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When will biofuels be economically feasible for commercial flights? Considering the difference between environmental benefits and fuel purchase costs

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ABSTRACT

This paper evaluates the financial outlays and environmental costs of using biofuel and traditional aviation fuel for selected flight routes. Cost-benefit analysis and the dose-response method were applied for evaluating the financial and environmental costs of both biofuels and traditional fuel. Selected flight routes originating from Taipei were used for empirical analysis, for the purpose of comparing the use of different fuels in monetary terms. The use of biofuel leads to a considerable increase in fuel purchase price; however, it results in fewer negative environmental impacts compared with the use of the traditional aviation fuel. The empirical results and sensitivity analysis show that the reduction in environmental costs will only outweigh the additional purchase cost of biofuel if the unit environmental social costs of pollutants are considered to be very high. The potential incentives for the use of biofuel in commercial flights could come from some form of government measures that internalize externalities, or from a reduction in biofuel price (e.g. through subsidy) or an increase in traditional fuel price (e.g. through tax). The environmental benefit of using biofuel in commercial flights, estimated in monetary terms and compared with its extra financial cost, provide good reference for policy makers when implementing policies and incentives for the development of biofuels.

1. Introduction

With increasing economic development, the environmental impacts that an industry brings have gained increasing attention. Air transport, as a highly energy-consuming transport mode, is certainly at the heart of international discussion on sustainable development.

Current commercial aircraft are powered by the combustion of jet-fuel which is derived from fossil crude oil and the commercial aviation sector is a major contributor to global warming and air pollution, generating around 2% of global man-made carbon dioxide emissions, and this is expected to reach around 4% by 2050 (IPCC, 2014). The quantity of jet-fuel consumed is expected to greatly increase with the high growth rate of air traffic demand, which is forecast to increase at an average annual rate of around 5–6%, despite the economic downturn, with the Asian region having the highest growth rate of all (Boeing, 2015). This means that the extent of global air pollution and climate change due to the aviation industry should also increase if measures are not taken.

To accommodate this traffic with limited environmental impact, the airline industry is committed to cutting its carbon emissions by half by 2050 compared with the 2005 level (IATA, 2016). Moreover, besides the climate-change implications of carbon dioxide (CO_2), air pollutants such as nitrogen oxides (NOx), carbon monoxide (CO), and unburnt hydrocarbons (HC), emitted during the combustion of jet-fuel, affect local air quality.

For aviation, in addition to improvements to aircraft/engine technology, air navigation and airport infrastructure and operations, and market-based measures, the use of alternative fuel plays a vital role in achieving this goal. Biofuels, which can be renewable, low-carbon, environmentally friendly, and clean, are considered to be the most promising alternative fuels for the aviation sector (Wise et al., 2017; IEA, 2011). Apart from alleviating environmental impacts, the development of alternative fuels will also contribute to increasing the security of the jet-fuel supply needed for the rapid growth of the aviation industry (Bogers, 2009; EC, 2012).

Of all of the alternative fuel concepts currently under development, those which are drop-in compatible with traditional

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kerosene have had the most rapid uptake, with many currently certified to ASTM D1655[1] equivalent for blending up to 50% with Jet-A1. Although these are not necessarily produced from bio feedstocks, they are generally referred to as “biofuels”. The first successful biofuel test flight was by Virgin Atlantic in February 2008. In June 2011, KLM operated the first biofuel flight with passengers onboard (using used cooking oil) on a Boeing 737 from Amsterdam to Paris. In 2011, Lufthansa was the world’s first airline to test the use of biofuel in regular operations on more than 1100 scheduled flights in the second half of 2011 (IATA, 2012b). Since then there have been many airlines operating more than 2500 flights, around the globe that have used various kinds of biofuel either for the test flights, or on regular scheduled flights (ICAO, 2016). The most commonly used feedstocks for biofuels in the aviation industry have been jatropha, camelina, used cooking oil, waste and algae (Kagan, 2010; ATAG, 2011; Blakey et al., 2011).

Given the fast growth in biofuel usage in the aviation industry, the International Civil Aviation Organization (ICAO) established the sustainable aviation alternative fuel (SUSTAF) Expert Group for the purpose of promoting the application of sustainable alternative fuels and encouraging member states to develop related projects and to give suggestions (ICAO, 2011). The International Air Transport Association (IATA) has also published annual alternative fuel reports since 2009. Various aviation-related organizations have been working together and looking into the issues from different aspects (IATA, 2012a). While reviewing the cases of biofuel flights, the related issues that need to be investigated or developed include national alternative transport-fuel policies, technology research, supply of feedstock, fuel qualification and certification, deployment, public-private partnerships and cooperation, framework of laws and regulations, life-cycle analysis and sustainability as well as financial resources etc. (ICAO, 2011; Lin and Huang, 2013; Arvidsson et al., 2012; Reimer and Zheng, 2017). Of all the related issues, however, the fundamental question to explore is whether the use of biofuel generates more benefits than costs from both the environmental and financial points of view, given current scientific knowledge.

