>Passengers Carried</th>
<th>Miles Traveled</th>
<th>Airborne Hours</th>
<th>Fuel Burned (gallons)</th>
<th>Fuel Burned (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Southwest (inc. AirTran)</td>
<td>130,786,000</td>
<td>914,277,617</td>
<td>2,184,377</td>
<td>1,811,149,46</td>
<td>5,619,221</td>
</tr>
<tr>
<td>2</td>
<td>Delta (inc. Northwest)</td>
<td>110,925,000</td>
<td>1,051,891,951</td>
<td>2,271,760</td>
<td>3,093,665,00</td>
<td>9,598,318</td>
</tr>
<tr>
<td>3</td>
<td>United (inc. Continental)</td>
<td>97,559,000</td>
<td>1,149,711,531</td>
<td>2,576,742</td>
<td>3,291,656,21</td>
<td>10,212,600</td>
</tr>
<tr>
<td>4</td>
<td>American</td>
<td>86,129,000</td>
<td>874,231,327</td>
<td>1,886,500</td>
<td>2,480,948,32</td>
<td>7,697,320</td>
</tr>
<tr>
<td>5</td>
<td>US Airways</td>
<td>51,814,000</td>
<td>442,433,845</td>
<td>1,005,414</td>
<td>1,072,960,39</td>
<td>3,328,937</td>
</tr>
<tr>
<td>6</td>
<td>Jetblue</td>
<td>24,199,000</td>
<td>248,121,386</td>
<td>561,040</td>
<td>486,416,851</td>
<td>1,509,143</td>
</tr>
<tr>
<td>7</td>
<td>Alaska Airlines</td>
<td>16,478,000</td>
<td>164,532,812</td>
<td>368,812</td>
<td>320,479,864</td>
<td>994,312</td>
</tr>
</tbody>
</table>

**Table 3:** Initial inputs
Figure 6: Calculated jet fuel burn rate in gallons/hour

Figure 7: Calculated CO2 emissions in pounds/passenger

Analysis

Southwest Airlines has proven itself to be most carbon emission efficient carrier while aggregating the third most amount of miles and carrying the most passengers in 2010 than any other carrier. Its fleet emits the least amount of CO2 per passenger and per
airborne hour and this is due to two primary factors. First, Southwest Airlines’ model has it using a single model of narrow-body aircraft, one that has been an efficient workhorse of the commercial aviation sector for years: the Boeing 737-series aircraft. Southwest Airlines reports that it currently uses “550 Boeing 737 aircraft among 72 cities” (Southwest Fact Sheet 2011). Southwest Airlines is also in the process of phasing out older models of the aircraft in favor of newer, more efficient 737-800 series aircraft (Mutzabaugh 2012). Second, Southwest’s short hopper business model directs it to fly “high-frequency, point-to-point” routes in around “3,300 flights per day”, allowing for carbon emissions to be distributed amongst passengers on relatively full flights (Southwest Fact Sheet 2011). It is important to note that though the legacy carriers do fly more extensive long-haul routes than Southwest Airlines as it doesn’t fly long-haul international routes, it does still gain some long-haul mileage through cross country and intra-North American travel.

Alaska Airlines shares a similar story to Southwest because it also only operates late model narrow-body 737s, after having operated fuel inefficient McDonnell Douglas MD-80s for many years (RedOrbit 2008). Alaska Airlines serves the least number of passengers of all the airlines in 2010, and ranked consistently low in CO2 emissions per passenger, CO2 emissions per airborne hour, and fuel burn per passenger. It also conducts long-haul operations along the west coast North America, including destinations from Alaska to Mexico. JetBlue enjoys similar CO2 emission rankings for largely due to the fact that it operates only young, fuel efficient Airbus A320 and Embraer 170 narrow-body aircraft (JetBlue 2012).

