The potential impact of a European Fuel tax on fuel demand and on the environment

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Abstract

Aviation emissions are increasing drastically along with an increasing demand for aviation globally. Even though energy efficiency has been improved significantly, it is far from enough to meet the desired climate goals. This thesis investigates the potential impact of a hypothetical European-level jet fuel tax on the demand of aviation fuel, and the total passengers carried. We find that average fuel price has a negative and significant impact on aviation fuel consumption as well as passengers carried. The impact of jet fuel tax is not large, but it provides an additional policy instrument to reduce aviation emissions.

Contents

1 Introduction

1.1 Problem Discussion

International aviation emissions are growing fast and the main environmental effects of aviation, described by the European Commission and recognized in the second European Aviation Environmental Report [EAER], are the aircraft noises and aircraft emissions. The former at a local level and the latter can have both local effects on air quality and global effects on the climate.

Keen & Strand (2006) argues that international aviation causes significant damage on the environment and more recently it was reported by the European Union Aviation Safety Agency [EASA] that the number of flights, internationally, has increased by 8 percent between 2014 and 2017. EASA also report that the forecast for 2040 is that it will continue to grow with 42 percent. According to the Environmental Report of the European Union, the total greenhouse gas emissions of the European Union is 96% more than the total greenhouse gas emissions in 1990, yet aeroplanes' energy efficiency has experienced significant improvement (European Environment Agency, 2019). Based on the work of Keen and Strand, one can conclude that these increases will also lead to an increased negative impact on the environment.

Despite that significant technological developments in the aviation industry have occured in several areas it is explained by (European Environment Agency, 2019) how the opposite can be said regarding the fossil-based fuel. According to the International Renewable Energy Agency (International Renewable Energy Agency, 2017), the developement of sustainable aviation fuels, such as electric-powered aircrafts and cryogenic hydrogen fuel, is in progress but unlikely to be ready for usage before 2030. International Renewable Energy Agency, (2017) further explains how bio-jet has a difficult time challenging the less expensive fossil-based jet fuels and that improved policies are needed to establish international standards to incentivise the development of bio-jet and thus to meet the international climate targets in the 2015 Paris Agreement. The price of bio-based aviation fuel is considered to be one of the greatest barriers when trying to penetrate the market and more initiatives are required at a European level in order to increase consumption to potential production capacity. (European Environment Agency, 2019)

Market failure is when markets allocate resources in a Pareto-inefficient way, for instance, if the decisions of producers and consumers affect others in ways that they do not take into account. Externalities can be explained as economic effects that arise from an entity and that are not accounted for they do not exist in transactions. It can further be explained that taxation and penalties are tools to internalize the external effects. Social costs arise from these externalities and can be defined as the cost of product paid by the society and not by the products producer. An example of this is the environmental cost due to the aviation industry, such as, air pollution, global carbon emissions, noise, pollution and congestion at airports and other emissions. As a result, the external effects of aviation affects the health and quality of life of the worlds citizens, and therefore it is argued that the environmental footprint of the aviation needs to be reduced in a sustainable way and thereby contribute in the fight against climate change. (European Environment Agency, 2019)

In 2018, The Intergovernmental Panel on Climate Change [IPCC] released its report which concluded that the worlds CO2 emissions, by the year of 2030, must have decreased by 50%.(Coninck and Revi, 2018) IPCC clarify the fact that energy consumption and emissions have to be reduced and that the heavy vehicles, such as airplanes, will have a challenge to decarbonize and states that "Since there is no silver bullet for this deep decarbonization, every possible measure would be required to achieve this stringent emissions outcome" (Rogelj, Shindell and Jiang 2018) p. 142. The efficiency improvements includes a more extensive consumption of low-carbon fuels which is advanced biofuels and these pathways requires a global coordinated policy action towards both the reduction of carbon offsetting and towards research and development (R&D)

1.2 Background

Violeta Bulc, European Commissioner for Transport, describes the aviation industry as "a strong sector for the European Union's economy, and an increasingly important means of transport for European Union citizens and businesses".(European Environment Agency, (2019), p.2) The growth of aviation with the enhanced connectivity, cheaper tickets and increasing flying options enables the connection with relatives, development of businesses, attracting investments and employees. All trends, according to Bulc, indicate an increase in demand for air travel by citizens in the European Union until 2040. (European Environment Agency, 2019)

Karima Delli, Member of the European Parliament and Chair of Committee on Transport and Tourism, adds that the forecast indicating increasing demand and air traffic, will not occur without a growing challenge on the environment since aviation, today, accounts for 3% of global emissions (European Environment Agency, 2019). The consequences of the increased consumption of traveling with aviation are described in the European Aviation Environmental Report [EAER]. The report concludes that growth of the industry contributes to negative health effects, air quality reduction, pollution, higher temperatures and rising sea-levels (European Environment Agency, 2019).

The environmental responsability is a global response according to (Coninck and Revi, 2018) in the report on Strengthening and Implementing the Global Response, published by the Intergovernmental Panel on Climate Change [IPCC]. The optional bio-based fuel or electrification substitutions are, in the IPCC report, explained as limited by institutional constraints. One constraint is the exemption of aviation fuel at an international level which is one of the statutes in the Convention on International Civil Aviation [Chicago Convention] from 1944 with later updates. (International Civil Aviation Organization, 2016*a*)

Altogether, numerous of aspects are considered when seeking to improve the aviation industry. In the European Aviation Environmental Report, aspects mentioned are:

- Technology and Design
- Air Traffic Management and Operations
- Airports
- Market-Based Measures
- Aviation Environmental Impacts
- Sustainable Aviation Fuels

This paper will mainly have the focus on the two last mentioned when investigating a potential fuel tax at a European Union level.

1.3 Contribution

This paper origins from the potential environmental threats of aviation and the political debate in Sweden (Statens offentliga utredningar, 2016) on how different policies, mainly tax, can force the industry in to a more sustainable direction and increase the demand of more environmental friendly bio-fuels. International barriers in the shape of different agreements, prohibit a mutual fuel tax on the aviation industry. However, with increased environmental awareness, these agreements are now being challenged at the political arena and politicians have opened up the debate for a potential fuel tax as they argue that it has to occur simultaneously in each country.

The purpose of this paper is to contribute to the debate with a further look upon what effect a mutual taxation of aviation-fuel in the European Union would have on the demand of the traditional fuel and if it could be a potential tool to decrease the environmental impact of aviation and increase the demand of bio-fuel. The intention is not to recommend a certain level of tax or dismiss other available tools. The purpose is to identify, analyze and assess the potential effect of a fuel tax.

The paper will focus to answer the following research question:

(1) In what way does a potential fuel tax, at a European Union level, affect the demand of aviation-fuel?

1.4 Outline

The research is divided into 5 further parts where the main headings are Aviation Regulations and Environmental Impacts, Method, Results, Discussion and Further Research.

In the first part, a comprehensive explanation on how a market in equilibrium creates negative externalities will be presented and examples especially linked to the aviation industry will be given. Furthermore, the environmental impacts and negative externalities of aviation will be presented more distinct. This will finally be followed by an explanation of the different historical agreements that regulates available policies, the different taxes available and the political discussion regarding a potential fuel tax.

The second part contains the econometric part of the research which contains a presentation of our models and the variables chosen. Limitations identified will also be given in this section as well as the expected results determined before the regression results were an actuality.

The third part of the paper will discuss the results of the regressions and the expected aviation fuel tax effect. Followed by the fourth part where a discussion regarding if a fuel tax has an impact on the aviation industry's fuel demand and if it is a potential positive tool to decrease the environmental effect of aviation will take place. Furthermore, a conclusion will be made and additional research will be suggested.

