

# PROJECTING CO2 EMISSIONS IN AVIATION

A literature review of emission projection models and policy theory in the industry of commercial aviation.

Bachelor's Thesis  
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### **Abstract**

This thesis analyses studies and the models utilized in projecting environmental externalities in aviation, in the form of CO2 emissions. The thesis will be looking at demand forecasting in the aviation industry, as well as more closely analyzing two different models for projecting emissions. A discussion of possible policy solutions to address the externalities is also included. The thesis is conducted as a literature review, and a small section is also gathered through an interview with a Finnair demand analyst. We find that due to the strong link between economic growth and the demand for aviation, macroeconomic models are often utilized in forecasting long term market development. Another key factor in projecting emissions is the rate of technological development assumed to take place. We find that such forecasting with a relatively long-time horizon can become quite difficult, due to the many assumptions needed to be made for analysis.

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## Table of Contents

|  |           |
|--|-----------|
| <b>Abstract</b> .....  | <b>4</b>  |
| <b>Introduction</b> .....  | <b>4</b>  |
| <b>1. Current Emissions and Development in Fuel Efficiency</b> ..... | <b>6</b>  |
| <b>2. Demand Forecasting</b> .....                                   | <b>7</b>  |
| 2.1. Long-Term Demand Forecasting.....                               | 8         |
| 2.2. Short-Term Demand Forecasting: Case Finnair.....                | 10        |
| <b>3. Analysis of Projection Models</b> .....                        | <b>11</b> |
| <b>3.1. Olsthoorn Projection</b> .....                               | <b>11</b> |
| 3.1.2. Summary of Model Scenarios.....                               | 12        |
| 3.1.3. Olsthoorn Results.....  | 13        |
| <b>3.2. Owen, Lee &amp; Lim Projection</b> .....                     | <b>13</b> |
| 3.2.2. Summary of Model Scenarios:.....                              | 14        |
| 3.2.3. Owen, Lee & Lim Results.....                                  | 15        |
| <b>4. Policy Discussion</b> .....                                    | <b>15</b> |
| 4.1. Profitable Regulation: The Porter Hypothesis.....               | 16        |
| 4.2. Choosing the Effective Policy.....                              | 17        |
| 4.3. Current Regulatory Situation in Aviation.....                   | 18        |
| <b>5. Discussion and Conclusions</b> .....                           | <b>21</b> |
| <b>References</b> .....  | <b>22</b> |
| <b>Appendix 1:</b> .....   | <b>24</b> |

# Abstract

This thesis analyses studies and the models utilized in projecting environmental externalities in aviation, in the form of CO<sub>2</sub> emissions. The thesis will be looking at demand forecasting in the aviation industry, as well as more closely analyzing two different models for projecting emissions. A discussion of possible policy solutions to address the externalities is also included. The thesis is conducted as a literature review, and a small section is also gathered through an interview with a Finnair demand analyst. We find that due to the strong link between economic growth and the demand for aviation, macroeconomic models are often utilized in forecasting long term market development. Another key factor in projecting emissions is the rate of technological development assumed to take place. We find that such forecasting with a relatively long-time horizon can become quite difficult, due to the many assumptions needed to be made for analysis.

# Introduction

The commercial aviation industry has been on a steady growth trajectory for decades, proving to be rather resilient to external market shocks. In its Global Market Forecast (2019), Airbus projects traffic to double in the next 15 years, with an average traffic growth of 4,3% p.a. over the next 20 years. Perhaps the most considerable growth driver can be mentioned in passenger traffic growth in emerging markets, particularly in Asian countries. While currently, according to The Air Transport Action Group (2018), the global aviation industry is responsible for only roughly 2% of all human-induced CO<sub>2</sub> emissions, the favorable growth projections of the industry raises questions on the possible emissions levels in the future. The aviation market has experienced some quite considerable environmental shifts in the current decade. Intra-EU aviation was included in European Trading System (ETS) in 2012, and in 2016 ICAO (International civil aviation organization) adopted the global framework of CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation) as reported by Transport & Environment (2019). In their publication however Transport & Environment express that CORSIA is unlikely to mitigate the environmental harm from aviation; pointing to its weak enforceability and conflict with the

Paris agreement. Nonetheless, the environmental pressure on airlines has no doubt been felt in the recent years.

