# Green Skies: Effects of Environmental Taxation on the U.S. Domestic Airline Industry

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# Green Skies

## Effects of Environmental Taxation on the U.S. Domestic Airline Industry

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# Abstract

Can an emissions tax reduce the carbon footprint of U.S. domestic air travel without hurting the vitality of the industry? This empirical analysis models the U.S. domestic airline industry using a structural equations system and simulates the effects of a hypothetical carbon emissions tax on the market for U.S. air travel. The price elasticity of demand for air travel in the long-haul U.S. domestic passenger market substantiates that a low level environmental policy would not cause unmanageable harm to the airlines or consumers. This thesis is a practical, quantitative analysis of the feasibility of an environmental policy for U.S. aviation.

# Contents

# 1 Introduction

> *"Global warming is no longer a distant threat; it's as real, as clear and present an issue, with profound effects on people's lives, as war and peace or recession and poverty--and the effects are only just beginning to be felt."*
> *– Al Gore (1993)*

This undergraduate thesis is motivated by the current political, economic, and social emphasis on the environmental movement. Successful environmental policy must respect the current state of both the U.S. and other economies. As the financial crisis challenges the status quo of economic policies and regulations, now is the time to put forward new creative policies that promote efficient technology and address environmental concerns.

Global warming is a very real concern of both current and future generations. According to a 2008 Emissions of Greenhouse Gases Report by the U.S. Energy Information Administration, nearly 83% of greenhouse gas emissions is from carbon dioxide. Approximately one-third of global carbon dioxide emissions is attributed to the transportation industry, of which almost 15% is from domestic air travel.

This paper is an empirical analysis of the effect of a carbon emissions tax on the U.S. domestic airline industry. It is neither a policy recommendation nor a cost-benefit analysis. This analysis uses a simultaneous equations model of the U.S. domestic air travel market to simulate a hypothetical carbon emissions tax and empirically judge the effects on the industry through the price elasticity of airline fares with respect to alternative emissions taxes (modeled through increases in fuel prices) and consumers' responses via their demand elasticity. While environmental concern for air travel's contributions to global warming is important, the airline industry is crucial to the U.S. economy and has been struggling in recent years. In a framework of balancing environmental concerns with industry profits, this paper will use an empirical analysis to answer the following question: *Can an emissions tax reduce the carbon footprint of air travel without hurting the vitality of the industry?*

After further exploring the airline industry from both an environmental and economic perspective, this paper will provide a background on environmental policy theory and review relevant economic literature on both environmental policies used in other countries and current U.S. airline taxation. This paper will then explain the method used to model the U.S. domestic airline industry and simulate a carbon emissions tax manifested through an increased price of fuel. This analysis will conclude with a discussion of the results and findings, providing evidence through both the fare elasticity with respect to fuel price and the price elasticity of demand that a carbon tax would not excessively harm the U.S. domestic long-haul air travel industry.

# 2 Background

> *"The key is indeed balance – balance between contemplation and action, individual concerns and commitment to the community, love for the natural world and love for our wondrous civilization."*
>
> *– Al Gore (1993)*

This background of the U.S. domestic airline industry provides further reasons for the importance of an environmental policy and discusses the significance of the industry in the U.S. economy. It highlights the arguments for imposing an environmental tax on U.S. domestic air travel while taking into account the balance of environmental and economic concerns.

## 2.1 Environmental Perspective on the U.S. Domestic Airline Industry

> *"Thank God men cannot fly, and lay waste the sky as well as the earth."*
>
> *– Henry David Thoreau*

A report from the Intergovernmental Panel on Climate Change (IPCC) speculates on the environmental impact of the worldwide airline industry and projects about its future growth. The report finds that between 1990 and 2050, air travel traffic will increase an average of 3-5% per year. In 1992, aircraft emissions were 2% of total global carbon dioxide emissions. Through various prediction methods, the report forecasts scenarios that emissions will increase anywhere from 1.6 to 10 times the 1992 amount by 2050. Among other factors, the forecasting methods account for the increase in air travel and the decrease in emissions from other pollution sources, like automobiles, with more aggressive environmental initiatives (IPCC 1999).

The aviation industry is divided into cargo and passengers services. Passenger travel is more impactful in terms of flight frequencies and industry revenue. The July 2008 Information Paper by the International Civil Aviation Organization (ICAO) shows that of the top ten countries in air travel, only 11% of aviation fuel was consumed for cargo services. The survey is categorized by cargo services, international passenger services, and domestic passenger services. The United States is the top fuel consuming country in all three categories. The 89% of global aviation fuel consumed by passenger air travel is essentially split between international and domestic air travel. 67% of global aviation fuel used for domestic air travel is consumed by flights within the United States. The next largest fuel consumer for domestic air travel is China, a distant second with only 10% (ICAO 2008). This draws attention to the environmental dilemma that the industrialized countries are responsible for the climate change problems that the entire world is currently facing (Rothengatter 2010).

U.S. domestic air travel consumes a substantial amount of fuel for a single market. The size of this market alone may be strong evidence for the successful impact that an environmental policy applied to these flights could have in terms of reducing global carbon emissions. The U.S. domestic airline market also has the unique advantage of being both a significant portion of global aviation fuel consumption and within one nation. National environmental policies have an advantage over international ones, since they do not have issues of coordination among governments and international legal bodies. Political feasibility is one of the most important aspects of successful environmental policies (Goulder and Parry 2007). While this paper focuses on the economic, not political, aspects of an environmental policy, this is further evidence for the potential success of such a policy. An environmental policy in this market has great potential for a realistic and impactful outcome in reducing carbon emissions.

## 2.2 Economic Perspective on the U.S. Domestic Airline Industry

> *"Civil aviation has become a vital component of today's lifestyle and of modern economic life. Just as Thomas Friedman asserts that cheap and ubiquitous telecommunications have lowered impediments to international competition and innovation, the airline industry has shattered barriers of distance that once limited many global economic transactions."*
>
> *– Federal Aviation Administration (2009)*

Airlines are a unique topic because they are central not only to the American economy, but also to the very essence and evolution of American culture and way of life. The United States has been historically defined by transportation. Through the introduction of railroads, the American population and industry spread westward to new frontiers. The popularity and prevalence of cars, first made affordable by Ford's Model T, defined the private lifestyle of American families. The commuting culture reshaped the country into cities and suburbs, defining the professional and domestic spheres that Americans value today. In WWII, the military fighter planes and bombers became a central part of the American mindset. In the 1990's, internet-based companies like Amazon.com and eBay rose to a profitable existence through a business model revolved around the cargo airline industry. Pinnacle moments in American history, like the tragedy of September 11$^{th}$, have revolved around this industry (Brands 2010).

Throughout its existence, air travel has evolved from a luxurious phenomenon to a common mode of transportation. In the current decade, airlines are essential to economic globalization, as seen by the IPCC's projected air travel traffic growth of 3-5% each year from 1990 to 2050. Air travel is becoming an increasingly necessary good as businesses and families rely on the ease of travel to stay connected, both within the United States and internationally. The 2010 Annual Report of the Air Transport Association (ATA) stated that in the previous year, the commercial airline industry contributed 5.2% to U.S. GDP and 10.9 million jobs to the U.S. economy. On top of this direct impact, the airline industry indirectly facilitates the success of many other industries that rely on its cargo and passenger services. For instance, the tourism industry relies heavily on air travel. The ATA report noted an increasing reliance of the business sector on air travel, especially consulting and technology firms. While the airline industry has a negative environmental impact, the crucial importance of aviation in the U.S. economy forces economists and policymakers to act with caution when considering taxing the industry.

The airline industry is unmatched in the U.S. economy. The industry is particularly vulnerable to shocks, for instance from natural disasters like volcano eruptions or security threats like September 11th. The industry is also sensitive to business cycles, as evidenced by the recent multitude of airline mergers.[1] Air travel is a relatively undifferentiated, highly perishable product. Airlines face an extremely high cost of capital. The industry is one of the most unionized in the U.S., resulting in a large percentage of airline revenue spent on wages and employee benefits. These uncommon features of the industry provide evidence that airlines are not easily profitable (O'Connor 2002).

# 3 Literature Review

The following literature provides a background on the economic theory of environmental policy. The two most effective policies are discussed in detail– emissions taxation and emissions allowance permits. Both policies manifest themselves in the industry by way of a higher fuel price, an equivalency that is importantly highlighted and will be central to the quantitative analysis later in this thesis. While this empirical analysis focuses on an emissions tax, it can be applied to a policy of tradable emissions permits. Much literature has been written about tradable permits with respect to the airline industry since the European Commission's mandate adding airlines to the European Union Emissions Trading Scheme in 2012. The context of this impending regulation on European aviation

[1] Recent U.S. Airline Mergers: U.S. Air and America West, 2005; Northwest and Delta, 2008; Southwest acquisition of AirTran, 2010; Continental and United, 2010 (Bureau of Transportation Statistics).

provides strong evidence for the immediate importance of reviewing potential environmental aviation policies in the U.S. This literature review also covers the current taxation on the U.S. airline industry and articles that will help predict the effect of an emissions tax on the U.S. domestic airline industry.

## 3.1 Economic Theory on Environmental Policy

> *"Nature provides a free lunch, but only if we control our appetites."*
> *– William Ruckelshaus*

There is a plethora of literature written about environmental policies and the debate among them. The environment is a public good. Everyone enjoys the benefits of the earth's resources, but no one actually owns them and no one can be excluded from their use. This leads to what is known as "the free-rider problem," where people use more than their share of the common resource since there is no limit on usage. Pollution is a negative externality– the marginal and total social costs of society are greater than the marginal and total private costs of the polluter. A polluting firm enjoys the benefits of production, but does not incur the cost of its own pollution. Environmental policies aim to internalize the cost of polluting for the polluter.