2 Aviation Regulations and Environmental Impacts

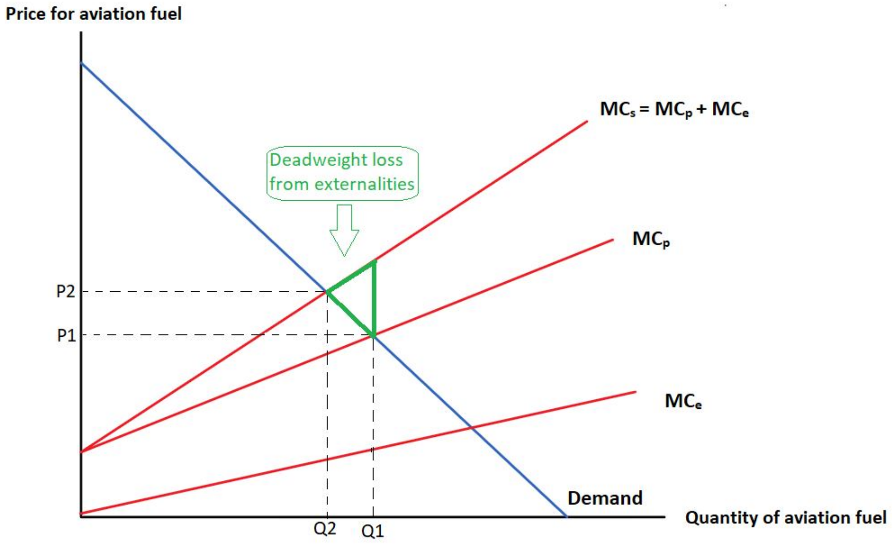
2.1 Externalities

This section is based on the second edition of Microeconomics and Behavior, written by Robert Frank and Edward Cartwright. The purpose is to provide an comprehensive understanding of how a tax can cover social costs and to understand this papers continued presentation and discussion of the aviation industry. The marginal cost of a company is represented by $\mathrm{MC}_{\mathrm{private}}$, however, there also exists the cost of the externalities from aviation, $\mathrm{MC}_{\mathrm{environment}}$. Together these two adds up to the marginal social cost $\mathrm{MC}_{\mathrm{social}}$.

$$MC_s = MC_p + MC_e \tag{1}$$

The market solution concerning perfect competition is given where the demand curve intersects the marginal cost of the company i.e. MC_{p}. The social optimal solution includes the external costs, and is therefore given where the demand curve intersects the total social cost i.e. MC_{s}. The competitive equilibrium with a negative externality is inefficient as it excludes these externalities and creates a Dead Weight Loss, DWL, because of overproduction relative to social optimum levels (Frank 2016).

Figure 1: The Inefficiency of Competition with a Negative Externality



The figure illustrates how, for example, a tax on fuel would work but in a simplified way, with the quantity of fuel on the horizontal axis and price of fuel on the vertical axis. In a simplified world, all fuel on the horizontal axis is representative for European aviation industry. Even though in reality, fuel is bought to supply different sectors. The marginal benefit is the downward-sloping curve and shows the additional benefit to the society of an additional quantity of fuel, which falls as the amount of fuel increases. The cost of each additional quantity of fuel is represented by the marginal private cost curve [MPC], which is defined as the increase in private cost that is a result of a marginal increase in activity, and further explained that the marginal private cost does not include any external effects (Black et al. 2012). For the aviation industry, examples of marginal private cost could be purchasing new planes and running them, opening new routes and, as in this case, purchasing fuel. Additionally, Black et al. (2012) defines the marginal social cost curve [MSC] as an increase in social cost that is a result of a marginal increase in an activity. Unlike the marginal private cost, marginal social cost does includes all external effects.

In this thesis the curve represents the increase in social cost to society resulting from a marginal increase of the purchase of jet fuel. The gap between MPC and MSC reflects the external costs which were generally presented earlier. At the initial level of fuel and price (q1 and p1), the quantity of fuel are at a level where benefits equal private marginal costs, meaning that the market is in equilibrium. However, the marked triangle shows that the social costs of the fuel purchase exceed the benefits and thus the triangle represents the welfare loss (dead weight loss) of excessive fuel. If one would, set a tax rate, it would mean that the private costs would shift to MSC where the marginal social cost equals the marginal benefits, resulting in an eliminated welfare loss, reducing fuel consumption to level q2 and the new price p2.

As the aviation industry grows, and there is free competition market, so does the negative externalities increase as well. Different interventions is needed to prevent this from happening and there are several used in the aviation industry.

2.2 Policy instruments To Reduce Negative Externalities

Different regulations depending on the ultimate goal can be used for the aviation industry and this subsection is used to present the different one being used.

Administrative Measures, where a limit of production is set based on an emissions standard. The regulation could, for instance, be a set limit of number of flights allowed each day or for a longer period. It could also be an indirect limit of purchasing fuel allowed.

Tax, either on the emission or the fuel that causes the negative externality. The tax shall also correspond to the externality. The tax will result in a internalisation between the companies and the externality.

Emission rights, which occurs when, for example, a government sets a ceiling where an amount represent the desired total output of emissions and companies then buy and trade rights to emit a certain amount. One concrete example is the European Union's cap and trade system in the aviation industry.

In addition to these interventions mentioned above another solution is that the policy makers could consider **subsidies** to the alternative bio-fuel which would have a more positive impact on society than the regular aviation fuel being used to day.

The particular fuel tax considered in this thesis is known as a Pigovian Tax. Pigouvian tax is a tax that is set to regulate for circumstances when private individuals or businesses engage in activities that create adverse effects on the society(Black et al. 2013). Examples of adverse side effects are pollution, noise, emissions and other side effects that have a negative impact. The tax is intended to:
(1) Tax producers of either goods or services that generate adverse side effects on the society. However, some economists argue that the costs of these externalities are born by society rather than the producer, since society demands are the ones travelling and impose the purchase of fuel.
(2) Readjust the cost back to either the producer or the user of the potential negative externality.
(3) Equal the cost of the negative externality, for example equal the cost of carbon emissions. But it can be difficult to determine the costs of different negative externalities and if wrongly estimated it could result in harming the society.

The ones in favour of a taxation on aviation are often pointing out how it would be in favour for the environment but in order to choose the optimal tax level, one has to be able to quantify the effects. However, quantifying the cost that aviation has on the environment is complex according to Keen & Strand (2006). it further points out that the main environmental externalities caused by aviation are many and that there are a lot to take into consideration:

- Air Pollution
  The exact effect of air pollution is difficult to quantify.

- Global Carbon Emissions
  The aviation fuel contributes to the greenhouse effect, and as the industry grows so does that contribution. What happens is that burning aviation fuel results in the emission of carbon dioxide, CO_2.

- Other emissions
  Other substances that contribute to global warming are nitrogen oxides, methane, water vapor, sulfates and soot and these substances are emitted by airplanes.

- Noise

Noise pollution depends on where the airport is located and how crowded the population are surrounding the airport. It is concluded by both Pearce and Pearce 2002 and by the (European Environment Agency, 2019) that noise problems are not a big problem if measured far from the airport and thus, noise are counted as local externalities.

- Pollution and Congestion at Airports

In this case, when analyzing the potential effects aviation has on the environment, one have to consider the costs or benefits of both the ones who do not buy or sell the product and those that do. The external cost in this thesis could be simplified and thus be the output of CO2 emissions caused indirectly by the amount of fuel being used in the operation in order to quantify the tax. However, in reality it would be desirable to include the other effects in the calculations to include them in the tax. Therefor the thesis excludes to give an exact level of tax and continues to investigate in what way, positive or negative, a tax would affect the fuel demand and thus the environmental effects.

2.3 Existing Instruments

Aviation is described to have a unique fiscal regime(CE Delft, 2019). In many countries, the industry is subject to different taxes and charges often added to the ticket price (CE Delft, 2019). It is clear that fuel tax is limited due to the Chicago Convention and as a result most countries refrain from such a tax. The tax limitations established in the Convention are now being challenged, the governments ministry of infrastructure in Sweden reported, the 25th of September 2019, that Tomas Eneroth, minister of infrastructure, at that time participated at the General Assembly of the United Nations International Aviation Agency, ICAO, in Montreal, Canada. The ministry of infrastructure further reported that Eneroth urged ICAO to change the international regulations and thus make it possible to tax fuel internationally and as a result reduce the climate impact of aviation and also help achieve the Paris Agreement (Regeringskansliet 2019).

There are different types of taxes that the aviation industry could be subject to. Potential taxes are:

- Departure Tax
- Value Added Tax
- Environmental tax
- Taxation on Aircraft Fuel

The European Commission's report on "Taxes in the Field of Aviation and their impact" explains different tax applicable and used in the European Countries.

A Departure Tax is charged on all passengers. It is a tax consumers pay when travelling and can depend on, for instance, the final destination or classification of the ticket. Examples of departure tax are the UK Air Passenger Duty and the German Air Transport Tax. The tax varies with the length of each travel. The German Air Transport Tax is, for example, divided into three categories; short haul, medium haul and long haul. The UK Air Passenger Duty is designed based on the length of the travel and what class one travel in. Other countries such as Norway has a fixed amount (CE Delft, 2019). This instrument addresses the problem by charging the operator a tax for passengers traveling with the operator, wishing to have an effect where the operator takes out a higher price to account for increased costs. This is in favour when the intention is to influence our behavior as consumers and thus the amount of aviation travelling as the higher price will result in a decrease in traveling and a reduction in CO2 emissions (The Government of the United Kingdom, 2019).

A Value Added Tax and other consumption taxes are common tools used by fiscal authorities. Exceptions for these taxes are limited and therefore it is stated that the normal practice, in terms of international transport, is to apply a zero VAT rate as the transport occurs outside any jurisdiction of tax. (International Civil Aviation Organization, 2016*a*) However, domestic air travel is more widely a subject to VAT. In 2018, the European Commission reported that most european countries charge VAT on their domestic flights. The VAT rates varies from 3% in Luxembourg up to 27% in Hungary. Countries in the European Union that are not listed has a rate of 0% (CE Delft, 2019).