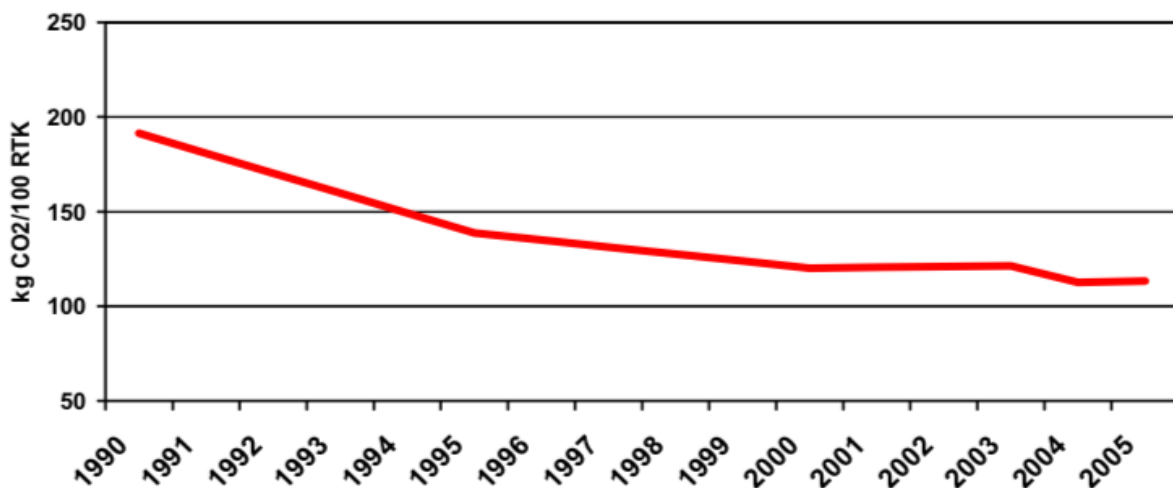
This thesis looks at evaluating the demand for aviation in the future, as well as models projecting the CO<sub>2</sub> emissions created. The goal is to gather an overview of some of the key aspects of the projection process and modeling. Another point of focus is a policy discussion concerning aviation. We find that the long-term demand of aviation is strongly linked to economic growth, which quite naturally leads to projection models utilizing macro-economic scenarios to predict possible market scenarios around the world. This creates quite considerable variance in the results studied, which highlights the uncertainty with regards to attempting to forecast at quite a considerably lengthy time horizon (the projections are up to the year 2100). Overall the results gathered indicate a strong growth in aviation's demand, particularly in Asian markets. This means that the technological advancements would need to be quite considerable in order to offset this surge in demand. From an environmental perspective the forecasts reviewed are indeed somewhat bleak; although it must again be pointed out that such long-term forecasting is anything but certain. Nonetheless, considering the somewhat unoptimistic emission projection results, it is quite natural to also discuss possible policy solutions in addressing the externality issue. We adopt the Porter Hypothesis as a framework for our analysis; this theory gives us a good framework to analyze how the policy's in question may affect not only the externalities, but also the efficiency of the market.

This thesis is laid out as follows: section 1 will provide a brief overview of the current level of emissions and showcase the improvements made in fuel efficiency. Section 2 deals with evaluating the demand that faces the aviation industry; this is mainly from a long-term perspective, but a small case interview of Finnair's short-term forecasting is included. Section 3 takes a more in depth look at two emissions projection models, exploring their key characteristics and results. Section 4 discusses possible policy solutions for addressing the externalities and looks at the current environmental regulatory framework concerning aviation. After this section 5 closes the thesis with some discussion and conclusions.

# 1. Current Emissions and Development in Fuel Efficiency

The Air Transaction Group (2018) reports that in 2018 flights produced 895% tons of CO<sub>2</sub>, which is roughly 2 percent of total human-induced CO<sub>2</sub> emissions. As the airline industry has experienced rapid growth over the past decades, it has also become considerably more fuel efficient. The development from 1990 to 2005 is shown in figure 1. The fuel efficiency improved at an especially rapid rate in the 1990's, with an annual improvement rate of 4,5 percent. Nonetheless, as pointed out by McIntosh and Wallace (2008) the total international CO<sub>2</sub> emissions from aviation still rose considerably during this period; by roughly 33 percent. Even the quite considerable technological advancements in efficiency were not enough to balance the growth in demand of aviation.

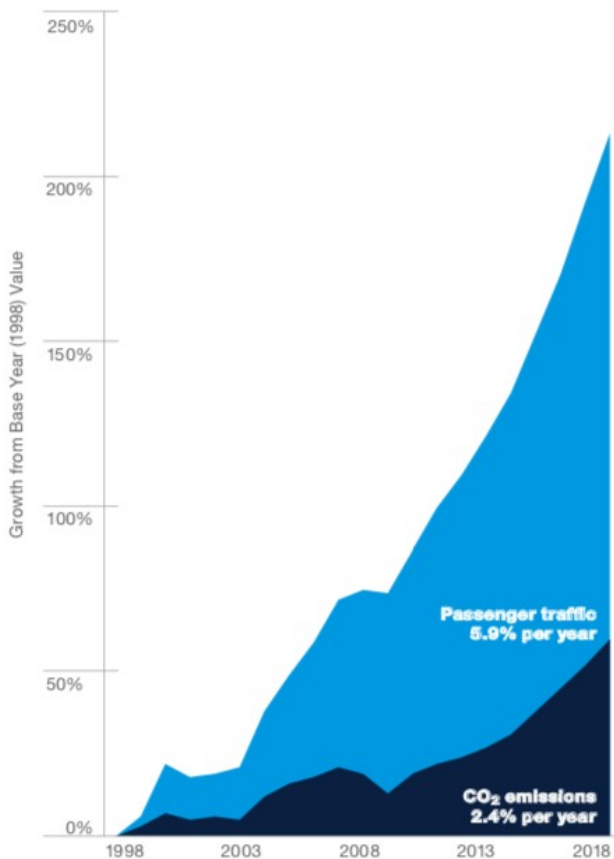
**Figure 1: emission intensity of total international aviation, 1990 to 2005, kg/CO<sub>2</sub>/100 RTK (Source: McIntosh and Wallace, 2008)**



IATA lists the industry priorities in addressing global climate change. It currently maintains a target of 1.5 percent average improvement in fuel efficiency per year, for the measurement period of 2009-2020. Carbon neutral growth from 2020 onwards is also listed, and the reduction of emissions by 50 percent by the year 2050 (comparison year 2005). The key factors mentioned for reaching these goals are the improvements in

aircraft technology and the CORSIA offsetting system, which we will take a closer look at later.