A performance-based command and control policy is an environmental policy where the government sets a limit on emissions or a technology standard for each producer. However, this provides no incentive for the producer to reduce emissions any further than the standard. Furthermore, the government does not usually have enough information about firms' abatement costs to set the right limit on emissions or technology standard. Since firms usually have varying abatement costs, this inefficient policy forces some firms to pay more than others to meet the set standard. A more efficient solution would require the polluter with a lower marginal abatement cost (presumably due to newer technology) to reduce emissions more than a polluter with a higher marginal abatement cost; this way both firms pay the same marginal abatement cost for reducing emissions.

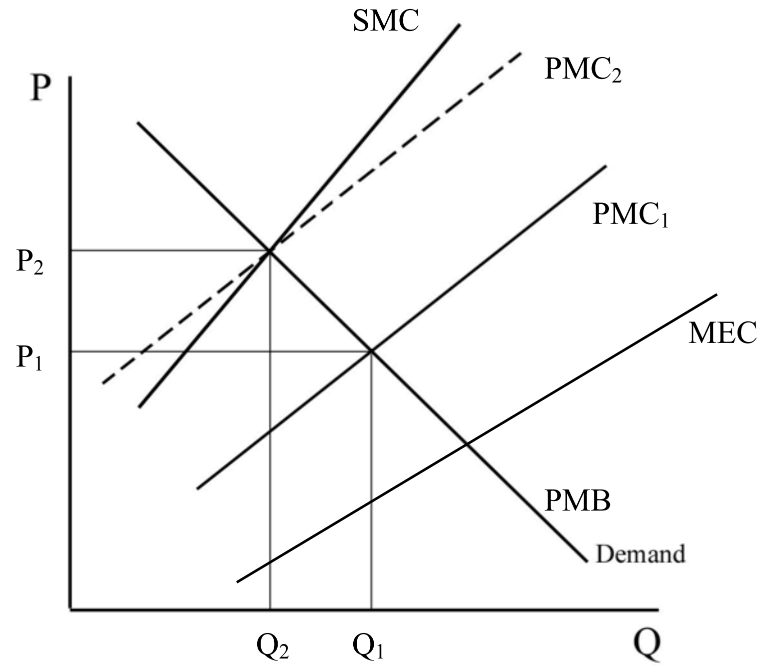
Incentive based policies encourage polluters to continually reduce their emissions through various methods. Two main incentive-based policies are an emissions tax[2] and tradable emissions permits (also known as tradable emissions allowances or cap-and-trade). Both tax and tradable permit policies place a price on pollution, internalizing the cost of the externality into a private cost for the polluter (See Diagram 2 on p.11). The polluter has an incentive to reduce its emissions so it can either avoid paying taxes or gain revenue by selling unused tradable emissions allowance permits.

Goulder and Parry (2007) offer insight on the choice between policies. Economists judge policies by two main criteria: economic efficiency and cost-effectiveness. Other important criteria include minimizing risks in the presence of uncertainty, distribution of benefits or costs across various groups (income, regions, generations, etc.), and political feasibility. Goulder and Parry conclude that there are many pros and cons to each policy. While no single instrument is clearly superior, incentive-based policies are superior to traditional command-and-control policies.

Both an emissions tax and a permit policy are cost effective, meaning they equate marginal abatement costs across firms at equilibrium. Under an emissions tax, the producer minimizes its production cost by choosing the cheaper of two options– pay the marginal abatement cost of reducing emissions or pay the tax on emissions. Each producer has an incentive to continually improve its technology and reduce emissions to avoid the tax. The government sets the tax level, and the market will naturally determine the level of pollution by minimizing total abatement cost (See Diagram 1 on p.10). However, due to unknown abatement costs, the government cannot predict with perfect accuracy what level of emissions a certain tax level will yield as a whole.

[2] A third incentive-based policy is an emissions subsidy. Through a subsidy, the government provides a positive incentive for producers not to pollute rather than penalizing the pollution through a tax. Both the tax and subsidy have the same outcome; however, a subsidy is seen as allowing pollution whereas a tax is condoning it. Therefore, a tax is much more politically favorable and socially acceptable. The famous Coase theorem states that as long as property rights over environmental assets are clearly defined, the efficient level of emissions will result no matter who is initially given the property rights (Coase 1960). An emissions tax assumes that property rights to environmental benefits, for example clean air, belong to society.

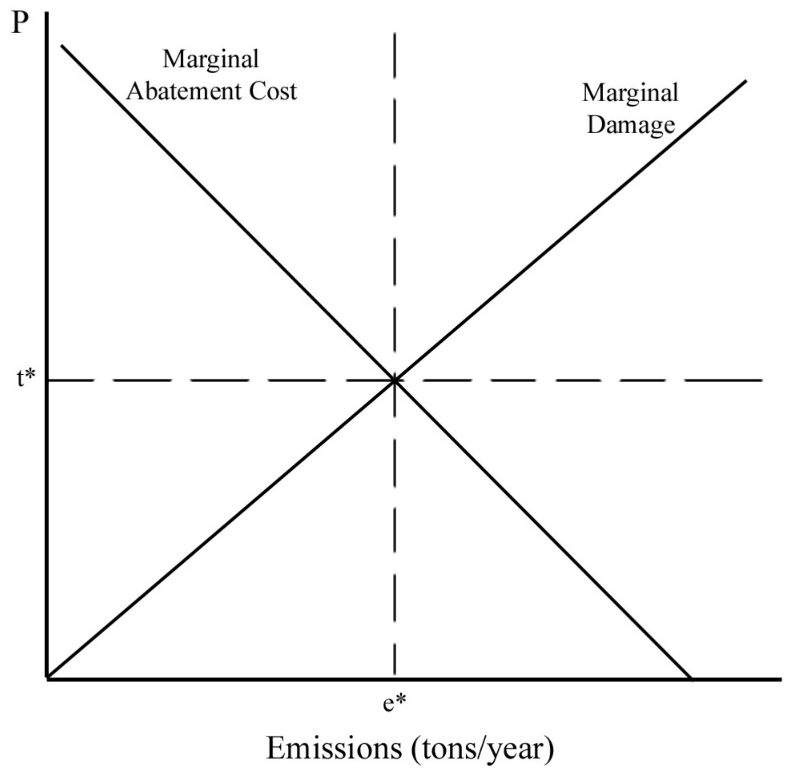
**Diagram 1:** Environmental Tax




PMB = Private Marginal Benefit
PMC = Private Marginal Cost
SMC = Social Marginal Cost = PMC + MEC
MEC = Marginal External Cost

An environmental tax would raise the price from $P_1$ to $P_2$, increasing the $PMC_1$ (supply) curve to the point where private marginal cost equals social marginal cost, decreasing the quantity of production from $Q_1$ to $Q_2$.

**Diagram 2:** Cost Effective Environmental Policies:
Emissions Tax and Tradable Permit Policy




A cost-effective environmental policy sets the marginal abatement cost equal to the marginal damage at the equilibrium point (e*,t*). An emissions tax sets the price at the level t* and the market naturally brings the emissions level to e*. A tradable permit policy sets the cap of emissions at e* and the market naturally allocates the permits among the firms in a cost efficient manner, bringing the price of emissions to t*. A tax uses a price-setting mechanism; a tradable permit policy uses a quantity-setting mechanism. The outcome in terms of price and quantity of emissions is equivalent.

Under a tax policy, the government sets the price level of emissions and the market determines the quantity level. In contrast, the government sets the quantity level of emissions with a tradable permit policy, and the market determines the most efficient price (See Diagram 2 on previous page). The government decides the aggregate level of emissions of the industry as a whole and allocates the corresponding amount of emissions allowance permits. Each specific producer limits its own pollution based on its quantity of permits. A polluter that can reduce its emissions more efficiently will sell its unused permits to a polluter with older technology and a higher marginal abatement cost. The market will naturally reallocate the permits in the most cost-effective manner. However, there is no limit on the price of the permits; if the quantity level is set too high or too low the permits could become, respectively, very cheap and ineffective or too expensive and hurt the industry.

The initial allocation of permits is another debate under this policy. The government can give these permits to already existing producers in the industry free of charge, known as grandfathering. The government can also initially allocate the permits by auctioning them off, or use a combination of grandfathering and auctioning. While the firms in the industry naturally prefer grandfathering, auctioning the permits allows the government to gain revenue comparable to the tax policy. Auctioning the permits makes this policy economically equal to the emissions tax.

Kaplow (2010) further demonstrates the equivalence and effectiveness of an emissions tax and a tradable permit policy. The central idea of a tax that corrects a negative externality, also known as a Pigouvian tax, is that the tax sets the expected marginal benefits of damage reduction equal to the marginal costs of reducing pollution. A permit scheme should also follow this principle (See Diagram 2 on previous page). At any moment in time, the tax rate should equal the most accurate estimate of the expected marginal harm from emissions. Expected marginal damage rises nonlinearly, so a corresponding nonlinear tax or a quantity-adjusted permit scheme that leads to an equivalent price is the second best option. Both policies provide revenue for the government, transfer the cost of pollution to the producer (thereby internalizing the negative externality), provide incentives for continual emissions reduction, and reduce pollution in a cost-effective manner through a market.

Fullerton (2001) confirms that both a tax on pollution and tradable permits with an initial auction will increase the price of the good by the same amount. Fullerton discusses the policy effects with respect to elasticity. If a good is completely inelastic, the producer can pass the entire burden of the tax onto the consumer in the form of an increased price. The consumer will buy the good at any price. However, in reality goods are not completely inelastic, so an increased price will reduce demand of the good. Therefore, the producer will bear some of the burden of the tax in the form of lower demand. The burden of the tax, or economic incidence, is usually shared between the producer and consumer, though how much falls on each side depends on the elasticity of the specific good.

