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AN ANALYSIS OF THE ENVIRONMENTAL IMPACT OF AIRCRAFT EMISSIONS: THE CASE OF JAPAN

（航空機エミッションの環境影響分析：日本の事例）

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“Thank God men cannot fly, and lay waste the sky as well as the earth.”

– Henry David Thoreau

DOCTORAL DISSERTATION

An Analysis of the Environmental Impact of Aircraft Emissions:

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General Introduction

The thesis that you hold in your hand is the final delivery of six years of research on the environmental impact of modern commercial aviation. Its purpose is to familiarise the reader with the general extent of aircraft emissions, their evolution and sustained growth and the importance to include them in every effort to curtail CO_2 emissions and to hold back climate change. It includes the most up-to-date information and reviews a substantial part of the available literature related to aviation and climate. Moreover, it presents a novel and detailed analysis of different aspects of aviation pollution that, to the best of the author's knowledge, has not been documented before.

To put it mildly, aviation is a resilient business. Ostensibly immune to recessions, terrorist attacks or external shocks of any nature, over the past two decades air travel has seen a steady growth of an average of 5% per annum (Airbus, 2017; Boeing, 2017; IATA, 2017a; ICAO, 2017a), and early statistics show a 7% growth between 2016 and 2017 (IATA, 2017b). Moreover, different forecasts from the main manufactures and authorities, agree to an estimate of twice as much traffic over the next 15 years, reaching 7 billion passengers a year by the early 2030s (op cit.). The main concern of this investigation is that the equally large growth of aviation emissions and their effect on climate, might not receive as much attention.

Although we have come a long way since early commercial jets in terms of passenger capacity and fuel efficiency, CO_2 from international aviation has grown at a critical rate, almost doubling between 1990 and 2014, and therefore faster than any other sector or source (IEA, 2016). Also, due to other effects of engine combustion at high altitudes, such a cirrus clouds and condensation trails (contrails), the total contribution of aviation to the greenhouse effect could be at 2.5 to 4 times that of CO_2 alone (Stern, 2007; Wuebbles et al., 2007; Brooker, 2009; Lee et al. 2010; McCarthy, 2010). Still, aviation is a minor contributor to world CO_2 emissions when compared to other sectors such as heating, electricity or manufacture. However, the rapid growth of its global market and the consequences that this might have on the environment, require a more precise analysis.

It behoves the author at this point to draw the reader's attention to the seriousness of climate change and the dire consequences that it brings to humankind. At the time that this investigation was written, the evidence of a disrupted thermic balance on Earth was compelling. The degree and frequency of hurricanes, floods and wild fires are both overwhelming and ubiquitous, causing enormous economic damage and equally large loss of human lives. In spite of these sad events, scientists find themselves anything but baffled. Additionally, the highly celebrated Climate Change Conference in Paris, 2015 (COP 21) brought a sense to the world that a new age of sustainable development had been agreed upon as was underway, but alas, these efforts might be either insufficient or too late. In 2016, the concentration of CO_2 in the atmosphere reached the highest figure ever recorded, rendering global temperature targets highly unattainable (WMO, 2017).

For the purpose of data and econometric analysis, this study focuses on the domestic aviation market of Japan, although general data on world aviation is duly provided and discussed, as well as the current state and forecast of global emissions. Japan constitutes a very fitting case study to analyse the effect of aviation on climate. It has a dynamic and sizeable domestic market, indeed one of the largest in the world (ICAO, 2017b; World Bank, 2017a), with an average of roughly 2500 domestic services per day (MLIT, 2017a). Furthermore, it has very well documented information on domestic routes, flights, passengers, fuel consumption and a vast array of data, which allows for numerous estimations with small room for statistical inadequacy. The author fully utilises these merits, completing the present analysis.

This thesis is divided into three chapters, each of which presents an individual study related to aviation emissions and to aviation in Japan. The first chapter is a revision of a previous study titled *Environmental impact of aircraft emissions and aviation fuel tax of Japan* (González and Hosoda, 2016), published in the Journal of Air Transport Management in October, 2016. The study employed a causal impact analysis to estimate the additional CO_2 generated by domestic aviation in Japan, after the Japanese government reduced by 30% an excise tax on aviation fuel, as a response to growing pressure by the airline industry to have it abolished it altogether. By means of a counterfactual analysis, the authors were able to estimate that between the years 2011 and 2015, CO_2 by aircraft rose by 12% as a result of the tax adjustment.

The results by González and Hosoda (2016) are of particular importance because the tax in question, *koukuukinenryouzei* (“aviation fuel tax”) is not on its own an environmental tax, but rather a surcharge arbitrarily set by the Japanese government in the 1970s, in order to allow

for further expansion of Japan's aerospace network, and for maintenance and upgrading of local airports and airfields. Nevertheless, the study was able to approximate the price elasticity of demand for aviation fuel, and to estimate the increase in fuel consumption that results from the adjustments to this tax. In other words, although it is not a tax levied for environmental purposes, it works as one, inasmuch as it offers an estimation of the additional amount of jet fuel (and subsequently of CO_2) that was generated as a response to a relatively cheaper fuel price.

The second chapter analyses Japanese people's attitudes and behaviour toward air travel and the environment. It employs behavioural intentions research to develop a mechanism to better understand individuals' choices related to aviation as well as to assess their general environmental behaviour. This is a crucial piece of research because of the importance of behavioural change in order to reduce CO_2 emissions. Indeed, as far as climate change is concerned, the understanding of the problem hardly translates into changes in behaviour, in what is known as "attitude-behaviour gap" or "value-action gap" (Blake, 1999; Kollmuss and Agyeman, 2002; Howarth et al., 2009; Davison et al., 2014). These concepts warn about the need to modify policy from an informational approach to a promotion of behavioural change.

The second chapter is based upon an online survey administered to 500 regular and non-regular flyers in three of the main cities of Japan: Tokyo, Osaka and Fukuoka. Based upon responses to a questionnaire about different aspects of aviation, attitudes toward the environment and sociodemographic information, it is possible to divide respondents into three segments by means of cluster analysis, thus allowing for an identification of the profile of individuals that are more likely to adjust their behaviour upon innovative environmental policy.

In other words, the segmentation of respondents into clusters, based on their responses to the questionnaires, allows for the identification a group of individuals who are more likely than others to modify their behaviour, their choice of transport, or even to pay a higher fee for air transport. By knowing the sociodemographic characteristics (age, income, level of education, etc.) that these individuals have in common, the author is able to potentially make a recommendation to the relevant authorities to focus on this segment of the population for any ruling that targets aviation pollution, rather than enforcing a policy that affects all users equally.

Finally, the third and last chapter takes a look at the controversial appearance of low-cost carriers (LCC), and particularly at their successful insertion into the Japanese market. There is small doubt in aviation literature, that budget airlines have not only snatched a substantial market share from incumbent airlines, but very much revolutionised the aviation industry as a whole (Barrett, 2004; Hooper, 2005; O'Connell and Williams, 2005; Dobruszkes, 2006; Francis et al., 2006; Graham and Shaw, 2008; Jung and Yoo, 2013; Jiang, 2014; and numerous others). In fact, LCCs have become so popular that, at present, more than one in four schedule passengers worldwide flies with a budget airline every day (ICAO, 2017c). In spite of this, to the best of the author's knowledge, there is no scientific publication that examines the environmental implications of the highly popular low-cost airlines.

As it turns out, Japan has proven a welcoming market to this flourishing industry. We look at the current situation of airlines in Japan, and at the surprising change that budget airlines have triggered in the domestic market: between 2000 and 2016, the share of LCCs in Japan's

aviation went from 2% to 25% of the total revenue passenger kilometres (RPK) (MLIT, 2017b)[1], leading traditional carriers to adjust their business practices and fares, in the face of growing competition. By means of a stated-preferences survey, the author is able to identify the factors that drive users to select one or the other service, examining responses of passengers from different operational airlines in Japan, as well as passenger's valuation of the environmental impact of air travel. Among other purposes, this allows for a clarification of whether LCCs have attracted new passengers who would otherwise not fly, or whether it has been a reshuffling of the existent market.

[1] This figure includes regional airlines (Air-Do, Starflyer, Solaseed Air and Skymark) that operate in Japan under a special business model that is akin to LCC and has a long trajectory in Japan, as opposed to more conventional LCC airlines (JetStar, Vanilla Air, Peach and Spring Japan) which started operating in Japan in 2012.

CHAPTER ONE

Aircraft Emissions and Aviation Fuel Tax in Japan

1.1 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 (Boeing, 2017; Airbus, 2017; ICAO, 2017a; IATA, 2017a), 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 author's 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.

The study investigated the Aviation Fuel Tax of Japan (*koukuukinenryouzei*) by considering both its impact on the national demand 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 2015. Thus, the study estimated the causal impact of the 30% reduction in the aviation fuel tax, which to the best of the author's 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, the study adopts 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 combine them into a single synthetic control that is 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. Section 2 briefly reviews 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, the author presents the model specifications and demonstrates how he proceeded with the analysis. Estimation results are explained in Section 5, which includes a policy implementation proposal to limit and mitigate the impact of air travel on the environment. Finally, concluding remarks are given in Section 6.

1.2 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, 2017; Boeing, 2017).

Based on these figures, current global air passenger traffic will have doubled by the early 2030s (Airbus, 2017; Boeing, 2017; IATA, 2017a; ICAO, 2017a) 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) and to 7.2% in 2015 (IEA, 2017). Furthermore, since 1990 aviation CO_2 emissions grew by 86.4% at 2012 (IEA, 2014a) and by 94.9% at 2015 (IEA, 2016) which dwarfs the growth rate of any other source.

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 (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 released by the combustion of aviation fuel at high (e.g., ozone, water vapour, and soot aerosols) and low altitudes (e.g., SO_2, NO_x, HC, etc.) (Figure 1.1) 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; Lu, 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 (Figure 1.2).

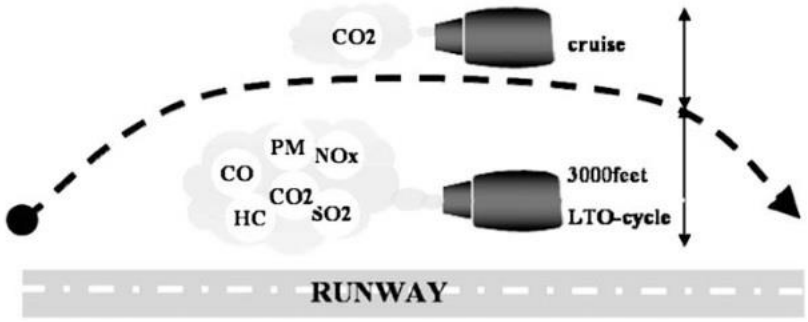


Figure 1.1 Diagram of pollutants emitted during landing and take-off, and cruise flight stages (Lu, 2009).

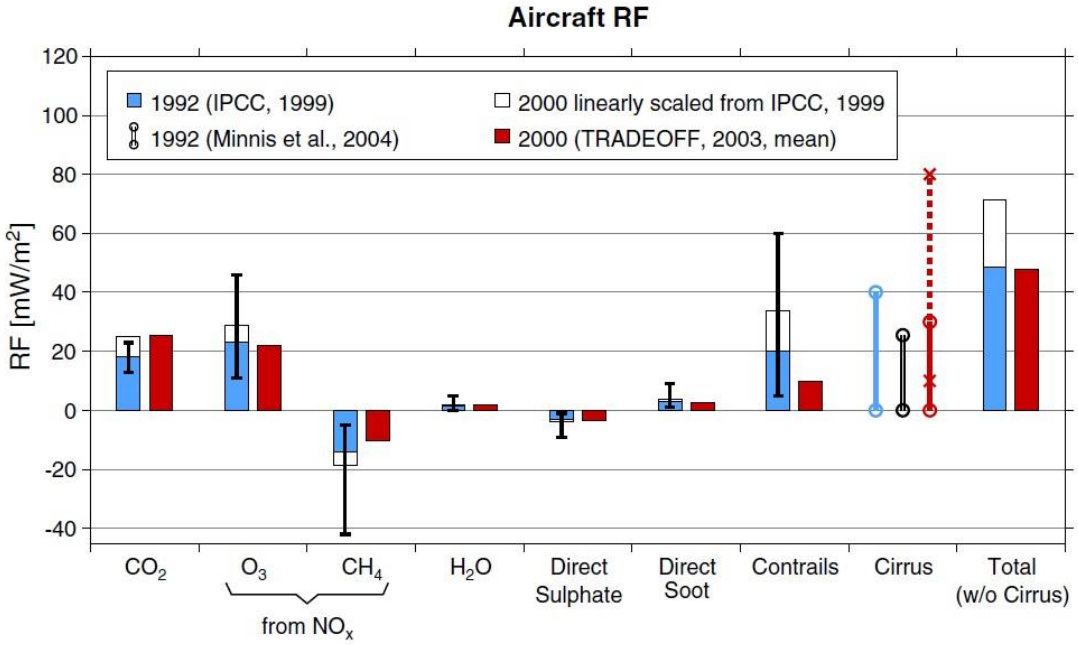


Figure 1.2 Radiative forcing (RF) [mW/m^2] from aviation for 1992 and 2000, based on IPCC (1999) and TRADEOFF results (Sausen et al., 2005). This chart can be found in numerous studies concerned with non-CO_2 emissions from aircraft. It is originally from a 2000 paper by Sausen et al. on aviation radiative forcing (RF), i.e. a climate sensitivity parameter, or rather, a measurement of an activity's contribution to climate change. The image shows the results of the TRADEOFF project, which was developed in order to obtain new estimates of aviation's RF as documented by an IPCC report from 1999 (IPCC, 1999). The study concludes that in spite of the difficulty to obtain reliable estimates of the associated RF by aircraft-induced cirrus clouds, their total effect on climate change might be as large as the estimate without accounting for these factors (Sausen et al., 2000).

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 taxation imposed on carbon emissions. For example, in Germany and Denmark, energy-intensive businesses have well-defined tax exemptions (BMF, 1999, 2006; DEA, 2012). If a carbon tax were applied to aviation, then unless this tax was common and equal among countries, airlines could change their operational behaviour to remain competitive (e.g., changing airports of choice and/or relocating to “low-tax” countries). Therefore, any tax applied regionally rather than globally could cause the taxed region to lose market share to non-taxed regions (Tol, 2007; Pearce and Pearce, 2010). However, such a problem would not arise if aviation fuel tax were imposed on domestic flights, which is the reason why only aviation fuel tax on domestic flights are considered in this paper.

Felder and Schleiniger (2002) analysed the trade-off between efficiency and the political expediency of certain environmental policies in Switzerland by considering different measures that compensated sectors for paying environmental taxes and thus, minimising intersectoral transfers. Their study evaluated a series of tax reform scenarios with different clauses related to the nature of the tax (e.g., uniform, exempted for energy-intensive sectors, and differentiated across sectors) and revenue use (e.g., lump sum to households, labour subsidies, and no subsidy). Then, they compared the trade-off results in terms of price-ratio distortions. Although their results are not directly applicable in terms of the scope of this study, a similar analysis of

the trade-off between efficiency and political expediency could provide a solution to the controversy surrounding the existing tax on aviation fuel in Japan.

1.3 Brief Overview of Japan's Aviation Industry

1.3.1 Circumstances of Japan's Aviation Industry

Unless indicated otherwise, the data concerning Japanese domestic aviation were provided by the Civil Aviation Bureau of the Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT). First, we present a brief overview of Japan's aviation industry.

Servicing 97 million passengers in 2016, Japan operates one of the largest domestic aviation networks in the world, which has experienced sustained growth over the past 20 years (Figure 1.3). It comprises 19 trunk lines and over 200 local routes, with an average of 2300 daily services. Between 1994 and 2015, Japan's domestic revenue tonne kilometres[2] (RTK) grew at an average annual growth rate of 1,8%, and the volume of passengers increased by 24 million. Japanese domestic aviation consumed over 4 Mt of jet fuel in 2015 (MLIT, 2017a).

[2] Although revenue passenger kilometres (RPK) is a more common unit to measure the growth of commercial aviation, this representation of revenue tonne kilometres (RTK) allows for a better appreciation of the growth of aviation, as in includes not only passenger transport but also freight, mail and additional luggage.

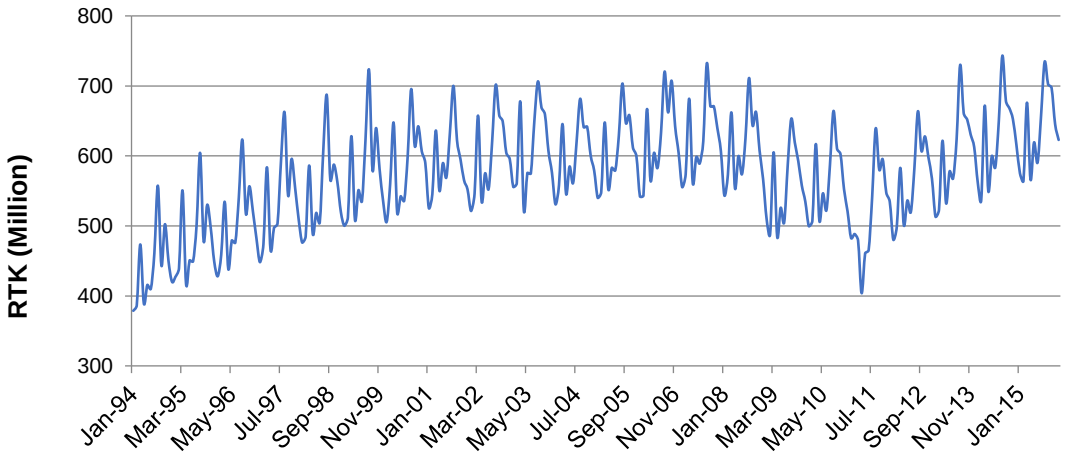


Figure 1.3 Evolution of Japanese domestic aviation: Monthly observations of Revenue Tonne Kilometres (RTK) of domestic flights in Japan (1994–2015). The chart shows traditional seasonality peaking during the months of Japanese holidays. The sharp drop in 2011 corresponds to the occurrence of the 2011 Tohoku Earthquake. Source: Author from MLIT (2017a).

The Japanese aviation sector is a well-organised network with modern and fuel-efficient aircraft (Figure 1.4). For the purposes of this research, we consider that a modern fleet would offer the lowest boundary to the extent of CO_2 reduction. Thus, broadly speaking, any country that was to apply a similar measure for CO_2 reduction adopted in this paper should expect at least similar or greater reductions in CO_2 emissions.

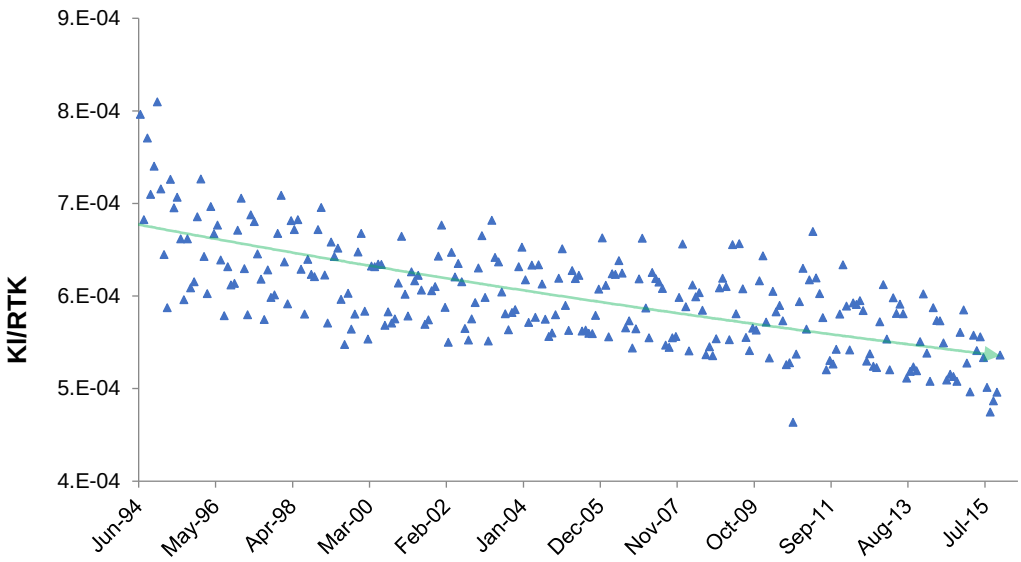


Figure 1.4 Evolution of fuel efficiency in Japanese domestic aviation. Scatter graph representation of the sustained decline of the ratio between consumed fuel and distance flown (Kl/RTK) in domestic flights (1994–2015). Source: Author from MLIT (2017).

Although domestic aviation accounted for <1% of Japan's total CO_2 emissions in 2015, it is a considerably large figure in absolute terms. As a reference, CO_2 emissions from Japanese domestic aviation were about 1.3 times the national CO_2 emissions of Costa Rica one year earlier (World Bank, 2017b). Furthermore, it must be highlighted that there was an increase in CO_2 emissions from the aviation sector after 2011, which correlates with the adjustment of the domestic aviation fuel tax (Figure 1.5). The following sections quantify this effect and assess the sensitivity of aviation's CO_2 emissions to a tax on fuel. Incidentally, for domestic aviation a factor of 2.576 Kg/l is used in order to estimate the generation of CO_2. This factor is reported under the Mobile Combustion CO_2 Emission Factors by the US Environmental Protection Agency (EPA) (EPA, 2014).

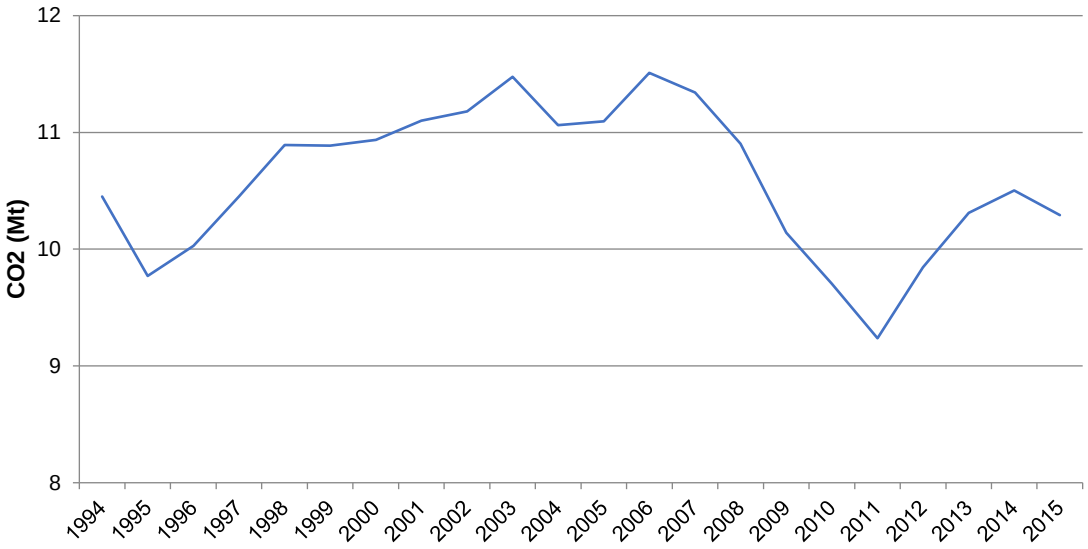


Figure 1.5 CO_2 emissions from domestic aviation in Japan (1994-2015). Annual estimation using data from jet fuel consumed by local flights at a factor of 2.576 Kg/l (EPA, 2014), between 1994 and 2015, in megatons (Mt). Source: Author from EPA (2014) and MLIT (2017a).

During the 20-year period of 1994–2013, the real-term price of jet fuel quadrupled, approximately doubling each year, except for the steep drop in 2008 following the Lehman Brothers shock. Indeed, the soaring price of jet fuel has increased the industry's operational costs on the global scale, with the percentage of airlines' operational costs attributable to fuel increasing from 13.6% in 2003 to 33.1% in 2013 (IATA, 2015), and then down to 26.5% in 2015 (IATA, 2017a). Figure 1.6 illustrates the change in monthly prices of jet fuel, as reported by the Bank of Japan (BOJ).

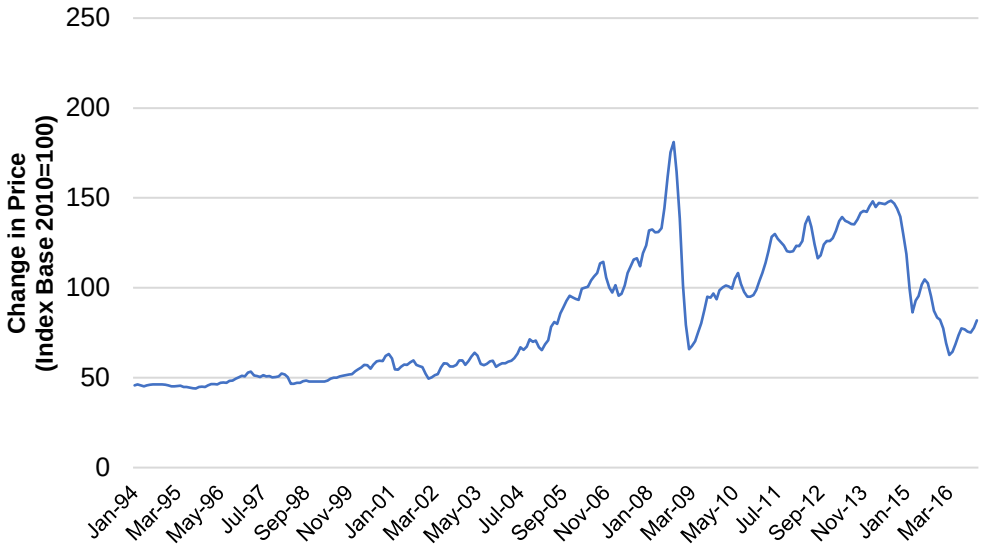


Figure 1.6 Jet fuel price change in Japan 1994–2016. [Services Producer Price Index] All items (excluding International transportation) / Year-on-year change 2010 = 100. Source: Author from BOJ (2017).