An Environmental Tax could be an emissions tax with the advantage to more precisely target the cause behind pollution damage, relative to other taxes. This sort of tax spur airlines, at a given input of fuel, to reduce emissions, which could be accomplished through development and choice of engines. At a local level, examples of environmental taxes are a noise tax and a local air pollution tax which more precisely target the more local damage caused by the industry. An advantage and possibility could be to add this sort of tax to the airport landing charges and as a result relocate some of the local air traffic volumes.

A taxation of aircraft fuel is limited. The 1944 ICAO Chicago Convention, which will be further described in the following section, is the basis for the fuel tax exemption. European Member States are exempt from applying this sort of tax based on the 1944 convention together with framework for the taxation of energy and electricity, produced by the Council of the European Union. Article 14(1)(b) in the framework clarifies that member states shall exempt energy products that has the purpose to supply air navigation from taxation except for private pleasure-flying (The Council of European Union, 2003). The same framework presents exceptions for the zero fuel tax policy. In article 14(2) it is stated that Member States may ignore the regulations on domestic flights or in the case where to states has an bilateral agreement. Although this exemption exist, none of the European Countries apply a tax on jet fuel on their domestic flights. Some argues that fuel tax in an individual country would not have a sufficient impact on the environment and that it would need to be decided and occur at an international level. Keen & Strand (2006) explains that if countries would set such tax individually, the potential low impact of taxes on international aviation as a result of a so called tax competition, which causes the taxes to be inefficiently low. Setting the tax-level simultaneously and at the same level would, according to Keen & Strand (2006), prevent a tax competition and also preserve different country specific interests, such as tourism.

According to Keen & Strand (2006), a rational explanation in this century regarding the legal undertakings in the convention does not seem to exist. In the early days of aviation the industry could have been viewed based on the beneficial externalities evident in that point of time. The conclusion is that most countries still comply with the statements from ICAO, however, statements have been made from some of the European countries in the fourth edition of the Supplement to ICAO's DOC 8632 (International Civil Aviation Organization, 2016*b*).

Germany stated that "The Government of Germany may decide to introduce a tax on the consumption of fuel and lubricants in international commercial transport, too, as well as taxes on the sale and use of international air passenger transport services".
Norway stated that "[...] Norway questions the reasons for the tax exemption concerning fuel in the Resolution. Tax policy in respect of environmental protection may be a reason for introducing taxes on fuel for the use by aircrafts in general."
Sweden stated that "In light of the discussions in various fora about market based measures as tools in the limiting of the impact of international civil aviation on climate change, our opinion is that taxes levied on the uplift of lift or levied on air transport should not be ruled out as possible future measures."
Switzerland stated that "The Swiss Confederation generally supports and applies ICAO's policies on taxation in the field of air transport as set out in Doc 8632. Not withstanding the Council's resolution, the Swiss Confederation is in favour of market-based measures aimed at reducing or limiting the environmental impact of aviation."

The statements above can be viewed as a proof of progress but as the exemption of the tax still is a reality, one needs to consider the potential obstacles at the political arena. **One political obstacle** could be that more countries are needed when challenging the agreements on tax exemption. If a country would hypothetically apply a fuel tax at a national level and also ignore the international exemption and thus apply the tax on international flights passing through then one possibility is that the tax would not fulfill its purpose. Airlines might just decide to refuel in another country where the tax is still exempt or choose another route. **Another obstacle** could be the historical lack of incentive from the EU to take on the debate for a potential tax, as they are the main decision making unit for Union as a whole. However, On December 11 last year, the European Union released The European Green Deal and one interpretation of it, is that the commission is coming to the same realization as the countries mentioned above, as they argue that environmental impact must be included in the price of transportation. It is highly important that the price reflects the environmental impacts. As a consequence the Commission suggests a revision on the current tax exemption (The European Commission, 2019).

The political debate and the potential revision of the exempted fuel tax have created a debate where the conflict of interest cannot be ignored. The Wall Street Journal reported, on December 17 last year, how the Commission, in the Green Deal, predicts emissions to reduce as a result from a fuel tax. In contrast, the journal further reported that the five largest airlines in Europe are opposed to the potential tax and refers to their international competition. One explanation is that airlines could be forced to relocate and refuel abroad. Another explanation is that competitiveness would further be harmed as the rest of the world might not face the same restriction. In addition to the international competition, carbon credits and lower investments in bio-fuels are also reasons for the airlines opposition (Bugault & Holger 2019).

Keen & Strand (2006) explains how tax-exempt fuel, at the same time as it enables international travel, significantly contributes to environmental damage. Keen & Strand (2006) further concludes that a tax on aviation fuel would, most directly, address the negative international externalities caused by aviation. However a ticket tax is more likely to raise more revenue, and finally departure tax is the one with the least legal obstacles.

Apart from each countries having their own strategies to improve the environmental impact of aviation, there exists a common one for the European Union as a whole. The EU Aviation Strategy (European Commission, 2015*a*) aims to improve the environmental impact of aviation and thus reduce its footprint. This strategy includes the publication of the European Aviation Environmental Report, which is a report that tracks the environmental performance of the European Union's air transport sector. Since 2010, EU and EFTA countries have worked through the International Civil Aviation Organization (ICAO) with the goal to achieve a 2% improvement of the annual global average of fuel efficiency. Later on, during 2012, the first action plan of the Member States was submitted to ICAO, in which their respective policies and actions were presented. To further support the development of Sustainable Aviation Fuel (SAF), a budget of 464 million euro has been available, between 2013 to 2020, to support the research on bio-fuels and other renewable sources.

2.4 ICAO and Sources of Emission Reductions

EAER reports an 8% increase in number of flights between 2014 and 2017, and is predicted to grow 42% from 2017 to 2040. It is further reported that in 2016, aviation was accountable for 3.6% of the total EU28 greenhouse gas emissions and for 13.4% of the emissions from transport. Noise from the 47 major European airports is considered to show potential stabilisation according to (European Environment Agency, 2019), but under the assumption that population change or expansion of airports has not occurred. Emissions such as Oxides of Nitrogen ($\mathrm{NO_x}$) and Carbon Dioxide ($\mathrm{CO_2}$) are estimated to increase by 16% and 21% respectively.

Carlsson & Hammar (2002) presents two types of aviation emission reductions that had often been mentioned by politicians when presenting new regulations.

- Reduce number of flights
- Reduce the emissions per flight

The first can be achievable by reducing the amount of passengers, increase the seat capacity and increase the load factors. The reduction of emissions however, depends on the fuel and the responsibility for aviation emissions at an international level belongs to the International Civil Aviation Organization, ICAO (Carlsson & Hammar 2002). What could be a solution to the different fuels being used by aviation is to implement a potential fuel taxation but there are still obstacles in the shape of Agreements that prohibit taxation of fuel since taxation of aviation fuel that is on an aircraft when landing in a jurisdiction is not allowed according to the ICAO 1944 Chicago Convention article 24 (International Civil Aviation Organization, 1944).

The Convention on International Civil Aviation is known as the Chicago Convention. It was established in 1944 and signed by 52 states on December 7 the same year. The Chicago Convention resulted in the creation of the above mentioned International Civil Aviation Organization (ICAO) with the goal to secure co-operation between countries and to establish regulations and standards for the civil aviation industry. There are 193 member states represented in ICAO and thus these member states get exposed to current and also new developed standards and recommendations of international aviation.

As the international barriers are described as obstacles, this paper will further continue the analysis to investigate a potential fuel tax applicable to the member states within the European Union, which exempts other international carriers to be subjects for such a tax. As the European Union already has established the described Emissions Trading Scheme in the next paragraph, a potential fuel tax, if affecting the fuel demand in the desirable direction, could be considered a complement.

2.5 The Emissions Trading Scheme

The Emissions Trading Scheme [ETS] of the European Union is the world's first international trading system and was set up in 2005. The main idea of ETS is that participants are allocated permits that give them the right to generate a certain level of emissions. The trading scheme covers 45% of the greenhouse emissions in the European Union. The emissions trading scheme is described with the "cap and trade" principle. The cap of the aviation industry has been separately calculated. A cap is set on the total amount that can be emitted, in this case, by the aviation industry. Within this cap, companies can receive or buy emission allowances meaning that, if a participant reduces emissions below the level they allocate, then they can sell the excess permits to other participants. This sort of trading ensures that emissions are cut where it costs least to do so and a robust carbon price promotes investments in clean, low-carbon technologies (European Commission, 2015*b*).