This is a concept that this paper will explore going forward. Asking how much an environmental tax will affect the airline industry is essentially asking how elastic air travel is. While this paper is based on a carbon emissions tax on air travel, the empirical simulation of the tax quantifies the effect of an increased ticket price due to higher fuel prices on the demand for U.S. domestic air travel. Therefore, the analysis could be applied to various environmental policies that result in an increased ticket price, including both an emissions tax and a tradable permit system.

## 3.2 Environmental Policy in Europe

> *"The evidence shows that ignoring climate change will eventually damage economic growth. Our actions over the coming few decades could create risks of major disruption to economic and social activity, later in this century and in the next, on a scale similar to those associated with the great wars and the economic depression of the first half of the 20th century. And it will be difficult or impossible to reverse these changes. Tackling climate change is the pro-growth strategy for the longer term, and it can be done in a way that does not cap the aspirations for growth of rich or poor countries. The earlier effective action is taken, the less costly it will be."*
>
> *– U.K. Executive Summary, The Stern Review (2006)*

In October of 2006, British economist Lord Nicholas Stern released a 700-page report to the British government. *The Stern Review on the Economics of Climate Change* presents one main point– "The scientific evidence is now overwhelming: climate change presents very serious global risks, and it demands an urgent global response." Stern describes climate change as the greatest and widest-ranging market failure ever seen, presenting an unprecedented difficulty for economists and an imperative need for international cooperation and collective action. His evidence makes clear that the benefits of strong, early action on climate change greatly outweigh the costs. Stern's review of the science and economics of climate change has further catapulted many environmental policy discussions in both the U.K. and around the world.

Aviation is an important industry for the future of environmental policy. Many countries are not questioning whether or not to have environmental aviation policies, but rather debating the level and type of policy. Currently, the European Union is operating the largest international trading scheme for greenhouse gas emission allowances. The EU Emissions Trading System (EU-ETS) is a cap and trade system that operates in 30 countries– the 27 EU member countries plus Iceland, Liechtenstein, and Norway. It covers carbon dioxide emissions from installations (power plants, factories, etc.) and certain nitrous oxide emissions. The EU has declared that in 2012 airlines will join the scheme. From 2012 onwards, all aircraft operators of commercial flights landing and departing from any airport in the EU must surrender allowances for their emissions.

Despite arguments that this mandate opposes international law, especially the Chicago Convention on Civil Aviation, the Commission of the European Commodities (2006) believes that the mandate conforms to international law and the inclusion of non-EU carriers is necessary to prevent competitive distortions in the international air transport market. The EU-ETS has set the 2012 quantity of emissions at 97% of the aircraft operator's historical aviation emissions (the average emissions reported for the years 2004-2006). 85% of the initial permits will be allocated free of charge. In the first year, additional allowance permits can be bought from within the aviation sector, but after that additional permits can be bought from other sectors or from the project based Kyoto Instruments "Joint Implementation" and "Clean Development Mechanism" (see European Commission Climate Action; Scheelhaase, Grimme, and Schaefer 2010).

Scheelhaase, Grimme, and Schaefer (2010) compare the predicted effects of the addition of airlines to the EU-ETS on an EU airline and a non-EU airline, using Lufthansa and Continental Airlines as their case study. The analysis concludes that the EU airline, Lufthansa, suffers a higher price than the non-EU Continental Airlines. More of Lufthansa's flights (both domestic and international within Europe) are subject to the EU-ETS; Continental, in contrast, only must conform to the allowance scheme for its international flights in Europe, not its short and long haul domestic flights. Even including non-EU aircraft operators into the trading scheme does not eliminate the competitive advantages that these airlines will gain over EU airlines from the inclusion of aviation in the EU-ETS.

Toru (2011) analyzes the effect that the 2012 inclusion of airlines in the EU-ETS will have on air traffic within the European Union. Toru notes that historically, increases in fuel prices have put downward pressure on the profitability of airlines due to increased ticket prices decreasing demand. Toru uses a very similar method to this analysis, creating a structural econometric model with a demand function and a pricing equation that represents the oligopolistic firms pricing strategy with respect to their given cost structures. After deriving the market equilibrium, Toru simulates potential scenarios of the cap-and-trade policy by raising the price of fuel. The estimations for the market price of the permits range from €10 to €60 per tons, resulting in a 5% to 31% fare increase. From the increase in the effective price of fuel, Toru concludes the following: airfares increase, air travel demand becomes more price sensitive, and air traffic declines.

## 3.3 U.S. Airline Taxation

*"We must adjust to changing times and still hold to unchanging principles."*
*– Jimmy Carter*

The Massachusetts Institute of Technology has established the Global Airline Industry Program consisting of faculty, staff, and graduate students from the MIT Schools of Engineering, Management, and Humanities and Social Sciences. The goal of the program is to better understand the global airline industry and educate its future leaders. The program identifies the airline industry as one of the most diverse, dynamic, and perplexing industries in the world. The existence of the project shows the increasing concern and focus on airline taxation.

One research project under the larger program is the Airline Ticket Tax Project– the only broad-based analysis of U.S. taxes and fees added directly to airfares that uses a representative sample of actual tickets. This project has provided many useful publications on U.S. airline taxation. The summary results of the project portray general trends of ticket taxation from 1993 to 2009. The analysis only covers taxes and fees collected by the federal government and passenger facility charges collected by airports, not fees charged by airlines such as a baggage fee. While the dollar value of total taxes and fees has stayed relatively constant in real terms, the effective tax rate has increased from 11% in 1992 to 16% in 2005. The main reason for the effective tax rate increase is the significant reduction in base fare, which decreased 34% from 1993 to 2005. In 2009, the effective tax rate was 16.7%.

There are currently four types of taxes and fees[3] levied on U.S. domestic airline tickets: the federal ticket tax, the federal flight segment tax, the passenger facility charge (PFC), and the federal security.[4]

**Table 1: Current Rates and Levels of U.S. Domestic Airline Ticket Taxes and Fees[5]**

| Tax or Fee | Rate | Use |
|---|---|---|
| Federal Ticket Tax | 7.5% of base fare | Fund Federal Aviation Administration (FAA) operations and the Airport Improvement Program |
| Federal Segment Tax | $3.70 per segment | Fund Federal Aviation Administration (FAA) operations and the Airport Improvement Program |
| Passenger Facility Charge | $4.50 | Specific airport improvement projects |
| Federal Security Service Fee | $2.50 | Passenger and baggage screening |

Button (2005) offers additional insight on current taxation in the U.S. airline industry. His interesting contribution is his insistence that though airline travel is no longer a luxury good, it is still taxed like one. According to Button's research, over 40% of today's airline trips are taken to visit friends and relatives and over 25% occur on low-cost carriers. Button does note that taxation on airlines is administratively convenient and politically expedient; however, he argues that taxes in this industry are not passed on in the short term, but are absorbed by the airlines in the form of weakened financial results.

Button (2005) summarizes the Ramsey principle of taxation, an economic theory on minimizing the excess burden of indirect taxation, i.e. the taxation of goods and services. This principle states that items should be taxed according to their elasticity of demand– highly elastic goods should be taxed less than goods with a lower elasticity. The definition of efficient taxation is a policy that minimizes distortion of the relative levels

[3] A pure tax is a levy made by public authority for which nothing is received directly in return. A fee, or benefit tax, implies that infrastructure and services are provided in return. Most airline ticket taxes are technically this second category, but the terms are often used interchangeably since in practice this theoretical distinction is not always clear (Karlsson 2006).

[4] Rates as of January 1, 2010. The PFC and security tax are collected each time a passenger boards an airplane, with a limit of no more than two collections made for each direction of travel. There is no such limit for the segment tax (MIT Airline Ticket Tax Project 2010).

[5] Table based on the MIT Airline Ticket Tax Project (2010).

of consumption of different goods. Though taxation in this manner would reduce the distortion by minimally changing consumption patterns, it tends to be regressive.[6] Necessary goods, for example food, tend to be less elastic, and therefore low-income households that buy only necessary items have a large effective tax rate. Button asserts that the demand for air travel is sensitive to price levels in the aggregate, or rather is elastic.

Button (2005), however, is not discussing an environmental tax, which is a form of corrective taxation. A tax to correct the negative externality of pollution would fall under the economic theory of Pigouvian taxation rather than the Ramsey principle. The Pigouvian theory states that the market will move to its efficient equilibrium when a tax equates the marginal cost of production and abatement to the polluter with the social marginal cost to society.[7] Button's analysis of the administrative convenience and political feasibility of airline taxation is helpful evidence that an emissions tax is an appropriate environmental policy for the airline industry.

## 3.4 Effects of an Emissions Tax on the U.S. Airline Industry

### *Tax Incidence*

As part of the MIT Airline Ticket Tax Project, Karlsson (2006) conducted an empirical analysis of the incidence of U.S. airline ticket taxes. Even before the negative shock in demand due to the tragedy of September 11, 2001, airlines were struggling for profits. Though profits may not have returned to their pre-2001 levels, lower airfares have allowed for a full recovery in passenger demand. Also, as measured by share of GDP, the industry has not yet recovered. In May 2008, Air Transport Association (ATA) spokesman David Castelveter expressed the industry's complaint that over-taxation is hurting its profits: "We've long said that we are one of the most overtaxed industries, and we now are dealing with record-level fuel increases. The airline industry is in a worse

[6] A regressive tax takes a decreasing proportion of income as the income rises. A progressive tax takes an increasing proportion of income as the income rises. The congressional Budget Office established that federal excise taxes are generally regressive (Karlsson 2006).
[7] Diagram 1 on p. 10 illustrates Pigouvian taxation theory.

financial situation than it was on 9/11" (Smith 2008). Karlsson's study of airline tax incidence is an empirical analysis of the ATA's claim that airlines' lack of pricing power inhibits the industry from passing on an increase in taxes to passengers. The ATA contends that producers bear the full burden of an increase in airline taxes. Karlsson presents an initial exploration of tax incidence in the airline industry, a topic not previously studied in the economics literature.