To compare the change in aviation fuel price with the actual cost of flying, the trend of domestic aviation prices is presented. It is interesting to observe that despite the increase in the price of jet fuel and therefore, of airlines' operational costs, the price of airline tickets has remained relatively unaltered for the same period. Figure 1.7 shows the behaviour of domestic air ticket prices from 1994–2016. The data have been adjusted to remove the seasonal component, which is very strong in Japanese aviation during the holiday months of April, July, and December.

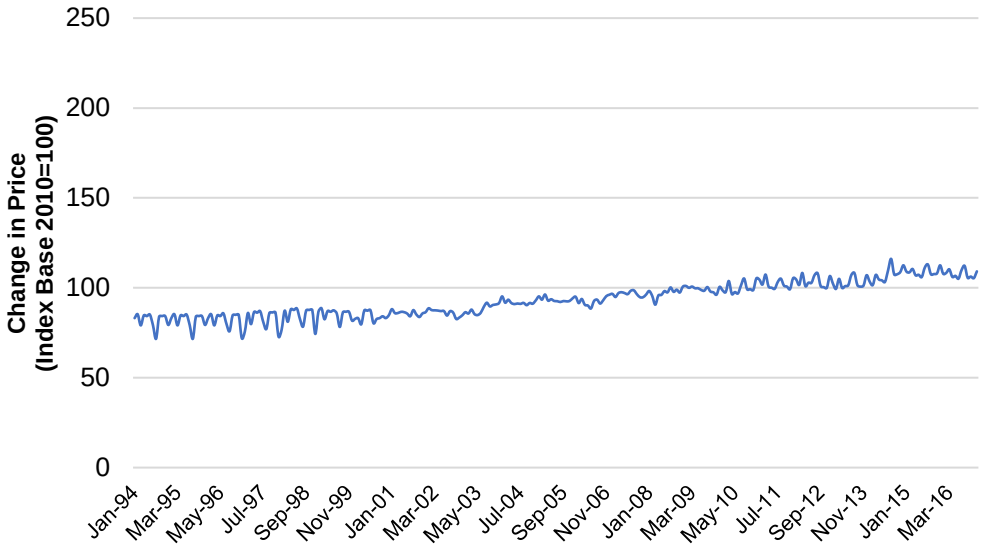


Figure 1.7 Domestic airline ticket price change in Japan 1994–2016. [Services Producer Price Index] All items (excluding International transportation) / Year-on-year change 2010 = 100. Source: Author from BOJ (2017).

1.3.2 Aviation Fuel Tax of Japan

The aviation fuel tax is an indirect tax imposed on aviation fuel loaded onto aircraft, including helicopters, in the territory of Japan. Taxpayers are required to file a return and pay the tax on a monthly basis, following the loading of fuel on their aircraft. Aviation fuel tax is an excise tax for which international flights are exempt in Japan. Eleven-thirteenths of the revenue from the tax is credited to the general accounts of the State and then transferred to the Airport Construction and Improvement Account within the Special Accounts for Social Infrastructure Improvement (*kuukouseibitokubetsukaikei*). The remaining two-thirteenths of the revenue are granted to local governments for expenditures related to airports (MOF, 2010).

Persons liable to pay the aviation fuel tax are as follows:

(1) Owners of aircraft.

(2) Where it is clearly shown by the contract that persons other than owners are “users of aircraft” as prescribed by the Civil Aeronautics Act, these users of aircraft instead of owners.
(3) Where owners or users of aircraft have no residence or office in Japan, pilots-in-command instead of owners or users of aircraft.
(4) Persons other than owners, users, and pilots-in-command who make test flights or repairs of aircraft.
(5) Persons who make repairs of or conduct test runs of aircraft engines themselves (in this case, the tax is imposed on the quantity of aviation fuel consumed for repairs or test runs).

It is important to note that the Japanese aviation fuel tax was never recognised as an environmental tax. Instead, it was enacted for the purposes of development, expansion, and/or maintenance of regional airports and airfields. During the 1970s and 1980s, this proved a successful measure and the Japanese aviation network benefited from considerable development; however, the need for additional infrastructure has diminished and the existing airports are deemed capable of being run autonomously.

In April 2011, the Japanese aviation fuel tax underwent a 30% cut, which was implemented as a Government response to the filing for bankruptcy protection by Japan Airlines and constant pressure from Japan’s Aeronautic Association (JAA) for the revision of fuel tax charges. The current fuel tax is applied to all domestic flights under the structure displayed in Table 1.1 (MLIT, 2017c).

Table 1.1. Tax structure of the aviation fuel tax in Japan. In 2014, the Government decided to extend the tax reform until April 2017, and later until April 2019. Source, Author from MLIT (2017c).

Route	Original Tax Rate (¥/Kl)	Adjusted tax rate (2011–2017) (¥/Kl)	Adjusted tax rate (2017–2019) (¥/Kl)
Domestic Flight (base)	26 000	18 000	18 000
Lines to Okinawa	13 000	9 000	9 000
Lines to "Remote Islands"	19 500	13 500	13 500

1.4 Model Specification

An empirical model is constructed following the theorical approach developed by Brodersen et al. (2015). First, it is important to explain Bayesian structural time-series models, as they are the base for the causal impact. These are a type of state-space models, i.e. models that describe the probabilistic dependence between the latent "state" variable and the observation (Chen and Brown, 2013), for time-series data.

The defining equations are as follows:

$$y_t = Z_t^T \propto_t + \varepsilon_t \qquad (1.1)$$

$$\propto_{t+1} = T_t \propto_t + R_t \eta_t \qquad (1.2)$$

where $\varepsilon_t \sim N(0, \sigma_t^2)$ and $\eta_t \sim N(0, Q_t)$ are independent of all other unknowns.

Equation (1.1) is the observation equation, i.e. it links the observed data y_t to a latent d-dimensional state vector $\propto_t$. Equation (1.2) is the state equation; it governs the evolution of the state vector $\propto_t$ through time.

For this model, the remaining parameters are defined as follows: y_t is a scalar observation, Z_t is a *d*-dimensional output vector, T_t is a d×d transition matrix, R_t is a d×q control matrix, ε_t is a scalar observation error with noise variance σ_t, and η_t is a *q*-dimensional system error with a q×q state-diffusion matrix Q_t, where q ≤ d. Writing the error structure of equation (1.2) as $R_t\eta_t$ allows us to incorporate state components of less than full rank (Brodersen et al., 2015).

Next, a local linear trend is defined by the following two equations:

$$\mu_{t+1} = \mu_t + \delta_t + \eta_{\mu,t} \qquad (1.3)$$

$$\delta_{t+1} = \delta_t + \eta_{\delta,t} \qquad (1.4)$$

where $\eta_{\mu,t} \sim N(0, \sigma_\mu^2)$, $\eta_{\delta,t} \sim N(0, \sigma_\delta^2)$, μ_t represents the value of the trend at time *t*, and δ_t is the expected increase in μ between times *t* and *t+1*, i.e. the slope at time *t*.

This approach, called a Bayesian structural time-series model, is designed to infer the causal impact that a market intervention has exerted on a time-series over time. The way that this metric would have evolved after the intervention – if the intervention had never occurred – is known as the *counterfactual*. The difference between the counterfactual and the actual time-series is that the former is built from set control series that are themselves not affected by the intervention. In other words, it is a synthetic variable generated from control series that show high correlation with the data points before the intervention, and the model assumes that this

relationship between covariates and treated time-series, as established during the pre-period (2004-2011), will remain stable throughout the post-period (2011-2015).

Seasonality is captured in the model through the following component

$$\gamma_{t+1} = -\sum_{s=0}^{S-2} \gamma_{t-s} + \eta_{\gamma,t} \qquad (1.5)$$

where *S* represents the number of seasons and γ_t represents their joint contribution to the observed data.

This model employs a "Spike-and-Slab" prior on the set of regression coefficients, which allows the model to choose (average over) an appropriate set and to relieve a posteriori uncertainty about which covariates to include and how strong an influence they should have, which avoids overfitting.

As for the evaluation (pointwise) of the impact,

$$\phi_t^{(\tau)} \coloneqq y_t - \tilde{y}_t^{(\tau)} \qquad (1.6)$$

is established in order to obtain results from the a posteriori casual effect, for each draw τ and for each time point $t = n + 1, \ldots, m$.

It is also important for this research to estimate the cumulative effect of the intervention over time. This cumulative sum of causal increments is estimated by

$$\sum_{t'=n+1}^{t} \phi_{t'}^{(\tau)} \quad \forall t = n+1, \ldots, m \qquad (1.7)$$

where *y* represents a flow quantity measured over an interval of time (in this case, one month).

1.5 Estimation Results

The treatment variable consisted of monthly observations of jet fuel consumed (in kilolitres) by domestic flights in Japan between January 2004 and December 2015 (144 observations). The 30% tax reduction became effective at the start of the fiscal year in April 2011; therefore, the counterfactual time-series was constructed with a set of covariates that explained the behaviour of fuel consumption until this point, using the causal impact (CausalImpact R Package) model.

The causal impact approach needs to establish a set of regressors that is able to explain the pre-intervention part of the time-series appropriately. By definition, the model does not commit to a fixed set of covariates. Instead, it is allowed to choose from an array of "candidate" controls, which are selected purely in terms of how well they explain the behaviour of the observed data, in this case, the fluctuation of jet fuel consumption in Japan before the tax change. For this study, the author employs data from web search queries provided by Google Correlate™ (https://www.google.com/trends/correlate).

As long as the variables employed are strictly not affected by the intervention, the model will construct a synthetic control variable that is based on a combination of markets that explain the outcome data before the 30% tax reduction, while automatically balancing the goodness of fit and model complexity (see Brodersen et al., 2015).

The variables used in this study as “candidate” regressors are Google web searches, i.e. words or phrases searched into Google in the United States. Based on the original jet fuel time series (Figure 1.8), Google Correlate renders seasonally-adjusted, monthly totals of web searches for the 100 most highly correlated entries. The randomness of Google searches, as well as the limitation to searches in the United States, make a solid case for the satisfaction of one of the conditions of the casual impact model, namely that these variables themselves are not affected by the intervention.

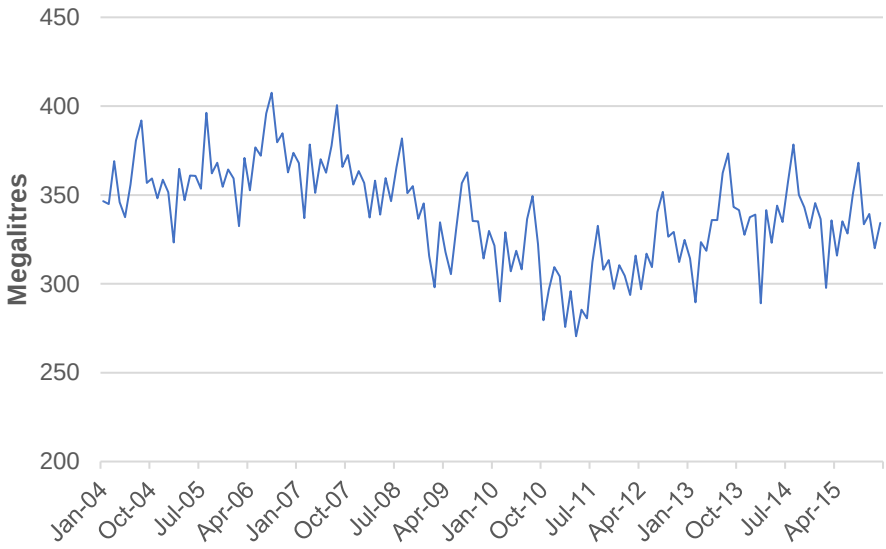


Figure 1.8 Monthly domestic consumption of jet fuel in Japan in Megalitres (Ml) (2004-2015)
Source: Author from MLIT (2017).

Causal impact places as spike-and-slab prior over these candidate predictors, which allows the model to “choose” an appropriate set of control variables. Spike-and-slab regression is a Bayesian technique in big data econometrics, often useful when the number of possible predictors exceeds the number of observations. For P possible predictors, a vector γ of length P is defined, composed of zeros and ones that indicate whether or not a particular variable is

included in the regression. The “spike” is the probability of a coefficient being non-zero, and the “slab” is the prior describing the possible values of the coefficient.

The list of “candidate” regressors provided by Google Correlate, as well as their partial correlation with the observed data, and probability of inclusion in the causal impact model are presented in Table 1.2

Table 1.2 Full data set of “candidate” regressors as provided by Google Correlate, partial correlation with observed variables and probability of inclusion in causal impact estimation.

Regressor	Inclusion prob.	Partial correl.
erase.boards	0.617	0.823
camera.repair	0.393	0.817
lewiston..maine	0.348	0.820
dry.erase.boards	0.346	0.819
manhattan..nyc	0.181	0.818
dollar.shop	0.139	0.828
jeff.ferry	0.070	0.814
port.jeff.ferry	0.053	0.816
camera.repairs	0.052	0.856
X1800mattress	0.050	0.808
sturbridge..ma	0.048	0.812
south.portland..maine	0.043	0.807
phone.code	0.040	0.807
scarborough..maine	0.033	0.813
nab.little.creek	0.030	0.820
wisconsin.zip	0.026	0.811
shore.line	0.026	0.816
oregon.zip.codes	0.023	0.813
bad.credit.loans	0.023	0.815
south.carolina.dnr	0.022	0.817
credit.loans	0.019	0.813

inducing.labor	0.018	0.824
florence..alabama	0.016	0.810
new.jersey.zip	0.016	0.820
manchester..vt	0.016	0.823
penn.station..ny	0.015	0.819
ma.	0.014	0.809
canada.zip	0.013	0.813
lee.	0.012	0.810
metra.chicago	0.011	0.809
overhead.doors	0.010	0.821
asheville.	0.010	0.828
lease.agreements	0.009	0.814
nh.	0.009	0.824
cox.communication	0.008	0.815
medford..oregon	0.008	0.816
magic.shops	0.008	0.820
cartoon.network..com	0.008	0.821
portsmouth..nh	0.007	0.808
spice.restaurant	0.007	0.816
xpress	0.006	0.809
aurora..colorado	0.006	0.809
bergen.county..nj	0.006	0.810
astoria..queens	0.006	0.810
warner.robins..georgi	0.006	0.811
mini.refrigerators	0.006	0.834
hotel.motel.for.sale	0.005	0.808
ny.subway.map	0.005	0.810
mercedes.forum	0.005	0.812
ny.subway	0.004	0.813
new.hope..pa	0.004	0.813
volvo.	0.004	0.814
hope..pa	0.004	0.815
minnesota.zip	0.004	0.823
bart.sf	0.004	0.827
dmv.	0.004	0.847

image.resize	0.003	0.808
credit.personal	0.003	0.810
verizon.cell.phone	0.003	0.814
boston..ma.	0.003	0.814
subaru.	0.003	0.817
eviction.notices	0.003	0.819
country.hits	0.003	0.822
direct.t.v.	0.002	0.807
ford.	0.002	0.808
top.mba.schools	0.002	0.808
fort.collins..colorad	0.002	0.808
blowing.rock..nc	0.002	0.808
simmons.beauty	0.002	0.809
pa.	0.002	0.809
bend..oregon	0.002	0.810
bmw.	0.002	0.811
police.dept.	0.002	0.811
bucks.county..pa	0.002	0.811
top.country.hits	0.002	0.812
amvs	0.002	0.816
free.rental.agreement	0.002	0.823
free.lease.agreements	0.002	0.823
san.francisco.zip.cod	0.001	0.808
winerys	0.001	0.808
mcminnville..oregon	0.001	0.808
transit.system	0.001	0.809
fort.collins.colorado	0.001	0.809
alert.bracelet	0.001	0.810
door.co	0.001	0.810
plano.texas	0.001	0.810
clark.county..nv	0.001	0.810
canby..oregon	0.001	0.812
collins.colorado	0.001	0.814
beaverton..oregon	0.001	0.817
newnan.utilities	0.001	0.822

bill.consolidation	0.001	0.823
galena..il	0.001	0.832
portland.oregon	0.000	0.807
newspaper.agency	0.000	0.809
postal.jobs	0.000	0.810
denver.colorado	0.000	0.812
X.82	0.000	0.817
credit.cards	0.000	0.821
cta.chicago	0.000	0.833

The following graphic illustrated the casual impact model for the observed jet fuel consumption time series and the counterfactual predictions based on the “candidate” regressors listed above.

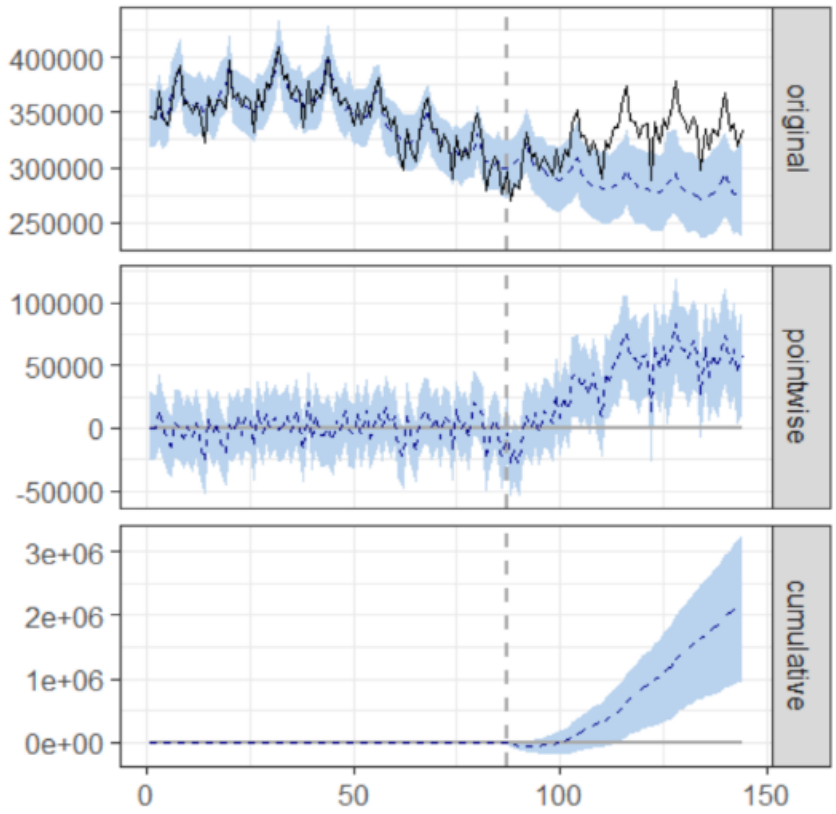


Figure 1.9 Visualisation of the causal impact object. It contains three panels and a straight vertical line that indicates the moment of the tax reduction, i.e., April 2011. The solid line in the upper panel shows the original data and the dotted line represents the counterfactual prediction. The middle panel displays the difference between the observed and predicted data in panel one. The lower panel sums the values of the middle panel, resulting in a plot of the cumulative effect of the intervention, i.e., the additional fuel consumed as a response to the tax adjustment. Source: Authors with Causal Impact R Package.

It is noticeable that the cumulative effect in the lower panel of Figure 1.9 is negative during the first months following the intervention. This could reflect a response to two different effects. The first is the time lag in the decision to increase consumption. Despite the relatively cheaper price of jet fuel, there is an associated delay before an airline decides to increase its number of flights, add to its fleet of aircraft, or diversify its routes to avail itself of the relatively more beneficial financial conditions. The second reason is the occurrence of the 2011 Tohoku

Earthquake, which occurred just one month before the tax structure was adjusted. As shown in Figs. 1.2 and 1.4, the totals of RTK and jet fuel consumption experienced sharp declines in 2011 because of the reduction in leisure and business travel in Japan.

Table 1.3 Summary of causal impact results (Megalitres (Ml))

	Average	Cumulative
Actual	330	19,000
Prediction (SD)	290 (11)	16,000 (627)
95% CI	[270, 310]	[15,000, 18,000]
Absolute Effect (SD)	**38.6 (11)**	**2202 (627)**
95% CI	[16.6, 57]	[946, 3249]
Relative Effect (SD)	**13% (3.8%)**	**13% (3.8%)**
95% CI	[5.8%, 20%]	[5.8%, 20%]
Posterior Tail-Area Probability:	0.001	
Posterior Probability of a Causal Effect:	99.9%	

The "Average" column represents the average value of monthly jet fuel consumption after April 2011. The "Absolute Effect" is determined as the difference between the predicted and actual value, i.e., the additional jet fuel that was consumed following the reduction in tax.

At an average 38.6 Ml of additional jet fuel used per month, the study approximated the annual extra fuel consumption as 463.2 Ml. Using the EPA factor, this corresponds to 1.19 Mt CO_2. The "Cumulative" column in Table 1.3 sums all the individual time points after the intervention, which renders the total additional fuel consumed between the tax adjustment in April 2011 and the final observation in December 2015.

The total extra fuel consumed during this period was 2,202 Ml, which converts to 5.67 Mt CO_2. In relative terms, the response values showed an increase of 13% in fuel consumption. The 95% confidence interval of this percentage was [5.8%, 20%], which means that the positive

effect observed during the intervention period was statistically significant and unlikely to be due to random fluctuations.

To better illustrate these results, we may refer to Japan's CO_2 levels during the adjustment years. In 2015, emissions from domestic aviation were at 10.3 Mt CO_2, of which the average estimate of 1.09 Mt CO_2 per annum represented 10.6%. Alternatively, one could conduct the inverse operation and determine that in order to reach the level reported by the MLIT, airlines had to purchase an extra 11.8% of fuel, a figure that is actually higher for other years (13.3% in 2011, 12.4% in 2012, and so forth), and thus consistent with the annual increase rate of 13%, as estimated by the model. The same standard can be applied to the cumulative estimation of additional CO_2 generated between 2011 and 2015 due to the tax adjustment.

During these years, the total emissions from domestic aviation were 50.2 Mt CO_2, of which 5.2 Mt – roughly 12.1% – are a direct result of additional fuel consumption as a result of a relatively lower price, according to the model's results. At the national level, Japan's total CO_2 emissions during the 5 years following the tax reform were 6.38 Gt CO_2 (JCCCA, 2017), of which domestic aviation represented a minor, although significant, 0.8%. Japan is currently the world's fifth largest emitter of CO_2 and the second net importer of oil products (IEA, 2016, 2017).

As a robustness check, the author has conducted the following tests:

(A) A rerun of the casual impact model after setting the intervention point at the moment of announcement of the tax reduction (December, 2011) rather than at the moment of implementation (April, 2010). This is because economists believe agents will respond to

policy announcements provided the announcement is credible. Figure 1.10 shows the results of the causal impact regression.

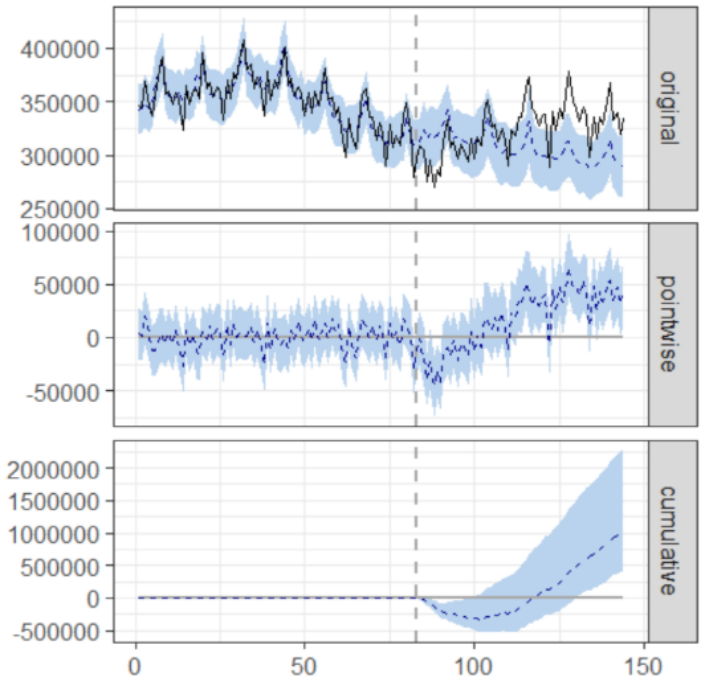


Figure 1.10 Estimation of causal impact with intervention point set at the moment of announcement (Dec, 2010) instead of the moment of implementation (Apr, 2011) of the tax adjustment.

Table 1.4 Summary of causal impact results with intervention set at moment of announcement (Megalitres (Ml)).

	Average	Cumulative
Actual	320	20,000
Prediction (SD)	310 (7.6)	19,000 (463)
95% CI	[290, 320]	[18,000, 19,000]
Absolute Effect (SD)	**17 (7.6)**	**1037.7 (463.2)**
95% CI	[6.9, 37.6]	[422, 2289]
Relative Effect (SD)	**5.5% (2.5%)**	**5.5% (2.5%)**
95% CI	[2.3%, 12%]	[2.3%, 12%]
Posterior Tail-Area Probability:	0.001	
Posterior Probability of a Causal Effect:	99.9%	

The "Average" column represents the average value of monthly jet fuel consumption after April 2011. The "Absolute Effect" is determined as the difference between the predicted and actual value, i.e., the additional jet fuel that was consumed following the reduction in tax.

Although the values for the monthly addition fuel consumption vary, the estimation is qualitatively (direction and significance) equal. Furthermore, the absolute effect (17Ml) falls between the 95% confidence interval for the original casual impact estimation detailed in Table 1.3, which shows how these two analyses are indeed consistent (do not contradict each other).

(B) An inclusion in the list of "candidate" regressors of a number of time series equally assumed to be unaffected by the intervention. Because results obtained through Google Correlate were restricted to time series from the USA, the author has included variables that are thought not to have been affected by the intervention:

- Construction spending (sewage and waste disposal) (US Census Bureau)
- Manufacturers' shipments, inventories and orders (fabricated metal products) (Op. cit.)
- Retail trade and food services (building materials and gardening equipment) (Op. cit.)