American Airlines and US Airways are more carbon intensive than the aforementioned airlines, but they are certainly not the worst offenders. They use a variety
of narrow-body and wide-body aircraft to service many domestic and international destinations (AA 2012 and US Airways 2012). Their carbon emission inefficiencies can largely be attributed to their varied fleet characteristics, as their aging fleet is employed in their hub-and-spoke business models that are less fuel efficient than the Southwest model.

Finally, the numbers paint an accurate portrait of the most carbon emission intensive airlines: United Airlines and Delta Airlines. Both have recently undergone blockbuster mergers (Yamanouchi 2010), making Delta and United the number 2 and number 3 airlines respectively in the US in terms of passenger volume (BTS 2010); these mergers have presumably led to route inefficiencies and overlapping as well. Both fly a variety of aircraft from Airbus and Boeing, with a variety of ages to match their diverse fleets. Finally, both airlines offer service to distant international destinations, necessitating the use of older, jet fuel-thirsty, wide body aircraft that increase carbon intensity and carbon emissions due to the sheer number of miles flown (and fuel burned) on these long-haul flights. Surely if they can become more fuel efficient on these necessary routes with no viable substitute, they will save fuel costs and abate carbon emissions.

This paper will now proceed to the culmination of the research. As the variety in carbon emission intensity among the major U.S. carriers show, aircraft fleets and operational characteristics play a significant role in how carbon emission intensity and carbon emissions are allocated. This paper argues, through the presented data, that the primary opportunity and common thread for carbon emission efficiency improvements across all airlines is the modernization of airline fleets. Regulatory policies and instruments have the ability to increase efficiency and decrease carbon intensity by incentivizing innovation and modernization; the challenge is determining the most appropriate policies
and management strategies to do so, given the reality of the regulatory and political environment in the U.S.

**Criterion Development & Policy Analysis**

There are many existing criteria constructed to evaluate policy mechanisms that reduce emissions from other emission-intensive industries. Each regulatory mechanism operates in a unique way to achieve emissions reductions while creating its own positive and negative externalities. Emissions from aviation primarily relate to climate change but also impact the local environment, are also associated with health consequences, and can contribute to radiative forcing through aviation contrails. Given that the aviation industry cannot feasibly switch to non-hydrocarbon based fuels in the short-run, the focus of this criterion will be on policies that can “induce the use of efficient and environmentally friendly technologies” (Dinica 2002) and improve carbon intensity. This is the most realistic approach to appreciably reduce carbon emissions while encouraging growth and innovation in this critical industry for the global economy. This paper will proceed to construct a standard criterion with which to evaluate the pros and cons of three major regulatory policy approaches, from the perspective of the U.S. Federal Government that cannot stand idly by. The following regulatory mechanisms will be evaluated against the constructed criterion:

1. Government Imposed Carbon Taxes
2. Direct “Command and Control” Government Regulations
   - Examples pollution licenses, emissions standards, and outright bans
3. An Emission Trading System with a carbon price
Examples include the Sulfur Dioxide trading scheme and the EU Emissions Trading System (EU ETS)

Methodology: Developing a Standard Criterion

First and foremost, the criterion will aim to assess the economic effects and distributional consequences of a proposed regulatory mechanism. It is important to determine how a set policy might impact the overall market for commercial aviation service from an efficiency standpoint, and how stakeholders like individual firms and consumers might cope with these changes given the stated policy.

Economic effects are not limited to firms and consumers however. Given that the incentivization of innovation and adoption of new aircraft and technology for the airlines represents the most realistic and tangible chance at mitigating carbon emissions and carbon emission intensity, regulatory options will not be considered viable options if they do not provide such instruments, which will be vital in lowering carbon emission intensity across all U.S. airlines. Some examples of these economic instruments are government subsidies, repayable grants, low interest rate loans, and tax allowances for firms.