Tax incidence generally falls between 0 and 1. A tax incidence of 0 means the entire economic burden of the tax falls on the producers. A tax incidence of 1 means it falls entirely on the consumers. In the case of the airline industry, Karlsson finds the incidence is shared between consumers and producers. While his results usually fell between 0 and 1, he notes that the incidence is more often closer to 1, meaning consumers might bear more of the burden. Karlsson also finds that a unit tax placed a higher burden on consumers than an ad valorem tax policy.[8] A 2004 study by the U.S. Government Accountability Office (GAO) claims that when an airline tax is increased, the burden falls on the consumer, but when it is decreased the burden falls more heavily on the producer. This asymmetric response to a tax change is uncommon. Karlsson empirically tests this using data from time periods 1994 to 1997 and 2002 to 2005. His findings are inconsistent with the asymmetric findings of the GAO. However, Karlsson notes a few shortcomings of his empirical work, including biased coefficients caused by structural changes in the airline industry and a mix of tax policies using both ad valorem and unit tax policies across the two time periods. Karlsson notes in his conclusion that the incidence of airline taxes is an important topic for future work due to the combination of rich data, little previously published literature, and high relevance in policy making.

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[8] A unit tax means a fixed monetary amount charged for each ticket or segment (i.e. the federal segment tax of $3.70 per segment). An ad valorem tax is a fixed percentage rate applied to the base fare (i.e. the 7.5% federal ticket tax). Airline policies usually use a combination of ad valorem and ticket taxes. Of the four current U.S. airline taxes, three are unit and one is ad valorem.

## *Elasticity*

The International Air Transport Association (IATA) released an Elasticity Report in December of 2007 examining fare elasticities in the passenger aviation market. The stated aim of the study is "to provide robust elasticity estimates to address policy issues related to liberalization, airport charges, taxation, emissions schemes, etc." The report is an extensive literature review of 23 papers over the last 25 years that examined research on airfare elasticities. The conclusion finds a significant demand response to changes in air fares– increases in air fare lead to lower passenger traffic demand, but the actual decline depends on a number of factors. Long-haul travel is less elastic than short-haul routes. Demand elasticity faced by individual air carriers is greater than the elasticity faced by the whole market, so policies applied to every air carrier affect demand less than policies applied to specific airlines. Business travelers tend to have a less elastic demand than leisure travelers. The study also finds positive income elasticities, many above 1, indicating that air travel increases at a higher rate than incomes.

Berry and Jia (2008) examine the recent financial struggles of airlines despite a recovery in revenue passenger miles. On the demand side, they hypothesize possible explanations: changes in air travel demand, tightened security, and the implementation of online ticket purchasing. On the supply side, there are many possible factors including the expansion of low cost carriers. Berry and Jia estimate a structural model of the airline industry, finding that from the late 1990s to 2006 the price elasticity of air-travel demand increased by 8%. They also find that passengers have a higher preference for direct flights.

## *Predictions of an Emissions Tax Effect*

Brueckner and Zhang (2009) explore the effect of airline emissions charges on airfares, service quality, aircraft design features, and network structure. Their use of a detailed and realistic theoretical model simulates competing duopoly airlines. Their results show that emissions charges cause fares to rise, reduce flight frequency, increase load factors, and raise aircraft fuel efficiency. They find no effect in aircraft size. An important observation made by Brueckner and Zhang is the recognition that these changes are moving society closer to a social optimum. Aircraft emissions are an externality that is currently unaddressed, so the response in the airline industry to an emissions charge moves the market toward its most efficient equilibrium. In their model, they also note that an emissions charge would have the same impact on air travel as a natural increase in fuel prices.

Their study includes a section analyzing the effect of charges on airline networks. The dominant airlines operate in a hub-and-spoke model, which allows them to have less routes and concentrates the majority of their flights around certain hub airports. Low-cost carriers, for instance Southwest Airlines, operate on a point-to-point or fully-connected network. While this network structure still has airports that have more flights than others (known as concentrated airports rather than true hubs), the hub-and-spoke structure has more fuel-efficient aircrafts, larger aircrafts, and higher flight frequency. Brueckner and Zhang (2009) find ambiguous effects of emissions charges on the different network structures depending on the parameters and the profitability of the specific airline; no general statement can be made about one network structure over the other.

David, Nimubona, and Sinclair-Desgagne (2010) present the majority economic opinion that the U.S. Domestic Airline market is an oligopoly. The standard theoretical analysis of an economic tax or tradable permit system is conducted under the assumption of a market with perfect competition; however, the U.S. airline industry operates more closely to a model of oligopolistic competition. Deviating from the case of perfect competition, David, Nimubona, and Sinclair-Desgagne assume a Cournot oligopoly with free entry, and find that initially a higher tax increases demand for abatement, attracting a larger number of abatement suppliers. This could possibly induce each producer to supply less. If each firm's output decreases with the tax, then the best policy is to set the emission tax below the Pigouvian level (where marginal damage equals marginal cost). David, Nimubona, and Sinclair-Desgagne conclude that in an oligopolistic competition scenario, the most efficient tax may depart from the Pigouvian rule of setting marginal damage equal to the marginal cost function, since the marginal cost function is not equivalent to the firm's supply equation.

*Environmental Impact*

While my analysis is neither a policy paper nor an analysis of the environmental benefits from a carbon emissions tax on the domestic airline industry, a major factor in considering an emissions tax policy is the resulting emissions reductions. Hofer, Dresner, and Windle (2010) offer a perspective on the environmental impact of a potential emissions tax on U.S. Domestic Airlines. Using data from 2004 and a conservative set of taxation assumptions, their analysis estimates a proportional decrease in air travel and related carbon emissions from an emissions tax. For example, if the rate is set at 2% to exactly offset the cost of the airline industry's carbon emissions, the emissions from the airline industry would decrease over 5 billion lbs per year. However, this analysis also predicts that substituting car travel for air travel in short-haul markets would cause vehicle carbon emissions to increase by 1.65 billion lbs. The study finds that about one-third of the savings in air travel carbon emissions are offset by the rise in vehicle emissions. The conclusion makes clear that ignoring this transportation mode substitution in short haul markets will lead to overestimating the carbon emissions reductions. The findings also assert that in the long run, the highest potential for a reduction in the airline industry carbon emissions is new technology in the form of lighter and more efficient planes.

## 4 Simultaneous Equations Model Methodology

The empirical analysis that follows is intended to quantify the effects of an environmental policy in the form of an increased ticket price on the U.S. domestic airline industry with the previously stated goal of balancing environmental concerns and airline industry profits. I use a simultaneous equations system with a structural econometric model of demand and airline pricing in the U.S. domestic airline industry. The model is the product of extensive research on the economics of the U.S. domestic airline industry, the availability of data, and the practical limits of the time constraints of this analysis. The econometric method used to estimate the price elasticity of airfare is two-stage least squares (2SLS) with robust standard errors using instrumental variables to specify the airline pricing and demand equations. The resulting coefficients are then used in a simulation of a hypothetical carbon emissions tax.

## 4.1 Data

My analysis uses cross-sectional data from the two most recent business cycles of the U.S. economy as defined by the National Bureau of Economic Research. The sample includes the peak or trough quarter, as well as the quarter before and the two following quarters.[9] The strategic timing around the two most recent business cycles is to account for the effect of the business cycle on the airline industry. The sample includes the following fifteen quarters: 2000 Q4, 2001 Q1, 2001 Q2, 2001 Q3, 2001 Q4, 2002 Q1, 2002 Q2, 2007 Q3, 2007 Q4, 2008 Q1, 2008 Q2, 2008 Q4[10], 2009 Q2, 2009 Q3, and 2009 Q4. Importantly, the quarters are also identified in terms of economic expansion or contraction periods. There are eight expansion quarters (including peaks) and seven contraction quarters (including troughs).

The main data source for this analysis is the Domestic Airline Fares Consumer Report. The Department of Transportation's Office of Aviation Analysis releases this quarterly fare report with information about the average prices paid by consumers in all city-pair markets in the domestic U.S. that average at least 10 passengers per day. Table 6 of the report is organized by origin and destination city-pair market. For example, Los Angeles and New York City is a city-pair market. This market includes one-way flights in both directions between these cities. For each city pair the following is listed in the report: the non-stop distance, the number of one-way passenger trips per day, the airline carrier with the greatest market share, the dominant carrier's average fare and market share, the

[9] The most recent trough was in 2009 Q2. The most recent peak was in 2007 Q4. The prior business cycle had a trough in 2001 Q4 and a peak in 2001Q1.
[10] Since the most recent trough occurred in the second quarter of 2009, technically 2009 Q1 should be included according to my sample method. However, one of my main sources of data, the Domestic Airline Fares Consumer Report, is unavailable for 2009 Q1 due to reporting issues. Therefore, 2008 Q4 was substituted in for 2009 Q1.

airline with lowest fare and its market share, the lowest fare, and the average fare of the market.[11]

Using Table 6 of this report from each of my sample quarters, I further limit my sample as follows. To remove the effect of non-air travel substitutes– mainly buses, trains, and car travel– I use only long-haul routes in the sample, defined as greater than 600 miles. For reference, this is the distance between New York City and Chicago.[12] I include only the top seven major national airlines: American Airlines, Delta Air Lines, United Airlines, US Airways, Northwest Airlines, Continental Airlines, and Southwest Airlines. These airlines are identified as major national carriers based on the Bureau of Transportation Statistics T-100 Domestic Segment (U.S. Carriers) aviation data table. For each airline, the table lists the number of passengers flown in each distance category. From 2000 to 2009, the seven airlines I have chosen were the only ones to have flights (meaning non-zero passenger totals) in every year and in every distance category from 500 miles to 3,000 miles– the approximate range of U.S. domestic flight distances that are in my sample.