The results from the estimation using these variables is shown in Figure 1.11.

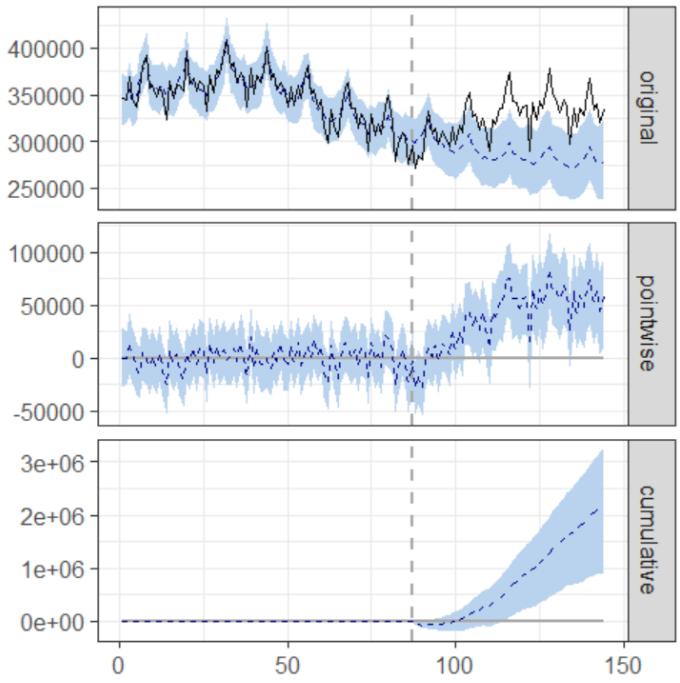


Figure 1.11 Estimation of causal impact with the manual inclusion of variables assumed to satisfy the condition of not being affected by the intervention. Notice how the estimated values are virtually exact to the original regression, which shows how the causal impact model is effective at selecting only the “candidate” regressors that correctly explained the observed data.

Table 1.5 Summary of causal impact results (Megalitres (Ml)) with the addition of assumed unaffected time series.

	Average	Cumulative
Actual	330	19,000
Prediction (SD)	290 (11)	16,000 (627)
95% CI	[270, 310]	[15,000, 18,000]
Absolute Effect (SD)	**38.6 (11)**	**2202 (628)**
95% CI	[16.1, 57.1]	[920, 3256]
Relative Effect (SD)	**13% (3.8%)**	**13% (3.8%)**
95% CI	[5.6%, 20%]	[5.6%, 20%]
Posterior Tail-Area Probability:	0.001	
Posterior Probability of a Causal Effect:	99.9%	

The "Average" column represents the average value of monthly jet fuel consumption after April 2011. The "Absolute Effect" is determined as the difference between the predicted and actual value, i.e., the additional jet fuel that was consumed following the reduction in tax.

One could also think about running a stability test for the pre-intervention period to see whether the relationship between observed variables and the predicted values hold. Because the casual impact is defined in a Bayesian technique where parameters are always changing (random coefficient α_t in equation 1.1), a traditional approach such as a Chow test is not valid. Nevertheless, checking this stability through alternative mechanisms would strengthen further the robustness check.

1.5.1 Fuel cost vs. fuel consumption

The analysis in the previous section has shown how a 30% reduction in fuel tax translates into an average monthly increase of 13% in fuel consumption. In order to distinguish between the demand-side and supply-side mechanisms to explain this outcome, it is important to first understand how airlines adjust to changes in fuel costs. There are a number of ways that airlines can cope with changing fuel costs, e.g. removing or adding aircraft to the fleet, modifying the operation strategies by rearranging schedules or adjusting operational routes, increasing/decreasing flight frequency and naturally, changing ticket prices and passenger service standards.

In general, when fluctuations in fuel costs are expected to be short lived, like the case of the tax reduction in Japan, airlines opt to adjust the frequency of flights before turning to the market demand through changes in airfares (Hsu and Eie, 2013). In fact, the absence of a pass-through from relatively cheaper fuel to lower airfares has been observed plenty in domestic aviation.

For example, between June, 2014 and December, 2015, the price of crude oil dropped from $111.8/barrel to $38/barrel (EIA, 2018). This translated into a reduction in fuel costs of roughly 30% for airlines such as United and Southwest. Nevertheless, industry analysts observed that airfares remained essentially unchanged during this period (Mouawad, 2016).

In Japan, the average number of monthly flights in Japan went from 59.6 thousand in 2011, to 70.4 thousand in 2015, which represents an 18.1% increase. Figure 1.12 illustrates the month-on-month changes in the number of domestic flights.

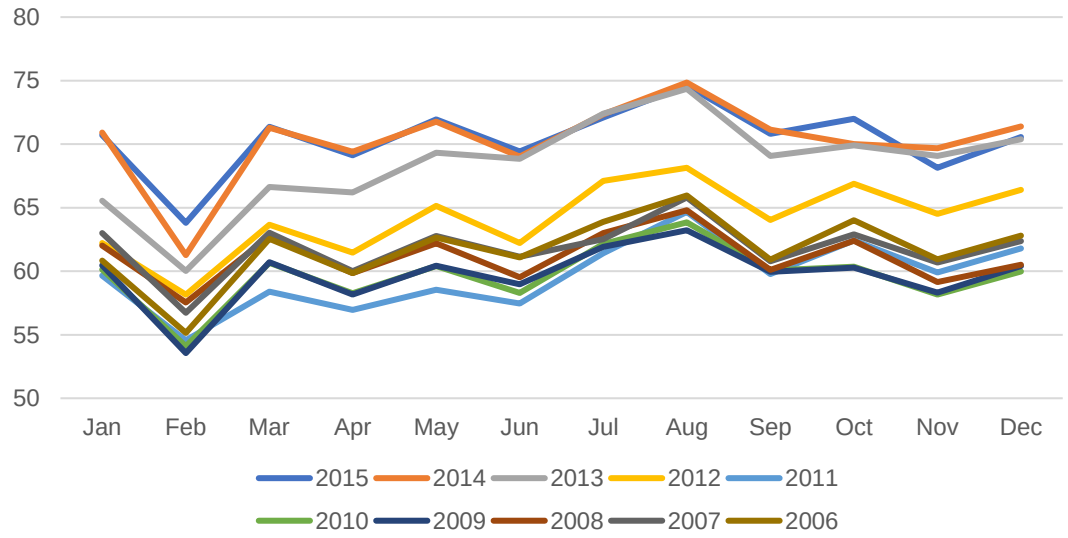


Figure 1.12 Illustration of yearly increase in number of flights in domestic aviation in Japan. Observe the differentiation in the total number of flights from 2012 onward. Source: Author from MLIT (2018).

Conversely, the price of flying over the same period has shown a sustained growth year on year, without any particular effect after the tax reduction. Except for the peak months of July and August, airfares for any given month do not show any particular difference in growth rate between the pre-intervention (2004-2011) and post-intervention (2011-2015) periods. Figure 1.13 illustrates the monthly indexed prices of domestic air transport between 2004 and 2015. Furthermore, Table 1.6 shows the compound annual growth rate (CAGR) in airfares for each month in both the pre and post intervention periods.

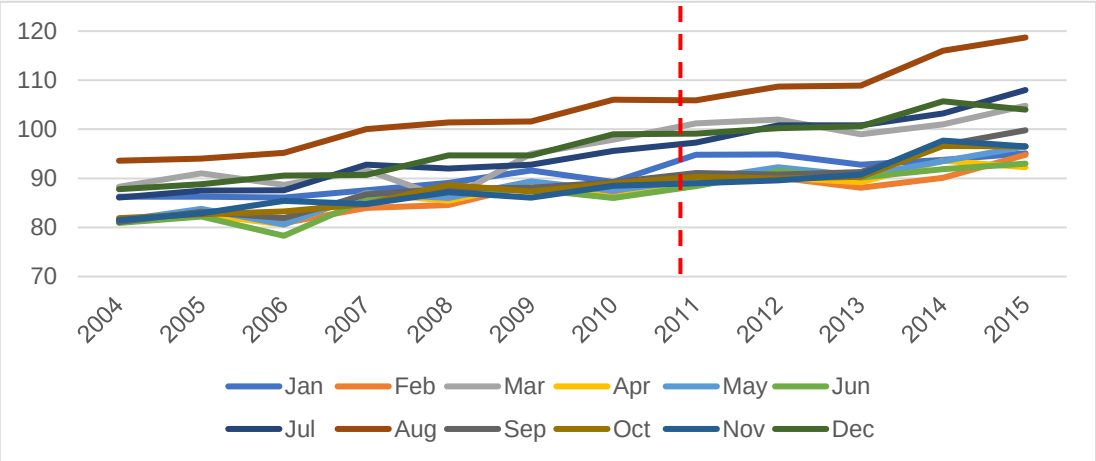


Figure 1.13 Illustration of month-on-month changes in indexed prices of domestic air travel. Red dotted line shows the moment of intervention (tax reduction). Source: Author from BOJ (2018).

Table 1.6 CAGR in airfares for each month during the pre-intervention (2004-2011) and post-intervention (2011-2015) periods, as well as the average CAGR for the full time series. Notice how there is no observable difference in average airfare increases between the pre and post intervention period. Source: Author from BOJ (2018).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Aver.
2004-2011	1.4%	1.5%	2.0%	1.4%	1.4%	1.3%	1.8%	1.8%	1.7%	1.4%	1.3%	1.7%	**1.55%**
2011-2015	0.1%	1.2%	0.9%	0.7%	1.8%	1.3%	2.6%	2.9%	2.3%	1.7%	2.0%	1.2%	**1.56%**
2004-2015	0.9%	1.4%	1.6%	1.1%	1.6%	1.3%	2.1%	2.2%	1.9%	1.5%	1.5%	1.6%	**1.55%**

These results suggest that during the period analysed, airlines in Japan most likely responded to relatively cheaper fuel by increasing the frequency of flights, and possibly the size of their fleets, rather than by adjusting airfares. As shown in Table 1.6, the average price of air tickets continued to grow after the intervention at an almost identical rate as they had been growing since 2004. These results are in line with those of Hsu and Eie (2013), Gayle and Lin (2017) and others, who show how operational adjustments are the main mechanism that might affect fuel consumption when the price of fuel fluctuates.

1.6 Concluding Remarks

Although the aviation sector is currently a relatively small contributor to global CO_2 emissions, it is expected that it will emit substantially more CO_2 in the future; therefore, it should not be ignored when considering measures to prevent global warming. This research has shown scientific evidence that illustrates the rapid growth of CO_2 emissions attributable to the development of the aviation sector, and it has demonstrated conclusively that aviation fuel tax can realise a significant reduction in the CO_2 emissions from aircraft, in a way that to the best of the author's knowledge has not been done before.

This research estimated the quantity of aviation-related CO_2 emissions that could be discouraged by the application of a fuel tax. Just as other means of transportation are almost universally bound to an environmental tax, there is no justification in terms of environmental economics for this particular sector to remain unaccountable for a problem that is of general concern.

The investigation has shown that large-scale reductions of CO_2 emissions could be achieved if measures similar to the Japanese Aviation Fuel Tax were replicated in other regions of the world. Japan, as a regional leader committed to the environment and to efforts to reduce CO_2 emissions, should consider the results of this paper to demonstrate the environmental implications to other Asian economies that are experiencing a boom in their regional and low-cost aviation sectors.

Considering the continued opposition to the existing fuel tax from Japanese domestic airlines, it is unlikely that jet fuel could be added to the current structure of environmental taxes in

Japan. Nevertheless, this paper proposes an alternative to environmental tax reform that comprises a simple price-elasticity approach comparing the effect of CO_2 reductions under implicit and pure carbon taxes and the figures estimated in this study. Naturally, public acceptance remains the main obstacle to such restructuring, especially by those sectors that are dependent on fossil fuels and sensitive to international competitiveness, such as airlines (Yokoyama et al., 2000).

The results of this study might appear unfeasible to the aviation industry in Japan, because the abolishment of the reduction in fuel tax would mean an increased cost for business. However, to promote sustainable development, the balance between environmental protection and business prosperity must be maintained. This paper offers a measured and balanced view of the environmental concerns associated with aviation emissions of CO_2. It is a matter of an equilibrated solution between the need for air travel and the severe impact of flying on climate change.

CHAPTER TWO

User Behaviour toward Air Travel and the Environment: The Case of Japan

2.1 Introduction

The following study analyses the different attitudes and behaviour of regular and non-regular air travellers toward aviation and its environmental impact. It examines the profile of an individual who, based on their revealed attitudes and statements, is more likely to modify their behaviour about the use of air travel, which is not only important to assess the general awareness of users around this matter, but is also key to efficient policy implementation. The study is developed around a household survey conducted over the internet in October, 2017, in three of Japan's most populated cities: Tokyo, Osaka and Fukuoka, which are not only strategic aviation hubs, but cities that are also connected by a more environmentally conscious alternative: the Shinkansen.

The objective of this study was to identify the sociodemographic characteristics of individuals who, based on their answers, are more likely to modify their behaviour in the face of growing aviation emissions. This is of particular importance given the urgency for policy to become behavioural rather than information-oriented. Indeed, numerous studies (Blake, 1999; Kollmuss and Agyeman, 2002; Howarth et al., 2009; Davison et al., 2014; others) have recurrently exposed the problematic "gap" between people's environmental awareness and their actions. The present study binds together a thorough assessment of people's behaviour and attitudes, with a statistical approach for more impactful environmental policy.

Commercial aviation is the fastest growing source of CO_2 in the world (IEA, 2016). The industry is experiencing a growth rate of 3,6% per annum (IATA, 2016), and recent forecasts estimate that the market will have doubled in size over the next 15 years (Airbus, 2017; Boeing, 2017; IATA, 2017; ICAO, 2017a). However, aviation today receives some of the most generous tax exemptions of any sector, and emission taxes on international aviation are, for all intents and purposes, inexistent. It is necessary to clarify at this point that the present study does not intend to impugn or belittle the remarkable contribution and economic importance of aviation in modern society, but rather to raise concern about whether its impact on the environment should continue to go undisputed, for it clearly neither goes unnoticed nor unpublished.

As for domestic aviation, its inclusion in emission taxes or trading schemes is also rather limited. As part of the EU Emission Trading System (ETS), the European Commission includes flights between airports located in the European Economic Area (EASA, EEA, EUROCONTROL, 2016). This measure was initially enacted to include all flights arriving at, and departing from, airports in the European Economic Area, however pressure from the airline sector and foreign governments led to the eventual exclusion and postponement of negotiations. In the United States, the Environmental Protection Agency (EPA)'s "LUST fuel tax" charges $0.1 cents per gallon in all motor fuels, including aviation (EIA, 2017). To the best of the author's knowledge, this is the extent of environmental taxes in the aviation industry.

There are certainly numerous non-environmental taxes that include aviation and vary by country and region. The current aviation fuel tax of Japan (*koukuukinenryouzei*) is one of such cases, which although not in itself an environmental tax, functions as one and certainly reduces emissions by air transport (Chapter One and see also González and Hosoda, 2016).

However, this tax is subject to constant pressure and periodic requests by the Japanese airline sector for a revision or ideally, a full discontinuation (SAAJ, 2017). With this issue in mind, the author is compelled to present an alternative to the existent tax system that would not allow for aircraft emissions to soar uncontrolled in the event of the abolition of the existent tax. Therefore, the current study contributes by identifying which segment of the Japanese population would be the most responsive to a policy that targets aviation emissions.

The structure of the remainder of this paper is as follows. Section 2 briefly reviews the preceding research, commenting on some of the previous work that inspired the current investigation, as well as the points in which it constitutes unprecedented work. Section 3 details the methodology employed in the study, which consists of a series of statistical analyses of the responses to the questionnaire. Section 4 presents the analysis of the results from cluster and principal component analysis. Finally, concluding remarks are given in Section 5.

2.2 Preceding Research

There is a plethora of previous work concerned with air travel attitudes, trends, choice behaviour, psychological constructs, and public perspective that link together aviation and the environment. For the present publication, the author found particular alignment with Davison et al. (2014), who based on a 2009 “Air travel and the environment” survey conducted in the East Midlands region of the UK, present a very insightful paper focused on two behavioural theories (Theory of Planned Behaviour and the Norm-Activation Model), that explain pro-environmental behaviour. Furthermore, it renders a market segmentation that makes it easy to identify which individuals have the greatest propensity to adjust their air travel choices and

thus limit increases in air travel emissions, which is the base to what we have conducted in Japan.

Davison et al. (2014)'s work explores the relationship between psychological constructs, behavioural intentions and behaviour, labelling factor loadings by the constructs discussed in the two behavioural theories employed. In the current paper we refrain as much as possible from psychological discussion, and very plainly observe the users' attitudes and perceptions toward flying and the environment, although for the factor analysis section, the statements that examine environmental perception are based on Davison et al.'s study. Moreover, the present cluster analysis renders three different market segments, which allow to identify the sociodemographic characteristics in those individuals who are more likely to adjust their behaviour toward air transport and therefore, to respond more efficiently to environmental policy.

There are numerous studies that have administered on-site stated preferences (SD) or revealed preferences (RP) surveys at boarding halls and waiting rooms at airports, in order to assess trends in air travel (Hess and Adler, 2011), to identify patterns in airline choice based on ticket prices (Xiao et al., 2008), service quality (Park et al., 2014), customer value and brand image (Brodie et al., 2009), airfare, access time, flight availability (Hess et al., 2007), travel purpose (Jung and Yoo, 2014) and others. It is surprising, however, that none of these studies have included the environmental impact of air travel in their surveys, and therefore the available literature about how passengers perceive the implications of air travel is rather scant. This paper presents a new analysis of users' perception in the context of aviation and the

environment, which significantly contributes to the available literature in air travel behaviour and aviation emissions.

Although very different studies, this research and one paper about airline passenger choices in Korea (Jung and Yoo, 2014) share some common ground. Korea and Japan have a similar network of public transport on the back that densely populated cities are serviced by full-service airlines (FSA), LCCs and high-speed rail. Jung and Yoo (2014) use a nested logit model to identify factors that affect passengers' choices between air and non-air travel. As expected, the paper concludes that business passengers are more sensitive to access time and less sensitive to airfares, and also that reducing access time is more important than reducing journey time for short-haul domestic travellers. Though the present study does not evaluate such aspects between air and high-speed rail travel, the conclusions are of enormous importance for the Japanese scenario, as Shinkansen is far more accessible than airports, especially Narita Airport which is largely used by LCCs[3] and lies 70Km away from the city centre.

There is a conceptual model that in spite of slight variations is duplicated throughout the existent literature on behavioural intentions in the airline sector. This diagram shows the relationships or paths that explain how different variables affect users' perception and ultimately determine airline choices. Though the environmental implications of flying, or the company's efforts for a responsible stand toward its externalities is excluded in the studies consulted, a variable such as "company image" or "user satisfaction" might very well be related

[3] From the four strictly LCC airlines operational in Japan, only Peach and Spring Japan service both Narita and Haneda airports, whereas Jetstar and Vanilla Air travel only to and from Narita Airport.

to the airlines' awareness of its emissions. Of course, the weight of such variable is not applicable to all users and therefore it is important to identify which ones seem to be concerned with aviation emissions and which ones are willing to adjust their behaviour based on that outcome, which is precisely what the present studies offers. Figure 2.1 shows the "conceptual model" proven by Park et al. (2004).

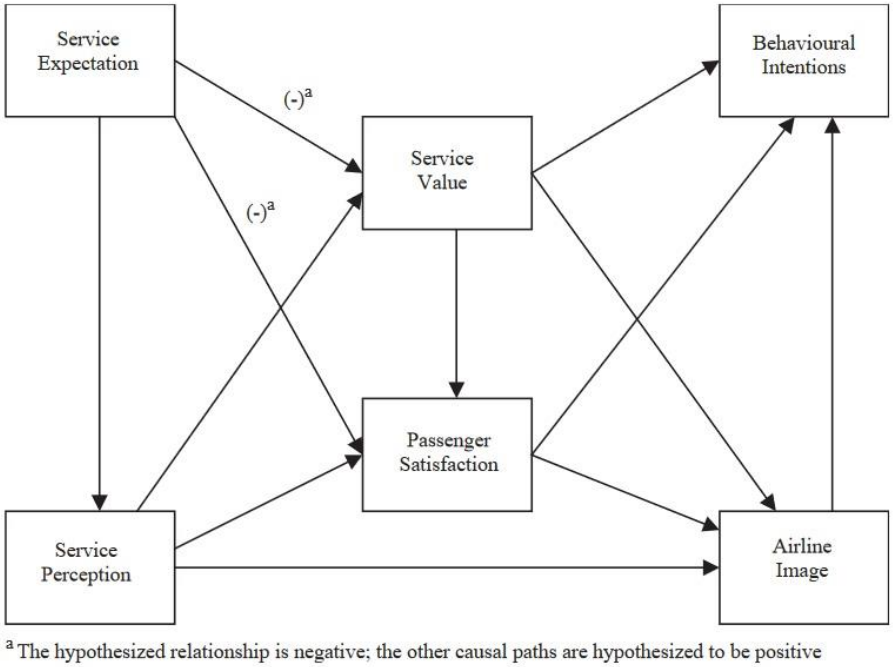


Figure 2.1 Conceptual model showing empirical hypotheses to be tested (path analysis). The paths from service expectation to service value and to passenger satisfaction are hypothesised to be negative, while all others are hypothesised to be positive (Park et al., 2014).

Although not centred on the aviation sector, a very important academic publication is that of Howarth et al. (2010). Their research investigates the extent to which information on climate change can influence travel behaviour. Their paper analyses a series of results from questionnaires and focus groups, concluding that in general, people regard climate change as

a complex and collective matter, where individual potential for change is “insignificant and futile in terms of impacts and adequacy”. This is a very important conclusion for the present study, and consistent with the intent of this paper, namely to draw attention to the importance of a policy implementation focused on behavioural change rather than on information. This approach can help to adjust the current focus of international policy about climate change, in which emission targets have been repeatedly set and revised, but hardly any achieved.

Another two studies that closely relate to the present investigation are those of Lu (2009) and Ryley et al. (2013). Lu (2009) presents a set of mathematical models that measure the social cost of aircraft noise and engine emissions, as a basis for setting up environmental charges. These charges are then hypothetically applied to intra-European airlines with two different business models: FSA and LCC. The study concludes that the potential percentage of demand reduction for both leisure and business passengers would be higher for the LCC carrier, although the pass-through of the environmental charges (environmental cost) per passenger would also be lower in the LCC case, as it is set as a proportion of airfare, which is of course lower. These results are crucial insofar as policy implementation in Japan is concerned, seen as the LCC industry has gone from a 2% to a 25% market share of the total domestic aviation between 2000 and 2016 (MLIT, 2017b).

Finally, the work by Ryley et al. (2013) examines public attitudes towards air transport and sustainability. Their work is based on two large survey datasets in the UK and the USA, and analyses the statements covering the economic and social benefits of air transport, as well as its contribution to climate change and the environmental responses around it. The study concludes that individuals highly value the economic and social sustainability aspects of

aviation, and although many acknowledge the environmental impact of air travel, few are willing to respond in terms of additional charges or reducing the number of flights. Their conclusions are consistent with some of the results of the current study. In the case of Japan, the mean of respondents who are willing to pay a higher rate or to fly less for environmental reasons also leans toward refusal.

2.3 Methodology

The author has specifically designed for this study a Likert-scale survey which includes questions on aviation use, the effect of aviation on the environment, and a series of other items that seek to identify patterns or behaviour toward the environment. The questionnaire was administered by MyVoice, a third-party company in Japan which specialises in online surveys and survey investigation and analysis.

The approach of a specific questionnaire that thoroughly analyses Japanese people's statements on aviation and the environment, the originality of the tool, as well as the through statistical analyses and conclusions that are drawn from the retrieved data, is a ground-breaking piece of research that had never been conducted in Japan, to the best of the author's knowledge.

2.3.1 MyVoice

MyVoice (www.myvoice.co.jp) is a Japanese investigation and data analysis company that specialises in conducting surveys/interviews in a vast array of disciplines. The company has a base of "members" (in Japanese, 会員) that are regularly invited to take part in surveys, as long as they meet the criteria requested by the client.

“Members” are recruited by affiliate publicity, i.e. by advertisement published over the internet calling for paid participation in a survey or investigation. The compensation to “members” is based on a point system (1 point = 1 yen). For every item or question answered, “members” receive 2 points. After reaching a certain amount of points, “members” are able to exchange it for the equivalent amount in yen.

The average response to any given survey invitation is of 30 to 40 percent. This means that for a target data set of 1000 answered questionnaires, MyVoice submits the request to 2500 to 3000 randomly selected “members”. MyVoice is an internet-based service, which means that the base of respondents is restricted to people with internet access and some degree of computer ability.

With regards to possible concerns about the income level of respondents, and people’s reluctance to answer this question, the author has specifically asked MyVoice for clarification on this point. Allegedly, the response rate of surveys with or without the question of income is virtually the same[45].

[4] In general, MyVoice avoids asking respondents about crime history, religion, medical history, sexuality and birth issues, and public order and values. Different from questions about income, when the topics above are asked to respondents, the decrease (refusal) in the response rate is of between 10 and 15 percent. For that reason, when such questions are asked, the topic or objective of the survey is clearly stated at first.

[5] Full detail on the contract conditions for “members”, as well as further information of the handling of information, privacy policy, point system, and others can be found in: https://www.myvoice.co.jp/voice/about/contract.html (in Japanese).

The author has chosen to run the study in three cities around Japan: Tokyo, Osaka and Fukuoka. These cities are not only densely populated and highly serviced by commercial aviation, but they are also connected by the Shinkansen, which is presented as an alternative to air transport, and included in the questionnaire in order to assess how people think of it as a (less polluting) substitute to boarding a plane. Once more, the nature of this study, and the specificity to which people are surveyed on these topics constitutes novel, original work not limited to Japan.