Although ETS is limited to the European Economic Area, the global progress has been a fact and in October 2016, the International Civil Aviation Organization agreed on, what is called, CORSIA [Carbon Offsetting and Reduction Scheme for International Aviation] to address CO2 emissions. Participation is voluntary for states in the first phases but all EU countries will join from the start. It is reported that ICAO continues to develop implementation rules and tools to make it even more operational for states. However, the operation of CORSIA will ultimately depend on national measures to be developed and thus enforced at domestic level. One conclusion is that the international implementations are depended on the national policy of each country (European Commission, 2015*b*). CORSIA will be adopted in 2021 and will be a three-year compliance period where airlines will be required to:

- Monitor emissions on the international routes and, after the three-year period, offset any increased CO2 emissions above the baseline level.
- Purchase eligible emission units generated by projects that reduce the emissions in other sectors meaning renewable energy.

Based on a baseline level, the scheme of CORSIA is intended to offset the annual increases in CO2 emissions. The baseline level was intended to be an average of the emissions for the years 2019 and 2020. However, one cannot neglect the dramatic impact COVID-19 has had in the global aviation industry and thus the potential impact the COVID-19 crisis could have on CORSIA and other political debates should briefly be discussed.

Reuters reported that, on January 23, the number of flights that departed from or landed in Europe exceeded 20 000. Two months later, Europe was marked by travel restrictions and the number of flights dropped to less than 5000 per day (Thomson, Reuters, 2020). As a result, The International Air Transport Association [IATA] forecasts a 314 billion dollar drop in airline passenger revenues due to the crisis of COVID-19 and furthermore a 48% drop in passenger demand is expected in the year of 2020 (Pearce 2020). With 25 million jobs at risks within the aviation industry one can consider it likely that COVID-19 causes some delays in the environmental establishments and discussions.

For CORSIA the defined baseline, with the average emissions of 2019 and 2020, will be problematic to confide in. The average result, based on the reports provided in the precious section, is expected to be unrepresentative. With no delay in CORSIA, the potential baseline being used could be predicted to result in an increased offsetting fulfillment which in turn could potentially put pressure on airlines, experiencing a current liquidity crisis. Continued establishment of CORSIA can, on the one hand, be seen as favorable to the environment, but, on the other hand, it can also create conflicts of interest and unwanted gaps between the parties that must work together to achieve the environmental goals.

The conflict of interest caused by the crises will most likely include debt service, shareholder value and environmental credentials and it is evident that the political fuel-tax debate could potentially be interrupted. However, up to this date, the exact effects of COVID-19 remains unclear and due to the lack of published data, this paper will not include the years of 2019 and 2020 in our regression model and this drawback will not be further discussed.

3 Method

This section describes the method used in the thesis to be able to answer the research questions. The procedure is demonstrated through explaining general equations, the models used in the thesis, data and variable selections, the limitations and the expected results. The procedure of the method is carried out in order to facilitate the interpretation of the calculated results.

3.1 Empirical framework

A quantitative study has been selected for the purpose of conducting a statistical study in order to calculate elasticities in a regression model. The Ordinary Least Squares (OLS) via Stata, is an instrument that analyses and estimates the relationship between the dependent variable and the independent variables. Similar studies on aviation fuel tax such as Fukui & Miyoshi (2017) have used the Ordinary Least Squares (OLS) as an instrument to calculate elasticities and effects of a tax implementation.

When calculating the regression in Stata, all the independent variables will be illustrated and the beta values will demonstrate how much an increase in the independent variables will affect the dependent variable. The Beta values will either have a positive or negative value illustrating the slope of the coefficient.

Furhter, as mentioned earlier in this thesis, a potential tax could, not only potentially reduce fuel consumption, but also reduce the amount of air travel. This thesis will consequently present three regression tables, with Jet Fuel as the dependent variable in the first and second regression and Total Passenger Carried as the depended variable in the third one.

The first two regressions which equations are visualized in equation (2) and (3) differ with one variable. The reason for excluding "EUpassengerkm", in the first regression and hence include the variable in the second, is due to the potential effect of a tax on air travel. One can therefore find it reasonable to measure the effect both with and without this particular variable. Again, the "EUpassengerkm" variable is excluded from the third regression as it appeared, from the first trial, to be a close correlation with the depended variable "Totalpassengercarried" and hence the two measure almost the same thing.

The models used for calculating the regressions and implementation of the jet fuel tax are following:

$$\begin{aligned} log(JK_i) = \alpha + \beta_1 log(P_{i-1}) + \beta_2 log(P_{i-2}) + \\ \beta_3 log(P_{i-3}) + \beta_4 log(GNI_{i-1}) + \\ \beta_5 log(PKM_i) + \beta_6 log(UE_i) \end{aligned} \tag{2}$$

$$\begin{aligned} log(JK_i) = \alpha + \beta_1 log(P_{i-1}) + \beta_2 log(P_{i-2}) + \\ \beta_3 log(P_{i-3}) + \beta_4 log(GNI_{i-1}) + \\ \beta_6 log(UE_i) \end{aligned} \tag{3}$$

$$\begin{aligned} log(TOTP_i) = \alpha + \beta_1 log(P_{i-1}) + \beta_2 log(P_{i-2}) + \\ \beta_3 log(P_{i-3}) + \beta_4 log(GNI_{i-1}) + \\ \beta_6 log(UE_i) \end{aligned} \tag{4}$$

$$\text{Changes in tax rate (\%)} = \frac{\text{Fixed average fuel price}}{\text{Fixed average fuel price + Tax level}} \tag{5}$$

The dependent variable in both of the regressions is JK(Jet Kerosene consumption) and TOTP(Total passenger carried in the European Union). P is the average jet fuel price, GNI is the Gross national income per capita in the European Union, PKM is the calculated total passenger kilometer flown in the European Union, UE is the unemployment rate in the European Union.

All the variables in the regression models have been transformed into the logarithmic variables in order to easier compare and understand the results. When using logarithmic values on both sides of the equations (2) and (4) results in a econometric model called the Log-Log model. The Log-Log model demonstrates the elasticity meaning it shows the relative changes from the coefficients and is helpful when the correlation between the parameters is non-linear. In real terms a 1% change in a coefficient would result in Y% change in the dependent variable. Equation (5) illustrates the calculation for the percentage changes in tax rate which is used for implementing the tax. A fixed average fuel price have been calculated by taking an average fuel price between the observed years and the tax level is added on the fixed average fuel price to be able to perform the calculation.

3.2 Data

In some of the data fluctuations are observed, what could explain this fact is the all-time high reached in 2008, a huge annual fall in 2009 and only a temporary recovery in 2011. Only from 2014 have the number of flights returned to a steady growth. What has grown even faster are the passenger numbers, which was, at a European level, 50 percent higher in 2017 than in 2005 (European Environment Agency, 2019).

The 9/11 terrorist attack in 2001 had a negative worldwide impact on the aviation industry where in the article from Fukui & Miyoshi (2017), the 9/11 attack is used as a dummy variable in their regression. They describe the September 11 attack as a variable that "caused extensive flight disruption" in the US and the effects did spread globally and also affected the European aviation market. Harumi Ito and Darin Lee wrote about the global impact from the September 11 attack (Ito & Lee 2005), and the effects are complex and look different between countries. In Europe it had a middling negative impact that depended partly on the high sensitivity risk among European travelers but also the alternative travelling methods available within Europe. But, the use of a dummy variable in this thesis is not considered necessary since there is no major deviating effects in the extracted data set.

3.3 Variables

Finding accurate data variables for the regressions is difficult since variables are in different units. The variables are collected from various international data sources and are necessary in order to run the regression without overfitting the model. The data presented in this section is illustrated in appendix A (7) and appendix B (8) presented in the end of the thesis.

Jet Kerosene consumption is the data variable in which the regression is computed for and extracted via "International Energy Agency" (International Energy Agency, 2019). Yearly Jet Kerosene consumption in Kilotons is shown and was difficult in this thesis to interpret because yearly jet kerosene consumption is very large within the European union. Since it is total consumption of jet kerosene it includes both commercial and private flights which affects the precision. By distributing the data more precisely over the including sectors would result in a more precise regression but it would both be hard to calculate and time consuming because of the large data.

Unemployment rate within Europe is extracted from "Eurostat" (Eurostat 2020*b*), which contains monthly data on "Unemployment rate" from countries in Europe. The available data is limited because of differences between registrations of unemployment rate data within Europe. These limitations have affected the way of calculating the annual average and may have an impact on the regression. From 1998, there is summarized calculated monthly data from the existing 25 country members of the European Union which facilitates the production of data and more members have joined the European union which adds up to 28 member countries with existing data. Prior to 1998 was there no existing summarized monthly data for the European Union and an average had to be calculated for countries within Europe with registered data. The target group is the unemployed as a percentage of the active population in a country.