**Figure 2: Decoupling of air traffic and CO2 emissions growth.**  
(Source: Boeing Commercial Market Outlook, 2019)



Note: CO<sub>2</sub> growth estimated for 2017 & 2018

The economic and environmental incentives for increasing fuel efficiency are somewhat aligned. Increasing the fuel efficiency directly ties to cutting costs, as well as CO<sub>2</sub> emissions, per unit of travel. The Boeing Commercial Market Outlook (2019) states that while total air traffic had tripled from 1998 to 2018, emissions had only increased by a third of the total volume growth during this period. This decoupling of air traffic- and emission growth is indicated in figure 2.

## 2. Demand Forecasting

In addition to predicting the future technological advancements, evaluating the long-term demand of aviation is in a key role in emission projections. This section will focus particularly on the long-term demand forecasting in aviation, but also includes a case interview with Finnair on short term demand forecasting, in order to form a more comprehensive view of the subject.

## 2.1. Long-Term Demand Forecasting

A strong link has been found in several studies between economic growth and the demand for transportation, and aviation in particular as pointed out by Owen, Lee & Lim (2010). Thus, long term demand is often evaluated through macro-economic models. Both of the models discussed in section 4 utilize macroeconomic scenarios in evaluating the long-term changes in the market. First, we highlight one demand forecasting approach by Vedantham & Oppenheimer (1998). They firstly define distinct economic groups within the aviation market. These definitions take into account factors such as the growth rate and level of industrialization in the countries observed. The group definitions Vedantham and Oppenheimer use is shown in table 3.

**Table 3. Defining economic groups. Source: Vedantham & Oppenheimer. (1998)**

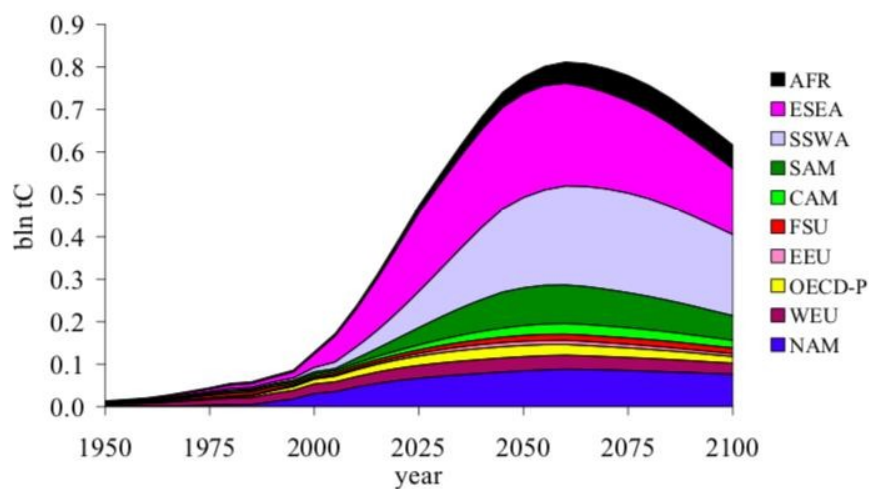
| No. | Group name                     | Members  |
|-----|--------------------------------|--|
| 1   | Industrial economies           | OECD members, except Japan                         |
| 2   | Newly industrialized economies | Asian Newly Industrialized Countries (NICs), Japan |
| 3   | Rapidly developing economies   | China and the rest of Asia                         |
| 4   | Slowly developing economies    | Africa, Latin America, the Middle East             |
| 5   | Post-Communist economies       | Post-USSR states, Eastern Europe                   |

After determining the distinct groups, Vedantham & Oppenheimer model three sectors of civil aviation to each of them separately: civil business passenger, civil personal passenger and civil freight. Business passenger as well as civil freight are highlighted as especially good indicators of the health of the economy. Personal passenger levels are derived from population and GNP growth assumptions. Vedantham & Oppenheimer point out that even though there will always be varied personal travel levels within all groups, total personal demand is likely dependent of the population trend within said group. The authors point out that this is based on the assumption that domestic income inequality will decrease between the different groups over time, and thus rapidly growing and developing economies will over time develop larger segments with stronger purchasing power.



Another example of evaluating long term demand comes from Mayor & Tol (2008). The study forecasts the emissions from international tourism out to 2100. The model used is the Hamburg Tourism Model (HTM), which evaluates total tourist demand by total population size and per capita income. The model utilizes historic data on total tourist numbers, international departures and international arrivals. The authors find that total demand for tourism grows with regards to per capita income, with an elasticity of 0,59. International trips in total holiday demand also grows in proportion to per capita income, with an elasticity of 0,37. The authors obtained these results by minimizing the squared relative distance between the model predictions of global tourism demand and the observations of historic tourist demand data. The study projects that international tourism will rise by a factor of 12 between 2005 and 2100. This growth is mainly fueled by Asian countries, and their model predicts that by the end of the century 56 percent of world emissions is accounted by Asia.

**Figure 4: Projection of CO2 emissions (in billion metric tons of carbon) shown by region. Source: Mayor, Tol. (2008)**



AFR=Africa; ESEA=East and Southeast Asia; SSWA=South and Southwest Asia; SAM=South America; CAM=Central America and the Caribbean; FSU=former Soviet Union;

EEU=Eastern Europe; OECD-P=Australia, Japan, New Zealand, and South Korea; WEU=Western Europe; NAM=North America.