The questionnaire was applied to respondents between 18 and 79 years, divided into three age groups, namely 18-34, 35-64 and 65+ year old respondents. To facilitate data collection, questionnaires were applied in the following equal proportion 18-34 (25%), 35-64 (50%), 65+ (25%) in all three cities. These proportions might not be exact to the age distribution in each of the cities targeted, but they are very close to the national age distribution in Japan in 2017: 18-34 (21%), 35-64 (47%), 65+ (33%).

This chapter focuses on the two most travelled city-pairs (air routes) in Japan, also serviced by the Shinkansen: Tokyo-Fukuoka/Fukuoka-Tokyo, and Tokyo-Osaka(Kansai)/Osaka (Kansai)-Tokyo. The sample was collected with this structure in mind, with 250 respondents in Tokyo, 125 in Osaka and 125 in Fukuoka, for a total of 500, fully-answered questionnaires. The sample was not selected based on the distribution of passengers flown, revenue passenger-kilometres (RPK), or indeed population, all of which vary among these three cities. Nevertheless, by analysing the collected data the author can determine if there is a statistically significant different in answers to the questionnaire attributable to the prefecture where respondents reside.

In order to address possible concerns around the representability of age-group and prefecture, the author has conducted a Kruskal-Wallis test in order to identify whether there are statistically significant differences in the responses to the questionnaire, attributable to age-group or prefecture of residence. This test is ideal for two reasons: (a) because it is a more reliable test than, for example, a one-way ANOVA, when analysing more than two groups, and (b) because it treats variables in an ordinal scale, which is desirable for Likert-scale answers.

The purpose of conducting a Kruskal-Wallis test, is to show how even though the sample was not collected in equal proportion to the actual population in these three cities, or indeed the underlying age-group in each prefecture, the analysis is still statistically sound. The results to these tests are shown in Table 2.1.

Table 2.1. Kruskal-Wallis test results for median differences by prefecture (Tokyo, Osaka, Fukuoka) and age-group (18-34, 35-64, 65+) for items in the survey. Responses of questions q1_1 through q1_6 are used to determined the three segments in the cluster analysis.

Question	Prefecture p-value	Age-group p-value
q1_1	0.80	0.10
q1_2	0.87	0.03***
q1_3	0.94	0.89
q1_4	0.19	0.08
q1_5	0.43	0.07
q1_6	0.76	0.73
q2_1	0.84	0.00***
q2_2	0.33	0.00***
q2_3	0.69	0.00***
q2_4	0.75	0.00***

q2_5	0.29	0.00***
q2_6	0.79	0.15
q2_7	0.73	0.53
q2_8	0.01***	0.00***
q2_9	0.82	0.00***
q2_10	0.74	0.00***
q3_1	0.04***	0.11
q3_2	0.25	0.00***
q3_3	0.71	0.00***
q3_4	0.13	0.38
q3_5	0.61	0.00***
q3_6	0.47	0.00***
q3_7	0.78	0.00***
q3_8	0.92	0.00***
q3_9	0.80	0.00***
q3_10	0.13	0.11
q3_11	0.23	0.00***
q4	0.04***	0.13
q5	0.01***	0.00***
q6	0.05***	0.00***
q7	0.04***	0.00***
q8	0.01***	0.44
q9	0.06	0.84

Cluster analysis was conducted only based on answers to questions Q1_1 through Q1_6 in the survey. The results above show that there is no difference in means in the answers to these 5 questions by prefecture or indeed age group (except for Q1_2) of the respondents. In other words, the Kruskal-Wallis test shows that there is no evidence of significant differences in responses to the survey based on prefecture of residence or age group of the respondents, which suggests that even though the sample is not proportional to the underlying population

of these cities, these characteristics would not be expected to determine how people answer differently to the questions that set the base for the cluster analysis.

Question Q1_2, namely that “Japan does not thoroughly address the effects of climate change” is the only item used in cluster analysis where there is an observable significant difference in respondents by age. Figure 2.2 illustrates the difference in answers by age-group.

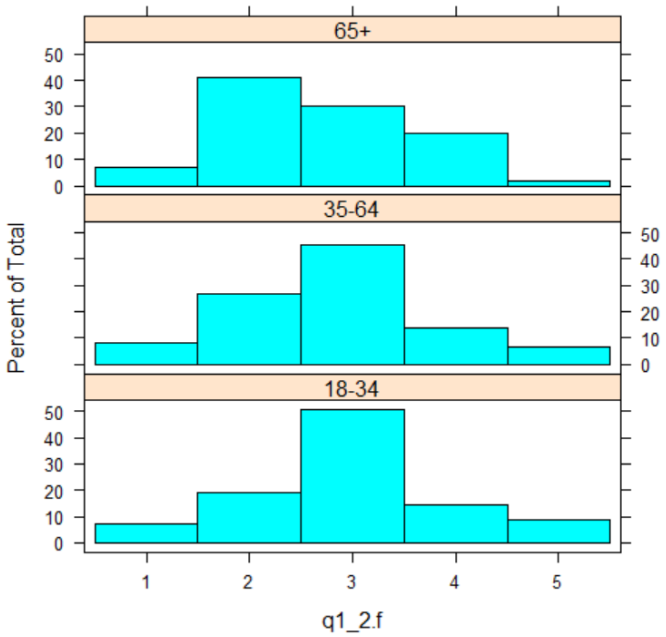


Figure 2.2 Distribution of answers to Q1_2, “Japan does not thoroughly address the effects of climate change” by age-group. Notice the higher incidence of agreement to the statement in respondents from age 65+.

Overall, age is also not a statistically significant determinant of differences in answers to the questions that determine cluster analysis, for which the sample can be used in spite of the underlying population having a different age-group distribution from the collected data. Nevertheless, because of the statistical significance of Q1_2, reading of age group in the segmentation of respondents (clusters), should be treated with caution.

It is important to mention that for any thesis replication, as well as keeping in mind the scope to which the results obtained wish to be extrapolated, a sample that is proportional to the underlying population, along the dimensions that can be controlled by the researcher, is recommended.

To add robustness to this analysis, the author has also conducted separate clustering models with a random subset matrix that exactly represents the underlying population of respondents, i.e. Tokyo (0.49), Osaka (0.33) and Fukuoka (0.19). In order to maintain these proportions, the author has to discard a considerable number of observations from Tokyo and Fukuoka, in order to maintain the 125 from Osaka, which was underrepresented. This approach is not ideal for it requires to delete important observations, which is why this test is only performed to understand how the cluster structure would be formed at the actual proportions for prefecture population.

The first observation is that, for a given random subset of 186 observations for Tokyo, 125 for Osaka and 72 for Fukuoka, the ideal number of clusters might not be necessarily 3. If the test is conducted repeatedly, the different dendrograms obtained suggest that 2 or even 4 could be a more fitting number of clusters for a given data set. Figure 2.3 illustrates the dendrograms of answer matrixes of two different random subsets at the revised proportion. Naturally, the size of clusters depends on the optimal number of clusters defined.

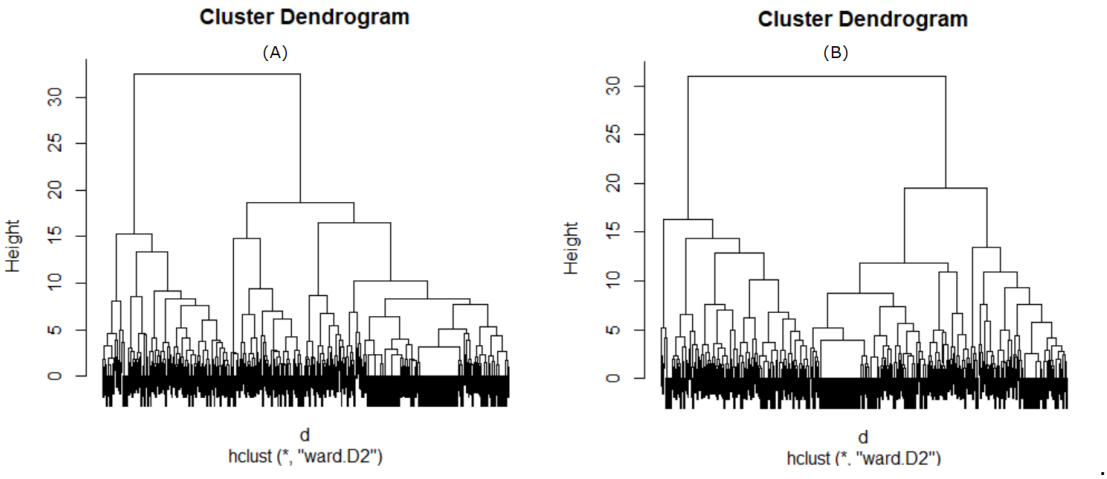


Figure 2.3 Graphical representation of two different random subsets of answers, taken from the original matrix at the underlying proportion: Tokyo (186), Osaka (125) and Fukuoka (72). Notice how the distribution of panel (B) suggests that the dataset could be arranged in 2 rather than 3 clusters.

Nevertheless, when data is segmented into three clusters in test random subsets, and compared to the original full-sample clustering, the proportional size of clusters is similar. Table 2.2 illustrates the size of 3 clusters for two test subsets compared to the original whole series.

		Segment 1		**Segment 2**		**Segment 3**	
	Sample size	Respondents	Proportion	Respondents	Proportion	Respondents	Proportion
Original	500	243	**0.49**	114	**0.23**	143	**0.29**
Subset (A)	*384*	*151*	***0.39***	*92*	***0.24***	*141*	***0.37***
Subset (B)	*384*	*193*	***0.50***	*70*	***0.18***	*121*	***0.32***

Table 2.2 Number of respondents and proportional size of sample for randomly selected test subsets proportional to underlying population (reduced matrix), and original full dataset.

The questionnaire was designed to examine the different attitudes and behaviour of Japanese people toward aviation, toward the environment and environmental practices in general. It seeks to elucidate to which extent are Japanese people, both regular and non-regular flyers, aware of aviation's impact on the environment, and whether they believe it should be regulated or, to some degree, compensated by higher fares. The questionnaire uses a 5-point Likert scale separated into two dimensions, namely a set of questions where respondents choose the level of agreement to a given statement (1= completely agree, 5= completely disagree), or the level of "application" of a given statement to a respondent (1= completely applies, 5= completely not applies). This differentiation was necessary strictly for language consistency of the questions in Japanese, although for the purpose of data analysis, the responses are taken as equivalent. The full questionnaire in Japanese is included in Appendix A.1 and in English in Appendix A.2.

Furthermore, the survey has assessed the willingness of users to adapt their behaviour to reduce the environmental impact of their general activities, as much at home as in the particular case of flying, thus making it possible to identify the all-important market segments. Also, it tries to uncover some of the psychological components of people's attitude toward the environment, for example, the way in which their actions are perceived by society and how the behaviour of others around them might affect their views and their relationship with the environment. This section takes a page from Davison et al. (2014)'s research on air travel attitudes and behaviour in the UK, and from the conceptual and analytical framework of environmental practices and policy developed by Barr and Gilg (2007).

This study's questionnaire, however, takes a novel and unique turn by including an alternative means of transportation (the bullet train) which interconnects the Japanese cities where the survey was administered. The study sets out to assess people's perceptions of both air and high-speed rail transport as substitutes, and to identify how users of one and the other feel about their particular impact on the environment.

Furthermore, to the best of the author's knowledge, no previous stated-preference studies on aviation emissions, air versus Shinkansen, or environmental impact perception of either means of transport, has ever been conducted at an academic level in Japan, for which the motivation to undertake this study is very high.

The questionnaire consists of four sections:

A) A set of six questions that examine people's perceptions about aviation and the environment, about the agreement to higher airfares as a means of compensation for emissions, and also about the possibility to substitute air travel by high-speed rail (Shinkansen). The answers to this section are used in the cluster analysis to identify the market segments.

B) A set of eleven questions measuring general attitudes toward the environment; the extent to which people perceive environmental deterioration as a threat, and the importance of environmentally-oriented actions and practices in the social view.

C) A set of nine questions assessing a range of possible behavioural changes, such as reducing the number of flights, choosing more energy efficient ways to travel and others. Principal component analysis (PCA) is later used in sections B and C to identify relations between variables.

D) The last section includes a set of sociodemographic questions including income, employment, education and others; as well as information relevant to the assessment of air travel behaviour, such as the number of flights in the last 12 months.

The purpose of the questionnaire is to separate respondents in subgroups based on their responses, a technique known as data clustering or cluster analysis (Stephenson, 1936; Zubin, 1938; Tyron, 1939; others). This segmentation is possible by means of pattern recognition algorithms that find statistical relationships among the data, rendering a set of subgroups with similar characteristics for further review. There is a broad variety of algorithm categories in cluster analysis, such as K-means, agglomerative hierarchical clustering, model based maximum likelihood estimation, DBSCAN and others. In this investigation, a hierarchical agglomerative analysis using Ward's method is preferred, which minimises total within-cluster variances, thus allowing for clusters of a similar size.

A common challenge in any cluster analysis is to determine the optimal number of clusters. This can be easily resolved by one of two methods: by using a dendrogram and determining the number of clusters by mere observation of the agglomeration of data, or by estimating the average internal sum of squares, i.e. the average distance between points inside of a cluster. This is known as the "elbow method", as the intra-cluster distance between points decreases to an increasing number of clusters, drawing an "elbow" shape at the data point where the series smoothens out. Figure 2.4 shows both of these analyses, after which an optimal number of 3 clusters was determined.

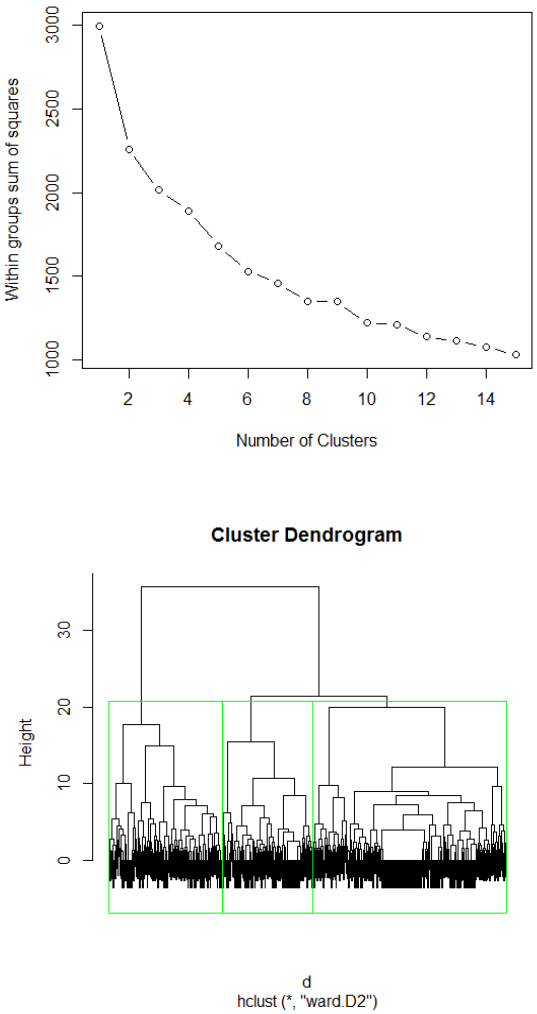
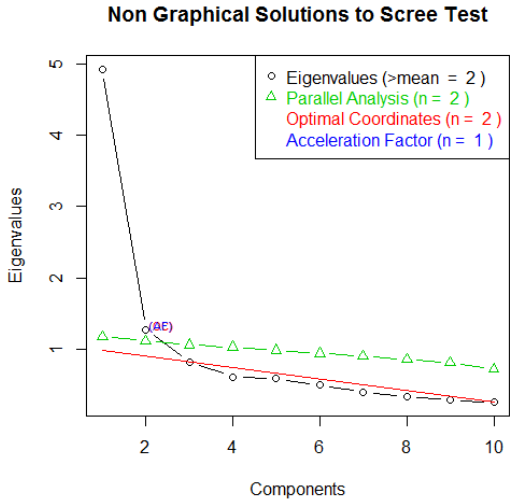


Figure 2.4 Graphic representation of the average internal sum of squares (left) and a dendrogram (right) which sets the optimal number of clusters at 3.

The technique of principal component analysis allows for a simplification of the correlation matrix of responses from Sections B and C of the questionnaire. Factor analysis is a statistical technique widely used in psychology and the social sciences, and a necessity in studies in which tests or questionnaires have been administered (Kline, 1994). A scree plot test allows us to set the number of factors at 2 (Figure 2.5), in order to drop those components with an Eigenvalue or characteristic root (column sum of squared loadings for a factor) below 1, in

compliance with Kaiser's criterion. In general, the larger the Eigenvalue, the more variance is explained by the factor (op cit.).

B)



C)

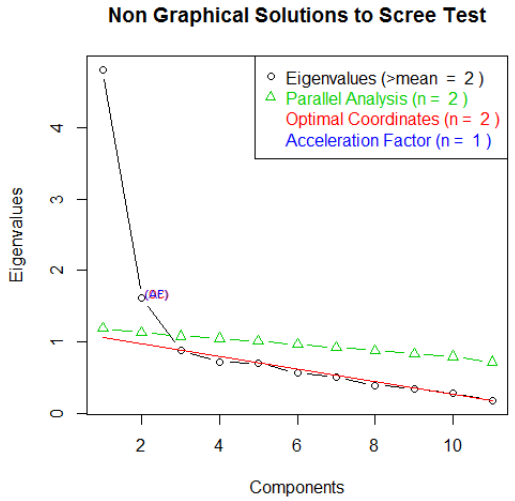


Figure 2.5 Scree plot of Eigenvalue for number of components for responses to sections B and C of the questionnaire. Factors with an Eigenvalue below 1 are dropped from the analysis, therefore the number of factors for each section is set at 2.

The purpose behind conducting a factor analysis is to infer the latent variables that influence users' responses to the pro-environmental and behavioural statements in sections B and C.

Furthermore, in order to allow for factors to be correlated, a direct oblimin rotation method is employed in the estimation of the final factor loadings, with loadings of >.5 retained (Hair et al., 1998; Davison et al., 2014). For the matrix of responses to questions from section A, Pearson's chi-squared tests are used to test the null hypothesis of variable independence (goodness of fit). As for the factor analysis components, internal consistency is verified by Cronbach's alpha to determine the accuracy of the test to measure each variable, which is not an uncommon test of reliability in Likert-scale based analysis (Santos, 1999; Gliem and Gliem, 2003).

2.4 Analysis of Results

Cluster analysis is perhaps the most basic and most widespread statistical method for estimating similarity. Through a simple arithmetical arrangement, this approach allows for the identification of similarities in the data matrix, which is the ultimate purpose of chapter 2. Cluster analysis was specifically selected as a classification tool because it is an efficient too to analyse data in a pre-classificatory procedure. This means, in the case of chapter 2, to rearrange data into clusters based solely on the answers to the Likert-scale questions and without partition of the subjects.

The presupposition of different groups, or clusters, is based on commonalities within the set of independent variables, in this case, the socio-demographic background of respondents. Other statistical approaches, such as discriminant analysis or automatic interaction detection, necessarily rely on the assumption that the dependent variable defines the groups of objects, and that the distinction is not made on the basis of profile resemblance in the data matrix itself.

The author's purpose was to use the matrix data from Likert answers to define the clusters and only then look at the sociodemographic characteristics, for which a pre-classificatory grouping tool, using arithmetical calculations such a dendrogram, were ideal for separating respondents into clusters and determining the user profile of people who share similar views on aviation and aviation's impact on climate.

PCA is a very effective tool to analyse ordinal scale items, such as a Likert-scale data. Because Likert-scale consists of ordered categories, i.e. there are no qualitative differences in the data, a statistical analysis is necessary in order to identify the underlying continuum of the ordinal discrete values. In other words, the agreement or disagreement to statements is not really categorical, it is qualitative, and identifying that continuum is where the interest of social scientists really lies.

PCA is ideal because it maps onto that continuum, creating a single index variable, normally distributed, that renders linear values to the different items in the questionnaire. Moreover, the goodness of fit of this approach, i.e. the internal consistency of items in each of the identified factors, can be measured by Cronbach's alpha, which represents the reliability of the PCA.

2.4.1 Cluster Analysis

For the present study a hierarchical cluster analysis was performed on the responses to the statements of section A of the questionnaire, which evaluates respondents' perceptions about air travel and the environment. Following the estimations of the optimal number of clusters, results are divided into three market segments according to their assessment of the environmental impact of aviation and the possibility to find an alternative to flying. These

results are summarised in Figure 2.6 and detailed in Table 2.3, which also shows the average frequency of air travel per segment in the last 12 months. Moreover, the statistical differences in sociodemographic characteristics as well as the goodness of fit of the model are shown in Table 2.4.

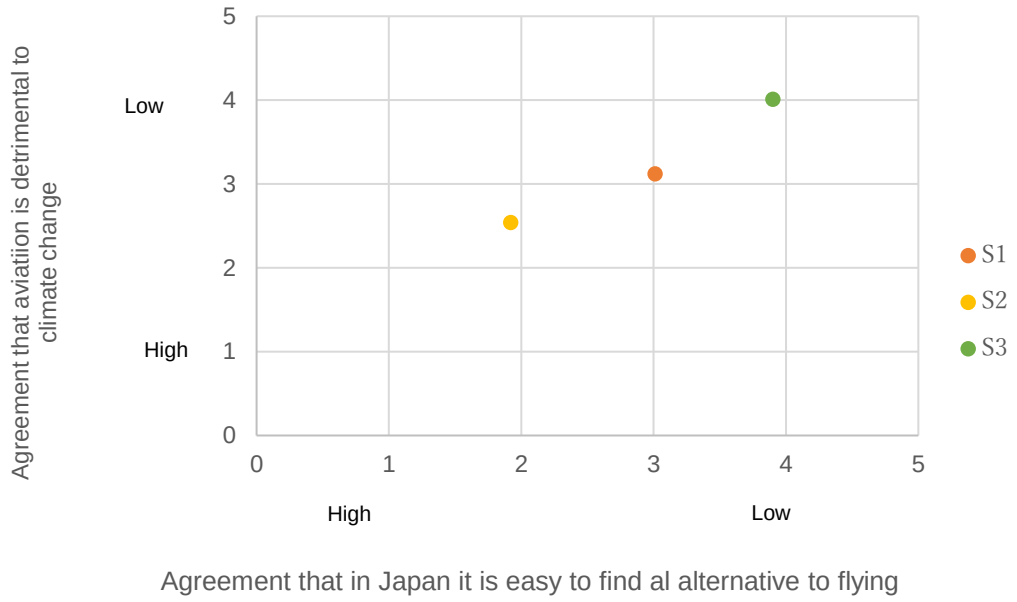


Figure 2.6. Graphic depiction of the three identified segments.

Figure 2.6 represents the three market segments in which Japanese respondents can be divided, in a scale of 1 to 5, consistent with the Likert scale employed in the survey. While Segment 3 shows an utter disagreement (4 out of 5 Likert points) to both statements, and Segment 1 is composed of individuals who are indifferent (middle point 3) any other way, Segment 2 shows both a higher awareness of the environmental impact of air travel as well as a higher agreement that it is possible to find an alternative to flying (Likert scale based on 1=Strongly Agree, 2=Agree, 3=Neither Agree nor Disagree, 4=Disagree, 5=Strongly Disagree).

Table 2.3 Summary of statistical properties of sociodemographic information and average number of flights per year, of identified market segments based on responses to Section A of the questionnaire.

Segments generated from the response to attitudinal statements [a, b]

Segment	Segment 1		Segment 2		Segment 3		All	
Number of respondents	243	48.6%	114	22.8%	143	28.6%	500	100.0%
Attitude toward Air Travel and the Environment	M	S.D.	M	S.D.	M	S.D.	M	S.D.
Air travel is a significant contributor to climate change	3.12	0.75	2.54	0.74	4.01	0.80	3.24	0.93
Japan does not thoroughly address the effects of climate change	2.80	0.80	2.18	0.76	3.42	1.04	2.83	0.97
Passengers should pay more to fly because of the negative environmental impact	3.57	0.80	2.80	0.85	4.26	0.76	3.59	0.95
It is easy for Japanese people to find an alternative to flying in they really want to	3.01	0.78	1.92	0.57	3.90	0.85	3.02	1.04
Shinkansen is an alternative to air travel	2.57	0.80	1.99	0.63	3.80	0.88	2.79	1.04
Profiting from air transport is more important than saving natural resources	3.17	0.64	2.95	0.93	3.07	1.04	3.09	0.84
Revealed Behaviour	M	S.D.	M	S.D.	M	S.D.	M	S.D.
Total number of flights in previous 12 months	1.39	3.22	1.18	3.07	2.18	3.55	1.72	3.72

[a] Survey ran in Japanese, translated by author for this publication.

[b] Measured on a 5-point Likert scale, where 1=Strongly Agree, 2=Agree, 3=Neither Agree nor Disagree, 4=Disagree, 5=Strongly Disagree

Table 2.4 Detail of sociodemographic characteristic and goodness of fit by segment. The subdivision of each category has been conducted by traditional Japanese disaggregation standards. Annual income is expressed in yen of 2017.