If a policy includes a permit system for the abatement of emissions, it will be important to determine how the permits will be initially allocated. For example, whether the scheme will involve grandfathered permits or auctioned permits, and whether revenue raised will go directly to industry or go directly to government. This initial allocation is important because it is often times the most controversial part of adoption of an emission trading system. Also included in the analysis of a permit system how a carbon reduction goal will be set and increased over a specific time horizon.
Finally, the political consequences of a policy action must be accounted for as well. While this can be largely an exercise in social science, political consequences are very important in that they will help the government determine which policies are worth the effort to implement, given the reality of the current U.S. political environment. Simplified, the standard criterion is as follows:

1. Economic Effects
   a. Effects on market Efficiency
   b. Distributional consequences of costs
   c. Incentivization for innovation for firms

2. Political consequences
   a. Friction from industry
   b. Political Feasibility to implement a policy

3. Initial allocation of credits (if applicable)
   a. Grandfathered Permits vs. Auction Permits

All of the above criteria will be used to judge the final effectiveness of a policy. The aim is to determine the most applicable policy or mix of policies for incentivizing innovation and efficiency, in order to make a policy recommendation to the federal government based on this analysis.

Discussion

Policy 1: Government Imposed Carbon Taxes

In environmental economics, a carbon tax is a Pigovian tax that is used to correct the market for a negative externality, in this case carbon emissions, “to encourage the producer
to reduce pollution and collect government revenues that may be used to counteract the negative effects of the pollution” (Edlin 2007). The cost of the tax per ton of carbon dioxide emitted is referred to by politicians and economists alike as a carbon price. Carbon taxes are regressive in nature, meaning that they disproportionately affect those with lower incomes (An 2008).

With regards to the criterion and market efficiency, “levying a tax on carbon emissions encourages emitters to reduce emissions to avoid large tax payments” and consumers to change their consumption behavior, while not actually specifying concrete emission level targets (Sands 2012). Distributional effects will be felt by the firms and subsequently the American consumer, with negative economic ripple effects felt across the businesses that are associated with the aviation industry. While the government will gain tax revenue, the increasing the cost of an airline ticket will be passed through to the buyer (noted Pb in Figure 5), while the seller will take a lower price of sale (noted Ps in Figure 5), far below the market equilibrium price (noted Pe in Figure 5).

Figure 5: Effect of a Carbon Tax on Market Equilibrium
Most importantly, a deadweight loss ensues as the carbon tax causes a market inefficiency that is not Pareto optimal. If the federal government were to impose this tax, the revenue would ideally be used as a tax rebate or tax incentive for the airlines to invest in more efficient capital equipment; specifically, airlines could be incentivized to phase out aging, carbon intense aircraft while leasing or purchasing newer, less carbon intensive aircraft.

From a social science perspective, the political consequences of a carbon tax on U.S. airlines are both revealing and confounding. The airlines and their respective labor unions could be vehemently opposed to the tax even with subsidies to purchase new aircraft, as the pass-through cost to consumers would inevitably dampen demand and have ripple effects across the industry, businesses associated with commercial aviation, and municipalities that collect tax revenue from airports, among other stakeholders. American aircraft manufacturer Boeing and its respective unions could see the carbon tax as an economic stimulus for its business, just as they are beginning to deliver its next generation 787 and 747-800 aircraft which are the least carbon intensive aircraft produced by Boeing to date. Of course in the toxic political environment currently enveloping American politics, “this redistribution of funding would be determined by the government and not the market” (Sands 2012), potentially leaving the carbon tax option open to a contentious and vitriolic fight in the U.S. congress.

**Policy 2: Direct “Command and Control” Government Regulations**

Command and control government regulations are a contentious, though in many circumstances effective, method of reigning in emissions. The Clean Air Act (CAA) as enforced by the U.S. Environmental Protection Agency (EPA) uses command and control
regulations to mandate that industrial polluters limit and maintain certain levels of pollutants. These regulations often place significant financial burdens on the firms involved but are in widespread use in the United States for other industries (Wright 2008). Examples of command and control regulations include emissions standards and outright bans of certain pollutants, though they are unlikely to apply to the commercial aviation industry.