Passenger carried is extracted from "The World Bank" (World Bank Group, 2019*a*) and contains numbers of passengers carried in the European Union. It is a large data set and not fully accurate because of different variables difficult to control for. The passengers carried in the European Union can both be European and international passenger with unknown origin and destination which may result in misleading data due to an excess of registered passengers. The optimal alternative would be data over passenger carried that has their origin and destination within European Union in order to screen off stopovers and most of the international passengers. By having the optimal data, the regression that is intended for Europe would be the most accurate and credible.

GNI per capita for the European Union is a measurement of income and is included in the regression since income affects people's intentions to buy a flight ticket. The GNI per capita is in constant US dollar prices from 2010 and is extracted from "The World Bank" (World Bank Group, 2019*b*). The usage of constant prices from 2010 is to adjust for the effects a price inflation could have. The variables are in logs and lagged in the regression, mentioned above are in logs because of the relative change calculations. People's intention to buy a flight ticket vary greatly with their income and since an annual GNI per capita is extracted, the variables are lagged one year because the hypothesis of what income people have one year earlier affects the amount of flight tickets they can buy the following year.

The average jet fuel price per month extracted from "US energy information administration" (Reuters 2020) is in US dollar per gallon[1] and recalculated into annual average in order to fit as a dependent variable into the regression. The available data for the average jet fuel price is limited and fluctuate with oil prices, because of the international agreements regarding no tax on jet fuel and contract prices between supplier and carrier. The contract prices between supplier and carrier can differ from the spot prices depending on the agreements between the parties and these prices is not available for the public. The prices available is in US dollar per gallon and one reason could be that the price for oil depends a lot on the supply of oil that the US offers and the US economy. Mazraati (2010) explains that, in all international markets, jet fuel prices are highly correlated and the US jet fuel price is therefore considered to hold for our region of interest, the European union.

In previous research, such as the one perfomed by (Shi et al. 2020), The variables are in logs for the usage of relative changes and lagged three times to control for hedging made by the carriers. In the same research, it is further explained that hedging by the carriers are made in order to control for the volatile jet fuel prices (Shi et al. 2020). The variation in price for jet fuel in short terms of a few months and even one to three years is difficult for carriers to hedge for because of their routes are relatively fixed. The investment in new technologies and equipment's does not signify any direct results, the results usually appears after a few years and this strengthen the use of lagged variables. The usage of price variables in logs is also to control for price endogeneity caused by reversed causality (Fukui & Miyoshi 2017), which means an augmentation in fuel consumption can lead to an augmentation in fuel prices. Therefore, a direct effect

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[1] 1 Litre = 0,264172 Gallons or 1 Gallon = 3,78541 Litres

on jet fuel prices will not have the same impact while using variables in logs, which results in a more realistic regression.

Data for **the total passenger kilometers** flown in the European Union is limited and has been calculated and extracted from Both "Eurostat"(Eurostat 2020*a*) and a cliamte Study within air travel from (Kamb & Larsson 2019). Extracted and calculated from "Eurostat" is the Percentage of passengers carried by the European Union in relation to the world. Using the European Union percentage of passenger carried and multiplying variables for each year with the million passenger kilometers extracted from (Kamb & Larsson 2019). Results after calculations is the variable total passenger kilometers flown in the European Union which is used as a logged variable in the regression. The limited data available can affect the precision in the regression because the percentage of passenger carried for the European Union may not fully reflect the total passenger kilometers flown since the length of a flight in kilometers differentiates between continents.

The tax level of choice is based on the work of (Keen & Strand 2006), in which the environmental damage has been assessed in order to find the corresponding tax. The optimal level according to the study is 20 US cents per gallon and this quantification required a large data collection, such as environmental damage of the aviation industry and the impact on the aviation market of an introduced fuel tax to find that optimal rate (Keen & Strand 2006).

However, while the estimations of the recent study are considered to cover the environmental damages, one need to consider the more recent fuel-tax levels proposed by the European Union. In July 2019, the European Commission released a working document in which a lower limit of taxation is set at 33 euro cents per litre (European Commission, 2019). As the decision will be made by the EU it can be considered likely that the 0.33 cent will be most applicable in reality. The converted tax rate to dollars per gallon is 1.4115[2], which can be considered substantially higher than the 0,20 cent per gallon. One explanation to the discrepancy, between the two levels suggested, could be due to that Keen & Strand (2006) did not account for necessary tax revenues in addition to the environmental correspondence. This study will therefor examine both tax

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[2] Calculation is as follow for the convertion: 0.33 Euro * 3.785 (Litre to Gallon) = 1.2491 * 1.13 (1 EUR = 1.13 Dollar per 2020-06-09) = 1.4115

levels as it will enable further conclusions regarding fuel demand and thus the calculated elasticity.

3.4 Limitations

The area of taxation within the aircraft industry is wide, meaning what is discussed and analysed in this thesis is limited in relation to other solutions and hence limitations have been necessary in order to carry out the desired analyzes.

The climate science aspects is briefly discussed in the thesis in relation where the consequences an implementation of fuel tax would have on CO2 emission will be mentioned. What will not be mentioned are other consequences airplanes have on the environment such as the non CO2 effects on high altitude, discussed widely in the report from (Kamb & Larsson 2019) or the noise level aircrafts makes around airports widely discussed in the environmental report from "European Union aviation safety agency" (European Environment Agency, 2019). Technological advances are not taken into account to a great extent but are only mentioned as a factor of interest contributing to the reduction in fuel consumption. Overall, the climate impacts from the different factors are discussed and analysed on an economic level meaning that the variables will be analysed in relation to their economic effects but not how the potential effects will be disposed in society in terms of real money.

Discussed and shown in the European Commission report (CE Delft, 2019) are several different tax policies beyond an aviation fuel tax. These tax policies is briefly mentioned in this thesis but will not be analysed in depth. Furthermore, the usage of the tax revenues from existing taxation and for the desired tax on aviation fuel will neither be discussed in depth.

The main focus for the thesis is the European Union with examples and cross-references from other international countries outside the European Union. Mentioned in the thesis is the requirement for bilateral agreements (International Civil Aviation Organization, 1944) between countries in order to implement the aviation fuel tax and no other emphasis will be placed on how the agreements are to be executed or if there are existing bilateral agreements today and how they are designed. The thesis assumes that implementation of these bilateral agreements is conceivable.

The observations in the regressions is restricted to EU level meaning that the observations in the regression is not extracted from every EU country itself but compiled into one variable. The reason for a compiled variable is because of the limitations in the available data from each EU country independently. The results from a compiled variable are the few variables used in the regressions.

3.5 Expected Results

When evaluating the variables included in our model we can expect some results based on the different economic theories behind them. According to Mazraati (2010), the demand of fuel depends on the aviation service demand which depend on the economic situation. In our model we have included GNI per capita due to the reason that peoples income effect, affect the purchasing power of consumers and their will to spend money as a better economic situation increases the demand for air travel (Mazraati 2010). When individual income increase, so does GNI per capita and as a result it is expected that the demand for air travel increases and thus the aviation industry's demand for fuel. It is expected to be a positive correlation between GNI per capita and fuel consumption.

It is also expected that the unemployment rate and fuel price will be negatively correlated with fuel demand and passengers carried. The unemployment rate should have a negative correlations since unemployment affects people's income which usually infer a smaller amount of air tickets purchased. The fuel price is expected to have a negative sign since an increase in fuel price is expected to have a negative correlation with the demand of fuel and thus also fuel consumption. As fuel price increase it is expected to have a negative correlation with passenger carried because the higher fuel price would intend higher ticket prices and result in less passenger carried.

When including the "EUPassengerkm", one can expect it to possibly be a positive correlation with the fuel consumption since, when the total passenger kilometers increases so does the fuel consumption. When not including the "EUPassengerkm" variable, one can expect that it might occur some different correlations in the other variables that are included in both regressions i.e. the correlations might not be identical.

The signs for the tax level on 1.4115 US dollar per gallon presented from (European Commission, 2019) and 0.20 US dollar per gallon presented from (Keen & Strand 2006) are expected to be different, where the higher tax on 1.4115 US dollar is expected to have a greater impact on the results.

4 Results

In this section, the results are presented from the regressions and tax calculations. First the results from the regression equations (2), (3) and (4) are presented in the tables (1), (2) and (3). Second, the results from the implementation of tax rate equation (5) are presented in the tables (4), (5) and (6).

4.1 Regression Results

To analyse the effect of a jet fuel tax implementation, regressions are made in three steps from equation (2), (3) and (4). First, the regressions are calculated on the dependent variables "Jet Kerosene Consumption" and "Total Passenger Carried in the European Union". As mentioned in the variables section, the dependent variables are logged in order to calculate the relative changes. Furthermore, the tax rate is implemented on the fuel price to calculate for the changes a tax would entail based on the regression results.