Summary of socio-demographic characteristics by segment [a]

Segment	Segment 1		Segment 2		Segment 3		All			Pearson's chi-square value segment and socio-demographic characteristics (N=500, α=0.05)
								Weighted average[b]		
Number of respondents	243	48.6%	114	22.8%	143	28.6%	500	N/A	100.0%	
Gender										
Male	123	50.6%	55	48.2%	72	50.3%	250	244.7	50.0%	χ2 (6df) = 0.184, p= .912
Female	120	49.4%	59	51.8%	71	49.7%	250	255.3	50.0%	
Region										
Tokyo	125	51.4%	53	46.5%	70	49.0%	248	241.2	49.6%	
Osaka	54	22.2%	38	33.3%	34	23.8%	126	164.6	25.2%	χ2 (4df) = 5.874, p=.209
Fukuoka	64	26.3%	23	20.2%	39	27.3%	126	94.3	25.2%	
Age group										
18-34	65	26.7%	23	20.2%	38	26.6%	126	103.5	25.2%	
35-64	119	49.0%	53	46.5%	76	53.1%	248	232.1	49.6%	χ2 (4df) = 6.533, p=.163
65+	59	24.3%	38	33.3%	29	20.3%	126	164.7	25.2%	
Marital Status								N/A		
Unmarried (single, divorced, widower)	110	45.3%	43	37.7%	54	37.8%	207		41.4%	χ2 (2df) = 2.915, p=.233
Married	133	54.7%	71	62.3%	89	62.2%	293		58.6%	
Occupation										

Full employee	89	36.6%	34	29.8%	51	35.7%	174		34.8%	
Self-employed	21	8.6%	10	8.8%	8	5.6%	39		7.8%	
Specialised work (medical, lawyer, designer, beautician, etc.)	10	4.1%	3	2.6%	7	4.9%	20		4.0%	
Public employee	14	5.8%	1	0.9%	7	4.9%	22		4.4%	
Student	4	1.6%	2	1.8%	5	3.5%	11		2.2%	$\chi 2$ (16df) = 14.207, p=.584
Housewife	37	15.2%	22	19.3%	24	16.8%	83		16.6%	
Part-time work	27	11.1%	22	19.3%	18	12.6%	67		13.4%	
Unemployed, retired	34	14.0%	17	14.9%	18	12.6%	69		13.8%	
Other	7	2.9%	3	2.6%	5	3.5%	15		3.0%	
Last attained education								N/A		
Junior high school	3	1.2%	4	3.5%	1	0.7%	8		1.6%	
High school	50	20.6%	37	32.5%	29	20.3%	116		23.2%	
Vocational college, specialised academy (2-year program)	50	20.6%	16	14.0%	24	16.8%	90		18.0%	$\chi 2$ (8df) = 20.374, p=.009
University	131	53.9%	53	46.5%	74	51.7%	258		51.6%	
Graduate school	9	3.7%	4	3.5%	15	10.5%	28		5.6%	
Annual income								N/A		
Below 2 million yen	90	37.0%	44	38.6%	49	34.3%	183		36.6%	
2-5 million	95	39.1%	48	42.1%	52	36.4%	195		39.0%	
5-10 million	46	18.9%	19	16.7%	28	19.6%	93		18.6%	$\chi 2$ (8df) = 10.716, p=.219
10-15 million	8	3.3%	1	0.9%	12	8.4%	21		4.2%	
Over 15 million	4	1.6%	2	1.8%	2	1.4%	8		1.6%	
Home circumstance								N/A		
Own home	117	48.1%	49	43.0%	54	37.8%	220		44.0%	$\chi 2$ (6df) = 12.035, p=.062

Detached house, stand-alone house, terrace house	2	0.8%	3	2.6%	1	0.7%	6	1.2%
Apartment, apartment building	122	50.2%	61	53.5%	82	57.3%	265	53.0%
Company house, dormitory	2	0.8%	1	0.9%	6	4.2%	9	1.8%

[a] Survey ran in Japanese, translated by author for this publication.

[b] Population Census (2017) and Statistics Bureau of Japan (2019) statistics were used for the weighted values.

The analysis of results reveals that Segment 2 has the highest level of agreement to both statements that determine group segmentation, namely that air travel is a significant contributor to climate change and that it is easy for Japanese people to find an alternative to air travel. Conversely, Segment 3 is at the extreme, in total disagreement with both statements. In spite of this, Segment 2 shows the lowest flight frequency of all three clusters, whereas those respondents from Segment 3 have the highest rate of air travel use during the year prior to this study. As expected, respondents from Segment 2 are in high agreement that passengers should pay a higher fare as compensation for the negative effect of flying in the environment, whereas Segment 3 shows a strong disagreement with this notion.

The disagreement between Segments 2 and 3 equally applies to the perceptions about the possibility to find alternatives to air travel, to the plausibility of Shinkansen as a substitute for airplanes and to Japan's efforts to address the problematic of climate change. For all these statements responses from Segments 2 and 3 are at the extremes of the observed responses. However, each one of these two groups, represents roughly one quarter of the sample, and Segment 1, whose valuation is closest to the media, is twice in size, with almost one half of the total respondents. It can be identified, therefore, that most Japanese people in metropolitan areas have a neutral position about the environmental impact of aviation. However, Segment 1 reveals the highest disagreement to the statement that profiting from air transport is more important than saving natural resources, which is a comforting result for environmental economists, namely to statistically show that most people have their priorities in line with sustainable development.

From the last row of Table 2.3 it is clear that a considerable difference in flight frequency exists in each group, which is confirmed by a single factor ANOVA (F= 7.52, (3.01), p= .00). Individuals

from Segment 3, who are the most sceptical of the environmental impact of aviation and of the likeliness to replace air travel by other transport, fly the most often. And respondents from Segment 2, who take a strong pro-environmental position, fly the least of all. Moreover, the largest difference (almost 2 Likert points) between Segments 2 and 3 is found in the responses to the statements about the feasibility to replace air travel by other means of transportation, or concretely, by Shinkansen. This suggests that people who are willing to refrain from flying are influenced more by the possibility to replace air travel than by the conviction that aviation is detrimental to the environment.

The sociodemographic characteristics of each group summarised in Table 2.4 are essential in order to identify target recommendation for new policy. The results appear statistically significant only for the level of last attained education. The most pro-environmental Segment 2 shows a slightly higher proportion of women, and higher frequencies of housewives, part-time workers and unemployed/retired persons. It also shows a larger percentage of respondents from Osaka and a lower frequency of Tokyo residents than the other groups. In terms of marital status, Segment 1 shows the highest frequency of unmarried respondents, whereas there is no substantial difference between Segments 2 and 3 in this category.

The most flight-dependent Segment 3 shows a slightly younger population, with no particular difference between men and women and with a higher proportion of fully employed, specialised workers, public employees and students. In terms of education, Segment 3 also shows a higher incidence of completed university or graduate school, whereas 32.5% of respondents from Segment 2 only completed high school. In terms of annual income, respondents from Segment 3 also show a larger proportion of individuals in the top levels. Finally, in terms of home

circumstance, the flight-dependent Segment 3 has the highest number of respondents living in apartments or company residences, and the lowest proportion of people living in their own house, which is consistent with the answers examined hitherto.

2.4.2 Principal Component Analysis

For sections B and C of the questionnaire, namely statements that assess general attitudes toward the environment and behavioural patterns, we employ PCA and determine the factor scores that load to each question. Statistically, the purpose of PCA is to condense a matrix of correlations (loads) in order to explain the variance therein with as few factors as possible. Even though this process generates a number of components as variables (indeed as many as there are variables in the matrix), only the largest (Eigenvalue >1) are extracted. The Eigenvalue of each component indicates the proportion of variance for which it accounts. A scree plot (Figure 2.3) can be used to recognise the number of components to be maintained. However, as a rule, PCA generally produces one general factor followed by bipolar factors, as these are extracted not from the original correlation matrix but from a residual matrix after the first factor has been "partialed out" (Kline, 1994).

The analysis is based on the psychological constructs and behavioural intentions included in sections B and C of the questionnaire. The PCA analysis of Section B generates two components that account for 59% of the variance between variables. The detail on the statistical characteristics of psychological constructs around the environment, as well as the components analysis for each question are summarised in Table 2.5. It is clear from the factor loadings that a strong correlation exists between the statements examined. Moreover, a reliability test (Cronbach's alpha) is conducted, which is excellent (α= .9) for the first factor (TC1), but shows relatively low internal

consistency (α= .54) for the second factor (TC2), for which the readings should be treated with caution.

Table 2.5 PCA of psychological constructs associated with respondents' perceptions toward the environment.

Psychological constructs associated to the environment [a, b]	Descriptive		Components		
	M	S.D.	TC1	TC2	Cronbach's alpha
Each person's behaviour can have a positive effect on society and the environment	2.24	0.845	0.87	-0.12	0.9
I feel it is my responsibility to help the environment in the best way possible	2.38	0.841	0.86	-0.03	
Choosing more energy efficient forms of transport helps reduce global warming	2.46	0.840	0.80	-0.26	
I am very concerned about environmental issues	2.56	0.925	0.76	0.11	
Environmental problems caused by over-use of resources is a threat to me and my family	2.70	0.943	0.65	0.16	
When other people around me help the environment, I feel I should too	2.64	0.878	0.64	0.29	
I feel guilty when I don't make an effort to conserve resources	2.80	0.928	0.62	0.36	
I like people to think of me as environmentally friendly	2.90	0.880	0.49	0.46	
I find helping the environment easy	3.43	0.922	-0.16	0.74	N/A
Most of my friends are environmentally friendly	3.13	0.754	0.10	0.71	
Choose to travel by Shinkansen rather than fly makes me feel good as something to help the environment	3.20	0.939	0.21	0.51	

[a] Survey ran in Japanese, translated by author for this publication.

[b] Measured on a 5-point Likert scale, where 1=Strongly Agree, 2=Agree, 3=Neither Agree nor Disagree, 4=Disagree, 5=Strongly Disagree

PCA results in Table 2.5 show both selected components (TC1, TC2) with their respective factor loadings for every item in the questionnaire. It can be seen that the highest readings are associated to statements that reflect individual behaviour (E.g. sense of personal responsibility to the environment, or choice of more energy efficient transport), rather than collective or communal actions (E.g. how individuals are perceived in terms of their environmental consciousness, or the influence of others on their environmentally-friendly behaviour). This means that statements related to personal behaviour account for the largest proportion of explained variance in the data, or in other words, that it is by means of personal actions where the difference between an environmentally conscious person and an environmentally indifferent person is clearer.

On Table 2.5, statements are presented in descending order based on their factor loadings for TC1. As a rule of PCA, variables with high eigenvalues tend to vary together and in the same direction. This means, for example, that a person who feels that he or she has a responsibility to preserve the environment in any way they can, will also tend to choose a more energy-efficient means of transport whenever possible.

The relatively higher importance of personal responsibility and individual actions is perhaps reflected in Japan's rates of recycling and exemplary garbage disposal systems. At present, Japan incinerates 76% of its waste, and as much as 20% is recycled (NIES, 2016).

The second application of PCA is designed to evaluate individuals' responses to behavioural intentions, specifically, their willingness to engage in certain behavioural changes that can potentially reduce emissions from air travel. This section also presents users with the possibility to use Shinkansen rather than flying, as a means to reduce CO_2 emissions. Table 2.6 summarises

the identified components and statistical characteristics of section C of the questionnaire. Again, an internal consistency test is run, which shows very satisfactory levels of reliability for both factors TC1 (α= .88) and TC2 (α= .82).

Table 2.6 PCA of behavioural intentions associated to air travel.

PCA of behavioural intentions [a, b]	**Descriptive**		**Components**		
	M	S.D.	TC1	TC2	Cronbach's alpha
Choose a more energy efficient airline	2.91	0.90	0.92	-0.11	0.83
Pay more to fly on a less polluting airplane	2.95	0.90	0.86	-0.03	
Choose a more energy efficient way to travel whenever possible	2.96	0.87	0.81	0.03	
Reduce energy used at home	2.64	0.95	0.65	0.05	
Pay to offset the carbon emissions from my flight(s)	3.41	0.94	0.60	0.23	
Reduce the number of times that I fly	3.31	1.05	0.48	0.46	
Not fly during the next holidays	2.43	1.38	-0.10	0.83	0.82
Holiday in Japan instead of overseas	2.57	1.14	-0.01	0.77	
Choose Shinkansen rather than fly	2.70	0.98	0.11	0.72	

[a] Survey ran in Japanese, translated by author for this publication.

[b] Measured on a 5-point Likert scale, where 1=Strongly Agree, 2=Agree, 3=Neither Agree nor Disagree, 4=Disagree, 5=Strongly Disagree

Responses to behavioural statements from Table 2.6 give evidence that Japanese people are willing to act responsibly when it comes to pro-environmental decisions, such as more energy-efficient airlines, even should this come at a higher fare. The choice of air travel, however, is apparently non-negotiable, at least in the number of times flown. This could be associated to the necessity of aviation for business rather than non-business purposes, i.e. holidays, visiting families and relations, and the like. In the case of holidays, results show a high factor load associated with refraining from flying during the next holiday season, or the alternative to spend the holidays at home rather than abroad. Results show a high level of internal consistency for both components estimated by the model, which suggests that this is a reliable measure of the underlying intentions of respondents.

2.5 Concluding Remarks

This chapter focuses upon Japanese people's attitudes and behaviour toward air travel and the environment, especially in urban areas with high population densities and a dynamic traffic of domestic flights. The study is based on a household survey administered online in the summer of 2017 in the cities of Tokyo, Osaka and Fukuoka. The objective was to present a statistically sound analysis of individuals' perceptions toward aviation, pro-environmental behaviour and the link between the two. To the best of this author's knowledge, this is an approach never conducted in Japan, where the available literature on behavioural intentions and the environmental impact of aviation is scarce and seldom published in English.

This study has revealed two essential underlying facts of people's attitudes toward air travel and the environment, that make it a key contributor in any environmental policy that targets aviation in Japan. The first one is the nature of the individuals who extremely agree or disagree with the

impact of commercial aviation on the environment and with the possibility to find alternative means of transport to flying, namely Segments 2 and 3 of the cluster analysis. The fact that the segment of the population who believes in the negative impact of air travel on the environment and who states their willingness to higher airfares to offset this externality is composed of a majority of housewives and retirees who seldom travel by air; and conversely, that fully-employed, more frequent flyers who are at the highest income level, are neither willing to pay for the environmental damage of air transport nor to acknowledge that there is any alternative to flying, is a strong suggestion that any environmental tax on aviation would see a lower impact on demand than alleged by airlines before now.

The second key contribution of this chapter is the relative importance of individual actions toward the environment, as revealed by the principal component analysis. People feel an individual responsibility to do what is within their possibilities to protect and preserve the environment. These individual actions are more important than other collective stances also analysed, such as the image that individuals might want to portray of being environmentally conscious, or the influence of others' in one's own practices of responsible resource use, recycling and so forth.

People who are indifferent toward the environment, and there are millions upon millions of them, will not start to care because of higher awareness of the problem. On the other hand, people who already have a sense of consciousness and responsibility toward the environment, will continue to conduct themselves in such a way independently of their surroundings. Frequent flyers are mostly business persons who depend on air travel and who would not willingly reduce their number of flights for the sake of environment protection. It is therefore concluded, that this group of people would continue to fly just as much even if faced with higher fares. Furthermore, leisure

travellers who fly far less often, clearly state their willingness to pay higher fares for the sense that they are being environmentally responsible, and in such a case, it is unlikely that a more expensive ticket would deter this segment from flying, which already happens in a sporadic way.

From the behavioural intentions analysis, results show how people are willing to select more energy-efficient airlines, even if at a higher price, or else to sacrifice the use of air travel for holiday purposes. However, the possibility to reduce the number of times flown, as well as the viability of replacing air travel with Shinkansen, score at the very bottom of the factor analysis. This is in line with some of the identified patterns of the cluster analysis that show how regular flyers have a lower estimation of the environmental impact of aviation, and therefore are less likely to modify their flight frequency.

As for policy implementation, the study concludes that Japanese people, in general, have a high sense of environmental responsibility and a conscious appraisal of the importance of sustainable development. As expected, results show that those individuals who are willing to do more to curtail the negative environmental effect of aviation, are those who fly the least and therefore find plausible to substitute the use of air travel by other means of transport, whether this is an option or not, in terms of practicality. Indeed, it is very improbable that frequent flyers would reduce their use of air travel even if at a higher fare (as a result of new regulation on carbon emissions), among other reasons because business travellers in general are less likely than tourists to respond to variations in price (Tol, 2007).

CHAPTER THREE

Analysis of the Environmental Repercussions of Low-cost Carriers: The Case of Japan

3.1 Introduction

Any aviation specialist may perfectly well affirm that low-cost carriers (LCC) have revolutionised the airline industry. By 2017, there had been 265 low-cost airlines ascribed to the International Civil Aviation Organization (ICAO), of which about one-half had merged with other companies or disappeared, and roughly 130 budget airlines were still operational around the globe (ICAO, 2017c). What makes an industry so dynamic and so appealing to new competitors? How did a local business initiative in the United States grow to become a global phenomenon that now transports one in four scheduled passengers every day? What are the environmental implications of flying cheap and why do they require attention? These are some of the ambiguities that this investigation will put to the test.

The purpose of this paper is to analyse the low-cost airline industry in a specific, limited region, in this case, the domestic market of Japan. The study analyses the factors that influence passengers' decisions to choose one of two types of service, namely full-service airlines (FSA) or LCC. By means of a stated preference survey, the study gathers the impressions and valuations of Japanese respondents who have used either one of the two types of airline in the last 12 months. Furthermore, the study tries to determine the extent to which there is a reason for concern about the environmental implications of the no-frills airline model. This follows some of the points concerning the environmental impact of air transport that were discussed at large in Chapters 1 and 2 of this dissertation.

The motivation to study the LCC phenomenon in Japan comes from the significant changes that the Japanese domestic market has undergone over the past two decades years. In 2000, Japanese aviation was for all intents and purposes an LCC-free duopoly. Together with their subsidiary companies, the two main airlines, Japan Airlines (JAL) and All Nippon Airways (ANA), controlled 98% of the national aviation (RPK) (MLIT, 2017b). However, by 2016, the market share of these two groups had dropped to 75%, after the appearance of regional and budget airlines.

Similar to Chapter Two, this study is original in its approach of designing a specific tool in order to assess what motivates Japanese people to fly a regular airline or a low cost one. It is the first time, to the best of the author's knowledge, that confirmed fliers from both types of service have been approached in order to screen and valuate their choices, and the implications for an expanding airline market in Japan can be considerable. The details on the way the survey was applied, as well as how MyVoice conducts the study, can be found on section 2.3.1 on Chapter Two.

Regional airlines are a special type of industry in Japan. They can be considered a third category, a service occasionally defined as a middle-cost carrier (MCC). These companies (Air-Do, Solaseed Air, Skymark and Starflyer) have a long trajectory in Japanese aviation, especially Skymark, which has been in service since 1996. They operate specific routes, often frequented by business men and regular travellers between city-pairs. Regional airlines today have a considerable share of the Japanese aviation market, accounting for 14% of the total RPK in 2017 (MLIT, 2017b). Indeed, regional airlines spurred the domestic market in the mid-2000s (Figure 3.1), and played a key role in the dissolution of the existent duopoly, forcing JAL and ANA to undergo operational adjustments in the face of growing competition (Figure 3.2).

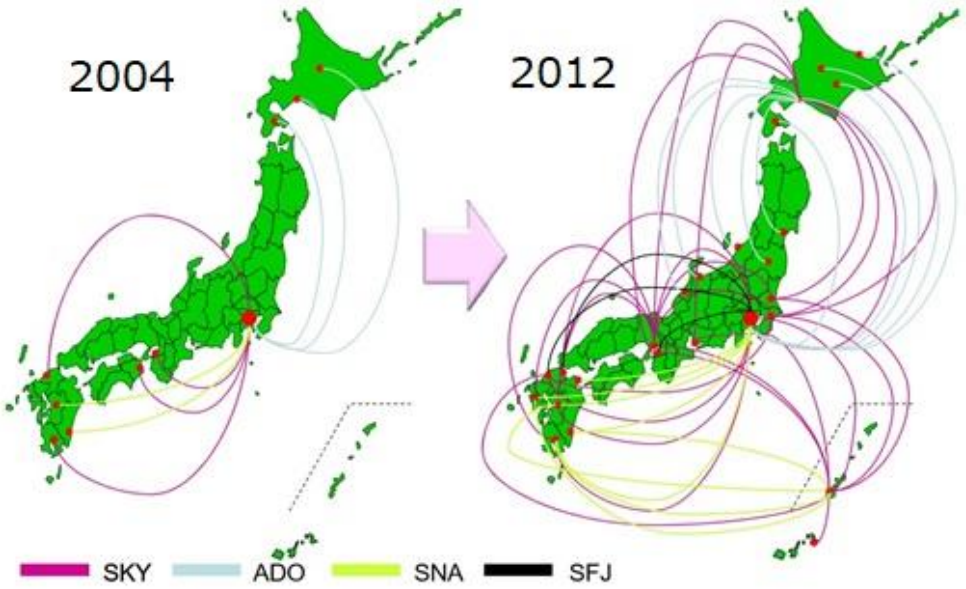


Figure 3.1. Expansion of domestic routes by regional airlines between 2004 – 2012. Labels left to right: Skymark, Air Do, Skynet Asia (today Solaseed Air) and Starflyer. Notice how formerly all flights to, and from the Kanto Region (Tokyo and surrounding areas) where handled at Haneda Airport. Narita Airport (right-hand side of Haneda airport on the chart) inaugurated its domestic terminal in 2011 (NAA, 2017). Source: MLIT (2013).

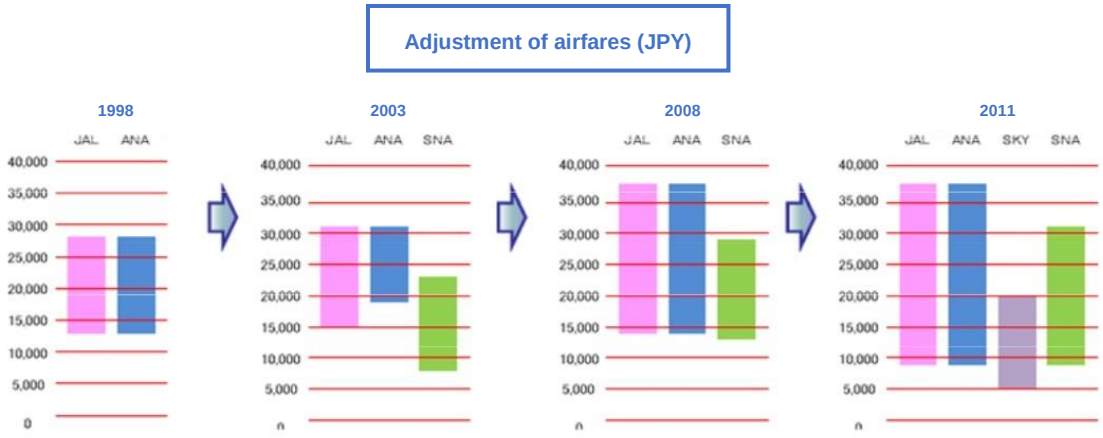


Figure 3.2. Adjustment of airfares by JAL, ANA, Skynet Asia (now Solaseed Air) and Skymark, between Tokyo and Kumamoto in June of 1998, 2003, 2008 and 2011. Notice the extended lower boundary of JAL and ANA's price range on the far-right graph. Source: MLIT (2013).

Regional airlines, however, are not LCCs in the traditional sense, and neither are they considered as such by Japanese authorities (MLIT, 2003). Furthermore, while an official picture of modern Japanese aviation, as depicted in Figures 3.1 and 3.2, was not available at the time of this investigation, it is bound to include the four currently operational LCCs: JetStar, Peach, Vanilla Air and lately, Spring Japan. Although these four airlines have operated for only six years or less, they already account for 11% of the domestic market (MLIT, 2017b). Figure 3.3 illustrates the distribution of domestic aviation by airline, between 2006 and 2016. Furthermore, for the same decade Figure 3.4 contrasts the decline in FSA's share of domestic RPK with the growth of regional airlines and LCCs.

As far as internal finances are concerned, it is worth noting that airlines in Japan have been forced to implement important adjustments in in order to remain competitive in the face of growing competition. Nowhere was this clearer than with JAL's filing for bankruptcy in 2010, which led, among other things, to the adjustment of the domestic aviation fuel tax (*koukuukinenryouzei*), which was discussed in Chapter 1. This study refrains from analysing individual companies' reforms in terms of yields and costs, rather focusing on passengers' choices and the factors that determine which airline they fly and why.

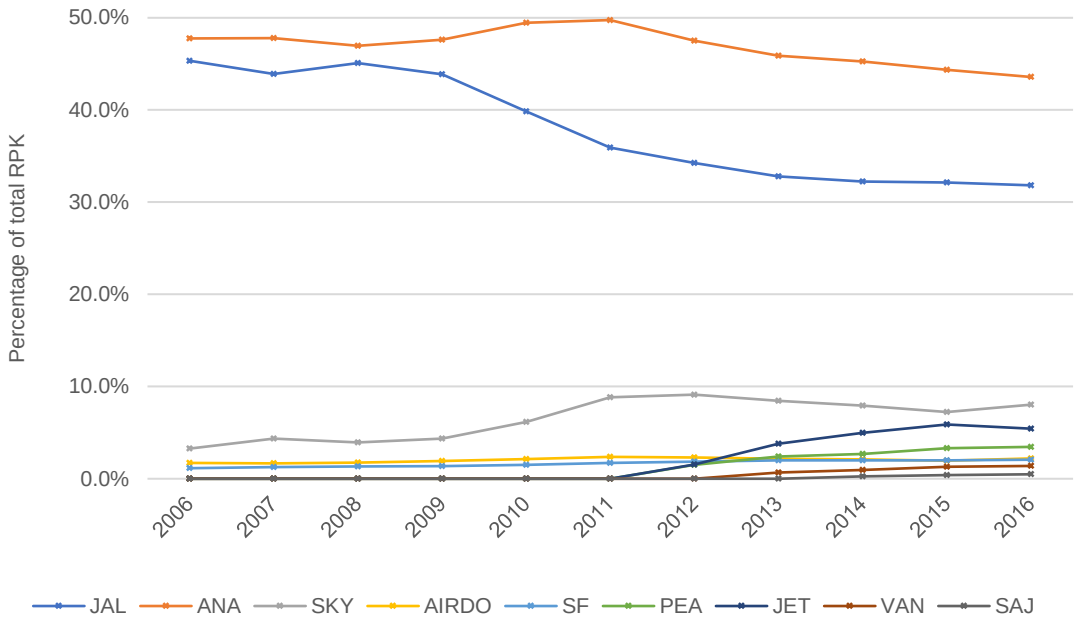


Figure 3.3. Distribution of Japanese domestic aviation by airline (2006 – 2016). Source: Author from MLIT (2017b).