If we look at some of the current demand forecasts, we find quite a clear driver for future demand in the Asia-Pacific area. The International Air Transport Association (IATA) estimates in their forecast (2017) that China will displace USA as the world's largest aviation market by 2022. India and Indonesia are also projected to move up to the top-5 markets by 2030. This projected rise of the Asian markets and their environmental impact is well shown in above figure 4.

## **2.2. Short-Term Demand Forecasting: Case Finnair**

The section is based on an interview conducted with Finnair demand analyst Matti Karjalainen; the questions can be viewed in appendix 1. The aim is to gather a basic understanding of the process Finnair employs in their short-term demand forecasting. Even though long-term demand forecasting is in a central role when evaluating the development of emissions, gathering a basic understanding of the short-term process is important as well for developing a more thorough understanding of demand forecasting. The key findings of the interview for this thesis are summarized below.

The aim of demand forecasting in the Revenue Management & Pricing -unit (RMP), is to optimize the ticket availability at different price points. The RMP -unit is focused solely on short-term passenger forecasting. Cargo- and longer-term forecasting, such as network planning, is handled in other departments at Finnair. The forecast horizon of a demand analyst is equal to the window for ticket sales, which is 1 year. The resolution of these forecasts gets more detailed as time moves closer to the departure. Each demand analyst has a portfolio of Origin-Destination (OD) pairs. The demand forecasts for OD pairs are prioritized based on revenue contribution. Asian markets are mentioned as highly emphasized, as the revenue potential of these OD's is considerable for Finnair. Aside from country-level GDP forecasts, also keeping up with the development of the predominant industries and companies within an analysts OD's is highlighted as important, especially for evaluating business travel. Some of the most important forecasting parameters mentioned are related to:

1. The willingness-to-pay function; which is essentially a vector time-series, as the function is not static with regards to the days to departure

2. The demand pick-up curve; the intensity of bookings at a given days-to-departure
3. Seasonality; day-of-week, week-of-year etc.

As we are dealing with relatively short-term forecasting, most of the forecast is based on statistical methods on historical data, with fewer exogenous parameters. The parameters are mostly modeled after past purchasing behavior, but also modified based on changes in the competitive environment, or other economic shocks.

### **3. Analysis of Projection Models**

In this section we will take a more in depth look at two models projecting the CO<sub>2</sub> emissions from aviation. The models chosen are from the studies by Olsthoorn (2001) and Owen, Lee & Lim (2010). It is worth mentioning that there have been some considerable political changes since these studies were conducted, for example the addition of flights within Europe to the EU's emissions trading system and the CORSIA agreement. It is not however of the utmost importance for this analysis that these models account for the most recent technological and political developments in the market. The goal is to rather observe the characteristics of these models and observe how different assumptions made compound over the timespan of the projections.

#### **3.1. Olsthoorn Projection**

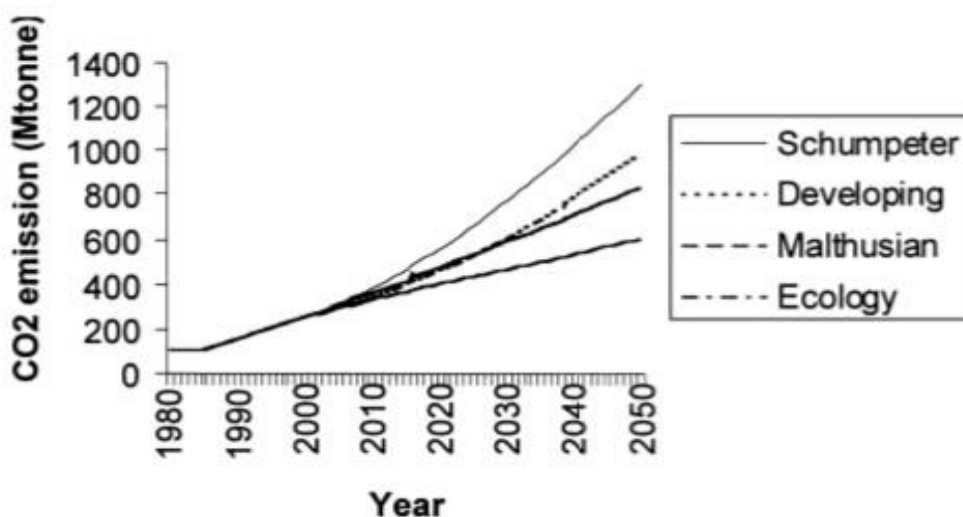
In this section we will be observing the Olsthoorn model (2001). It is an auto-regressive moving average (ARMA) model which studies the statistical relation between the international use of bunker fuels (which serves as an indicator for aviation demand) in relation to global GDP and world oil prices. It projects only international transport, so no domestic aviation is included. This means that the analysis covers roughly half of all commercial aviation, but the author points out that there are signs of saturation in the domestic airline market, unlike the international market. The projection operates within the framework of the Netherlands Bureau for Economic Policy (CPB) WorldScan model, which is a general equilibrium model that constructs long term scenarios for the world economy. It compasses 12 world regions, producing scenarios for example in GDP, energy consumption and oil prices.