Table 1: Regression on Jet Fuel without variable "EUpassengerkm"

VARIABLES	ConsumptionJetKerosene(log)	ConsumptionJetKerosene(log)
Averagefuelprice(log)(i-1)	-0.12207***	-0.03473
	(0.00685)	(0.53688)
Averagefuelprice(log)(i-2)		-0.00202
		(0.97718)
Averagefuelprice(log)(i-3)		-0.11825**
		(0.02584)
GNIpercapita(log)(i-1)	1.42565***	1.49668***
	(0.00000)	(0.00007)
Unemployment rate	-0.02613	-0.02510
	(0.11037)	(0.15590)
Constant	-5.71766**	-6.45901*
	(0.02602)	(0.05332)
Observations	27	25
R-squared	0.74896	0.80712
Adjusted R-squared	0.716	0.756
Prob > F	0.0000	0.0000

p-values in parentheses, ***P<0.01, **P<0.05, *P<0.1

Table 2: Regression on Jet Fuel with variable "EUpassengerkm"

VARIABLES	ConsumptionJetKerosene(log)	ConsumptionJetKerosene(log)
Averagefuelprice(log)(i-1)	-0.11268**	-0.02379
	(0.01695)	(0.64924)
Averagefuelprice(log)(i-2)		-0.00028
		(0.99652)
Averagefuelprice(log)(i-3)		-0.15506***
		(0.00520)
GNIpercapita(log)(i-1)	0.79510	0.02903
	(0.39724)	(0.97038)
EUPassengerkm(log)	0.18018	0.51966*
	(0.48665)	(0.05682)
Unemployment rate	-0.02669	-0.01031
	(0.10796)	(0.55924)
Constant	-3.73616	-4.51452
	(0.32453)	(0.15702)
Observations	27	25
R-squared	0.75455	0.84320
Adjusted R-squared	0.710	0.791
Prob > F	0.0000	0.0000

P-values in parentheses, ***P<0.01, **P<0.05, *P<0.1

Based on the regression from table (1), the Average fuel price, laged by 1 year in column 1, is statistically significant and appear to have a negative impact on jet kerosene consumption. The result suggest that the short-run price elasticity of jet fuel consumption is -0.12207, i.e. a one percent increase in the average fuel price decreases the jet fuel consumption the following year by approximately 0.12%. Column 2 in Table 1 report the results from the distributed lag model. As mentioned, similar to the previous research of (Fukui & Miyoshi 2017), the distributed lag model is intended to estimate the long-run price elasticity of fuel consumption. As presented in the results of column 2, the average fuel price is negatively correlated with the fuel consumption by -0.03473, -0.00202 and -0.11825 for year one, two and three respectively. if the average fuel price constantly increase with 1%, the estimated long-run price elasticity is -0.155(= -0.03473 -0.00202 -0.11825). Hence, given a permanent one-percent increase in fuel price, fuel consumption decreases by approximately 0.15% after three years, if the elasticity is statistically significant.

From the results displayed in table (2), where the dependent variable is ”ConsumptionJetKerosene(log)” and ”EUPassengerkm” is included, the coefficient ”average fuel price” has a negative impact on the jet fuel consumption. In table (2) column 1, the Average fuel price lagged by one year is statistically significant. The short-run price elasticity of jet fuel consumption is -0.11268, i.e., a one-percent increase of jet fuel price leads to a decrease of jet fuel consumption by 0.11268%. Column 2 in Table (2) report the results from the distributed lag model. This regression is also, similar to table (1), intended to estimate the long-run price elasticity of fuel consumption. The fuel demand is negatively correlated with the average fuel price, if it constantly increase with 1%, by -0.02379, -0.00028, -0.15506 for year one, two and three respectively. Hence, the estimated long-run price elasticity is -0.17913(= -0.02370 -0.00028 -0.15506). Given a permanent one-percent increase in fuel price, fuel consumption decreases by approximately 0.18% after three years, if the elasticity is statistically significant.

Neither in table (1), nor in table (2) are the one and two year lagged variables in column 2 statistically significant. One possible explanation is that the OLS regression show the average relationship between the different variables and that the price elasticity varies substantially due to hedging and that all the carriers are summed into one in this study, which results in a limited aspect of the price effect. Another possible explanation to the insignificant lagged variables is that multicollinearity might exist between the three variables and as a result the effect of each lag might be difficult to obtain.

When further analyzing the additional variables included in the two regressions, the lagged variable for one year ”GNI per capita” has the expected positive sign, which could mean that an increase in income one year could result in a higher consumption of aviation fuel the year after. The variable is statistically significant in table (1) which the conclusion drawn above is based on. However, when including the ”EUPassengerkm” in table (2) it is not statistically significant. One possability to this is that any variance that can be explained by ”GNI per capita” can be expressed merely by C and thus, no further conclusions can be made from the particular variable. The total passenger kilometers flown in the European Union is the variable that discerns the two tables (1) and (2), where the variable is not included in table (1). This, because of the intentions behind the fuel tax to reduce air travel and therefore it is important to see results both with and without the variable ”total passenger kilometers”. The variable has the expected positive coefficient and is statistically significant in table (2) column 2, meaning that the jet fuel consumption increases as more people fly. The unemployment rate has a negative impact on the jet fuel consumption which entails that an increase in unemployment results in less traveling and hence less jet fuel consumption. However, the unemployment rate variable is not statistically significant and thus, further conclusions will not be drawn other than that the variable had the expected sign. The lack of significance could suggest that the model is not properly specified although we do consider it to be since the model as a whole is significant.

When observing the regression and its observations one have to consider the coefficients of determination (R-squared and adjusted R-squared) which presents how much the variance of the dependent variable is defined by the independent variables. The Adjusted R-square is a modified version meaning that it is adjusted for the number of terms in a model which gives the regression an output on how useful the variables are. The regressions results illustrates a R-square and adjusted R-square results in table (1) of 0.74896, 0,716, 0.80712 and 0.756 respectively. furthermore, in table (2), 0.75455, 0.710, 0.84320 and 0.791 respectively which indicates that the variance is partly explained by the independent variables and marginally larger in table (2) than in table (1). The F value of 0.000 in the two tables, illustrates that the group of independent variables together is statistical significant and statistical conclusions can be drawn from the models as a whole.

Table 3: Regression on total passenger carried

VARIABLES	Totalpassengercarried(log)
Averagefuelprice(log)(i-1)	-0.08547
	(0.14255)
Averagefuelprice(log)(i-2)	-0.00622
	(0.93056)
Averagefuelprice(log)(i-3)	0.12366**
	(0.02180)
GNIpercapita(log)(i-1)	3.05104***
	(0.00000)
Unemployment rate	0.00505
	(0.77201)
Constant	-11.87593***
	(0.00137)
Observations	25
R-squared	0.97627
Adjusted R-squared	0.970
Prob > F	0.0000

P-values in parentheses, *** p<0,01, ** p<0,05, * p<0,1

The regression result based on the dependent variable "Total passenger carried in the European union" is presented in the table (3). The lagged variables for average fuel price on one and two years have both a negative impact on the total passenger carried whilst the lagged variable for three years have a positive impact on the total passenger carried meaning, a 1% change in the average fuel price for lagged year three would result in a 0.12366% increase in total passenger carried three year after the increase. The lagged variable for three year is statistical significant at level "P<0,05" whilst there is no statistical significance for year one and year two, therefore no statistical conclusions will be made from the lagged variables of the second and third year.

The GNI per capita have a positive impact on passenger carried meaning an increase in people's income (lagged for one year) results in an increase in the numbers of passengers carried and the variable is statistical significant at level "P<0,01". The unemployment rate is statistically insignificant meaning no statistical conclusions will be drawn but from the result it is interpreted as a variable which coefficient has a positive sign on total passenger carried, entailing that as the unemployment rate increases the total passengers carried will augment.

The regression includes the observations as the first regression from table (1) but the differences is noticeable in the adjusted R-squares where both the original R-square and adjusted R-square explained previously are marginally higher in table (3) than in (1) and (2). This indicates a more specific model with smaller differences between the fitted values and the observed data. Here, the F-value of 0.0000 illustrates same as in table (1) and (2) where the independent variables in our regression together is statistically significant and a statistical conclusion can be drawn from the model as a whole .