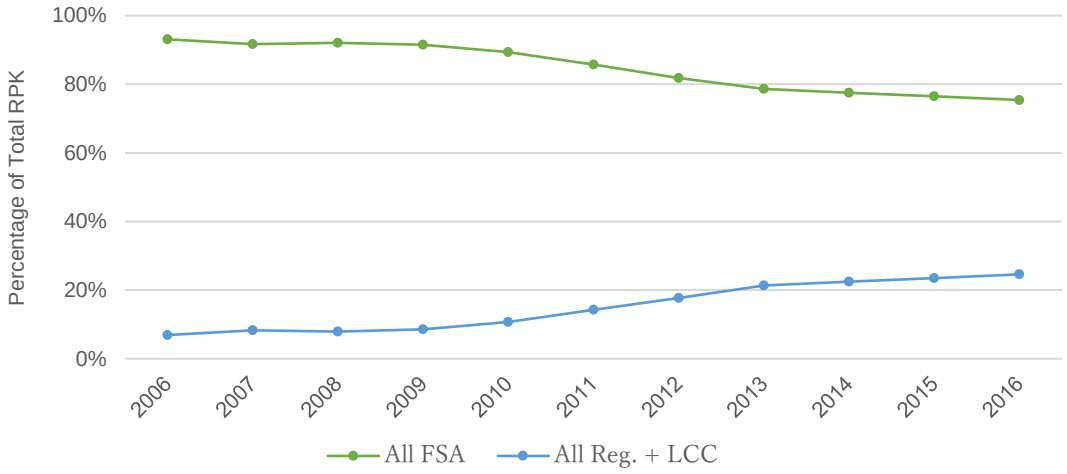


Figure 3.4. Distribution of Japanese domestic aviation by type of service (2006 – 2016). Source: Author from MLIT (2017b).

LCCs started operating in Japan in 2012. There were several conjunctures in 2011 that possibly led to an alteration of Japan's domestic market. A substantial reduction of the aviation fuel tax,

the opening of Narita Airport's domestic terminal, and the success evidenced by regional airlines, in time led to the simultaneous arrival of the three LCCs, which one year later had 4% of the domestic market (Spring Japan started operating in 2014).

Because of these conditions, the author is concerned with the profitability of the LCC industry if some of these conditions were to revert to a previous state, for example, if the aviation fuel tax were to be restored to its original full amount of ¥26,000.00 per kilolitre of fuel. The study wishes to estimate the impact on the LCC business if operational costs increased proportionally to a tax readjustment. In order to do this, the additional fuel cost per flight is estimated for each airline, and based on the average passenger load factors (as reported by airlines), it is possible to estimate the additional fare increase per passenger in the event of a fuel tax return to its original pre-reduction amount, before 2011.

The structure of the paper is as follows: In Section 2, the author presents a summary of the previous findings and publications concerned with budget-airlines and the environmental repercussions of its quick-paced expansion. Section 3 details the methodology employed and explains the way in which the questionnaire was built, and how it was used to collect passengers' assessment of service quality and airline choice. Section 4 analyses the answers to the questionnaire and the environmental implications of LCCs in Japan. Concluding remarks and recommendations are given in Section 5.

3.2 Preceding Research

LCCs are airline companies committed to what Lawton (2003) calls "the cult of cost reduction". In general, the margin of profit for most airlines is minimal. Any given flight has almost the same

average cost and necessary factor load per flight to make it profitable. This makes aviation particularly vulnerable to market fluctuations and falls in traffic, for which lowering costs and increasing employee and aircraft productivity is crucial (op cit.). In general, cost differences are determined by an airline's fleet structure, route network and company policies on remuneration and work rules (Seristö and Vepsäläinen, 1997), and it is in these areas were LCCs cut corners to the full. Doganis (2001) and Graham and Shaw (2008) estimate that an LCC can operate as low as 60% of the unit cost of FSAs.

In general, an LCC airline is defined by Graham and Vowles (2006) under the following key principles:

- High-capacity seating
- Minimum legal crew
- Cabin service only at additional cost
- Fast turn-rounds
- On-board air stairs instead of airport air bridges
- Operating procedures to minimize take-off thrust and braking on landing, congruent with runway length
- Point-to-point traffic only
- No freight
- Advantageous rates from airport operators
- Generally, sectors of less than 2 hours to maximize aircraft utilization
- Online booking to eradicate travel agent commission
- Supplements for payment by credit card
- Sophisticated websites with extensive information on destinations

- One size and type fleets (although some LCC have compromised on this point)

The LCC business model was introduced in the United States in the 1970s by Southwest Airlines, and has been successfully and ubiquitously introduced thereafter. First by other North American competitors, and later and more importantly in Europe, following the liberalisation of the European Union (EU) air transport industry. After 1997, all EU airlines had open access to virtually all routes within Member States (15 at that time), and Iceland, Norway and Switzerland entered the agreement the year after (Graham and Shaw, 2008). After its success in Europe, the industry made a successful appearance in the Australian domestic market (Francis et al., 2006) and finally it reached Asia. With one third of the world population, a vibrant economy and a vast geography abundant in archipelagos and island states, Asia was a dream new market for the LCC industry.

An essential environmental preoccupation around the expansion of the LCC industry, is the appearance of new travellers (technically an increase in the propensity to fly) attracted by the affordability of the service. Previous scientists (Graham and Shaw, 2008) have raised concerns about the promotion by LCCs of behavioural changes in leisure and business travel patterns. All too clear shift in demand, is possible not only as a response to cheaper fares but also to the possibility to use new airports. Passengers now can fly to, or from, local or secondary airports that had long been underused and that are serviced (almost exclusively) by LCCs (E.g. Ciampino Airport in Rome, Ryanair). This phenomenon not only awakens a latent demand of residents close to these airports, but also brings economic development to areas located near them. This is perceived as advantageous to national and regional economic growth, and for that reason the provision of LCCs is supported by national and local government agencies throughout the EU (op cit.).

As an economist, it is not appropriate to ignore the clear benefits that have arisen with the expansion of LCCs in Europe and elsewhere, in spite of environmental costs. Indeed, tourism and mobility are key drivers of economic development, which makes LCCs important contributors to national and regional growth, not to mention the many jobs directly generated by the industry. For that reason, it is important to clarify that the purpose behind the current research, as well as has been pointed out by Stern (2007), Graham and Shaw (2008) and others, is to flag the respective authorities about the negative externalities that are being overlooked. As any industry, aviation should pay its full carbon price by any means available (carbon taxes or emission trading), and in the case of airlines, this becomes especially necessary given its rate of growth.

Further research on the sustainability of the LCC model was conducted by Barrett (2004), who examines the specific case of one airline in Europe: Ryanair. His analysis is exhaustive in the factors that made Ryanair's insertion so successful, such as airline outsourcing, labour productivity, and aspects previously discussed such as corporate culture and the use of secondary airports. At the time, Ryanair was the third largest airline in Europe by number of passengers carried, following Lufthansa and Air France/KLM group. However, its popularity and growth have been so impressive (Figure 3.5) that today Ryanair ranks as the number one airline in Europe (112 million in 2016) (IATA, 2017b), operating over 400 aircraft at a record load factor of 97% (Ryanair, 2017a).

As a point of reference, in 2016 passengers carried by all airlines in Japan combined, was 95 million (MLIT, 2017b).

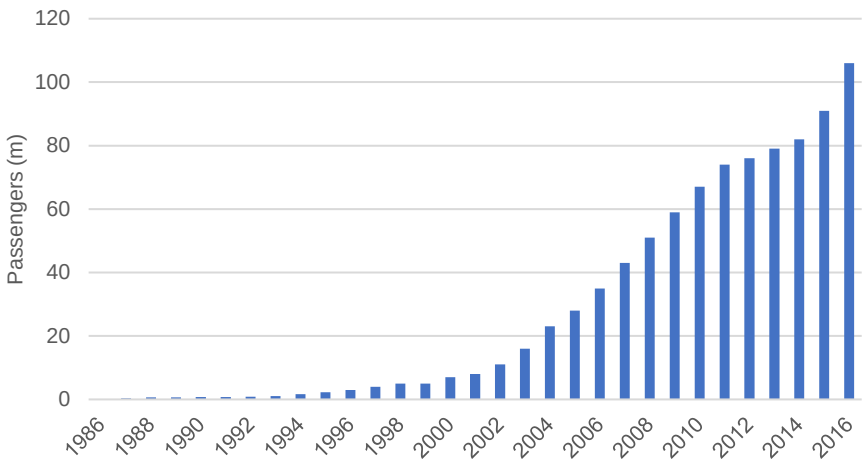


Figure 3.5 Evolution of Ryanair (1986 – 2016) by number of passengers (million). Source: Author from Ryanair (2017b).

Barrett concludes that Ryanair's "predatory success" resulted from a combination of a positive response by passengers to low fares in exchange for traditional frills, and a clear philosophy based upon cost reduction and high productivity. Different scientists (Dobruszkes, 2006; Francis et al., 2006, others) have studied the reasons behind the expansion of Ryanair and the LCC industry in general. This preoccupation has not been limited to the European market. As a matter of fact, in recent years the comparative analysis of passenger airline choice, service quality and the general environment for the expanding LCC market in Asia, has been vast (Hooper, 2005; Lawton and Solomko, 2005; O'Connell and Williams, 2005; Zhang et al., 2008; Chiou and Chen, 2010; Ong and Tan, 2010; Chang and Sun, 2012; Yang et al., 2012; Jiang, 2013; others). Nevertheless, the environmental impact of the expanding low-cost carrier industry, has received little attention in research from academics in Asia as well.

Because of the region's favourable conditions for a booming LCC market, it is paramount to analyse whether there are grounds for environmental concern about the industry's rapid growth.

Concretely, this study will look at the statistical evidence to show whether LCCs have generated a new group of air travellers who fly primarily for leisure: visiting friends and relations, and who do it encouraged by low fares alone. If indeed such market exists, the study will make the necessary recommendations in order to address this overlooked externality.

3.3 Methodology

The paper employs a 5-point Likert Scale questionnaire administered online in specific regions of Japan, in November, 2017. The survey was directed to passengers who had used either FSA or LCC airlines on domestic flights at least once during the last 12 months. At first, respondents were asked to select one airline from a list of air carriers and later to answer the questionnaire based on their experience(s) with that airline alone. The airlines involved were the two main Japanese FSA carriers: JAL (including Japan Transocean Air) and ANA, as well as the existent LCCs: Jetstar, Vanilla Air, Peach Aviation and Spring Japan. Regional airlines were not included in order to allow for a well-defined segmentation between the two targeted services.

The questionnaire had two purposes. First to assess how passengers evaluate each airline in terms of service quality, and their general level of satisfaction with their flight experience. Second, to identify whether there is significant evidence that the LCC industry has generated a change in demand for air travel, concretely, a new group of air travellers who fly motivated exclusively by low fares, and almost exclusively for leisure. In turn, these results make it possible to address the main concern of this chapter, namely the environmental repercussions of the expanding LCC industry. The full questionnaire in Japanese is included in Appendix B.

The questionnaire consists of four sections:

A) A collection of passengers' sociodemographic information (age, income, scholarly attainment, etc.) in order to determine whether there are significant differences in the profile of traveller that chooses one airline service or the other.

B) A set of 10 questions that evaluate users' airline choice, such as the reason to fly, the reason to choose a particular carrier, the sense of reliability and safety about a given airline and the extent to which they would consider to change to another service (FSA or LCC) upon variations on airfare.

C) A set of 22 Likert scale questions were travellers evaluate the airline in terms of service quality, punctuality and regularity of flights, airline image and others.

D) A set of 3 Likert scale questions were passengers are asked, independently of airline choice, about their perception of the environmental impact of air travel, and their level of agreement to higher fares as means to compensate for environmental damage from aviation.

Based on passengers' responses to statements from Sections A through D, the study tests a number of hypotheses that are relevant to distinguish between users of one or the other service. Some of these hypotheses have been tested in previous studies relevant to LCC user preference (for example in Jiang, 2013). However, the demographic characteristics (age, gender, income, etc.) are basic to an important part of the literature reviewed, and they are tested by the author as plausible determinants of user's choice for type of airline service. These are:

H1. Gender is a determinant for the type of service (FSA or LCC) purchased.

H2. The preference for either FSA or LCC services is determined by age.

H3. The use of FSA or LCC carriers is determined by marital status.

From the data collected by the MLIT, no separation is made by gender, age or marital status in any of the available statistics on Japanese aviation. Age is an especially important factor to test because the very low fares of LCCs, as well as the relatively more difficult conditions (flights in the early morning or late at night, additional charge for check-in luggage, on-tarmac boarding, etc.) suggest that younger people are more likely to fly budget airlines.

Furthermore, by testing whether these socio-demographic factors determine the type of airline that travellers choose, policy makers could follow a more effective approach to designing an instrument that relieves the growing environmental impact of commercial aviation.

H4. The purpose of travel is a determinant of the type of service (FSA or LCC) used.

One of the purposes of this chapter is to correctly identify the profile of the average FSA and LCC passenger, in order to determine, among other things, whether or not both types of service are struggling to retain the same type of customer. The purpose of travel, i.e. business or non-business, is an essential variable to test, as it can define whether exceptionally low fares are restricted to leisure travel or if organisations and companies also resort to reduce costs in business trips.

H5. The occupation of passengers is a determinant of the type of service (FSA or LCC) purchased.

H6. The use of either FSA or LCC carriers is determined by the educational background of passengers.

Whether the occupation or educational background of passengers determines the type of service chosen is tested with these two hypotheses. The study is concerned with the possibility that a

particular industry has a relatively larger share of the demand for either type of service, or that a relation exists between passengers' last attained educational degree and their choice of air carrier. Once more, this information is highly important to identify who flies either type of service and for what reasons, given the impending need to define assertive environmental policy toward growing emissions from air travel.

H7. Income level is a determinant of the type of service (FSA or LCC) used.

The study divides respondents into five different level of income and analyses whether there is a relation between the yearly income of travellers and the kind of service that they choose (FSA or LCC).

H8. The quality of service aboard determines user preference for either FSA or LCC carriers.

Because by definition LCCs do not offer food, drinks or entertainment on-board, and because they have a reduced number of cabin attendants, this hypothesis tests whether this separation in quality is a determinant factor in passengers' choice of airline service.

3.4 **Analysis of Results**

3.4.1 Survey Analysis

This section analyses the answers to the questionnaire by users of both services. In this section Because the underlying populations of FSA to LCC are so dissimilar in size (0.88 to 0.12 accordingly, in terms of passengers flown, or 0.87 and 0.13 accordingly, in terms of RPK in 2017), collecting a sizeable, proportional sample was difficult, among other reasons because of budget constraints. Therefore, the author has deliberately overrepresented the proportion of LCC fliers and collected an equal sample of respondents from each group.

Nevertheless, a rudimentary statistical review of the data should allow for a robust enough analysis even if samples are not in equal proportion to the underlying population. One way to do this, is to test whether the average difference between groups is due to random chance. The author has conducted a Welch two sample t test, followed by a supplementary Wilcoxon test to conclusively show that there are statistically significant differences in responses from FSA and LCC fliers in the sample. The results of these tests are summarised in Table 3.1.

Table 3.1 t test p-values and Wilcoxon test p-values of responses to the survey from FSA and LCC fliers. '***' denotes significance at 95 percent confidence interval.

Question	t test p-value	Wilcoxon p-value
q11_1	0.02***	0.04***
q11_2	0.00***	0.01***
q11_3	0.00***	0.00***
q11_4	0.00***	0.00***
q11_5	0.00***	0.00***
q11_6	0.00***	0.00***
q11_7	0.00***	0.00***
q11_8	0.00***	0.00***

q12_1	0.00***	0.00***
q12_2	0.00***	0.00***
q12_3	0.00***	0.00***
q12_4	0.00***	0.00***
q12_5	0.00***	0.00***
q12_6	0.00***	0.00***
q12_7	0.00***	0.00***
q12_8	0.00***	0.00***
q13_1	0.00***	0.00***
q13_2	0.00***	0.00***
q13_3	0.67	0.98
q13_4	0.00***	0.00***
q13_5	0.00***	0.00***
q13_6	0.00***	0.00***
q13_7	0.00***	0.00***
q14_1	0.79	0.66
q14_2	0.23	0.15
q14_3	0.96	0.66
q15	0.02***	0.02***
q16	0.00***	0.00***

The low p-values in both t test and Wilcoxon test for virtually all items in the questionnaire clearly shows that the difference in responses from FSA and LCC users is not due to chance. This statistical significance allows the author to perform the analysis of the data with the collected sample, without further concern for whether the underlying population is proportionally represented or not.

Q13_3, “fares and extra charges are clearly outlined and understood”, is the sole item about airline service where the difference between LCC and FSA is not statistically significant. This may reflect the lack of clarity in airlines’ guidelines on fares and additional charges, regardless of the

type of service used. Furthermore, questions Q14_1 through Q14_3 refer to general statements about aviation and the environment and do not specifically evaluate the type of service used by the respondents, for which a lack of a marked difference between users of either service was expected.

The survey was administered to an equal number of FSA and LCC travellers for a total of 500 entries, i.e. 250 FSA and 250 LCC passengers, between November, 2016 and November, 2017. The study was restricted to domestic flights and excluded regional airlines (or MCC), in order to show a more depurated contrast between traditional and low-cost airlines in Japan. The survey was conducted in areas where both services are available, although LCCs in Japan do not all cover the same regions, and rather have a more divided share of the market. The areas and number of respondents from each are were: Kanto Region (243), Kinki Region (126), Hokkaido (46), Kyushu (38), Chubu Region (26), Shikoku (17), Tohoku Region (3) and Hokuriku Region (1).

Table 3.2 presents a summary of the sociodemographic characteristics of passengers from both services, as well as the corresponding goodness of fit statistic, for which we employ Pearson's chi-square test with Yates' continuity correction.

Table 3.2 Disaggregation of passengers of both types of airlines service by sociodemographic characteristics.

Summary of sociodemographic characteristics by choice of airline [a, b, c]

Type of service	**FSA**	**LCC**	All	Pearson's chi-square (N=500, α=0.05)
Gender				
Male	59.6%	55.2%	57.4%	χ2 (1df) = 0.82, p= .37
Female	40.4%	44.8%	42.6%	
Age group				
18-34	12.8%	18.4%	15.6%	χ2 (2df) = 13.08, p= .00
35-64	64.4%	70.4%	67.4%	
65+	22.8%	11.2%	17.0%	
Marital Status				
Unmarried (single, divorced, other).	35.2%	39.2%	37.2%	χ2 (1df) = 0.7, p= .41
Married	64.8%	60.8%	62.8%	
Purpose of travel				
Business	24.8%	9.2%	17.0%	χ2 (1df) = 20.47, p= .00
Non-business	75.2%	90.8%	83.0%	
Occupation				
Full employee	46.0%	42.0%	44.0%	χ2 (8df) = 9.28, p= .32
Self-employed	5.2%	6.8%	6.0%	
Specialised work (medical, lawyer, designer, beautician, etc.)	5.2%	2.8%	4.0%	

Public employee	2.8%	3.6%	3.2%	
Student	3.6%	3.6%	3.6%	
Housewife	14.4%	11.2%	12.8%	
Part-time work	7.6%	14.0%	10.8%	
Unemployed, retired	14.0%	14.0%	14.0%	
Other	1.2%	2.0%	1.6%	
Last attained education				
Junior high school	0.4%	2.0%	1.2%	$\chi 2$ (4df) = 9.32, p= .05
High school	16.0%	18.4%	17.2%	
Vocational college, specialised academy (2-year program)	19.6%	23.6%	21.6%	
University	54.8%	52.0%	53.4%	
Graduate school	9.2%	4.0%	6.6%	
Annual income				
Below 2 million yen	31.6%	39.2%	35.4%	$\chi 2$ (4df) = 20.80, p= .00
2-5 million	26.8%	36.8%	31.8%	
5-10 million	30.4%	20.0%	25.2%	
10-15 million	9.6%	2.8%	6.2%	
Over 15 million	1.6%	1.2%	1.4%	
Total number of respondents	**500**			

a Survey ran in Japanese, translated by author for this publication.

b The subdivision of each category has been conducted by traditional Japanese disaggregation standards.

c Annual income expressed in yen of 2017.

Our results show that, in general, men travel by plane considerably more than women, although women use LCC more. The p-value is larger than the significance level, for which the null hypothesis is rejected for **H1**. Respondents' age ranges between 19 and 78, with the average age of passengers being of 49.7. Passengers of LCC are slightly younger (48), on average, than those of FSA (51.5). For convenience, respondents are divided into three age groups: 18-34, 35-64 and 65+. The analysis identifies age as a significant factor (**H2**) that determines user choice of airline service. LCCs in Japan today, carry about one half more young passengers than traditional airlines, whereas FSA carry twice as much senior citizens. Marital status is insignificant (**H3**) to determine airline choice.

In terms of purpose of flying, there is a clear predominance of leisure travel over business, in both groups. Of all FSA passengers, 75% flies for non-business purposes (vacation, visiting friends and relations, others), and this figure rises to 91% in the case of LCC users. The results for **H4** are highly significant. This reflects how in Japan, aviation is the leading means of transport for middle to long-distance leisure travel, not business. That place is reserved for the Shinkansen, which is used mostly by men (78.2%) of which 88.8% of them, are there strictly on business (JRTA, 2017).

The study found that full employees, specialised workers and housewives have a higher propensity to fly FSA; whereas students, part-time workers and retirees/unemployed are more likely to choose LCCs. These results, however, are not statistically significant (**H5**). This can be explained in the broad spectrum of occupations that befell some of the categories. For example, doctors are found on the same group as beauticians, and retirees are sorted together with unemployed people, in spite of how circumstances between the two might be different. The survey,

however, was thus conducted in compliance with the traditional Japanese segmentation system for this kind of study.

The data suggests that passengers with a high level of last attained education, especial those with graduate school degrees, will fly FSA. Indeed, LCCs have a higher incidence of passenger whose last degree of attained education is vocational college or lower. Nevertheless, the econometric analysis fails to render a statistically significant coefficient for the incidence of educational background on the type of service (FSA or LCC) of choice, for which **H6** is rejected.

On the other hand, yearly income appears as a highly significant determinant of airline choice, for which we do not reject the statement of **H7**. In fact, more than three quarters of LCC travellers are in the basic two levels of annual income, i.e. below ¥5 million. On the other hand, 40% of FSA fliers reported yearly incomes in the top three levels, i.e. between ¥5 million and ¥15 million. The level of last attained education and the level of income show a correlation of 34%.

In order to discuss the statistical significance of **H8**, the information relevant to user assessment of service quality between types of service is required. Table 3.3 summarises the results of the questionnaire's Section C. The list consists of 22 questions on a Likert scale where on a 5-point Likert scale, where 1=Strongly Agree, 2=Agree, 3=Neither Agree nor Disagree, 4=Disagree, 5=Strongly Disagree. Moreover, Table 3.3 presents the ANOVA results for each one of the statements.

Table 3.3 Descriptive statistics of users' responses to the questionnaire regarding service quality between airlines, and number of flights in the past 12 months.

Type of service	FSA		LCC		Absolute difference
	Mean	Ranking	Mean	Ranking	
Q1. The airline has an efficient website/app for online booking	1.88	3	2.06	1	0.17
Q2. Helpful follow-up notifications (online check-in, departure date proximity, change in flights, etc.)	2.18	17	2.41	10	0.23
Q3. The airline is conveniently located within the airport	2.03	11	2.80	19	0.77
Q4. It is easy to access the terminal and gate for this airline	2.06	12	2.74	18	0.69
Q5. The airline has efficient check-in and baggage handling service	1.97	8	2.46	14	0.49
Q6. Staff on the ground are helpful and understanding	2.02	10	2.51	16	0.49
Q7. Boarding and disembarking take place in a swift and efficient manner	2.00	9	2.46	15	0.47
Q8. Baggage allowance/restrictions are satisfactory for this airline	2.23	19	2.87	20	0.64
Q9. The aircraft interior is in good condition	1.93	6	2.30	8	0.37
Q10. Seats and leg space are comfortable	2.42	21	2.95	21	0.54
Q11. Cabin crew are helpful and understanding	2.06	13	2.40	9	0.34
Q12. Employees are neat and tidy	1.83	2	2.18	6	0.35
Q13. The aircraft is clean and tidy	1.88	4	2.13	3	0.24
Q14. The airline is punctual (flights depart and arrive in time)	2.10	14	2.45	13	0.36
Q15. If a flight is cancelled, you feel reassured about reimbursement, accommodation or rebooking	2.19	18	3.06	22	0.87
Q16. You feel safe when travelling with this airline	1.74	1	2.17	4	0.43
Q17. The airfare charged by this airline is fair	2.46	22	2.10	2	0.36

Q18. Fares and extra charges are explicit and easy to understand	2.24	20	2.27	7	0.03
Q19. You feel satisfied with the frequency and flight schedule of this airline	2.14	15	2.63	17	0.49
Q20. You have a good image of this airline	1.93	7	2.42	11	0.48
Q21. You would use this airline again	1.89	5	2.18	5	0.30
Q22. You would recommend this airline to others	2.15	16	2.44	12	0.29
Total number of flights in previous 12 months	2.94		2.59		

a Survey ran in Japanese, translated by author for this publication.

b Measured on a 5-point Likert scale, where 1=Strongly Agree, 2=Agree, 3=Neither Agree nor Disagree, 4=Disagree, 5=Strongly Disagree

The survey refrained from asking passengers about on-board services that are by definition not included in the LCC experience, such as the habitual meal service, on-board entertainment and mileage/frequent flyer programs[6]. The largest difference between respondents from one and the other service has to do with the reliability of the airline in the event of a flight cancelation, specifically in the reassurance felt about fee reimbursement, accommodation or rebooking on a different flight (Q15). The second and third largest differences have to do with the location of the airline within the airport, (Q3) and the terminal and gate access (Q4).