Aircraft engine manufacturers are already aiming to create the most efficient, least polluting products possible, generation after generation. Physical pollution control devices for aircraft engines are not used throughout the aviation industry; the costs of these devices are so astronomical that they only exist in the laboratory. Additional research and development of these devices would certainly be useful, but may not yield dividends for many decades.

**Policy 3: An Emission Trading System (ETS)**

“A cap-and-trade system, on the other hand, does not set a government defined price for carbon emissions, but rather a defined carbon reduction goal for the economy as a whole” (Sands 2012); in this case, it would be the federal government setting a defined carbon reduction goal for the commercial aviation sector. As the government issues permits to firms for the right to emit carbon dioxide in a certain quantity, through either an auction or a grandfathering system, the less carbon intense airlines will be able to sell their excess permits to airlines that are more carbon intense. Through this system, upon setting the rules for the marketplace, the government no longer has a role and firms engage in permit trading independent of the government. If a more carbon intense airline can innovate and modernize their fleet through investment, causing the fleet to emit lower than
the allocated emission permits, that airline can of course sell their excess permits in the marketplace.

With regards to the criterion, negative economic and distributional effects on the aviation sector and associated industries can be limited if a cap-and-trade system is implemented gradually. Conversely, the effectiveness of an ETS depends on how aggressive the reduction target is. The important aspect to consider is how permits are allocated to firms in the first place, be it through an auction or through the grandfathering of emissions allowances up to a certain amount. Airlines are likely to oppose the auction system for permits given the costs that would result for having to purchase permits for every amount of carbon dioxide emitted. Under a system of grandfathering, firms “have to purchase any additional [credits] they may need to meet their assigned emission standard” instead of buying credits “to cover all uncontrolled emissions” (Tietenberg 2005).

Politically speaking, this approach is likely to be more palatable to lawmakers and industry leaders alike in that it is a private sector, market-based approach to controlling carbon emissions from commercial aviation. Certainly this approach alone does not foster the quickest investment and innovation into newer aircraft and emissions reduction research and development, but it moves the industry in the right direction without harming economic growth and industry viability. This policy has the ability to gain acceptance easier than a government-imposed carbon tax as well because it has the benefit of not being the first cap-and-trade system in the U.S. (By 1992). Assuming that some policy must be adopted, this policy also has the advantage of being analogous to other emissions trading programs in the U.S., as grandfathering is the method used to allocate permits in many of those programs.
**Discussion**

In examining the command and control regulations like a carbon tax versus market-based policy options like an emissions trading system, it is clear that neither is perfect and should not be implemented as a standalone program by itself. From the standpoint of promoting innovation, perhaps the most important characteristic of a regulatory policy for the aviation industry, the carbon tax is the best option. It provides a concrete revenue stream with which the government can rapidly support investments in new aircraft as well as critical research and development for future carbon-mitigating aircraft technologies. Older aircraft in the U.S. fleet are raising the carbon emission intensity unnecessarily when options for newer efficient aircraft exit. Yet the carbon tax is a politically objectionable policy that would be unlikely to pass both houses of congress. Moreover, it provides for a significant deadweight loss in the marketplace that is not Pareto optimal, and thus is not maximizing social welfare.

An emissions trading system does provide for a reduction in carbon intensity and thus carbon emissions, but as it would have to be a very gradual emissions reduction target for political and economic considerations, emissions would not be reduced quickly nor would the ETS go nearly as far in supporting rapid modernization and retirement of older aircraft. Again, it is a market-based policy instrument that requires minimal government intervention in the private sector, and is a much more politically expedient manner in which to go about carbon emission mitigation in the sector. From an economic efficiency standpoint, if implemented correctly with grandfathering of emissions credits and the targeted reduction is a gradual goal, the policy stands a better chance of being accepted by the industry.
Final Policy Recommendation for U.S. Federal Government

As a final policy recommendation to the U.S. federal government using the standard criterion developed at the outset of the policy analysis, this paper recommends the implementation of an emissions trading system that uses a very gradual emissions reduction target. The ETS should be combined with considerable economic safeguards and additional incentives for innovation. Without economic safeguards, as foreign carriers would not be subject to an American ETS, U.S. carriers are put at a competitive disadvantage when they have to incur the expense of additional emissions credits. Thus, this paper proposes that any foreign carrier that operating within U.S. airspace must also incur a similar fee, paid to the federal government, which will keep them on equal financial footing with U.S. carriers.