I also limit my sample to only flights between hub cities to ensure that the analysis is of homogenous flights. An observation is included from the sample taken from Table 6 of the Domestic Airline Fares Consumer Report if the airline with the largest market share is one of the seven and if the city-pair included two of that airline's hubs. I exclude an observation if the dominant carrier is also the carrier with the lowest fare. My total sample has three-hundred-and-forty observations.

Since the deregulation of the airline industry in the early 1990s, traditional national carriers have organized in a hub-and-spoke model, which requires fewer routes to connect to all destinations and leads to more efficient transportation. Low-cost air

[11] Average fare calculations include prices paid by all fare paying passengers, including first class passenger fares and fares charged by both dominant carriers and lower-cost carriers.
[12] The December 2007 IATA report on airline elasticities notes that elasticities differ across flight distances. Long haul air travel is less elastic than short haul, intuitively because of less available substitutes.

carriers, on the other hand, tend to fly in a point-to-point transit model. These discounted airlines offer fewer comforts and services, but attract costumers with their low fares. Southwest Airlines has been a low cost carrier in the U.S. since 1973. This analysis focuses on major national carriers based on flight frequencies and distances. Southwest is the only low cost carrier in the U.S. that meets the requirements I have identified for a major national carrier, and is therefore included in my sample. The other six airlines in my sample are traditional dominant carriers. Though Southwest technically operates in a point-to-point model, it has focus airports with a significant volume of flights. Since these focus airports are the closest that Southwest has to hubs, I will treat them as hubs for the purpose of my sample.

Financial struggles in the airline industry have caused many airline mergers in the last ten years.[13] The only merger that occurs among the seven chosen airlines during my sample time period is between Delta and Northwest in April of 2008. However, up until January of 2010, the new combined airline, merged under the name Delta Inc., kept both Delta and Northwest plane operations separate, so there are still Delta and Northwest flights in 2009 quarter 4 (the latest quarter in my sample). The 2010 merger of Continental Airlines and United Airlines does not affect this analysis.

The cost-side data for the price of fuel is taken from Bureau of Transportation Statistics Research and Innovative Technology Administration Air Carrier Financial Tables. The price of fuel is measured as cost per gallon of fuel. It is calculated as the total U.S. domestic fuel cost in dollars by quarter divided by the total gallons of consumption by airline by quarter. Fuel prices are a key component of airline operating costs (see Toru 2011; Banker 1993). The price of labor variable uses data from the BTS RITA Employment Statistics. It is computed for each quarter as the total salaries and related fringe benefits of each airline divided by the airline's total employees

[13] Recent U.S. Airline Mergers: U.S. Air and America West, 2005; Northwest and Delta, 2008; Southwest acquisition of AirTran, 2010; Continental and United, 2010 (Bureau of Transportation Statistics).

## 4.2 Simultaneous Equations Model: Air Travel Demand

Demand is a function of own price, price of substitutes, and tastes. I have identified a model of U.S. domestic airline demand as follows.

$$\mathbf{ln}(\textbf{\textit{Fare}}) = \alpha + \beta_1 \mathbf{ln}(\textbf{\textit{Passengers}}) + \beta_2 \mathbf{ln}(\textbf{\textit{Miles}}) + \beta_3(\textbf{\textit{Pass\_Exp}}) + \beta_4(\textbf{\textit{Pass\_Miles}}) + \beta_5 \mathbf{ln}(\textbf{\textit{Hub Competition}}) + \beta_6 \mathbf{ln}(\textbf{\textit{Low Fare}}) + \beta_7 \mathbf{ln}(\textbf{\textit{Low-Fare Market Share}}) + \beta_8(\textbf{\textit{Season 0}}) + \beta_9(\textbf{\textit{Season 1}}) + \beta_{10}(\textbf{\textit{Season 2}}) + \beta_{11}(\textbf{\textit{CO}}) + \beta_{12}(\textbf{\textit{DL}}) + \beta_{13}(\textbf{\textit{NW}}) + \beta_{14}(\textbf{\textit{UN}}) + \beta_{15}(\textbf{\textit{US}}) + \beta_{16}(\textbf{\textit{WN}}) + \beta_{17}(\textbf{\textit{Shock911}}) + \beta_{18}(\textbf{\textit{Exp}}) + \varepsilon$$

The dependent variable, ***Fare***, is the average fare of the observed airline, i.e. the carrier in the city-pair market with the largest market share. The ***Passengers*** variable measures the volume of passengers on the observed carrier of a certain city-pair market. It is computed as the number of one-way passenger trips per day as reported by the Domestic Airline Fares Consumer Report multiplied by the market share of the dominant airline.[14] ***Miles*** is the distance of a flight from the origin to the destination city. ***Pass_Miles*** is the interaction term of the variables ***Passengers*** and ***Miles***. ***Low Fare*** is the lowest fare in the city-pair market. This variable is a main indicator of competition among airlines on the same route. ***Low-Fare Market Share*** is the market share of the carrier with the lowest fare. This variable also identifies competition among airlines within a city-pair market. The continuous variables are all scaled to their means and used in log form in the regression, thereby allowing all estimated coefficients to be interpreted as elasticities.

***Exp*** is a binary variable with a unit value for observations in quarters of economic expansion (quarters following a trough, including peaks). ***Pass_Exp*** is an interaction variable between ***Passengers*** and ***Exp***. ***Shock911*** is a binary variable measuring the effect of the demand shock following the tragedy of September 11th. The variable has a unit value for 2001Q3 through 2002Q2.

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[14] In economics, it is assumed that price and quantity are reversible as independent and dependent variables. Therefore, the equation could read p=f(q) or q=f(p). The regression coefficients did not change when estimated with fare or passengers on the left hand side.

***Hub Competition*** is a dummy variable with a value of 1 if either the origin or destination city is a hub for more than one of the airlines used in the sample. This also measures competition in the city-pair market. If a city is a hub for more than one airline, presumably passengers will have more choice in flights. ***Season 0***, ***Season 1***, and ***Season 2*** are dummy variables identifying the season that the sample is in. Season 0 is the first quarter– January through March. Season 1 is the second quarter– April through June. Season 2 is the third quarter– July through September. Season 3 is the fourth quarter– October through December. These variables pick up the potential sensitivity in flight demand due to weather and vacation and holiday schedules. The last variables are dummy variables representing the seven major airlines used in the sample to capture airline-specific characteristics that affect consumer demand. See Appendix Table 2 for airline abbreviations and names. The $\alpha$ constant term represents a flight that is American Airlines with no hub competition in the winter (season 3) in a contraction period of the business cycle.

The demand side variables that are not present in the supply equation and therefore solve the 2SLS identification problem are ***Pass_Exp, Hub Competition***, ***Low Fare***, ***Low-Fare Market Share, Season 0***, ***Season 1***, ***Season 2***, and ***Shock911***.

## Table 2: Regression Variables

| Variable Name | Definition |
|---|---|
| CO | Binary Variable: 1 = Continental Airlines |
| DL | Binary Variable: 1 = Delta Airlines |
| Exp | Binary Variable: 1 = Expansionary quarter (quarters in sample following a trough) |
| Fare | Average fare of dominant carrier in city-pair market |
| Hub Competition | Binary Variable: 1 = origin and/or destination city is a hub for more than 1 of the 7 airlines in the sample |
| Low Fare | Lowest fare in city-pair market |
| Low Fare Market Share | Market share of carrier with lowest fare |
| Market Share All Others | Market share of all carriers except dominant carrier and carrier with lowest fare |
| Miles | Distance of flight from origin to destination city |
| NW | Binary Variable: 1 = Northwest Airlines |
| Pass_Exp | Interaction Variable: Passengers * Exp |
| Pass_Miles | Interaction Variable: Passengers * Miles |
| Passengers | Number of one-way passenger trips per day in city-pair market |
| Price Fuel | Cost (USD) per gallon of fuel |
| Price Fuel 1 | Cost (USD) per gallon of fuel for 2000-2002 |
| Price Fuel 2 | Cost (USD) per gallon of fuel for 2007-2009 |
| Price Labor | Total salaries and related fringe benefits / total employees |
| Season 0 | Binary Variable: 1 = Winter (January–March) |
| Season 1 | Binary Variable: 1 = Spring (April–June) |
| Season 2 | Binary Variable: 1 = Summer (July–September) |
| Shock 911 | Binary Variable: 1 = Quarter affected by September 11th demand shock (2001Q3–2002Q2) |
| Time | Binary Variable: 1 = 2007–2009, 0 = 2000-2002 |
| UA | Binary Variable: 1 = United Airlines |
| US | Binary Variable: 1 = U.S. Airways |
| WN | Binary Variable: 1 = Southwest Airlines |

## 4.3 Simultaneous Equations Model: Airline Pricing Equation

The conventional supply function indicates a firm's willingness to supply output at each possible market price. However, a true supply function only exists for perfectly competitive industries where the supply function is wholly defined by a firm's marginal cost curve. The U.S. domestic airline industry is not perfectly competitive, but rather exhibits oligopolistic competition. The quantity of outputs supplied is a function of demand and cost factors and therefore there is no well-defined "supply" function. Since the seven major airlines have some control over airline fares, a true supply equation cannot be indentified. Instead, a pricing equation is used as a simultaneous equation with the above demand equation. The pricing equation includes factors that affect how a representative airline sets its price given the cost and market structure that it faces.

$$\ln(\textit{Fare}) = \alpha + \beta_1\ln(\textit{Passengers}) + \beta_2\ln(\textit{Miles}) + \beta_3(\textit{Pass\_Miles}) + \beta_4\ln(\textit{Price Fuel 1}) + \beta_5\ln(\textit{Price Fuel 2}) + \beta_6\ln(\textit{Price Labor}) + \beta_7(\textit{Exp}) + \beta_8(\textit{Time}) + \beta_9(\textit{CO}) + \beta_{10}(\textit{DL}) + \beta_{11}(\textit{NW}) + \beta_{12}(\textit{UN}) + \beta_{13}(\textit{US}) + \beta_{14}(\textit{WN}) + \varepsilon$$

***Fare***, ***Passengers***, ***Miles***, ***Pass_Miles***, ***Exp***, and the airline dummy variables are the same as in the demand equation. The airline dummy variables in the pricing equation also pick up the airline-specific supply-side characteristics, including differences in technology and the variation in the cost of capital. ***Price Fuel 1*** is the fuel price for observations in the years 2000 to 2002. ***Price Fuel 2*** is the fuel price for observations in the years 2007 to 2009. In 2000 to 2002, the mean fuel price per gallon was $0.73. In 2007 to 2009, it was $2.42. This drastic jump in fuel prices makes it necessary to split the price of fuel variable into two time periods. The ***Price Labor*** variable is computed for each quarter as the total salaries and related fringe benefits of each airline divided by the airline's total employees. ***Time*** is a binary variable with a unit value for observations in the years 2007 to 2009 and a value of 0 for observations between 2000 and 2002.