LCC travellers in Japan have a rather troublesome experience, depending upon the airports used. At Narita Airport (NRT), LCCs (Jetstar, Vanilla Air) are assigned to Terminal 3, which is not accessible by train from the city centre, only by shuttle or on foot from another terminal. Furthermore, passengers are often transported by shuttle directly to the foot at the aircraft, and board using airstairs, rather than the more traditional passenger boarding bridge directly from the gate. Another example: to the Kinki Region, LCCs fly to Kansai International Airport (KIX) which is farther from the city centre than Osaka International Airport (ITM), and forces passengers travelling there to make longer commutes. For these and other reasons, these results are to be expected.

Other variables where differences are considerable are passenger satisfaction with baggage allowances and restrictions (Q8), and seat comfort and leg space (Q10). Furthermore, the difference between both groups about airline image (Q20) is almost at on half of a Likert point. This result suggests that a considerable part of LCC users fly strictly because of the cheap fares, in spite of having reserved opinions about the company. Efficiency during check-in and baggage

[6] Vanilla Air does offer a mileage/frequent flyer program to its customers.

handling (Q5), as well as helpfulness and understanding of the airlines' ground staff (Q6) were also one half of a Likert point apart between the two services.

A key contribution of this investigation lies on passengers' assessment of airline safety between the two types of service. In the questionnaire, users from both groups gave generally favourable answers to the question of how safe they feel when traveling with a specific airline (Q16), although the scores for full-service airlines are higher. Nevertheless, the author included an extra question in the questionnaires administered only to FSA passengers. They were asked if safety was the reason why they refrained from flying low-cost, and 53% of them responded "yes".

The sense of unsafe air travel is unbearable to any air passenger, and it would require a different type of study to assess the willingness of passengers to sacrifice safety for cheaper fares. For that reason, airlines must ubiquitously comply with international and regional safety standards and regulations. Because of the existence of these, there is no theoretical reason for concern about one airline being more or less safe than another. This is why an airline might earn the favour of its customers by appealing to its safety record, but hardly by highlighting its safe way of operating.

Very small differences between FSA and LCC passengers are reflected in their assessment about the airlines' efficient software for online booking (Q1) and posterior follow-up notifications (Q2). These results show that companies have up to date technology and communication strategies to allow passengers to find and book their flights smoothly. Indeed, in the case of LCCs, online booking is the only available method to buy a plane ticket with these companies, as the industry

has eradicated the unnecessary expense of travel agencies' commissions (Graham and Shaw, 2008).

Table 3.4 presents the results of the analysis of variance for the service quality statements. Based on the results the hypothesis **H8** is almost fully supported by the data, i.e. it cannot be rejected that the quality of service determines airline choice. In fact, the only variable that does not appear to be statistically significant is the assessment of the explicitness of fares and extra-charges (Q18).

Table 3.4 Analysis of variance of service quality statements.

ANOVA results for service quality statements (H8) [a, b]

	F	p-value	F crit	Significance
The airline has an efficient website/app for online booking	5.19	0.02	3.86	***
Helpful follow-up notifications (online check-in, departure date proximity, changes in flights, etc.)	8.51	0.00	3.86	***
The airline is conveniently located within the airport	69.84	0.00	3.86	***
It is easy to access the terminal and gate for this airline	57.23	0.00	3.86	***
The airline has efficient check-in and baggage handling service	40.75	0.00	3.86	***
Staff on the ground are helpful and understanding	42.81	0.00	3.86	***
Boarding and disembarking take place in a swift and efficient manner	38.39	0.00	3.86	***
Baggage allowance/restrictions are satisfactory for this airline	51.99	0.00	3.86	***
The aircraft interior is in good condition	28. 6	0.00	3.86	***
Seats and leg space are comfortable	35.1	0.00	3.86	***
Cabin crew are helpful and understanding	21.76	0.00	3.86	***
Employees are neat and tidy	26.55	0.00	3.86	***
The aircraft is clean and tidy	13.75	0.00	3.86	***
The airline is punctual (flights depart and arrive in time)	18.80	0.00	3.86	***
If a flight is cancelled, you feel reassured about reimbursement, accommodation or rebooking	102.99	0.00	3.86	***
You feel safe when travelling with this airline	50.14	0.00	3.86	***
The airfare charged by this airline is fair	25.95	0.00	3.86	***

Fares and extra charges are explicit and easy to understand	0.18	0.67	3.86	
You feel satisfied with the frequency and flight schedule of this airline	40.01	0.00	3.86	***
You have a good image of this airline	46.06	0.00	3.86	***
You would use this airline again	18.28	0.00	3.86	***
You would recommend this airline to others	14.62	0.00	3.86	***

a Survey ran in Japanese, translated by author for this publication.

b * '***' denotes significance at 95 percent confidence interval.**

3.4.2 Multivariate Regression Analysis

In order to strengthen the econometrical precision in this chapter, the author has additionally chosen to conduct a multivariate regression analysis with the choice of airline service (FSA or LCC) as dependent variable, and the responses to statements from hypotheses H1 to H7 as explanatory ones. The analysis of the dependence between airline choice and the sociodemographic characteristics included in the questionnaire, becomes more robust and more realistic in the presence of controlled variables. Because the predictors in this study are both continuous and categorical, a logistic regression is employed. The results are summarised in Table 3.5.

Table 3.5 Multivariate logit-type regression of airline service type (FSA/LCC).

	Estimate	Std. Error	z value	Pr(>|z|)	
(intercept)	-1.22	0.78	-1.55	0.12	
Gender (male)	0.36	0.26	1.37	0.17	
Age	-0.03	0.01	-2.73	0.01	***
Marital status (unmarried)	-0.23	0.23	-1.03	0.30	
Purpose of travel (non-business)	1.09	0.29	3.71	0.00	****
Occupation (housewife)	-0.56	0.43	-1.29	0.20	
Occupation (part-time work)	0.23	0.41	0.57	0.57	
Occupation (public employee)	0.37	0.55	0.68	0.50	
Occupation (self-employed)	0.49	0.44	1.11	0.27	
Occupation (specialised work)	-0.31	0.53	-0.59	0.56	
Occupation (student)	-0.96	0.59	-1.64	0.10	
Occupation (unemployed, retired)	-0.18	0.37	-0.50	0.62	
Occupation (other)	0.57	0.81	0.71	0.48	
Last Education Attained (Jun. High school)	2.08	1.19	1.75	0.08	*
Last Education Attained (High school)	0.51	0.49	1.03	0.30	
Last Education Attained (University)	0.46	0.44	1.04	0.30	
Last Education Attained (Vocational, spec.)	0.52	0.48	1.08	0.28	
Annual Income (below 2 million)	1.35	0.56	2.41	0.02	**

Annual Income (2 to 5 million)	1.29	0.51	2.55	0.01	**
Annual Income (5 to 10 million)	0.61	0.50	1.22	0.22	
Annual Income (over 15 million)	1.01	0.94	1.08	0.28	
a *p<0.1; **p<0.05; ***p<0.01, ****p<0.001					

The multivariate regression surmised in Table 3.5 allows for a more complete appreciation of airline choice (FSA or LCC) when controlling for a set of different variables (age, income level, purpose of travel, etc.). Technically, a logistic regression illustrates the probability of the occurrence of an event that is subject to variations in a set of explanatory factors that are analysed simultaneously. The analysis makes it possible to know the direction and magnitude of the incidence of each of these factors on the explained variable, as well as its statistical significance. The importance of knowing the precise extent of this incidence, as well as our expectations for direction and magnitude of the explanatory variables, was discussed on Section 3.3, where we presented the hypotheses that are tested in both the bivariate and multivariate regressions.

As it turns out, the results from this section are consistent with the simpler bivariate analysis conducted in Section 3.4.1., insofar as that the same explanatory variables have statistically significant coefficients, both when analysed individually, as well as in the presence of controlled variables.

This is a major breakthrough of this thesis, as this section renders results that are robust enough to confirm that variables such as income, age and purpose of travel are key determinants of airline choice when analysed independently or when controlling for all variables included in the questionnaire.

It is important to highlight that “purpose of travel” and “age” distinctly show the strong association between young people and leisure travel with low-cost airlines. Indeed, it is evident that the industry acknowledges this fact and focuses on this market, which shows in the flight destinations offered and the publicity and promotions carried out by LCCs. Conversely, the negative coefficient of the predictor “age” suggests that all other variables kept the same, Japanese people are far less likely to fly low-cost as they become older, and as it happens, as they have more available income. Results show that individuals with a total income below ¥5 million a year, are statistically more prone to purchase low-cost airline tickets than people from the higher income levels analysed in this study.

Other factors such as marital status, gender and occupation were also considered in the multivariate regression. Although eight different categories of occupation were analysed in the logistic model, not one of them has a statistically significant weight in determining whether an individual flies low-cost, and the same is true for gender or marital status differences. In other words, there is no statistical evidence to suggest that any of these factors determines a person’s airline of choice, and definitely, that none of them is as important as age, income or purpose of travel when a person books an airline ticket in Japan.

3.4.3 Log Odds Chart

Theoretically, response variables in logistic regressions are log odds defined as: ln(odds) = ln(p/(1-p)) = a*x1 + b*x2 + … + z*xn. Because the survey employs a set of categorical values for most sociodemographic characteristics (except age), the responses are modelled with dummy variables.

To interpret these results, we can compare the coefficient of two statistically significant predictors with a different direction. For example, to only attend junior high school increases the log odds by 2.08, while a unit increase in age, conversely, decreases the log odds by 0.03.

It can be concluded that income level holds an underlying relation to the age of passengers as well, as younger users are not discouraged by the inconveniences associated to flying low-cost and are more willing than older and wealthier passengers to sacrifice longer commute times and less comfortable conditions in exchange for inexpensive air tickets.

Gender, marital status and type of occupation remain non-significant variables in both bivariate and multivariate regressions.

In order to evaluate the goodness of fit of the logit regression, we can analyse the table of deviance below:

Table 3.6 Deviance table from logistic regression.

Analysis of deviance table [a]						
	Df	Deviance	Resid. Df	Resid. Dev	Pr(>Chi)	
NULL			499	693.2		
Gender	1	0.99	498	692.2	0.32	
Age	1	7.1	497	685.1	0.01	**
Marital status	1	0	496	685.1	0.99	
Purpose of travel	1	21.25	487	651.4	0	***
Occupation	8	12.41	488	672.7	0.13	
Education	4	6.08	483	645.3	0.19	
Annual Income	4	11.42	479	633.9	0.02	*
a *p<0.1; **p<0.05; ***p<0.01						

The difference between the null deviance and the residual deviance shows how the model performs against the null model, i.e. a model with only the intercept. The wider this gap, the better. By analysing the numbers, we can appreciate the reduction in deviance when subsequently adding each variable one at a time (each row down).

It is possible to see how the addition of the statistically significant variables, namely age, purpose of travel and income, has a larger impact on deviance than other non-significant variables, such as gender. To put it differently, a large p-value, for example that of marital status, indicates that the model without the variable explains more or less the same amount of variation.

Additionally, it is possible to verify the robustness of these results by using robust standard errors, or by estimating the model by ordinary least squares (OLS), i.e. treating the estimation as linear probability model. Tables 3.7 and 3.8 summarise the results for these two robustness checks.

Table 3.7 Multivariate logit of airline service type (FSA/LCC) with robust standard errors

	Estimate	**Robust SE**	**z value**	**Pr(>|z|)**	
(intercept)	-1.22	0.76	-1.61	0.11	
Gender (male)	0.36	0.25	1.41	0.16	
Age	-0.03	0.01	-2.74	0.01	*
Marital status (unmarried)	-0.23	0.23	-1.04	0.30	
Purpose of travel (non-business)	1.09	0.29	3.81	0.00	****
Occupation (housewife)	-0.56	0.45	-1.26	0.21	
Occupation (part-time work)	0.23	0.42	0.56	0.58	
Occupation (public employee)	0.37	0.57	0.66	0.51	
Occupation (self-employed)	0.49	0.47	1.05	0.30	
Occupation (specialised work)	-0.31	0.53	-0.58	0.56	

Occupation (student)	-0.96	0.60	-1.60	0.11	
Occupation (unemployed, retired)	-0.18	0.37	-0.50	0.62	
Occupation (other)	0.57	0.79	0.72	0.47	
Last Education Attained (Jun. High school)	2.08	1.22	1.70	0.09	*
Last Education Attained (High school)	0.51	0.48	1.06	0.29	
Last Education Attained (University)	0.46	0.44	1.06	0.29	
Last Education Attained (Vocational, spec.)	0.52	0.47	1.10	0.27	
Annual Income (below 2 million)	1.35	0.56	2.39	0.02	**
Annual Income (2 to 5 million)	1.29	0.50	2.57	0.01	**
Annual Income (5 to 10 million)	0.61	0.50	1.21	0.22	
Annual Income (over 15 million)	1.01	0.83	1.22	0.22	
a *p<0.1; **p<0.05; ***p<0.01, ****p<0.001					

From Table 3.7, is can be observed that when using robust standard errors, purpose of travel and income continue to be highly significant variables that determine the choice of airline, as well as age and educational background in a lesser degree. This further confirms the qualitative consistency and robustness of the results.

Table 3.8 OLS regression results

	Estimate	**Std. Error**	**t value**	**Pr (>|t|)**	
(intercept)	0.28	0.16	1.68	0.09	*
Gender (male)	0.08	0.06	1.33	0.19	
Age	-0.01	0.00	-2.72	0.01	***
Marital status (unmarried)	-0.1	0.05	-0.95	0.34	
Purpose of travel (non-business)	0.24	0.06	3.72	0.00	****
Occupation (self-employed)	0.11	0.1	1.09	0.27	
Occupation (specialised work)	-0.07	0.12	-0.57	0.57	
Occupation (public employee)	0.08	0.13	0.67	0.50	
Occupation (student)	-0.22	0.14	-1.61	0.11	
Occupation (housewife)	-0.14	0.01	-1.35	0.18	
Occupation (part-time work)	0.06	0.09	0.58	0.56	
Occupation (unemployed, retired)	-0.05	0.09	-0.54	0.59	

Occupation (other)	0.12	0.18	0.68	0.5	
Last Education Attained (Junior high)	0.42	0.22	1.90	0.06	*
Last Education Attained (High school)	0.1	0.11	0.92	0.36	
Last Education Attained (Vocational, spec.)	0.1	0.1	0.96	0.34	
Last Education Attained (University)	0.09	0.1	0.92	0.36	
Annual Income (below 2 million)	0.28	0.12	2.4	0.02	**
Annual Income (2 to 5 million)	0.27	0.11	2.57	0.01	**
Annual Income (5 to 10 million)	0.11	0.10	1.09	0.28	
Annual Income (over 15 million)	0.20	0.20	0.99	0.32	
a *p<0.1; **p<0.05; ***p<0.01, ****p<0.001					

Once more, results from the OLS conclusively show that age, purpose of travel and income are statistically significant and therefore consistent with the results obtained from the multivariate logit regression.

Thus far, this paper has presented evidence to low fares being a high incentive for passengers to choose LCCs in Japan. In the following section, this statement is quantified. Figures 3.6 and 3.7 illustrate a comparative assessment of the most important reason why passengers chose to fly either FSA or LCC airlines. Respondents were able to select only one answer from the options given.

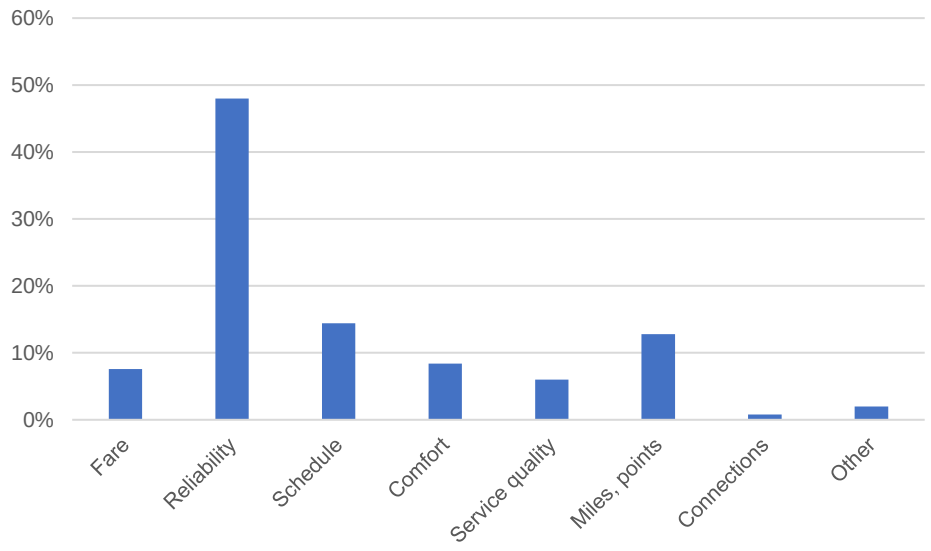


Figure 3.6. Depiction of FSA passengers' most important reason for choice of airline.

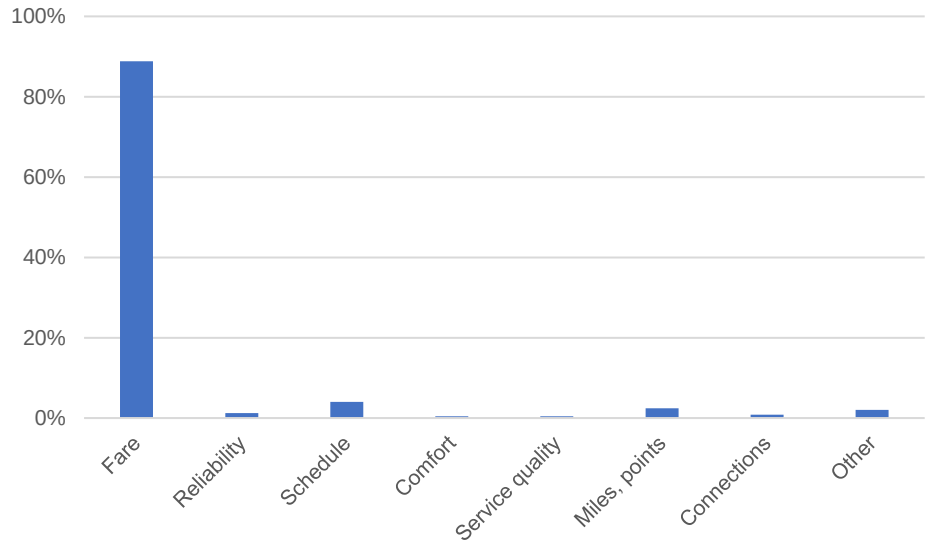


Figure 3.7. Depiction of LCC passengers' most important reason for choice of airline.

89% of LCC passengers in Japan choose this kind of service encouraged by low fares. As for traditional airlines, almost one half (48%) of their travellers prefer one of the two traditional airlines because of the company's reliability. Nevertheless, it is also a point of interest to explore how passenger choices would be affected by changes in airfares. Specifically, the study wished to identify how much of a price difference would encourage FSA traditional

customers to switch to budget airlines, and similarly, how many LCC passengers would change to traditional airlines if LCC fares increased. The answers to these statements are illustrated in Figures 3.8 and 3.9.

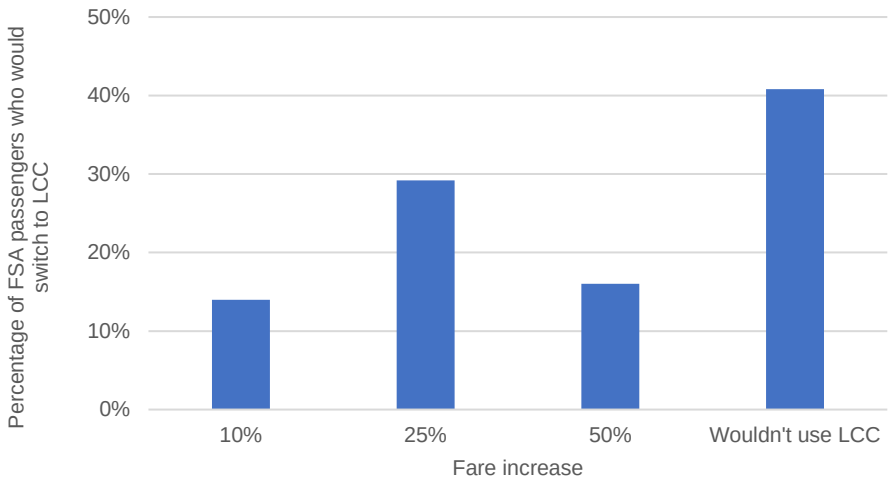


Figure 3.8 Fare sensitivity of FSA passengers.

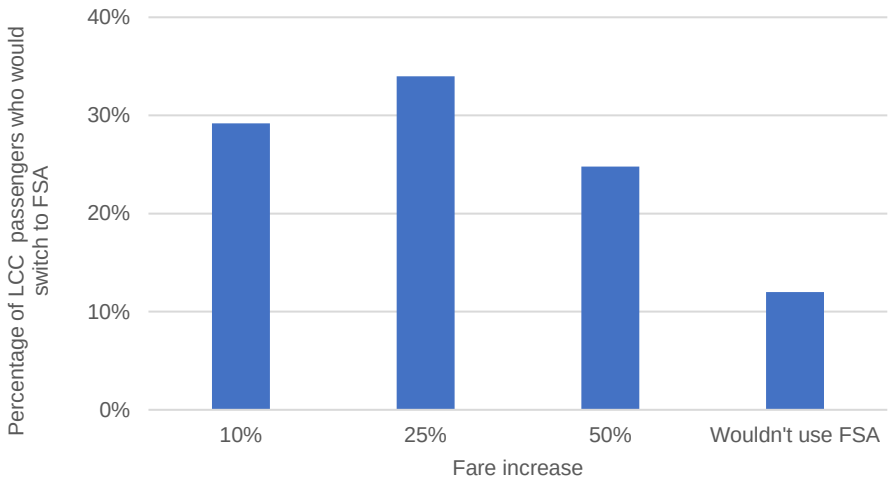


Figure 3.9 Fare sensitivity of LCC passengers.

These results show that 41% of FSA passengers would not switch to LCC carriers in spite of increased fees by their airlines of up to 50%. Conversely, more than one half of LCC passengers would prefer to fly traditional airlines if LCC increased by 10% (29% of respondents) or by 25% (34% of respondents).

This section of the paper has presented enough statistic information that resolutely confirms that LCC users choose this service based solely on price. Passengers will fly budget-airlines repeatedly (Q21) in spite of discomforting conditions, poor accessibility and uncertain outcomes upon flight cancellations. It is important not to forget that this is an industry that serves mostly leisure travellers. What efforts are being made to ensure that this service is covering its due cost for its externalities? The next section analyses an aspect of LCCs that has been discussed throughout the whole thesis: its environmental impact.

3.4.4 Environmental implications of LCC in Japan

Aviation in Japan is growing. Since the aviation fuel tax reduction in 2011, both FSA and LCC have experienced growing RPK rates, as shown in Figures 3.10 and 3.11.

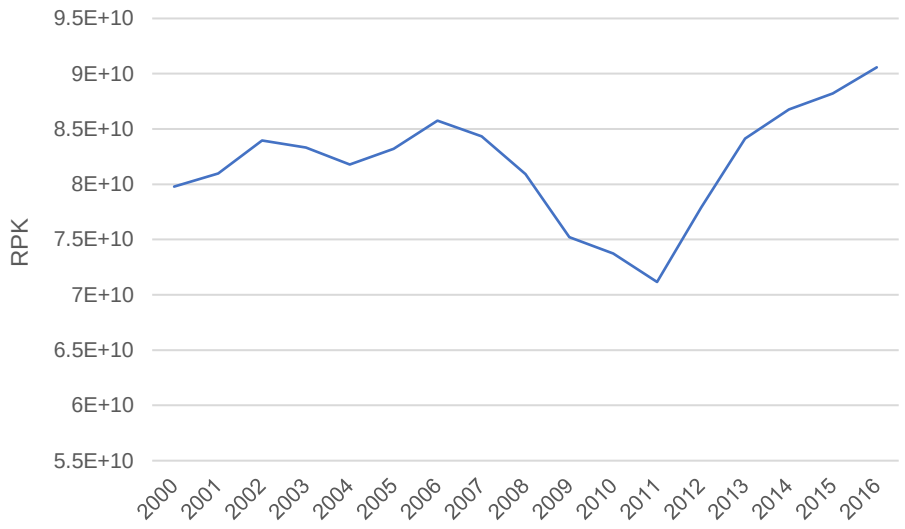


Figure 3.10 Evolution of FSA in Japan (RPK) (2000 – 2016). Source: Author from MLIT (2017b).

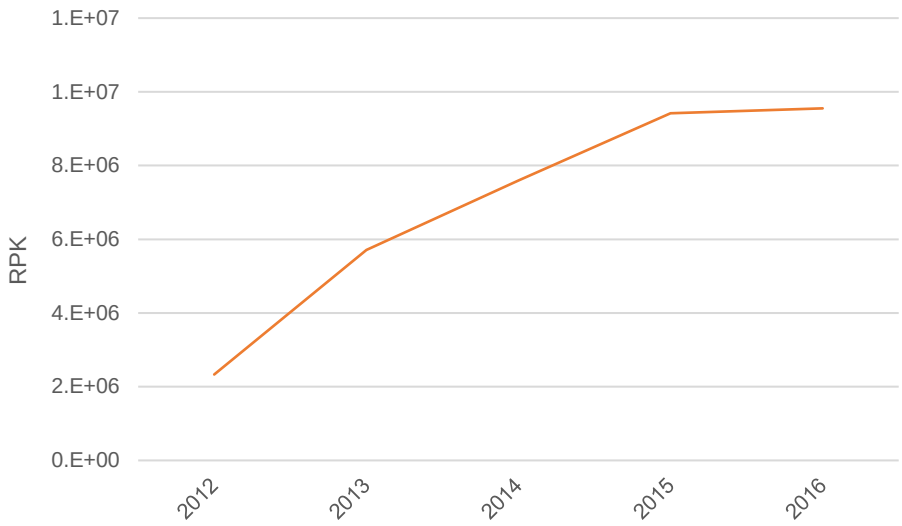


Figure 3.11 Evolution of LCC in Japan (RPK) (2000 – 2016). Source: Author from MLIT (2017b).