4.2 Aviation Fuel Tax Effect

Table 4: **Aviation fuel tax effect on jet fuel consumption without variable "EUpassengerkm"**

Variable	**Jet Kerosene consumption (log)**	**increase of tax(%)**	**Estimated elasticities after tax (log)**	**Decrease in Jet Kerosene consumption (%)**
Average fuel price (log)(i-1)	-0.03473 (0.05522)	12.61 [50.46]	-0.03911 [−0.05225]	-0.43795 [−1.75248]
Average fuel price (log)(i-2)	-0.00202 (0.06961)	12.61 [50.46]	-0.00227 [−0.00304]	-0.02547 [−0.10193]
Average fuel price (log)(i-3)	-0.11825** (0.04891)	12.61 [50.46]	-0.13316 [−0.17792]	-1.49113 [−5.96690]
GNI per capita (log)(i-1)	1.49668*** (0.29487)	-	-	-
Unemploymentrate	-0.0251 (0.01699)	-	-	-
Constant	-6.45901* (3.13481)	-	-	-
Observations	25			
R-squared	0.80712			
Adjusted R-squared	0.756			

Standard errors in parentheses, *** p<0,01, ** p<0,05, * p<0,1
European minimum tax (0,33 Euro) converted to USD per gallon in brackets "[ ]"

Table 5: **Aviation fuel tax effect on jet fuel consumption with variable ”EUpassengerkm”**

Variable	**Jet Kerosene consumption (log)**	**increase of tax(%)**	**Estimated elasticities after tax (log)**	**Decrease in Jet Kerosene consumption (%)**
Average fuel price (log)(i-1)	-0.02379	12.61	-0.02679	-0.29999
	(0.05143)	[50.46]	[−0.03579]	[−1.20044]
Average fuel price (log)(i-2)	-0.00028	12.61	-0.00032	-0.00353
	(0.06449)	[50.46]	[−0.00042]	[−0.01413]
Average fuel price (log)(i-3)	-0.15506***	12.61	-0.17461	-1.95531
	(0.04879)	[50.46]	[−0.23330]	[−7.82433]
GNI per capita (log)(i-1)	0.02903	-	-	-
	(0.77111)			
Total passenger km (log)	0.51966*	-	-	-
	(0.25533)			
Unemploymentrate	-0.01031	-	-	-
	(0.01734)			
Constant	-4.51452	-	-	-
	(3.05701)			
Observations	25			
R-squared	0.84320			
Adjusted R-squared	0.791			

Standard errors in parentheses, *** p<0,01, ** p<0,05, * p<0,1
European minimum tax (0,33 Euro) converted to USD per gallon in brackets “[ ]”

The result of a tax effect on Jet Kerosene consumption are presented in tables (4) and (5) and contains the regression results from the tables (1) and (2) but with standard errors instead of the p-values to demonstrate the accuracy of the coefficients in other terms. The increase of both taxes presented in the tables are calculated via equation (5) and is imposed on the average jet fuel price[3]. The estimated elasticities after tax are negative for the lagged variables at both tax levels in the tables (4) and (5). The percentage decrease in Jet Kerosene consumption[4] demonstrates in real terms the difference that the tax implies. To interpret the percentage decrease in jet kerosene consumption we

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[3] Calculations for the estimated elasticities after tax: Average fuel price * (1 + imposed tax)

[4] The decrease in Jet kerosene calculation: ((Estimated elasticities after tax (logged) - Jet Kerosene consumption) * 100)

consider the significant three year variable in table (4) without the variable ”EUpassengerkm”, where an imposed tax of 0.20 dollar per gallon would in real terms have a declining effect of approximately -1.49% on fuel demand. Considering the same significant variable, with an imposed tax suggested by the European Union, at 1.4115 dollar per gallon would in real terms have a declining effect of approximately -5.97% on fuel demand. In addition, an interpretation of the significant three year variable in table (5) is also made, with the variable ”EUpassengerkm”. This to illustrate the difference in tax effect between the tables as one of the intentions behind a tax is to reduce air travel and the variable ”EUpassengerkm” can be considered as a measurement of that. An imposed tax of 0.20 dollar per gallon would in real terms have a declining effect of approximately 1.96% on fuel demand. With the same significant variable considered, an imposed tax, suggested by the European Union, at 1.4115 dollar per gallon would in real terms have a declining effect of approximately -7.82% on fuel demand.

Table 6: **Aviation fuel tax effect on total passenger carried**

Variable	**Total passenger carried EU (log)**	**increase of tax (%)**	**Estimated elasticities after tax (log)**	**Decrease in total passenger carried EU (%)**
Average fuel price (log)(i-1)	-0.08547 (0.05587)	12.61 [50.46]	-0.09625 [−0.12860]	-1.07778 [−4.31282]
Average fuel price (log)(i-2)	-0.00622 (0.07044)	12.61 [50.46]	-0.00700 [−0.00936]	-0.07843 [−0.31386]
Average fuel price (log)(i-3)	0.12366** (0.04949)	12.61 [50.46]	0.10807 [0.06126]	-1.55935 [−6.23988]
GNI per capita (log)(i-1)	3.05104*** (0.29836)	-	-	-
Unemploymentrate	0.00505 (0.17192)	-	-	-
Constant	-11.87593*** (3.17193)	-	-	-
Observations	25			
R-squared	0.9763			
Adjusted R-squared	0.9700			

Standard errors in parentheses, *** p<0,01, ** p<0,05, * p<0,1
European minimum tax (0,33 Euro) converted to percentage change in USD per gallon in brackets "[ ]"

The tax effect on total passenger carried is presented in table (6) and contains regression result from table (3) and the tax calculated from equation (5). The standard errors is presented as in table (4) and (5) to demonstrate the accuracy of the coefficients and the tax rate is imposed on the three lagged variables for average fuel price[5] to be able to calculate the impact a fuel tax entails.
Elasticity expresses the percentage change in demand (Frank 2016), in this case it expresses the percentage change in demand for fuel when applying a tax. The estimated elasticities for both taxes have increased negatively for the lagged first and second year variables. Furthermore, both tax levels have an estimated elasticity which is positive for the lagged variable three years. The Decrease in total passenger carried shows that both of the potential tax levels have the greatest impact on the positive lagged variable for three year. When considering

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[5] The calculated estimated elasticities after tax: Average fuel price * (1 + imposed tax), exceptions for lagged variable on three years with: Average fuel price * (1 - imposed tax)

the significant lagged variable on three year in table (6), the decrease, in real terms, in total passenger carried will approximately be -1.56% when imposing a tax on 0.20 dollar per gallon and approximately -6.24% when imposing a tax suggested by the European Union on 1.4115 dollar per gallon. For the lagged variable one year there is a decrease in total passengers carried with approximately -1.08% with tax level 0.20 dollar and approximately -4.31% with tax level of 1.4115 dollar per gallon. The lagged variable on two years will have a decrease in real terms of approximately -0.08% with an imposed tax of 0.20 dollar per gallon and approximately -0.031% with an imposed tax of 1.4115 dollar per gallon. However, the first and second year lagged variable are statistically insignificant and no further conclusions can be drawn.

5 Discussion

The purpose with this paper was to examine the potential effects a fuel tax, in the European Union, would have on the aviation industry's demand for fuel and if the tax could be used as a tool to navigate aviation into a direction that would benefit the environment. The results presented confirm that a connection exist between the dependent variables and a potential fuel tax. Which was expected based on the facts behind a potential tax.

As mentioned, one way to affect the environmental impact of aviation, according to (Carlsson & Hammar 2002), is to reduce the number of flights by reducing the amount of passengers. In addition, it is possible that a tax also affect the fuel demand directly as it is added to the costs of the companies. Therefor it was important to examine our data in different regressions to minimize the risk of including variables that measures the same effect of a tax. Our results supports that suggestion as the total passenger kilometers flown in the European Union has a positive correlation with fuel demand, and thus, policy makers is not wrong by continuing to focus on reducing the passenger kilometers by reducing the amount of passengers. This can be achieved with global policy intervention, mentioned by the IPCC, to support R&D within the aviation industry which can lead to development within technology and design, mentioned in the European Aviation Environmental Report, where seat capacity and load factors can be developed and more passengers could potentially be carried in each airplane (CE Delft, 2019). The results also show a more direct affect on fuel demand without the variable "EUPassengerkm" included, and one can conclude that a potential tax still has an effect on fuel demand.

The results of our study with regard to what role a potential fuel tax on aviation has on reducing the demand for fuel and hence reducing emission suggests that a fuel tax most likely contributes to reducing the two. However, it is important to note that the size of the sample is small and limited. It could on one hand be argued that the effectiveness of a fuel tax is not impressive but on the other hand it is important to remember that it does not exist a single silver bullet that control the fuel consumption or the emissions. The suggested tax by Keen & Strand (2006), 0,20 dollar per gallon, had a lower impact on both fuel demand an passengers carried than the 1.4115 dollar tax level, suggested by European Commission, (2019). The conclusion that can then be drawn is that if a greater effect on demand is desired, the higher tax rate should be implemented.

In the discussion regarding the effects of the different tax levels, one should consider the elasticities and conclude if the demand being studied is elastic or inelastic. When the elasticity is negative, a price increase leads to a decrease in demand, however, the demand for a good is considered inelastic if its elasticity exceeds -1 (Frank 2016). All elasticities in this paper meets the requirement for inelasticity and thus, fuel demand could be considered difficult to affect through a tax implementation. Despite this fact, it is evident that the higher the tax the more it affects our dependent variables and for that reason a potential fuel tax can be considered to contribute in reducing the demand for fuel.