***Price Fuel 1*** and ***Price Fuel* 2**, ***Price Labor***, and ***Time*** are identifying variables for the demand equation.

## 5 Simultaneous Equations Model Results

Demand for U.S. domestic air travel:

$$\ln(\textit{Fare}) = \alpha + \beta_1 \ln(\textit{Passengers}) + \beta_2 \ln(\textit{Miles}) + \beta_3(\textit{Pass\_Exp}) + \beta_4(\textit{Pass\_Miles}) + \beta_5 \ln(\textit{Hub Competition}) + \beta_6 \ln(\textit{Low Fare}) + \beta_7 \ln(\textit{Low-Fare Market Share}) + \beta_8(\textit{Season 0}) + \beta_9(\textit{Season 1}) + \beta_{10}(\textit{Season 2}) + \beta_{11}(\textit{CO}) + \beta_{12}(\textit{DL}) + \beta_{13}(\textit{NW}) + \beta_{14}(\textit{UN}) + \beta_{15}(\textit{US}) + \beta_{16}(\textit{WN}) + \beta_{17}(\textit{Shock911}) + \beta_{18}(\textit{Exp}) + \varepsilon$$

Pricing equation for U.S. domestic airline:

$$\ln(\textit{Fare}) = \alpha + \beta_1 \ln(\textit{Passengers}) + \beta_2 \ln(\textit{Miles}) + \beta_3(\textit{Pass\_Miles}) + \beta_4 \ln(\textit{Price Fuel 1}) + \beta_5 \ln(\textit{Price Fuel 2}) + \beta_6 \ln(\textit{Price Labor}) + \beta_7(\textit{Exp}) + \beta_8(\textit{Time}) + \beta_9(\textit{CO}) + \beta_{10}(\textit{DL}) + \beta_{11}(\textit{NW}) + \beta_{12}(\textit{UN}) + \beta_{13}(\textit{US}) + \beta_{14}(\textit{WN}) + \varepsilon$$

This two-equation system is the main model (1) in the regression results listed in Tables 3 and 4 on the following pages. Overall, both the demand and supply side of the simultaneous equations model yield solid and sensible results, with expected signs on almost all coefficients. As previously mentioned, the continuous variables were all scaled to their means and the natural log was taken in order to interpret the coefficients as elasticities at the mean. To demonstrate the stability of the results, two other models are presented. Model (2) has the price of fuel listed as a single variable, ***Price Fuel***, rather than split by time. Model (3) has the single ***Price Fuel*** variable and an additional variable to measure competition in the demand equation, the market share of all other airlines (excluding the dominant and low fare carriers). The robustness of the model is clear from the comparable coefficients seen across all three models in Tables 3 and 4.[15]

[15] Additional modifications were also made to the models, such as adding variables like average fare of all others, an interaction term between passengers and average fare of all others, and an interaction term between passengers and low fare. These changes also yielded statistically identical coefficients.

## Table 3: Demand Results

Instrumental Variables 2SLS Regression

Dependent Variable: **Fare**

| Independent Variable | (1) | (2) | (3) |
|---|---|---|---|
| **ln(Passengers)** | -0.346** | -0.284** | -0.250** |
| | *(0.138)* | *(0.136)* | *(0.124)* |
| **ln(Miles)** | 0.350*** | 0.348*** | 0.320*** |
| | *(0.046)* | *(0.043)* | *(0.044)* |
| **Pass_Exp** | 0.155** | 0.125* | 0.107* |
| | *(0.071)* | *(0.069)* | *(0.063)* |
| **Pass_Miles** | -0.375** | -0.307* | -0.252* |
| | *(0.168)* | *(0.165)* | *(0.148)* |
| **Hub Competition** | -0.112 | -0.150 | -0.183** |
| | *(0.097)* | *(0.096)* | *(0.087)* |
| **ln(Low Fare)** | 0.195*** | 0.212*** | 0.249*** |
| | *(0.065)* | *(0.061)* | *(0.056)* |
| **ln(Low Fare Market Share)** | -0.045** | -0.948** | -0.051*** |
| | *(0.021)* | *(0.020)* | *(0.019)* |
| **ln(Market Share All Others)** | | | 0.055** |
| | | | *(0.030)* |
| **Season 0** | -0.0195 | -0.016 | -0.014 |
| | *(0.036)* | *(0.033)* | *(0.031)* |
| **Season 1** | -0.012 | -0.009 | -0.006 |
| | *(0.033)* | *(0.031)* | *(0.030)* |
| **Season 2** | 0.008 | 0.010 | 0.013 |
| | *(0.032)* | *(0.029)* | *(0.028)* |
| **CO** | 0.220*** | 0.210*** | 0.220*** |
| | *(0.072)* | *(0.066)* | *(0.061)* |
| **DL** | -0.176* | -0.147 | -0.125 |
| | *(0.096)* | *(0.091)* | *(0.083)* |
| **NW** | 0.053 | 0.051 | 0.019 |
| | *(0.081)* | *(0.078)* | *(0.077)* |
| **UA** | 0.227*** | 0.219*** | 0.196*** |
| | *(0.048)* | *(0.047)* | *(0.045)* |
| **US** | -0.464** | -0.380** | -0.336* |
| | *(0.191)* | *(0.191)* | *(0.176)* |
| **WN** | -0.339*** | -0.326*** | -0.360*** |
| | *(0.058)* | *(0.055)* | *(0.061)* |
| **Shock 911** | -0.062* | -0.052 | -0.049 |
| | *(0.036)* | *(0.035)* | *(0.034)* |
| **Exp** | 0.079** | 0.069** | 0.065** |
| | *(0.036)* | *(0.034)* | *(0.033)* |
| **Constant** | -0.076 | -0.033 | 0.015 |
| | *(0.121)* | *(0.120)* | *(0.110)* |

Notes:

1. (1) includes PriceFuel1 and PriceFuel2 in cost equation
2. (2) includes PriceFuel in cost equation
3. (3) includes PriceFuel in cost equation and Market Share All Others in demand equation
4. Estimated coefficients are reported with standard errors included below in parentheses
5. Significance levels: * denotes $p<0.1$, ** denotes $p<0.05$, *** denotes $p<0.01$.

## Table 4: Supply Results

Instrumental Variables 2SLS Regression

Dependent Variable **Fare**

| Independent Variable | (1) | (2) | (3) |
|---|---|---|---|
| **ln(Passengers)** | -0.206* | -0.196*** | -0.190*** |
| | *(0.030)* | *(0.030)* | *(0.030)* |
| **ln(Miles)** | 0.446*** | 0.445*** | 0.445*** |
| | *(0.038)* | *(0.038)* | *(0.038)* |
| **Pass_Miles** | -0.191** | -0.171* | -0.158* |
| | *(0.090)* | *(0.089)* | *(0.089)* |
| **ln(Price Fuel)** | | 0.282*** | 0.281*** |
| | | *(0.058)* | *(0.058)* |
| **ln(Price Fuel 1)** | 0.416*** | | |
| | *(0.123)* | | |
| **ln(Price Fuel 2)** | 0.233*** | | |
| | *(0.069)* | | |
| **ln(Price Labor)** | -0.144* | -0.127 | 0.123 |
| | *(0.083)* | *(0.083)* | *(0.083)* |
| **Exp** | 0.050** | 0.053** | 0.052** |
| | *(0.022)* | *(0.022)* | *(0.022)* |
| **Time** | -0.021 | -0.358*** | -0.359*** |
| | *(0.022)* | *(0.071)* | *(0.071)* |
| **CO** | 0.175*** | 0.177*** | 0.176*** |
| | *(0.057)* | *(0.056)* | *(0.056)* |
| **DL** | -0.097* | -0.094 | -0.088 |
| | *(0.058)* | *(0.058)* | *(0.058)* |
| **NW** | 0.036 | 0.031 | 0.029 |
| | *(0.082)* | *(0.081)* | *(0.081)* |
| **UA** | 0.163*** | 0.163*** | 0.161*** |
| | *(0.038)* | *(0.038)* | *(0.038)* |
| **US** | -0.371*** | -0.344*** | -0.332*** |
| | *(0.085)* | *(0.083)* | *(0.083)* |
| **WN** | -0.375*** | -0.370*** | 0.369*** |
| | *(0.046)* | *(0.045)* | *(0.045)* |
| **Constant** | -0.116*** | 0.109* | 0.111* |
| | *(0.042)* | *(0.061)* | *(0.061)* |

Notes:

1. (1) includes PriceFuel1 and PriceFuel2 in cost equation
2. (2) includes PriceFuel in cost equation
3. (3) includes PriceFuel in cost equation and Market Share All Others in demand equation
4. Estimated coefficients are reported with standard errors included below in parentheses
5. Significance levels: * denotes p<0.1, ** denotes p<0.05, *** denotes p<0.01.