This research aims to evaluate the financial expense and environmental costs of using biofuel and traditional aviation fuel for selected flight routes. In the current market situation, the purchasing cost of biofuel is generally higher than that of fossil fuel. However, it is generally recognized that burning biofuel emits less exhaust pollutants than burning fossil fuel (IATA, 2016; ICAO, 2016). By comparing the difference in purchase cost between biofuel and Jet A1 fuel, and the reduction in the environmental social cost, which can be considered an environmental benefit, one can obtain insights into whether the use of biofuel is more economical from the social point of view. The current low crude oil price, which reflects on Jet A1 fuel price as well, is likely to jeopardize the development and use of biofuels. Hence, the sensitivity analysis will explore further in which circumstances the use of biofuel could be feasible compared with traditional fuel.

This paper first explores the key issues of biofuel applications in the aviation industry. A cost-benefit analysis and the dose-response method are then applied for evaluating the financial and environmental costs of substituting biofuels for traditional fuel, using selected flight routes originating from Taipei. Further discussion on the potential implementation and policy implications of biofuel is then given in Section 4, followed by conclusions and recommendations.

2. Environmental cost of fuel emissions

The amount of aircraft engine emissions from flights varies by aircraft operation, engine type, emission rate, flying and cruise time, and even the level of airport congestion etc. Exhaust emissions at ground level resulting from the landing and take-off (LTO) phases of flight is distinguished from the cruise level impact, and therefore analyzed separately in this research, as the damage pattern and magnitude are different between these two phases of flight.

A number of articles in the literature have dealt with the impacts of exhaust pollutants from different aspects. The most commonly discussed impacts are on human health and climate change (EUROCONTROL, 2005). Of all the pollutants emitted from aircraft engines, six - particulates (PM), oxides of sulfur (SO_X), NO_X, HC, CO and CO_2 - have been found to have different degrees of negative implications for human health, with PM having the highest unit cost and CO_2 the lowest. However, CO_2 has the highest volume emitted during flights.

The climate change impact from the cruise phase of a flight is complex and only the cost of CO_2 emissions has been included here. Three pollutants in particular - CO_2, NO_X and H_2O - which are considered GHGs and result in climate change, are discussed in the literature (Snijders and Melkert, 2011). The impact of CO_2 on climate change has been recognised worldwide (US FAA, 2012). Other pollutants emitted during the cruise stage are generally non-linear to fuel burn (EUROCONTROL, 2015). However, there are already existing available models, such as the IMPACT model from European Organisation for the Safety of Air Navigation (EUROCONTROL) and US Federal Aviation Administration’s (FAA) Aviation Environmental Design Tool (AEDT), which include more exhaust pollutants for the cruise stage using industry-provided data.

There are different approaches to evaluating the environmental impacts, varying from global scales (Daly, 2007; Costanza et al., 2014) to impacts of individual pollutants. This paper aims to estimate the aggregated impacts of each pollutant during flights; therefore, the dose-response technique is applied. This is considered a comprehensive method for evaluating the damage resulting from aircraft engine exhaust pollutants (Pearce and Markandya, 1989). This is done by estimating the environmental costs imposed through the damage on human health, vegetation, buildings, and climate change and global warming, based on the dose-response relationships between pollution and effects, and then summing the individually derived monetary result. A summary of scientific findings to date on the unit social costs per pollutant is given in Table 1 (€/kg); where results are expressed in ranges, these are the minimum and maximum values. As the monetary evaluation of the damage is still uncertain (as is reflected in the wide range of monetary impacts), the unit social cost estimates for each pollutant have been averaged across all the studies for use in the later empirical analysis (Lu, 2011). It would be better to adjust the unit social cost for specific airports but it is impossible to achieve this with the scientific results that have been published to date.

The social costs for individual aircraft movements with specific engine types and standard flight modes can be derived, applying the average unit social cost for each pollutant listed in Table 1 to fuel flow and emissions data for the various phases of flight (ICAO, 2015).

F_{ijk}, the amount (kilograms) of the jth pollutant emitted during the ith flight mode for the kth fuel, can be derived from the following formula:

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[1] Standard specification for aviation turbine fuels.