This fee provides a unique opportunity for the government to raise revenue from non-U.S. firms and use it towards supporting the aviation industry’s carbon intensity reduction efforts, in order to provide some of the same innovation benefits that would have been offered under a carbon tax. For example, this new revenue stream can be used to fund low interest government loans, loan guarantees, tax rebates for new aircraft purchases, and grants for carbon emission reduction research and development. The European Union Emissions Trading System also mandates that foreign carriers contribute to offset their emissions when they operate in or out of Europe, and this would put the U.S. on equal trade footing with the EU.

Moreover, with both the Eurozone and the American market mandating these additional expenses derived from carbon emissions, the opportunity exists for a regulatory domino effect to spread across the major aviation markets; it is conceivable that continent-
wide blocs of emissions trading systems would emerge over time. The end goal should be for all carriers worldwide to abate carbon emissions through a unified system, as carbon emissions and climate change are global problems whose effects are not separated by manmade geopolitical boundaries. This domino effect would put all carriers on a path towards innovation and carbon emissions abatement.

**Management Strategies and Technological Innovation**

In addition to the aforementioned final policy recommendation, it is important for the federal government and the aviation industry to stay abreast of technological changes and management strategies that are being deployed in the near future across the industry. These innovations will yield synergistic effects with the proposed regulatory policy changes, resulting in significant fuel savings and reductions in carbon emissions from the aviation industry.

**NextGen and TBO Traffic Management**

The Federal Aviation Administration (FAA) is in the process of upgrading its air traffic management system from a structure based on radar and controller issued clearances, to one based on GPS technology called NextGen. The FAA says that “trajectory-based operations (TBO) will replace clearance-based operations in many parts of the airspace” while “new automated separation assurance functions are intended to help overcome the [manual controller limitations], maintaining safe separation between aircraft” (NASA 2009). Currently, aircraft are routed in a superhighway-like system in the sky, where they maintain greater than necessary separation as radar readings are not nearly as accurate as a GPS-based system. TBO will allow for aircraft to fly more direct,
efficient routes, as the aircraft themselves broadcast digital location data in real time, thus increasing air safety, saving fuel and fuel costs, and reducing carbon emissions drastically by shortening routes and reducing spacing.

Aircraft will need to be equipped with newer avionics in order to integrate into this new system, as well as the new EU system termed Single European Sky (SES). SES will replace a patchwork of a national air traffic systems across Europe and offer similar gains in operational efficiency (E.U. 2010). These infrastructure improvements are costing the U.S. and E.U. significantly in the short-run and will cost carriers significantly as they work to modernize their fleets, but will pay dividends in the long run as efficiency gains are realized and fuel savings improve carriers’ operational solvency.

**Improved Aircraft and Aircraft Technology**

Each generation of commercial aircraft has shown significant gains in fuel efficiency and carbon emissions than the previous generation. This has been achieved largely through engine improvements, airframe adjustments and redesigns, and to a smaller extent, weight reductions from new materials. The industry is now on the cusp of adopting the most fuel efficient planes ever, starting with the wide-body Boeing 787 Dreamliner. Boeing says that the 787 incorporates “advanced materials, systems and engines to provide unprecedented performance levels, including a 20 percent improvement in fuel performance on a per-passenger basis” (Boeing Corp. 2007). The first 787 aircraft was finally delivered after years of delays to launch customer All Nippon Airways of Japan in 2012, and it has begun operating international routes in East Asia.