## 5.1 Simultaneous Equations Model: Air Travel Demand

The demand coefficients for the continuous variables are the long-run elasticities at the mean. The demand function as stands states fare as a function of passengers. Thus, the coefficient on fare, or partial derivative of fare with respect to passengers, is:

$$\frac{\partial \ln(fare)}{\partial \ln(passengers)} = \beta_1 + \beta_3(Exp) + \beta_4 \ln(miles)$$

The price elasticity of demand, conventionally defined as the quantity demanded as a function of price, is therefore the inverse of the above equation.

$$\frac{\partial \ln(passengers)}{\partial \ln(fare)} = 1 \Bigg/ \left[ \frac{\partial \ln(fare)}{\partial \ln(passengers)} \right] = 1 \big/ \left[ \beta_1 + \beta_3(Exp) + \beta_4 \ln(miles) \right]$$

The three parameters of interest in the above elasticity are $\beta_1$, $\beta_3$, and $\beta_4$– the coefficients on ***Passengers***, ***Pass_Exp***, and ***Pass_Miles***, respectively. ***Passengers*** ($\beta_1$) is statistically significant (see Table 3) at the 5% level and negative, as is expected in the inverse demand-side relationship between price and quantity. The binary variable ***Exp*** has a positive and statistically significant coefficient at the 5% level. The ***Pass_Exp*** variable measures the incremental demand elasticity effect of passengers on fares in expansionary periods. Its positive coefficient shows that during an expansionary period, ceteris paribus, passenger demand for air travel is more elastic. This may be due to the higher amount of discretionary travel, which is more sensitive to fares. For example, a family might substitute driving to the beach for vacation instead of flying to an island destination if airfares are high. The interaction variable between passengers and miles, ***Pass_Miles*** ($\beta_4$), has a negative coefficient and is significant at the 10% level.

The price elasticity of demand is calculated at various distances for both expansion and contraction quarters in Table 5 below:

**Table 5: Price Elasticity of Demand**

| | *Flight Distance (miles)* | | |
|---|---|---|---|
| | **1,000** | **1,500** | **2,000** |
| **Expansion** | 11.98 | 4.24 | 2.91 |
| **Contraction** | 4.19 | 2.56 | 2.01 |

The computed elasticities above show the expected trend that as the flight distance increases, the price elasticity of demand decreases. Long-haul air travel passengers are less sensitive to price changes, presumably due to the lack of substitutes for traveling long distances (IATA 2007). The price elasticity of demand is higher in expansion periods relative to times of economic contraction. The elasticity spread between expansion and contraction periods of the business cycle reflects the greater amount of discretionary travel during expansion periods. As expected, the spread in elasticities between the rising and declining periods of the business cycle narrows as distance increases, reflecting the lack of transportation options as distance increases.

The ***Miles*** coefficient of 0.35 is significant at the 1% level. As expected, as the flight distance increases, the fare increases– hence the positive relationship between the two variables. The mean of the distances in the sample is 1,332. At this distance, the elasticity is 0.35. A 1% increase in miles leads to a .35% increase in fares willingly paid. The flight distances range from 600 to 2,442. When computed at the two extremes, the elasticity at 600 miles is higher than the elasticity at 2,442 miles. This result is logically sound– passengers are more price sensitive at lower distances, presumably due to more travel substitutes.

***Hub Competition***, ***Low Fare***, ***Low Fare Market Share***, and ***Market Share All Others*** (in the third regression) all measure the effect of market competition on air travel demand. ***Hub Competition*** has the expected negative coefficient. If a city is a hub to more than one airline, the passenger presumably has more travel options. The increased competition drives the fare down. The ***Low Fare*** coefficient is significant at the 1% level. The positive coefficient shows that again as expected as the lowest fare increases, the fare of the dominant carrier also increases. The ***Low Fare Market Share*** has a negative, significant coefficient. As the market share of the lowest fare increases, the fare of the dominant carrier decreases to account for the increased competition in the market. ***Market Share All Others*** is only included in the last regression, but its positive coefficient is significant at the 5% level. Though it is significant, the other variables' coefficients remain stable whether or not this variable is included, showing the robustness of the model.

***Shock 911*** was significant at the 10% level. The negative coefficient shows that other things equal, the tragedy of September $11^{th}$ forced fares downward, reflecting a lower willingness to pay. The ***seasonal dummies*** account for the change in air travel throughout the year. Their signs intuitively make sense. October through December, the peak holiday season, is the benchmark of comparison. Fares in January through May are expectedly lower than the holiday months. Fares in the summer months are higher, presumably reflecting peak tourism travel. However, none of these variables are particularly significant. The ***airline dummies*** account for the seven major airlines studied, though their estimated coefficients are not of particular importance to this analysis. Continental and United Airlines, however, have significantly higher fares than the benchmark American Airlines, while Southwest and to a lesser extent US Airways and Delta have significantly lower fares. These results make sense based on the quality and clientele of these airlines.

## 5.2 Simultaneous Equations Model: Airline Pricing Equation

The supply-side model is a pricing equation of factors that affect how a representative airline sets its price given its cost and market structure. While a perfectly competitive market would yield an upward sloping supply curve, a market of oligopolistic competition, such as the airline industry, does not have a supply curve equal to the marginal cost function. The negative coefficient of ***Passengers*** is not of concern. There is no *ex ante* sign expectation for the pricing equation relationship between fare and quantity. The ***Miles*** coefficient yields the expected positive relationship between the fare and the distance and is statistically significant at the 1% level.

In the first regression, the price of fuel is split according to the two time periods in the sample: 2000-2002 and 2007-2009. Both variables are significant at the 1% level and show the expected positive relationship between fuel price and fare. ***Price Fuel 1*** has a higher elasticity (0.416) than ***Price Fuel 2*** (0.233). Since the mean fuel price ($2.42) in 2007-2009 is almost triple the 2000-2002 mean price ($0.73), a 1% increase in the price of fuel in 2007-2009 is equal to a 3% increase in the price of fuel in 2000 to 2002. The higher fuel prices in 2007-2009 correspond to passengers being less sensitive to changes in the fuel price. These coefficients also reflect an increasing burden on the airlines over time. In 2000-2002, when the price of fuel increase by 1% the fare increases by .4%. In 2007-2009, the same increase in the price of fuel led to only a .2% increase in the fare. Airlines in 2007-2009 are only able to pass to the consumer one-half of each percent increase in fuel prices than the amount that they were able to in 2000-2002.

In the second and third regressions, the ***Price Fuel*** coefficients for fuel prices across all sample years (0.282 and 0.281 respectively) are also positive and statistically significant at the 1% level. These coefficients, as expected, fall within the range of the first regression coefficients for ***Price Fuel 1*** (0.416) and ***Price Fuel 2*** (0.233), once again showing the robust results of the regression models. The ***Time*** binary variable accounts for differences in the years 2000-2002 and 2007-2009. The ***Time*** coefficient is negative in all three regressions, indicating that fares have dropped in more recent years. This trend may be due to air travel becoming an increasingly normal good rather than a luxury one. It also may be attributed to the introduction and increasing prevalence of low cost carriers, which drives market prices down. The ***Time*** coefficient is not significant in the first regression; however, it is statistically significant at the 1% level in the second and third regressions. This may be due to the split in the price of fuel variable by time period in the first regression, but not in the second and third regressions.

The ***Price Labor*** variable is significant in the first regression only at the 10% level and is insignificant in the second and third regressions. The coefficient is negative, which is counter-intuitive. As an input price, like the price of labor, increases, the airline should likewise increase its fare. However, the airline industry has a unique labor market that unlike other U.S. industries is characterized by a highly unionized labor force (O'Connor 2002). The price of labor does not vary much within each airline in 2000-2002 or in 2007-2009, presumably due to set labor contracts. This may account for the negative sign on the coefficient of ***Price Labor***. The cost equation shows that the **price of fuel** is more influential in an airline's fare-setting decision than the price of labor. The point estimate .28 is consistent with the industry's historical average of 25-35% of each airline's total expenses being spent on fuel costs (BTS).

The ***Exp*** binary variable is positive and significant, showing that, ceteris paribus, airlines raise their fares in expansionary periods. The airline binary variables once again are compared to American Airlines as the benchmark. Airlines like Continental and United have statistically significant positive coefficients since they advertise slightly higher quality services and target a slightly more affluent and business-oriented clientele. Southwest (and to a lesser extent US Air and Delta) have statistically significant negative coefficients, consistent with the priority of cheaper fares for a slightly lower quality service.

# 6 Carbon Emissions Tax Simulation

## 6.1 Methodology

Having created a simultaneous equations model of the U.S. domestic airline industry, this analysis uses the previously identified coefficients to judge the effect of an emissions tax. The tax would raise the price of fuel, causing the airlines to increase fares and, depending on the magnitude of the demand elasticity, negatively affect passenger demand for air travel.

This simulation begins with the projected price of an EU-ETS emissions allowance permit for airlines in 2012 of €15 per ton of $CO_2$ (Clements, Wilkins, and Beyzh 2011). This permit price is converted into U.S. dollars per kg $CO_2$ and then multiplied by the air travel fuel emission coefficient (from the U.S. Energy Information Administration) to form the tax per gallon of fuel.[16] Using the price elasticity of fuel, the effect of this tax on the fare is then calculated. Finally through the price elasticity of demand and adopting the usual convention that demand functions are invertible, the effect of an increased fare on passengers is calculated, as shown in the equations that follow.

$$\% \uparrow P_{fuel} \times \frac{\partial \ln(fare)}{\partial \ln(P_{fuel})} = \% \uparrow fare$$

$$\% \uparrow fare \times 1 \Big/ \left[ \frac{\partial \ln(fare)}{\partial \ln(passengers)} \right] = \% \downarrow passengers$$

The effect of the tax is calculated at various tax levels during the 2007-2009 period. In addition to the €15 starting permit price, the simulations include a lower permit price of €10 and a higher price of €30 (this range of permit price levels is adapted from the tax simulation in Toru 2011). For each time period and each permit price level, the effect of the tax is calculated for an expansion quarter and a contraction quarter, since the price elasticity of demand is different in these two economic environments. The effect of the tax is then calculated for a range of flight distances (1,000, 1,500, and 2,000 miles), again for both an expansion and a contraction quarter.