### 3.1.2. Summary of Model Scenarios

The model operates under four different scenarios developed by CBP, which are explained below:

1. Schumpeterian: liberalization of global goods and service markets adopted worldwide. Market driven policies, high technological and economic growth.
2. Malthusian: the relative gap between OECD and non-OECD countries widens. Open market policies are not reached, but rather cautious investment strategies prevail due to social and political tensions.
3. The Developing Scenario: market-oriented policies lead to relatively high growth rates in developing countries, but weak level of co-operation within OECD-countries stagnates overall growth.
4. The Ecological Scenario: environmental issues become a primary concern on an institutional level. Technological innovations are focused on energy efficiency and sustainability. International economic linkages are more limited, and level of growth is lower.

**Figure 5: Scenarios from 1995 to 2050 for CO<sub>2</sub> emissions from international aviation in relation with GDP and world oil prices. Source: Olsthoorn (2001)**



### **3.1.3. Olsthoorn Results**

As shown in figure 5, the model projects an increase of emissions by a factor of 3-6 from 1995 to 2050, depending on the CBP world economic scenario. The model also allows for calculations on the effect of imposing an international tax on jet fuel (kerosene). Indications are that a tax on jet fuel would only result in little reduction in CO<sub>2</sub> emissions as the price elasticity for fuel demand is low, at least in international aviation. The calculations indicate that the price elasticity of jet fuel would be roughly -0,04, and the author points out that this seems like a plausible result considering the existing empiric data. Olsthoorn's calculations show that in order for emissions to stabilize to current levels some quite extreme requirements would have to be met. A very high tax of 1500 US dollars per ton would have to be imposed on jet fuel, and the world economy would have to be in the "Ecology" scenario. Olsthoorn points out that this is economically unfeasible, as it would mean a drastic increase in costs for airlines. The share of jet fuels cost to airlines would (*ceteris paribus*) jump from roughly 10% to 90%. Similar results on the effect of direct environmental fuel taxes have been found: Hoen et. al (2014) found that emission related charges have a very small effect on the freight transportation choice of an individual decision maker.

### **3.2. Owen, Lee & Lim Projection**

In this section we will be observing the Owen, Lee & Lim model (2010). The model utilizes a logistic function which is derived from time series of global GDP growth from the UN World Bank and ICAO passenger demand statistics. This function is then applied to SRES (Special Report on Emission Scenarios) scenarios developed by the Intergovernmental Panel on Climate Change (IPCC). These scenarios called A1B, A2, B1 and B2 estimate population, GDP and other macroeconomic variables. These have quite a similar concept as in the CBP scenarios: A1B and B1 are increasing globalization scenarios, where as A2 and B2 are economically more regionally focused in comparison. Calculating fuel efficiency to 2020 is done based on the retirement and replacement of older aircraft types with never known types. Projecting trends beyond 2020 becomes more speculative, as some aircraft engines etc. are not yet in production. The long-term, more speculative, technological trends for unknown aircraft is determined from the aeronautical industry ACARE technology goals and the ICAO/CAEP (International civil aviation organization and Committee on aviation environmental protection) long-term technology goals. The

implementation rate of these goals is in dependent on the scenario in question. Assumptions made for technology trends are implemented to each SRES scenario based on “their general storyline”. A more detailed explanation of each scenario, and the technological assumptions can be found below.

### **3.2.2. Summary of Model Scenarios:**

A1B: Fuel efficiency improvements to 2050 are assumed to match the recent rate of approximately 1% year. This is noted to be quite an optimistic assumption, but this is in line with the A1 storyline of considerable technological innovation and high demand.

A2: Improvements to fuel efficiency after 2020 are low and only marginal annual improvements are achieved. The lowest overall demand and level of international cooperation.

B1: Local air quality an important driver for technological advancements. Fuel efficiency improvements increase to 1,3% per year from 2020 onwards, thanks to the possible access to alternative fuels and other technological innovations.

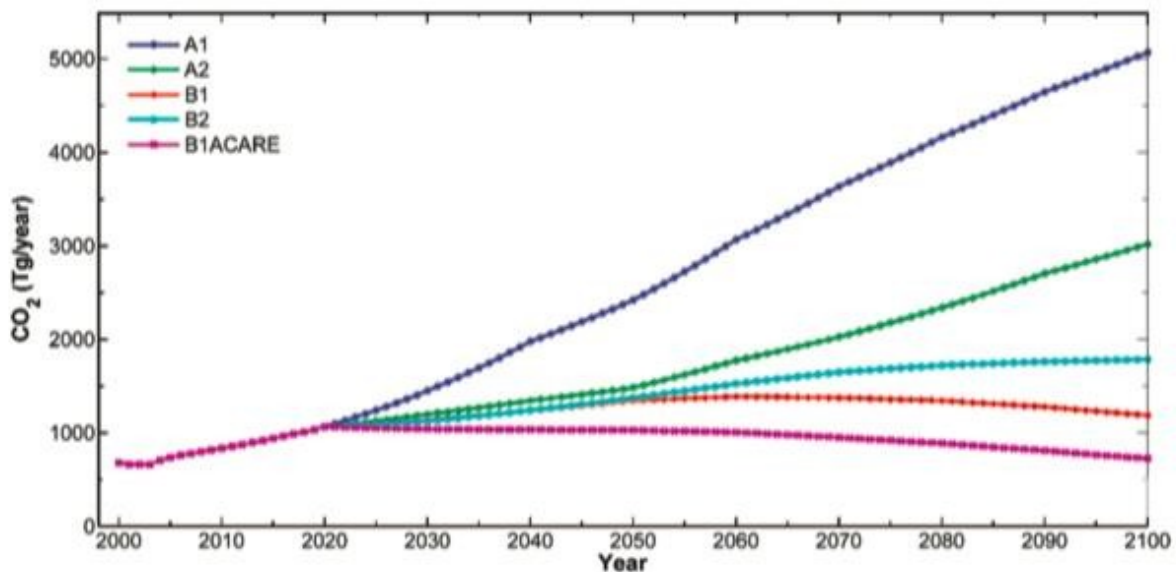
B1-ACARE: An environmental mitigation scenario of sorts; ACARE fuel efficiency goal of 2,1% per year is achieved by all new aircraft entering the fleet in 2020. This pace of efficiency would then be kept up until 2100. The author points out that this scenario is not realistic, as the ACARE goals are quite demanding and realizing them for all new models would be extremely unlikely.