The Airbus A380 Superjumbo is a wide-body, double decker aircraft and is the largest commercial aircraft ever built. It was delivered to launch customer Singapore
Airlines in 2007 (Singapore Airlines 2007) and is now operated by multiple international airlines every day. While the A380 burns more jet fuel volume per voyage than any other commercial aircraft, when its carbon emissions are split amongst the nearly 600 to 850 passengers (Emirates 2007) depending on aircraft configuration, it is one of the least carbon intensive aircraft ever built, making for great fuel economics. Similarly, Boeing also launched the Boeing 747-800 this year to launch customer Lufthansa which is 20% more fuel efficient than its most recent 747 (Caswell 2011), and will compete directly with the A380 on similar medium-range international routes.

For shorter routes with less passenger demand than one that would be served by an A380, Airbus is also developing the A320neo signifying a “new engine option,” which is basically a retrofit of its current A320 aircraft with new engines and some aerodynamic airframe modifications (Airbus 2012). While it is yet to be delivered to a customer, it is set up to compete directly with Boeing’s new 737-MAX aircraft, which is just an efficiency retrofit of one of Boeing’s most successful aircraft of all time, the 737 (Boeing 2012). Older variants of these aircraft are already operated worldwide by nearly every major carrier, and as they take delivery of these newer variants, fuels savings and emissions reductions will ensue.

The important fact to note is that this generation of aircraft already exists and is being delivered or will be in production in the near future. These aircraft are not cheap investments, and airlines typically budget aircraft assets to operate for nearly 20 years. If they are to increase turnover to newer aircraft in a shorter time frame, it is clear that government incentivization through the means previously described will be needed for airlines to buy more efficient aircraft sooner. These new aircraft will drastically reduce the
amount of carbon emitted into the atmosphere, and help to compensate for emissions growth the air transport sector is set to undergo. The modernization of U.S. aircraft fleets will further serve to provide an economic boost for the manufacturing sector, improve safety for passengers, and guarantee that aircraft will be equipped to handle future traffic management strategies.

**Single Engine Idling**

Pertaining to carbon emissions but also to local air quality around airports, air carriers have begun the directing aircraft to engage in single-engine idling when ground conditions require static holding of aircraft on the tarmac. This measure reduces ground-level pollution and negative health externalities associated with this pollution for individuals living and working near airports. This fleet management strategy was not previously in use by airlines given lower fuel prices and the time it takes to restart a jet engine, but changing economic conditions, increased congestion, and growing environmental concerns around major airports have resulted in this change (Daniels 1990). Thus, in the event of bad weather or traffic congestion, this measure reduces carbon emissions and ground-level pollution while reducing fuel costs to the airlines.

**Conclusion**

There is no question that the United States and the global community must work to appreciably reduce carbon emissions from the aviation industry, even in the face of sector growth. For U.S. policymakers and industry leaders to successfully reduce carbon intensity and carbon emissions across the U.S. aviation sector, a system-wide effort of improvements and significant changes in regulatory policy are required to drive change. Much resistance
will be driven by many stakeholders in the process, but the U.S. policymakers cannot afford to sit idly by and allow the industry to keep operating in the hydrocarbon-intensive way that it is, given the serious threat posed by global climate change. As explained by this paper, there is no single silver bullet as long as hydrocarbon-based fuel is the energy source moving aircraft, people and goods around the world. There are, however, realistic prospects of maintaining a steady carbon footprint even as demand continues to grow across the world. This would be accomplished through a combination of the aforementioned emissions trading system, economic safeguards against foreign carriers, economic drivers of innovation, and system-wide improvements in traffic management and fleet modernization.

**Further Research**

This paper has attempted to give policymakers a unique insight into the airlines they regulate through a carbon intensity analysis, and a regulatory policy analysis for an economically complex and volatile industry. To improve upon the results presented in the analysis, future research could yield a clearer picture of where commercial aviation is headed. As such, a more multifaceted econometric analysis of the airlines and the regulatory policies could be conducted, but only with the proper recent data from the International Air Transport Association (IATA). Additionally, moving forward in the era of global climate change, it would be important to continue tracking emission intensity across the U.S. aviation sector and the global aviation sector to determine trends and drivers in efficiency.
References


