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Environmental impact of aircraft emissions and aviation fuel tax in Japan

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ABSTRACT

This investigation analysed the growing impact of commercial aviation on CO_2 emissions, as well as its potential impact on climate change. It reviewed the effects of the Japanese Aviation Fuel Tax (*koukuu-kinenryouzei*), which has been levied on fuel loaded into all domestic flights in Japan since 1972. Using a Bayesian structural time series model, based on monthly observations of fuel consumption between 2004 and 2013 provided by the Ministry of Land, Transport, Infrastructure and Tourism - Japan, this research estimated the effect that this tax has had on the national demand for aviation fuel. It was established that the fuel tax has unequivocally reduced the amount of CO_2 emissions from aircraft.

1. Introduction

Aviation is a vital component of most economies and it represents one of the greatest developments of the 20th Century. There is an indisputable expectation that the industry will continue to grow, particularly given the rapid development of low-cost carriers. It is anticipated that the amount of CO_2 emissions related to aviation will also increase rapidly, keeping pace with the expansion of the industry. Given the constraints on CO_2 emissions are becoming tighter, as evidenced by the agreement of the Paris Climate Change Conference in 2015, it is crucial that the implications of the expansion of aviation with regard to global CO_2 emissions, and the effects of an incentive-based tool represented by a fuel tax for reducing CO_2 emissions, should be evaluated carefully. To the best of the authors' knowledge, however, there have been relatively few studies exploring the effectiveness of jet fuel tax on the reduction of aircraft CO_2 emissions.

The purpose of the present paper is to address this problem by analysing data relevant to the aviation fuel tax adopted in Japan. Specifically, it investigates the effects of a reduction in aviation fuel tax on CO_2 emissions by the aviation sector. Because of the 30% reduction in tax implemented by the Japanese government in April 2011, it is possible for us to compare the amount of CO_2 emissions before and after the tax adjustment. We find that the amount of CO_2 emissions from Japanese domestic flights would increase significantly compared with a situation where such a tax reduction was not implemented, reflecting the effectiveness of fuel tax for reducing CO_2 emissions by aircraft. This finding is of great importance because an increase in the amount of CO_2 emissions is considered unavoidable, especially in a region that has a rapidly expanding airline market.

We investigated the Aviation Fuel Tax of Japan (*koukuuki-nenryouzei*) by considering both its impact on the national demand

Abbreviations: BMF, Federal Ministry of Finance (Germany); BOJ, Bank of Japan; DEA, Danish Energy Agency; ENV, Ministry of the Environment Japan; EPA, Environmental Protection Agency; IATA, International Air Transport Association; ICAO, International Civil Aviation Organization; IEA, International Energy Agency; IPCC, Intergovernmental Panel on Climate Change; JAA, Japan's Aeronautic Association; MLIT, Ministry of Land, Transport, Infrastructure and Tourism Japan; MOF, Ministry of Finance Japan.

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for aviation fuel and its indirect contribution to Japan's environmental efforts for reducing the amount of CO_2 emissions, using a Bayesian time series approach that contrasted the results before and after the 30% tax reduction. Through the application of causal impact analysis, based upon Brodersen et al. (2015), this study constructed a scenario that predicted the market's response in the absence of the tax reduction, which allowed an estimation of the quantity of additional fuel consumed between April 2011 and December 2013. Thus, we estimated the causal impact of the 30% reduction in the aviation fuel tax, which to the best of our knowledge, has not been undertaken before.

The causal impact analysis method adopted in this paper is an analysis of a causality mechanism that measures the difference between the observed values of fuel consumed after the tax was adjusted and the (unobserved) values that would have been obtained had the tax not changed. In accordance with the recent interest in "big data" sets and predictive analysis, we adopted a modern approach of using Google Correlate™ to generate a collection of time series variables showing high correlation with the data before the intervention, and then we combined them into a single synthetic control that was used to estimate the causal impact. Thus, the modelling of the counterfactual of the time series observed both before and after the tax cut can be achieved. The key to the selection of the control variables is that they should not be affected directly by the intervention, such that it is possible to assume that the relationship that existed before the tax change would continue afterward. This is because they account for the variance components that are shared by the series, including those effects of other possible unobserved causes that otherwise would be ignored by the model. Because these control series are chosen purely in terms of how well they explain the pre-intervention values, no attention is given to their external characteristics (Brodersen et al., 2015).

The structure of the remainder of this paper is as follows. In Section 2, we review briefly the preceding research. Although some papers have dealt with the environmental impact of the aviation industry, there has been little empirical research similar to that conducted in the current study. Section 3 provides a brief overview of Japan's aviation industry, and it explains the aviation fuel tax that has been adopted. In Section 4, we present the model specifications and demonstrate how we proceeded with the analysis. We explain the estimation results in Section 5, which includes a policy implementation proposal to limit and mitigate the impact of air travel on the environment. We emphasise that aviation fuel tax is effective for reducing the amount of CO_2 emissions from aviation; however, in Japan, it was not introduced primarily for that purpose. Finally, our conclusions are given in Section 6.