B2: Ecological policy making on a more local level compared to B1. Also lacking in some of the technological advancements seen in B1 and thus improvements in fuel efficiency are more modest.

The projections under these five scenarios can be viewed below in figure 6. Once again, it should be noted that the B1-ACARE is more of a hypothetical than practically possible scenario.

**Figure 6: Emission projections under four SRES scenarios from 2000 to 2100.**

**Source: Owen, Lee & Lim (2010)**



### **3.2.3. Owen, Lee & Lim Results**

As indicated in figure 6 CO<sub>2</sub> emissions between 2000 and 2050 projected to grow between a factor of 2.0 and 3.6 depending on the scenario. By 2100 in A1 scenario there is growth by a factor of 7.5 and respectively 1.7 in B1 scenario. In the more speculative ACARE “what if” scenario there is growth by a factor of 1.1. As pointed out in the study, these projections suggest that aviation will cause an increasing share of the world’s emissions. In the year 2000 aviation was responsible for roughly 3% of all emissions. The model predicts that by 2100 that number will have grown to between 3 and 11%. This reflects aviation’s relatively slower transition to alternative nonfossil fuels in comparison to other means of transportation. It is also worth pointing out that the SRES scenarios by design do not account for mitigation policies. International policy and regulation could thus have a great impact on the emission levels projected.

## **4. Policy Discussion**

The projection models observed suggest that the environmental externalities from aviation could be growing to an unsustainable level. Even in the most environmentally positive B1-

SRES scenario the temperature increase of is roughly 2.6 Celsius by the year 2100 as stated by Owen, Lee & Lim (2010). As the authors point out, this is still in excess of the level commonly associated with “dangerous climate change”. McIntosh & Wallace (2008) argue that only a considerable economic shock, rapid technological development or a global economic slowdown would stabilize the emission levels. The authors also argue that without aggressive policy measures in enforcing technological standards, the slow rate of fleet turnover will hinder progress in curbing emissions. Considering these findings, in this section different policy options in addressing aviation externalities will be discussed.

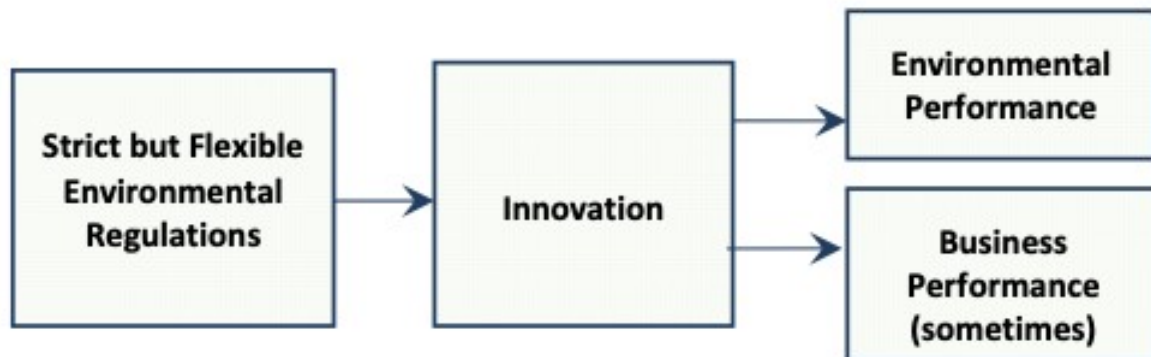
#### **4.1. Profitable Regulation: The Porter Hypothesis**

One could argue that the relationship between companies and regulators is often thought of in quite a black and white way; the regulators impose rules on the companies, which then affect their business and profitability negatively. This thought pattern was flipped on its head when Porter & van der Linde (1995) argued that flexible market-based regulations might in fact be beneficial for the companies, offering them a competitive advantage in the marketplace. The authors challenge the notion that companies are always making optimal choices in an environment where information is perfect, and thus all profitable environmental actions would have already been discovered. Instead they argue that the additional innovation from regulation often offset the regulatory costs, as there are many reasons why companies may not take advantage of the possibilities for innovation without a regulatory “push”. This core idea of regulation having the potential of creating a win-win situation has become dubbed as the “Porter Hypothesis”. Since its inception it has been widely discussed and studied; Ambec et al. (2013) summarised the five key points of a win-win regulatory system from Porter & van Der Linde:

1. Regulation has a signalling effect for the companies involved; unoptimal resource utilization, thus potential for technological improvement
2. Raising corporate awareness, when regulation is based on information gathering
3. Reduces uncertainty of environmental investing
4. Creates pressure that motivates innovation and progress
5. Regulation levels the transitional playing field: regulations prevent some of the negative spillover effects from R&D for companies. Pareto-improving equilibrium with higher R&D investments.