The decrease in fuel demand does not automatically imply that the emissions reduce, that the demand for bio-fuels increase and thus benefits the environment. One drawback is that a tax could increase the incentive for airlines to take a higher ticket price and continue with business as usual. However, This could decrease the amount of demand for travelling and as a result reduce the environmental impact indirectly. A second drawback is, if it is not implemented in all European States unanimously, then the statement regarding Keen & Strand (2006) regarding the tax competition could be a reality, which causes the taxes to be inefficiently low and as a result the incentive to invest in bio-fuels could potentially be nonexistent.

What will be crucial, as a potential tax shows a decrease in fuel demand, is the tax must be set at optimal level to fulfill the ultimate goal and as bio-fuel is considered to be substantially higher (International Renewable Energy Agency, 2017), then the tax must be set at a level that increase the incentive to invest in such. Another crucial component is the conflict of interest that appeared from the suggested revision on the tax exemption (European Commission, 2019). The goal of the potential fuel tax should be to benefit the environment by reducing the fuel demand, however, it should not adversely affect the competitiveness of the European aviation industry. Based on the regression results, the aviation industry's arguments presented by Bugault & Holger (2019), and other political statements, an implementation of this tax is recommended at a European level. This enables the European competitiveness to of aviation remain high and that a debate on an international fuel tax can continue.

What can be concluded is the direction of a potential fuel tax and what it could result in, which was the goal with the research. What is clear, even though with a small percentage impact, is that a tax would have a negative impact on the demand of fuel and thus contribute to a reduced environmental impact.

6 Further Research

This research concerns an important issue and one of the complex problems of the human pollution of the environment. Further research is necessary.

First, the negative impacts need to be clearly identified and how to quantify the external effects remains problematic. It could be useful to do a similar study as (Keen & Strand 2006) to further know if the 1.4115 dollar tax level is the optimum. If further research would be able to quantify the external costs in a distinct and reliable way then it could potentially strengthen one of the conclusion in this thesis; that a fuel tax is a potential positive tool, if implemented by all states, for the environment and the development of bio-fuels. It is also possible that such quantification would enable and encourage governments to apply a tax at a global level.

Second, given that data would be available, a complimentary study would be to suggest, where each carriers contribution to negative environmental impact could be examined. This, to determine if the elasticity depend on the size of the carriers and if the tax, as a result, would burden the smaller ones. In this suggested study, dummy variable for the ETS scheme, CORSIA and COVID-19 should be considered to further study the data before and after these events as well as to examine the interactions between average fuel price and the dummies. Thirdly and in addition to the second mentioned, an examination of how the market behaves quarterly would give a larger sample and thus, a more reliable result in the regression.

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8 Appendices

8.1 Data variables: A

Table 7: Appendix: A

YEAR	Jet Kerosene consumption (Kilo-Tonne)	Unemployment rate EU in (%)	GNI per capita EU (Constant 2010 US Dollar)
1990	4671	7	24247,14479
1991	4765	7,6	24673,27015
1992	4820	8,7	24865,38807
1993	4847	10,2	24632,01239
1994	4791	10,3	25123,77054
1995	4930	9,8	25742,59467
1996	5153	9,6	26223,7055
1997	5397	8,8	26907,50172
1998	6285	9,6	27643,59036
1999	6640	9,3	28492,09287
2000	6902	9	29547,03462
2001	6620	8,8	30085,20302
2002	6309	9	30261,22978
2003	6510	9,2	30454,16956
2004	6749	9,2	31223,79783
2005	7182	9	31733,67653
2006	7263	8,2	32839,26269
2007	7553	7,2	33647,82944
2008	7265	7,1	33666,41775
2009	6610	9	32300,14111
2010	6777	9,6	32988,20556
2011	6571	9,7	33683,35493
2012	6200	10,5	33437,27975
2013	6055	10,9	33362,96605
2014	6022	10,2	33750,26987
2015	6177	9,4	34338,32806
2016	6352	8,6	35031,88811
2017	6535	7,7	35986,68964

8.2 Data variables: B

Table 8: Appendix: B

Year	**Passenger carried, EU**	**Average fuel price (US dollar per gallon)**	**Passenger km, EU**
1990	157891000	0,7622	4,193941037E+10
1991	150528000	0,6083	3,548825775E+10
1992	164292000	0,5700	3,934899516E+10
1993	169958600	0,5292	4,290731261E+10
1994	182625300	0,4933	4,443671081E+10
1995	193536844,1	0,4942	4,616247236E+10
1996	213329200	0,6125	5,012326079E+10
1997	235129900	0,5608	5,521999114E+10
1998	245065100	0,4042	5,963463935E+10
1999	266190600	0,4958	6,511180131E+10
2000	288449342	0,8492	7,160093740E+10
2001	286388891	0,7242	6,884512298E+10
2002	287161373	0,6850	7,054876525E+10
2003	317807082	0,8258	7,726258427E+10
2004	347767674	1,1500	8,436280054E+10
2005	359471494	1,7092	9,433012478E+10
2006	390742949	1,9200	1,025974610E+11
2007	425646377	2,1300	1,123704707E+11
2008	427781328	2,9642	1,141497815E+11
2009	419908189	1,6608	1,078826841E+11
2010	442721426,2	2,1450	1,027081301E+11
2011	468821255,3	2,9983	1,080984928E+11
2012	465108860	3,0575	1,076619724E+11
2013	471018726,1	2,9242	1,085922305E+11
2014	490844607,8	2,6975	1,126121646E+11
2015	529467494	1,5267	1,213858297E+11
2016	565289154	1,2500	1,297215840E+11
2017	605233486	1,5625	1,391023775E+11

8.3 Summarized variable statistics

Table 9: Appendix:D

VARIABLES	**Obs**	**Mean**	**Std. dev**	**Min**	**Max**
ConsumptionJetKerosene(logged)	28	8.7124	0.1486	8.4491	8.9297
Averagefuelprice(logged)	28	0.0966	0.6755	-0.9059	1.1176
EUPassengerkm(logged)	28	25.0596	0.4165	24.2925	25.6585
GNIpercapita(logged)	28	10.3096	0.1265	10.0965	10.4909
Totalpassengercarried(logged)	28	19.5672	0.4251	18.8297	20.2211

8.4 Regression results

Table 10: Appendix:C

VARIABLES	**Totalpassengercarried(logged)**	**ConsumptionJetKerosene**
Averagefuelprice(logged)(i-1)	-0.06442*	-0.02379
Standard errors	(0.03280)	(0.05143)
T stats	-1.96376	-0.46254
P value	(0.06519)	(0.64924)
95% Confidence intervals	-0.13333 - 0.00450	-0.13185 - 0.08427
Averagefuelprice(logged)(i-2)	-0.00288	-0.00028
Standard errors	(0.04113)	(0.06449)
T stats	-0.07013	-0.00442
P values	(0.94486)	(0.99652)
95% Confidence interval	-0.08929 - 0.08352	-0.13577 - 0.13520
Averagefuelprice(logged)(i-3)	0.05282	-0.15506***
Standard errors	(0.03111)	(0.04879)
T stats	1.69755	-3.17831
P values	(0.10682)	(0.00520)
95% confidence intervals	-0.01255 - 0.11818	-0.25755 - -0.05256
GNIpercapita(logged)(i-1)	0.22589	0.02903
Standard errors	(0.49179)	(0.77112)
T stats	0.45933	0.03765
P values	(0.65150)	(0.97038)
95% Confidence intervals	-0.80732 - 1.25910	-1.59103 - 1.64909
EUPassengerkm(logged)	1.00031***	0.51966*
Standard errors	(0.16284)	(0.25533)
T stats	6.14293	2.03524
P values	(0.00001)	(0.05682)
95% Confidence intervals	0.65820 - 1.34243	-0.01677 - 1.05609

Table 10: (continued)

Unemployment rate	0.03352***	-0.01031
Standard errors	(0.01106)	(0.01734)
T stats	3.03214	-0.59501
P values	(0.00717)	(0.55924)
95% Confidence intervals	0.01030 - 0.05675	-0.04673 - 0.02611
Constant	-8.13290***	-4.51452
Standard errors	(1.94963)	(3.05701)
T stats	-4.17150	-1.47678
P values	(0.00057)	(0.15702)
95% Confidence intervals	-12.22892 - -4.03687	-10.93705 - 1.90801
Observations	25	25
R-squared	0.99234	0.84320
Adjusted R-squared	0.990	0.791
F test model	388.4	16.13
Prob > F	0.000	0.000

Standard errors and P-values in parentheses, *** p<0.01, ** p<0.05, * p<0.1