2. Preceding research

The first extensive investigation of the environmental impact of aviation emissions was the Intergovernmental Panel on Climate Change Special Report on "Aviation and the Global Atmosphere" (IPCC, 1999). It revealed that global passenger aviation had grown at a high rate of 9% annually since 1960 (2.4 times the average Gross Domestic Product (GDP)). Furthermore, the report found that emission reductions from technological and operational improvements (i.e., air transport management and airframe/engine design) had not kept pace with the increasing demand for air transport (IPCC, 1999). The report projected that between 1990 and 2015, global passenger air travel would grow by approximately 5% annually. This is similar to predictions by other studies that have estimated the growth of world aviation at 4.5–5.5% annually over future 15–20-year periods (Lee et al., 2001, 2004; Macintosh and Wallace, 2009; Lee, 2010; Mayor and Tol, 2010; Chèze et al., 2011, 2013; Airbus, 2015; Boeing, 2015). Based on these figures, current global air passenger traffic will have more than doubled by the early 2030s (IATA, 2015a; ICAO, 2013) with commensurate increases in jet fuel demand (Mazraati, 2010) and greenhouse gas emissions. Indeed, the demand for aviation fuel is currently at a record high, having increased from 4.2% of the world's oil-refining output in 1973 to 6.5% in 2012 (IEA, 2014b). Furthermore, CO_2 emissions from air transport have grown by 86.4% between 1990 and 2012 (IEA, 2014a).

This study focuses on the analysis of CO_2 emissions from aircraft and on specific mitigating policies. However, it is important to mention that substantial research has been conducted on the effects of non-CO_2 emissions from aviation and their aggregated impact on radiative forcing[1] (IPCC, 1999; Sausen et al., 2005; Sewill, 2005; Stordal et al., 2005; Forster et al., 2006; Marais et al., 2008; Lee et al., 2009). Non-CO_2 emissions refer to other particles (e.g., ozone, water vapour, and soot aerosols) released by the combustion of aviation fuel at high altitudes, as well as the formation of linear condensation trails (contrails) and aviation-induced cirrus clouds (Wuebbles et al., 2007; Brooker, 2009; Lee et al., 2009; McCarthy, 2010). The combined effects of CO_2 and non-CO_2 emissions makes the total contribution of aviation to global warming 2.5–4.0 times that of CO_2 emissions alone.

Despite the rapid pace of growth of aviation, aircraft fuel has remained almost ubiquitously tax-free, as defined in the "Policies on Taxation in the Field of International Air transport" (ICAO, 1994): "…fuel should remain exempt from customs and other duties (…), levied by any taxing authority within a State, whether national or local" (op cit.). Consequently, as with other measures proposed to mitigate aviation pollution, e.g., the short-lived inclusion of air transport emissions in the EU Emissions Trading System in 2012, carbon taxation has encountered tremendous resistance from the airline industry and governments.

There is clear evidence that taxation has affected fuel consumption in other sectors and therefore, its importance as an instrument of climate policy is unquestionable. For example, Li et al. (2014) analysed how gasoline taxes affect consumption in the United States. They found that a five-cent tax increase reduced short-term gasoline consumption by 1.3% in comparison with a 0.6% variation attributable to an equivalent five-cent increase in the tax-exclusive gasoline price, highlighting the "salience" of carbon taxes over price movements. Similarly, Rivers and Schaufele (2015) examined the short-term decline in gasoline demand following the imposition of a carbon tax in British Columbia. They concluded that the tax yielded a greater change in demand (is more salient) than equivalent market price movements. It was found that for the period 2008–2012, the imposition of the carbon tax resulted in a reduction of CO_2 emissions from gasoline of 2.4 Mt CO_2.

Research on the effects of carbon taxes on fuel consumption, market behaviour, and the benefits that accrue in the form of reduced CO_2 emissions can be traced back to before the Kyoto Protocol. A paper by Pearce (1991) showed the advantages of carbon taxes over the alternatives of command and control policies, especially the "double dividend" characteristic of tax, which not only corrects the externality of the excessive use of environmental services, but also allows governments to use income to finance reductions in incentive-distorting taxes such as corporate tax. Obviously, the same argument could be considered applicable to aviation fuel tax.

It must be noted, however, that there might be loopholes in

[1] Radiative forcing is a measure of the thermal balance of Earth between incoming and outgoing solar energy (Chandler, 2010). In short, radiative forcing is a means by which to measure global warming.