**Figure 7: Schematic representation of the Porter Hypothesis. Source: Ambec, Cohen, Elgie & Lanoie (2011)**



Ambec et al. (2013) divide the PH into two versions: the “weak” and the “strong” version. The weak version simply states that the environmental regulation may spur innovation, whereas the strong version states that the regulation would actually improve the firm’s competitiveness, thus negating the regulatory costs. The authors summarize that the empirical evidence for the weak version is rather well established, whereas the evidence is more mixed. Empirical results from Lanoie et al. (2008) indicate that the level of external competition in the regulated industry is a key component in companies turning environmental constraints to their gain. One could say that the international and quite heavily competitive industry of aviation would satisfy this characteristic.

## **4.2. Choosing the Effective Policy**

The Porter Hypothesis offers an interesting framework for a policy discussion, as the role of the regulator can be viewed in a more nuanced way, rather than merely creating a hindrance to the market. In this way, we can think of the optimal policy for addressing CO<sub>2</sub> emissions also having qualities which in fact boost the performance of airline companies, at least in the medium- to long term. Ambec et al. (2013) approach the design of policies from the perspective of enhancing competitiveness, and some of the key findings are discussed below.

The authors argue that market-based instruments, for example emissions taxes or tradable allowances, or performance standards, allow for firms to operate with more freedom in comparison to more rigid technological standards. Thus, this would minimize

unnecessary compliance costs of the regulation. Pollution taxes also have the upside of having a continuous incentive for improvement for the taxable party, whereas technological standards merely have to be met at the minimum standard. The authors also discuss the fact that revenues generated from taxation can be used in ways which increase competitiveness in the market. The importance of industrial and patent policies is also discussed by Ambec et al. (2013). The authors argue that well defined property rights could foster innovation, due to the prevention of R&D spillovers. Subsidies and tax credits are also discussed as viable options for supporting R&D innovations. Mandatory licenses are viewed as an alternative that could foster technological development, but also might reduce the incentive to invest in R&D.

Lankoski (2010) discusses the difficulty in trying to measure the competitiveness advantage that might be gained from a certain policy action. The author points out that it is quite easy to either overstress the costs that a policy may cause, or respectively be unrealistic with the win-win potential of a policy measure. This is especially a risk when the particular characteristics of a certain industry or legislation is not adequately taken into consideration; a one size fits all implementation of the PH is quite unfeasible. Thus, the obtaining of sufficient information regarding the effects of a certain policy action is of paramount importance. Gathering such data can be quite a difficult task however: Lankoski (2010) raises the point that weighing the benefits and costs can also become a challenge due to different preferences of the parties involved. This means that analyzing the net effect for the whole economy can become a real challenge.

### **4.3. Current Regulatory Situation in Aviation**

Having discussed some theoretical viewpoints of regulation, this chapter will focus on the current environmental regulatory situation concerning aviation. The main subjects discussed are the main functions of ETS and aviation's addition to its scope in 2012, and how this led to the CORSIA framework which is currently ongoing implementation.

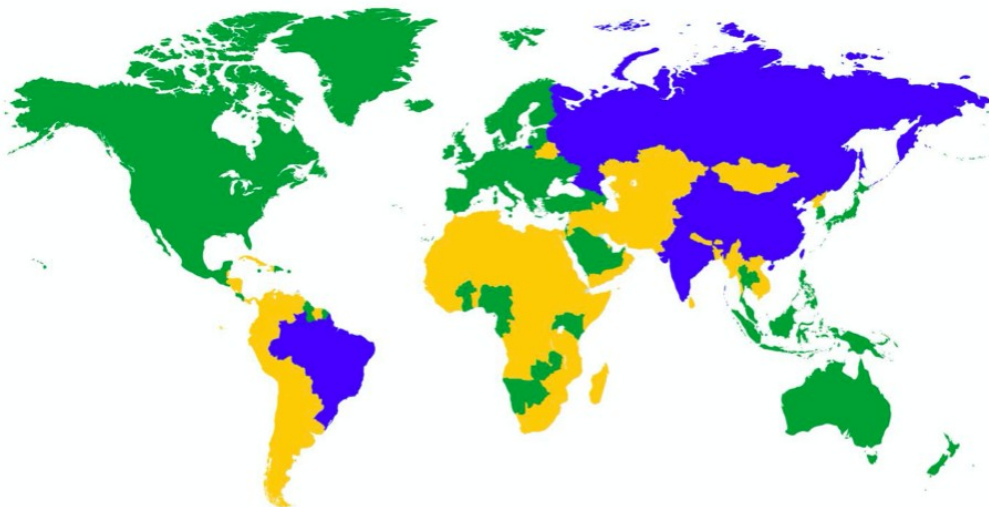
The ETS works on a cap and trade principle. The European Commission's website explains that a cap is set on the total of amount of greenhouse gases that can be emitted, and that this cap is reduced over time to lessen the total emissions within the system's scope. Companies included in the system than can buy or receive emissions allowances, which they can also trade with each other as needed. If a company exceeds the emission

level they hold permits for, they will be faced with heavy fines. According to Transport & Environment, aviation was originally included in the ETS in 2012, covering all flights to and from EU airports. This arrangement was faced with considerable industry opposition, which led to the scope being reduced to intra-EU flights. Transport & Environment states that this reduction period was labeled as “stop the clock”, and the intention was to give ICAO more time to develop a global framework, which led to the birth of CORSIA.