[16] Permit Price (Euro per ton of $CO_2$) = Permit Price (USD per 1,000 kg of $CO_2$)/1,000
= Permit Price (USD per kg $CO_2$) × Air Travel Fuel Emission Coefficient (kg $CO_2$ per gallon)
= (**Fuel Price Increase (USD per gallon)** / Mean Fuel Price (USD per gallon))× 100 = **%↑ $P_{fuel}$**

## 6.2 Results

The price elasticities of demand computed in Table 5 (p. 34) are calculated under the standard economic assumption of ceteris paribus, with all other things held equal. Therefore, the price elasticity of demand is showing the effect of a 1% increase in the dominant carrier's fare on the number of passengers, holding all else equal. However, in the proposed tax, the fares of all airlines would be increased by the same percentage, not just the dominant carrier's fare. The independent variable measuring the market's lowest fare would also increase, as well as the fares of every airline in the market. The Table 5 elasticities are the firm elasticities; however, in order to judge the effect of the tax, the market price elasticities of demand must be used. The market price elasticities of demand are calculated by multiplying the firm price elasticities of demand by the average market share of the dominant carrier (58%), a calculation derived from the Cournot oligopoly model.

The results of the tax simulation at the mean flight distance of 1,332 miles are presented in Table 6.

## Table 6: Tax Simulation Results

| Quarter Type | Price of EU-ETS Carbon Permit (1 ton of CO2) | US Price per ton of CO2 | Increase in Fuel Price Per Gallon | Increase in Fare | Firm Price Elasticity of Demand | Market Price Elasticity of Demand | Decrease in Passengers |
|---|---|---|---|---|---|---|---|
| Expansion | € 10.00 | $14.40 | $0.12 | 1.13% | 5.23 | 3.04 | 3.42% |
| Contraction | € 10.00 | $14.40 | $0.12 | 1.13% | 2.89 | 1.68 | 1.89% |
| Expansion | € 15.00 | $21.60 | $0.18 | 1.67% | 5.23 | 3.04 | 5.07% |
| Contraction | € 15.00 | $21.60 | $0.18 | 1.67% | 2.89 | 1.68 | 2.80% |
| Expansion | € 30.00 | $43.20 | $0.36 | 3.22% | 5.23 | 3.04 | 9.81% |
| Contraction | € 30.00 | $43.20 | $0.36 | 3.22% | 2.89 | 1.68 | 5.42% |

Notes:
1. Price Elasticities of Demand computed at the mean flight distance (1,332 miles)
2. Euro/USD exchange rate on 4/13/2011

At the €15 EU-ETS carbon permit price, there would be $0.18 increase in the fuel price per gallon.[17] Therefore, the level of an emissions tax would be $0.18 on each gallon of fuel used by a U.S. airline during a domestic flight. The Table 6 results are for a flight distance of 1,332 miles, the mean of the sample. During the 2007-2009 period, this level of tax would increase airfares by 1.67%, resulting in a 5.07% decrease in passengers during an expansionary period.[18] As previously mentioned, passenger demand is more elastic in an expansionary period than in a period of economic contraction, and therefore the tax has a greater effect on passengers during these quarters. During a period of contraction, a 1.67% fare increase would decrease the amount passengers by only 2.80%.

In the same 2007-2009 time period, a €10 permit price would increase airfares by only 1.13%, decreasing passengers by 3.42% in a period of expansion and 1.89% in a period of contraction. A €30 permit price would increase airfares by 3.22%, resulting in a 9.81% and 5.42% decrease in the number of passengers in an expansion and contraction period respectively.

The results of the tax simulation on varying flight distances are presented in Table 7.

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[17] €15 per ton $CO_2$ = $21.60 per 1,000 kg $CO_2$ / 1,000 = $0.0216 per kg $CO_2$ × 8.32 kg $CO_2$ per gallon = $0.18 per gallon (Euro to US currency exchange rate based on 4/13/2011)

[18] Mean Fuel Price = $2.42.

% ↑ $P_{fuel}$ × elasticity of fuel with respect to fare = % fare ↑ = ln(2.60/2.42) ×100 = 7.17% × .233 = 1.67%

## Table 7: Tax Simulation at Varying Flight Distances

| Flight Distance (Miles) | Quarter Type | Market Price Elasticity of Demand | Decrease in Passengers: €10 level | Decrease in Passengers: €15 level | Decrease in Passengers: €30 level |
|---|---|---|---|---|---|
| 1,000 | Expansion | 6.96 | 7.83% | 11.61% | 22.45% |
| 1,000 | Contraction | 2.44 | 2.74% | 4.07% | 7.86% |
| 1,500 | Expansion | 2.47 | 2.77% | 4.11% | 7.95% |
| 1,500 | Contraction | 1.49 | 1.67% | 2.48% | 4.80% |
| 2,000 | Expansion | 1.69 | 1.90% | 2.82% | 5.45% |
| 2,000 | Contraction | 1.17 | 1.31% | 1.94% | 3.76% |

Notes:
Market price elasticities calculated as the Table 5 firm price elasticities of demand multiplied by the average market share of dominant carriers (58%).

The price elasticities of demand decrease a significant amount over the range of flight distances, presumably due to a decrease in substitution modes of transportation as the flight distance increases. At the tax equivalent of a €15 permit price, passengers only decrease by 2.82% in an expansion and 1.94% in a contraction for a 2,000 mile flight difference. The percentage decrease in passengers is minimal at the €10 permit price level– 1.90% in an expansion and 1.31% in a contraction. These tax simulations show the great effect that flight distance has on the passenger decrease due to the varying price elasticities of demand. Long-haul travel is affected much less by an emissions tax.

# 7 Discussion of the Effect of a Carbon Emissions Tax

The projected carbon permit price for airlines in 2012 is €15. While the price is not expected to reach the €30 level, the range of permit prices gives a full picture of the effect of a carbon emissions tax at varying levels (see Toru 2011). The permit price will most likely stay close to the €15 level. A tax at this level would raise the fare by 1.67% (see Table 6), resulting in a 5.07% passenger decrease in an expansion period and a 2.80% decrease in a contraction period.

While a 5.07% decrease in passengers during an expansion may seem high to the industry, the percentage decrease is smaller for long-haul passenger travel. For a 2,000-

mile flight distance, there is only a 2.82% decrease in passengers at the same tax level during an expansion (see Table 7). The economic conditions of air travel make an environmental policy tolerable from an industry perspective and very reasonable from an environmental standpoint. Furthermore, air travel traffic is estimated to increase 3-5% per year from 1990 until 2050 (IPCC 1999). The simulation results show that depending on the specific tax design, the policy could decrease passengers by less than air travel traffic is expected to grow in one year.

Taken in context with the EU-ETS policy in 2012 and the resulting skewed competition between EU and non-EU airlines (see Scheelhaase, Grimme, and Schaefer 2010), a U.S. airline emissions tax looks increasing feasible. The hypothetical tax levels are derived from the EU-ETS to show the range of effects that a tax could have on passenger demand for air travel. While the higher EU-ETS permit price levels may be too high to be politically or economically favorable in the U.S. airline industry, the €10 permit price level only increases the fare by a little over 1%. In contraction periods, the number of passengers minimally decreases by a little over 1.67% for 1,500-mile flights at this tax level (2.77% in expansion periods). The taxation level in the U.S. could be lower than the €10 permit price level, or could be applied to only long-haul flights (for instance greater than 1,500 or 2,000 miles) to minimize the distortion on air travel demand.

# 8 Shortcomings and Reasons For Caution

The simultaneous equations model of this thesis yields very consistent coefficients, providing a strong basis for the tax simulation. However, there are a few shortcomings and reasons for caution due to the constraints of this analysis. In the cost equation on the supply side of the model, ideally price should be a function of three inputs: the price of labor, the price of fuel, and the price of capital. The data provide strong measures for the first two of these inputs. The variation in technology and capital costs among the airlines is addressed through the airline dummies in the cost equation, but is buried with all the not otherwise specified airline-specific data. Though attaining a true measurement of capital is beyond the time constraint of this thesis, a more accurate price of capital should be measured as a function of many factors, including but not limited to each airline's acquisition costs of aircrafts, economic depreciation of these aircrafts, tax treatment of capital assets, and capital gains.

In the measurement of the price of labor, company-wide labor expense per employee across the whole airline is used. The inclusion of company-wide and not route-specific labor data provide a solid proxy for the price of labor; however, data on the number of cabin crew and related labor expense would yield an even more accurate portrayal of the air operation costs (the costs most related to emissions).

This analysis is also limited by the data not including actual numbers of flights underlying each city-pair market observation. The Domestic Airline Fares Consumer Report allows for the use of passengers and miles as a measure of output, but fuel use (and therefore emissions) is also a function of the number of flights.

# 9 Conclusion

*"Economic advancement is not the same thing as human progress."*
*– John Clapham (1957)*

This analysis offers basic empirically grounded insight into the impact that an environmental tax would have on the U.S. domestic airline industry. This paper is not a policy review; it is an economic analysis looking at how an environmental policy would affect the vitality of U.S. domestic airlines. While concerns for the profitability and economic stability of the U.S. airline industry are valid, this empirical analysis suggests that an environmental policy on long-haul air travel would not be unreasonably damaging to airlines or passengers. While there may be a debate over the level of taxation applied to the U.S. domestic airline market, the results of the tax simulation in this thesis show that a low-level tax has a minimal negative effect on passenger demand for air travel. This is even more the case for a tax only applied to long-haul flights.

The history of the airline industry has shown volatility around various events and business cycles, a trend that will likely continue due to the unique characteristics of the industry. However, the serious effects of climate change are a pressing issue that will not decline in the future without significant policy and behavioral change.

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