CORSIA looks to expand the environmental regulatory elements of international aviation to a global scale. According to the ICAO the program is implemented in phases: the pilot phase and first phase are voluntary, whereas the second phase from 2027 to 2035 has some terms for voluntary participation. It concerns all states that individually account above 0.5 percent of total revenue ton kilometers (RTKs) or whose cumulative share in the list of states from the highest to the lowest amount of RTKs reaches 90 percent of the total sum. There are also some outlier categories (for example, Least Developed Countries, LDCs) for which the participation for this phase is also voluntary. According to IATA, the system is based on offsetting emissions. This means that companies indirectly compensate for their emissions by financing an emission reduction in another area; for example, investments in renewable energy sources. IATA states that all airline operators whose annual emissions total at least 10 000 tons of CO<sub>2</sub> will be responsible for annual reporting of their fuel usage. These reports will then be inspected by an independent third party. The criteria for where the offsetting resources are spent are quite strictly defined. Firstly, the offsets must be permanent in nature, they cannot be easily be reversed. The activity generating offsets must also not create unintended emissions as a side product. Secondly, the calculation of the offsets needs to be carefully quantified using valid protocols and measurements, so that the results can be compared to the baseline situation. IATA states that it is forecast that CORSIA will mitigate around 2,5 billion tons of CO<sub>2</sub> between 2021 and 2035.

Now that we have a basic understanding of the regulatory environmental regulatory framework in the aviation industry, we can observe it through the lens of the Porter Hypothesis. Based on the profitable regulation theory, do the systems in place seem like an effective tool not only for reducing unwanted externalities, but perhaps also promoting growth and innovation in the industry at large? Firstly, it can be stated that both the cap and trade as well as offsetting systems have some positive key characteristics discussed earlier: the incentive for continuous innovation as well some of the flexible elements of

market-based systems (particularly in the case of the original ETS system). On the other hand, Brenden & Mackey (2017) criticize the offsetting system arguing that it alone is not an efficient enough tool to address emissions. The authors argue that an offsetting system does not set an absolute cap for the demand and supply of air travel, but rather it allows for airlines to simply continue purchasing credits to compensate for the absolute growth in emissions. This would mean that in order to gain absolute reductions in emission levels, considerable efforts would need to be made in other areas. IATA does point out that the offsetting measures are not meant as a sole solution to the externality issues facing aviation. Advancements in technology and other operative aspects are raised as a very important source for reducing the sector's emission levels, and the industry is committed to these alongside the offsetting plans.



**Figure 8: CORSIA volunteering situation as of 1 May 2019. Countries indicated in green have volunteered, and countries in yellow are expected to be exempted after 2027. Source: IATA, Fact Sheet: CORSIA**

## 5. Discussion and Conclusions

Due its strong link to economic growth, long-term demand for aviation is often modelled utilizing macro-economic scenarios. Both of the models more closely analyzed in this thesis utilize these scenarios in predicting the possible turns of the global marketplace. The factors analyzed include things such as the level of globalization, economic policies etc. These scenarios create considerable variance in the outcomes, which showcases the uncertainty involved in predicting the economic trends of coming decades. Another key factor in the projection process is the technological advancements assumed to take place. This is yet another factor which is quite difficult to forecast beyond a certain time horizon, and some considerable assumptions have to be made. This means that the forecasts give an indication of the possible trends of the future, but are resting on so many assumptions, that utilizing them directly as a tool for policy creation could perhaps be ill-advised.

It is still noteworthy that even the most optimistic emission scenario cannot be considered particularly environmentally positive. As the study points out, the B1 SRES scenario still has a temperature increase of roughly 2.6 Celsius by the year 2100. This is still in excess of the level commonly associated with “dangerous climate change”. As far as the tools for policy interventions are concerned; Olsthoorn’s results in particular indicate the ineffectiveness of an environmentally focused direct jet fuel tax. The current environmental policies in place are reviewed from the perspective of the Porter Hypothesis; could the policies not only counteract the environmental externalities, but also enhance the innovation process of the companies within the industry? The main environmental framework, CORSIA, currently being implemented to the aviation sector certainly has some of the characteristics of a “win-win” regulatory framework. The offsetting system it relies upon creates an incentive for continuous improvement (rather than technological standards for example, which merely have to be met), and doesn’t create unnecessary obstructions for the companies involved. On the other hand, some have criticized that the framework isn’t capable of addressing the growth in demand that aviation faces, and thus the aggregate emissions will continue growing. It remains to be seen if the emissions can be addressed without taking action that would considerably limit the demand for aviation.

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# Appendix 1:

E-mail interview with Finnair Demand Analyst Matti Karjalainen.

22.11.2019.

Questions:

1. Does your work mainly revolve around evaluating short- or long-term demand, or perhaps both?
2. What kind of geographical breakdown is utilized when analyzing demand? Do some Asian markets for example have a particular priority for Finnair?
3. What are some of the key differences in forecasting passenger vs freight demand?
4. What are the most important trends/signals of the global economy for Finnair to follow, when evaluating long term demand?
5. Does Finnair utilize different macroeconomic scenarios in its analysis, when predicting long term market development?
6. What are the most important factors for evaluating short term demand?