Aviation will continue to rely exclusively on fossil fuels for the foreseeable future. Electric engines have proven a highly accepted substitute for combustion engines in the automobile industry, but the technology still looks unreachable for commercial-size aircraft. Therefore, CO_2 emissions from aviation, as well as other effects on the environment and the rate at which they are growing, is a major point of concern for some environmental economists.

The LCC industry deserves a closer analysis given its large popularity and high growth rate. The current study has shown how in Japan it serves a market niche particularly composed of young leisure travellers, many of whom travel in spite of (relatively) uncomfortable conditions, and largely because of the attractive low fares. It is possible that leisure air travel at very low fares would not be a common service in the absence of LCCs. Therefore, we conclude that budget airlines have generated a market for a specific type of service, rather than causing a rearrangement of customers from traditional airlines.

It is difficult to estimate the percentage of passengers who indeed change from FSA airlines to LCCs (from our results, the change in the opposite direction would occur strictly because of service quality). Furthermore, as shown in Figure 3.2, traditional airlines have been pressed to extend their lower airfare boundary in order not to lose market to budget-airlines. 40% of FSA customers stated that they would not change to LCCs at any price difference and 53% of FSA passengers feel that it is unsafe to travel LCC. All of this indicates that indeed LCCs have created a new market for inexpensive air travel, and one that unfortunately has detrimental consequences to the environment.

The purpose of this section is to analyse how environmental policy could affect the expanding business of LCCs. Specifically, what the effect of a charge or tax on emissions would be, in terms of airfare and operational costs. For the case of Japan's LCC, the study estimates how much airfares would raise, on average, in the Japanese aviation fuel tax (*koukuukinenryouzei*) went back to its original standard as it was before 2011, the year when the government reduced it by 30%, and the year that brought about the entrance of budget-airlines in the Japanese market.

Using data from the MLIT (2017b), the paper calculates the average fuel consumption per kilometre, and the average kilometres per flight, for all currently operational airlines in domestic flights in Japan (op cit.). With these datasets, it is possible to estimate the average fuel consumption (in kilolitres) per flight per airline, and multiply that by the tax difference at the original rate before 2011, to calculate the average extra fuel cost per flight. This additional cost is divided by the average number of passengers per flight. To do this, the study uses the passenger load factor as reported by each airline (ANA, 2017; AirDo, 2017; JAL, 2017a,

2017b; Jetstar, 2017; Peach, 2017; Skymark, 2017; Solaseed Air, 2017; Starflyer, 2017; Spring Japan, 2017; Vanilla Air, 2017), and presents the figures for different scenarios, suggesting different aircraft models often used by LCCs almost uniformly (as is common by the industry's practices). Table 3.9 shows how much airfares would increase per passenger, assuming a perfect pass-through of the tax to the passenger.

Table 3.9 Additional cost per passenger of the aviation fuel tax reverting to its original amount, as before the 30% reduction in 2011. Source: Author from MLIT (2017b) and ANA (2017), AirDo (2017), JAL (2017a, 2017b), Jetstar (2017), Peach (2017), Skymark (2017), Solaseed Air (2017), Starflyer, (2017), Spring Japan (2017) and Vanilla Air (2017).

Estimation of additional cost per passenger for different aircraft upon a full-tax restoration in domestic flights a, b

Airline	Additional fuel cost per flight (JPY)	Pass. load factor	A320 Neo 189	A320-211 165	Boeing 737-800 166
JAL	43857.2	0.69	334.9	383.6	381.2
ANA	42855.0	0.66	345.7	395.9	393.5
JAL Transocean	45098	0.81	294.2	337.0	335.0
Skymark	50538.4	0.85	313.5	359.1	356.9
AirDo	44716.2	0.80	296.9	340.0	338.0
Solaseed	49918	0.68	386.1	442.3	439.6
Starflyer	45718.4	0.75	321.7	368.5	366.2
Peach	45193.4	0.85	280.0	320.7	318.8
Jetstar	50729.3	0.85	315.8	361.7	359.5
Vanilla Air	54928.9	0.89	326.6	374.1	371.8
Spring Japan	45193.4	0.94	254.1	291.1	289.3

a Estimations for base domestic flight tax rate. Tax rates for Okinawa and remote islands are excluded.

b Values in yen of 2017.

Table 3.9 illustrates the additional cost per passenger if the aviation fuel tax on domestic flights went back to its original standard of ¥26,000.00 per kilolitre. The estimation has also included regional airlines (or MCC) to present a broader perspective of how a theoretical readjustment of the tax would affect the industry as a whole. Less than 30% of LCC travellers would switch to an FSA airline if the airfare increased by 10% or less. Within a certain confidence range, it is possible to assume that an average ¥300-350 increase in airline tickets, would have very little impact in the quantity of demand for LCC travel, and much less so, for full-service, traditional Japanese airlines.

Another relevant aspect to this section, is the analysis of how passengers from one and the other type of service perceive the environmental impact of aviation. As part of the survey, passengers were asked three questions that relate air travel and the environment. The answers to these questions are summarised in Table 3.10.

Table 3.10 Passenger's responses to statements about the environmental impact of aviation.

Descriptive statistics of responses to the questionnaire

Type of service	FSA		LCC	
	Mean	SD	Mean	SD
Air travel is a significant contributor to climate change	2.88	0.85	2.90	0.85
Passengers should pay more to fly because of the negative environmental impact	3.44	0.98	3.54	0.95
Profiting from air transport is more important than saving natural resources	2.92	0.83	2.93	0.82
Total number of flights in previous 12 months	2.94	2.05	2.59	1.78

a Survey ran in Japanese, translated by author for this publication.

b Measured on a 5-point Likert scale, where 1=Strongly Agree, 2=Agree, 3=Neither Agree nor Disagree, 4=Disagree, 5=Strongly Disagree

Results show that Japanese FSA passengers on average fly more often than LCC users. However, passengers' perception about the environmental impact of air travel, is independent of their choice of airline service, as answers to question Q23 show. There is a slight agreement by FSA users that passengers should pay more to fly in order to account for the negative repercussions to the environment. This result contrasts some of the findings from Chapter 2, namely that the segment that flies the most is the least willing to adjust their behaviour toward air transport, or to pay higher fares for environmental reasons. This difference might be justified in the purpose of flight, since Segment 3 (Chapter 2) was composed mostly of middle age workers with high levels of income education, suggesting that they travel more for business, as opposed to the results of the second survey, where 83% of respondents from both types of airline, travel only for leisure.

3.5 Concluding Remarks

LCC airlines in Japan entered service in 2012, and to date they have reclaimed 11% of the national domestic market (RPK) (MLIT, 2017b). They are used especially for leisure travel, by customers who are strictly motivated by the low fares. Passenger who use the main two traditional carriers: JAL and ANA, are reluctant to change to budget-airlines in spite of the large airfare difference, and highly value the reliability of their airline of choice.

The fact that LCCs are drawing new business into the market is clearly shown by non-decreasing numbers in both sectors. It is difficult to estimate the percentage of this growth that corresponds to passengers moving from one type of service to the other and how many of them stays there. Based on the information available, LCCs attract a mostly young population that travels for non-business purposes and who do so incentivised by very cheap airline tickets.

This option would not be possible in absence of the LCC industry, therefore it can be concluded that budget-airlines draw a new demand for aviation, rather than redirecting business from their FSA counterparts.

There is no difference in the environmental impact between one type of service and the other. As a matter of fact, because of their philosophy of ever-reducing operational costs, it is common for LCCs to operate state-of-the-art aircraft that are highly fuel-efficient, often more so than their FSA counterparts. However, both industries benefit from a regulation system that exonerates them from any environmental responsibilities and does not enforce carbon taxes or emission-trading permits. This dissertation contributes to draw attention to the need for environmental policy that holds airlines responsible for their negative externalities. Furthermore, the study has shown that if the aviation fuel tax was restored to its original pre-reduction level, the effect on airfare per-passenger would not strongly affect the demand for airline tickets in either service.

General Concluding Remarks

It is the categorical recommendation of this analyst that the tax on aviation fuel existent in Japan (*koukuukinenryouzei*) remains in force. Following the conclusions of our previous study (González and Hosoda, 2016) which showed how aviation taxes have a directly proportional effect on fuel consumption, figures by the Japanese authorities show that over the five years since the 30% reduction of the aviation fuel tax (2011 – 2016), domestic aviation in Japan increased in 125 thousand flights and carried as many as 20 million more passengers (MLIT, 2017a).

Aviation is a fast-expanding industry with a blatant disregard for its negative externalities, and whose contribution to CO_2 emissions, although minor at a global scale, continues to grow faster than any other human activity. Forecasts by both airline associations, regulators and aircraft manufactures agree that commercial aviation will have doubled current standards over the next 15 years (Airbus, 2017; Boeing, 2017; IATA, 2017a; ICAO, 2017a). It is paramount that this activity, whose effect on the environment has been repeatedly reported in academic journals, is hold accountable for its role in climate change, and that both companies and passengers fulfil their due part.

Japan is a country where people are very aware of their responsibility toward the environment, and this thesis has provided empirical evidence that consolidates such statement. Japanese people are willing to contribute to offset their carbon emissions, financially if necessary. In the case of aviation, people who fly the most are more reluctant to pay higher fares for environmental reason, and they are equally doubtful of the environmental impact of aviation. At the same time, results show that Shinkansen is not a likely substitute for aviation, however

environmentally preferable. Nevertheless, it is also clear that both means of transport serve different types of traveller and for different purposes.

Low-cost carriers are a world phenomenon that has revolutionised the air travel industry. In North America and in Europe, budget-airlines have displaced traditional airlines and spurred a new era of cheap flying, servicing secondary airports long underused, and reactivating the economy around these areas, for which they receive important government support. In Japan, the industry is still new, but it has already occupied more than 10% of the national domestic market. The study concludes that the LCC industry generates a new demand for leisure travellers, drawn unequivocally by the low fares. By estimating the amount per passenger that a restoration of the Japanese fuel tax would amount to, it can be concluded that environmental regulation around aircraft emissions, would have a very mild effect on airline fares.

This dissertation has presented an extensive analysis of aircraft emissions and the importance to address the continued growth of the airline industry. The purpose of this study is neither to discredit the important role of commercial aviation in modern economy, nor to suggest that it can be replaced by alternative means of transport, or powered by less polluting fuels. The intention of the author is merely that airlines are held responsible for their unmistakable role in carbon emissions; one that affects all people equally, travellers or otherwise, and that requires a long overdue reform.

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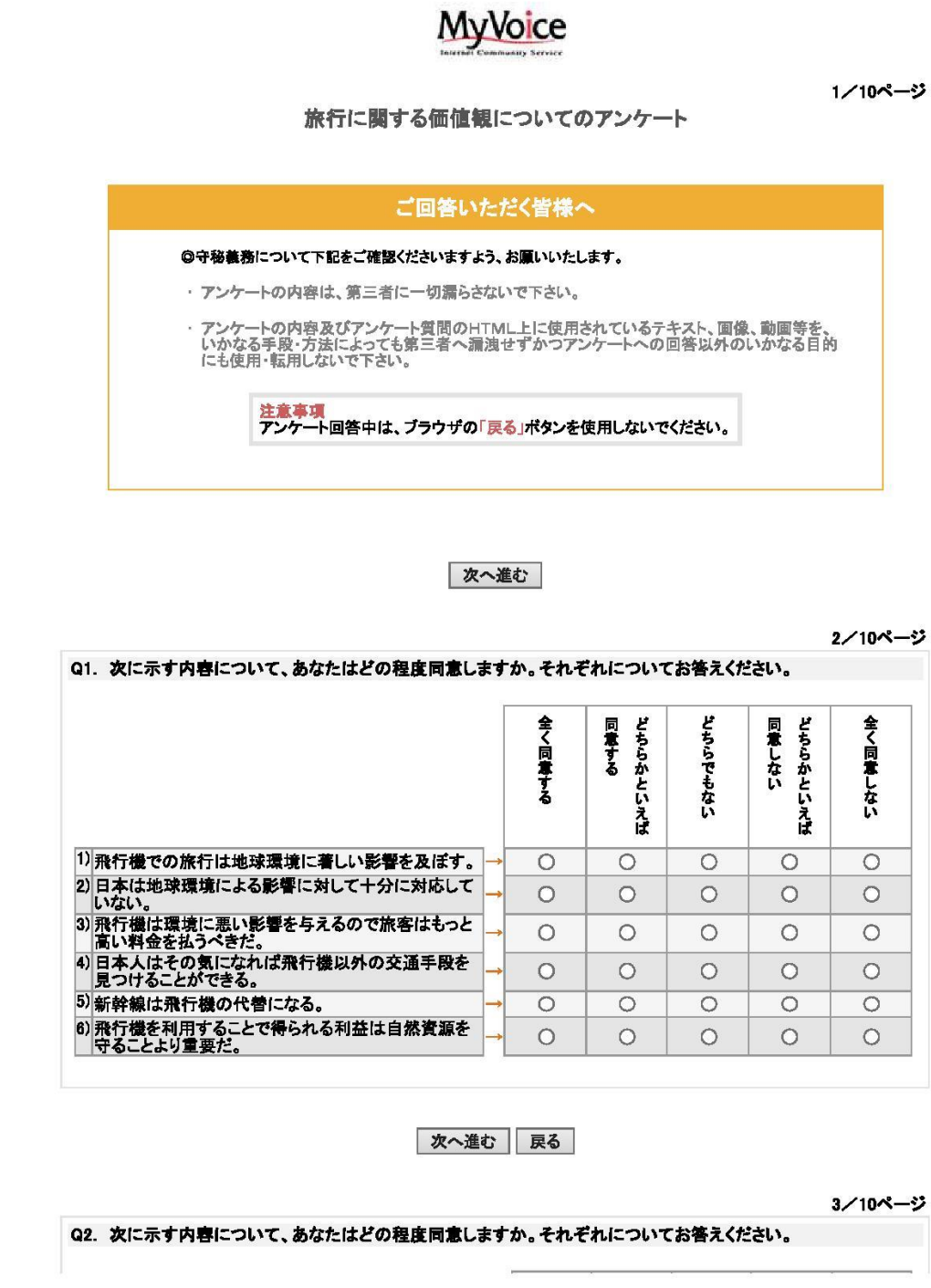
Appendix A.1

Analysis of Environmental-based Choice Behaviour in Domestic Aviation in Japan (Japanese) (Chapter Two)



MyVoice
Internet Community Service

1／10ページ

旅行に関する価値観についてのアンケート

ご回答いただく皆様へ

◎守秘義務について下記をご確認くださいますよう、お願いいたします。

・アンケートの内容は、第三者に一切漏らさないで下さい。

・アンケートの内容及びアンケート質問のHTML上に使用されているテキスト、画像、動画等を、いかなる手段・方法によっても第三者へ漏洩せずかつアンケートへの回答以外のいかなる目的にも使用・転用しないで下さい。

注意事項
アンケート回答中は、ブラウザの「戻る」ボタンを使用しないでください。

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Q1. 次に示す内容について、あなたはどの程度同意しますか。それぞれについてお答えください。

	全く同意する	どちらかといえば同意する	どちらでもない	どちらかといえば同意しない	全く同意しない
1) 飛行機での旅行は地球環境に著しい影響を及ぼす。	○	○	○	○	○
2) 日本は地球環境による影響に対して十分に対応していない。	○	○	○	○	○
3) 飛行機は環境に悪い影響を与えるので旅客はもっと高い料金を払うべきだ。	○	○	○	○	○
4) 日本人はその気になれば飛行機以外の交通手段を見つけることができる。	○	○	○	○	○
5) 新幹線は飛行機の代替になる。	○	○	○	○	○
6) 飛行機を利用することで得られる利益は自然資源を守ることより重要だ。	○	○	○	○	○

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Q2. 次に示す内容について、あなたはどの程度同意しますか。それぞれについてお答えください。

		全く同意する	どちらかといえば同意する	どちらでもない	どちらかといえば同意しない	全く同意しない
1)	自然資源を過剰に使用することによって起こる環境問題は私と私の家族にとって大きな問題だ。	○	○	○	○	○
2)	エネルギー効率のより高い交通手段を使用することは地球温暖化の緩和に良い効果をもたらす。	○	○	○	○	○
3)	私たち一人ひとりの行動が社会や環境に良い効果をもたらすことができる。	○	○	○	○	○
4)	私は環境問題をとても危惧している。	○	○	○	○	○
5)	私は環境をできる範囲で守る責任があると思う。	○	○	○	○	○
6)	環境を守ることは簡単だと思う。	○	○	○	○	○
7)	私の友人のほとんどは環境にやさしい。	○	○	○	○	○
8)	私の周りの人たちが環境にやさしくしていると自分もそうしなければと思う。	○	○	○	○	○
9)	資源を守る努力をしないと罪の意識を感じる。	○	○	○	○	○
10)	自分は環境にやさしいと人に思われたい。	○	○	○	○	○
		全く同意する	どちらかといえば同意する	どちらでもない	どちらかといえば同意しない	全く同意しない

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Q3. 次に示す内容について、あなたはどの程度あてはまりますか。それぞれについてお答えください。

		全くあてはまる	どちらかといえばあてはまる	どちらでもない	どちらかといえばあてはまらない	全くあてはまらない
1)	次の休暇中は飛行機に乗らない。	○	○	○	○	○
2)	自然環境に影響を及ぼさないように、飛行機に乗る回数を減らしたいかもしれない。	○	○	○	○	○
3)	航空運賃が10%値上がりしたら、飛行機に乗る回数を減らしたいかもしれない。	○	○	○	○	○
4)	海外に行く代わりに日本国内で休暇を過ごす。	○	○	○	○	○
5)	私が飛行機に乗ったことで放出した二酸化炭素の埋め合わせ料金を払う。	○	○	○	○	○
6)	環境を汚染するレベルがより低い飛行機で飛ぶ。	○	○	○	○	○
7)	エネルギー効率のより良い航空会社を選ぶ。	○	○	○	○	○
8)	家の中でのエネルギー使用を控える。	○	○	○	○	○
9)	できる限りエネルギー効率の高い方法で旅行する。	○	○	○	○	○
10)	飛行機に乗るより新幹線を使う。	○	○	○	○	○

11) 飛行機の代わりに新幹線を利用することは環境にやさしいことをしているようで気持ちがいい。	○ 全くあてはまる	○ どちらかといえばあてはまる	○ どちらでもない	○ どちらかといえばあてはまらない	○ 全くあてはまらない

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Q4. あなたの最終学歴をお答えください。

○1. 中学校
○2. 高校
○3. 短大、専門学校
○4. 大学
○5. 大学院

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Q5. あなたの個人年収をお答えください。

○ 200万円未満
○ 200万円以上500万円未満
○ 500万円以上1,000万円未満
○ 1,000万円以上1,500万円未満
○ 1,500万円以上

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Q6. 現在お住まいの住居について、あてはまるものをお答えください。

○1. 一軒家
○2. 連棟住宅（長屋、タウンハウス等）
○3. アパートメント、集合住宅（マンションを含む）
○4. 社宅あるいは寮

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■現在お住まいの住居で「一軒家」「連棟住宅」「アパートメント、集合住宅」とお答えの方に伺います。

Q7. 現在お住まいの住居の所有状況について、あてはまるものをお答えください。

○1. 持ち家（配偶者・両親・祖父母など、家族所有を含む）
○2. 賃貸（公営・UR）
○3. 賃貸（公営・UR以外）

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■全員に伺います。

Q8. 現在のお住まいから、最寄りの飛行場までの距離として、あてはまるものをお答えください。
※東京駅から羽田空港までの直線距離は約14km、新宿駅から羽田空港までの直線距離は約16kmです。
※大阪駅から関西空港までの直線距離は約39km、大阪駅から伊丹空港までの直線距離は約11kmです。
※博多駅から福岡空港までの直線距離は約2km、北九州駅から北九州空港までの直線距離は約15kmです。

○ 10km未満
○ 10km以上25km未満
○ 25km以上50km未満
○ 50km以上

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10／10ページ

Q9. 過去１年間に飛行機を何回利用しましたか。あてはまるものをお答えください。
※目的地までの往復での利用を１回と数えて、お答えください。（飛行機の乗り継ぎがあった場合を含む）

○ 1回も利用していない
○ 1回
○ 2回
○ 3回
○ 4回
○ 5回
○ 6～10回
○ 11～20回
○ 21回以上

回答　戻る　やり直し

Appendix A.2

Analysis of Environmental-based Choice Behaviour in Domestic Aviation in Japan (English) (Chapter Two)

SURVEY

Analysis of environmental-based choice behaviour in domestic aviation in Japan

Please assess your agreement to the following statements using the scale:
1 = Strongly Agree, 2 = Agree, 3 = Neither Agree nor Disagree, 4 = Disagree, 5 = Strongly Disagree

Part I. Assessment of awareness of environmental impact of aviation

1. Air travel is a significant contributor to climate change

1 2 3 4 5

2. Japan does not thoroughly address the effects of climate change

1 2 3 4 5

3. Passengers should pay more to fly because of the negative environmental impact

1 2 3 4 5

4. It is easy for Japanese people to find an alternative to flying in they really want to

1 2 3 4 5

5. Shinkansen is an alternative to air travel

1 2 3 4 5

6. Profiting from air transport is more important than saving natural resources

1 2 3 4 5

Part II. Assessment of attitude toward environment

7. Environmental problems caused by over-use of resources is a threat to me and my family

1 2 3 4 5

8. Choosing more energy efficient forms of transport helps reduce global warming

1 2 3 4 5

9. Each person's behaviour can have a positive effect on society and the environment

1 2 3 4 5

10. I am very concerned about environmental issues

1 2 3 4 5

11. I feel it is my responsibility to help the environment in the best way possible

1 2 3 4 5

12. I find helping the environment easy

1 2 3 4 5

13. Most of my friends are environmentally friendly

1 2 3 4 5

14. When other people around me help the environment I feel I should too

1 2 3 4 5

15. I feel guilty when I don't make an effort to conserve resources

1 2 3 4 5

16. I like people to think of me as environmentally friendly

1 2 3 4 5

Part III. Assessment of possible behavioural change

17. Not fly during the next holidays

1 2 3 4 5

18. Holiday in Japan instead of overseas

1 2 3 4 5

19. Pay to offset the carbon emissions from my flight(s)

1 2 3 4 5

20. Pay more to fly on a less polluting airplane

1 2 3 4 5

21. Choose a more energy efficient airline

1 2 3 4 5

22. Reduce energy used at home

1 2 3 4 5

23. Choose a more energy efficient way to travel whenever possible

1 2 3 4 5

24. Choose Shinkansen rather than fly

1 2 3 4 5

25. Choose to travel by Shinkansen rather than fly makes me feel good as something to help the
environment

1 2 3 4 5

Part IV. Personal and demographic information. Circle the appropriate answer.

Gender: M F

Age group: 18-34 35-64 65+

Property: Detached house

Tenement of row houses

Apartment house, residential complex

Company owned residence or dormitory

Education: High School Completed

Vocational College Completed

University Completed

Graduate School Completed

Home circumstance: Own home / Parent’s home

Public management rental

Urban regeneration / public corporation rental

Private management rental

Salary rental (company owned house, dormitory, etc.)

Room rental

Employment: Self employment

Employed full time

Employed part time

Retired

Distance to airport: Less than 10Km

10-25 Km

25-50 Km

More than 50Km

Annual income

Less than 2.0.000

2.000.000 - 5.0.000

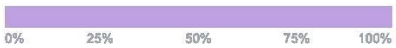
5.000.000 - 10.000.000

10.000.000 - 15.000.000

More than 15.0.000

Appendix B.1

Analysis of Airline Choice and Passenger Profile in Japanese Domestic Air Transport (Chapter Three)



F1 F2 F3 F4 F5 Q1 Q1B Q2 Q3 Q4 Q5 Q6 Q7 info1 Q8 Q9 Q10 info2 Q11 Q12 Q13 info3 Q14 info4 Q15 Q16

プレビュー一覧 | 設定一覧

F1.
あなたの性別をお知らせください。

（ひとつだけ）【必須】

○ 男性
○ 女性

F2.
あなたの年齢をお知らせください。

【必須】

[ ] 歳

F3.
あなたのお住まいをお知らせください。

（ひとつだけ）【必須】

（回答を選択してください）

F4.
あなたは結婚していますか。

（ひとつだけ）【必須】

○ 結婚していない（未婚・離死別）
○ 結婚している

F5.
あなたの職業をお知らせください。

（ひとつだけ）【必須】

○ 会社員・役員（契約・派遣社員を含む）
○ 自営業
○ 専門職（医師、弁護士、美容師、デザイナー等）
○ 公務員
○ 学生
○ 専業主婦・専業主夫
○ パート・アルバイト・フリーター
○ 無職・定年退職
○ その他

Q1.
あなたが過去1年間で直近で利用した国内線の航空会社を1つお選びください。

（ひとつだけ）【必須】
※ビジネス利用、ビジネス利用以外にかかわらずお答えください。
※国際線ではなく国内線の航空会社をお答えください。

○ 全日本空輸（ANA）
○ 日本航空（JAL）（日本トラストオーシャン航空を含む）
○ ジェットスター・ジャパン
○ ピーチ・アビエーション（Peach）
○ バニラ・エア
○ 春秋航空日本
○ その他 [ ]
○ 過去1年間で国内線の航空会社を利用していない

Q2.
あなたは過去1年間に国内線の飛行機を何回利用しましたか。当てはまるものをお答えください。

（ひとつだけ）【必須】

○ 1回
○ 2回
○ 3回
○ 4回
○ 5回
○ 6～10回
○ 11～20回
○ 21回以上

■Q1で過去1年間で直近で利用した国内線の航空会社は全日本空輸（ANA）、日本航空（JAL）（日本トラストオーシャン航空を含む）とお答えの方にお伺いします。

Q3.
FSAを選択する主な理由は何ですか。

（ひとつだけ）【必須】
※FSAとはフルサービスエアラインの略語で、LCCに対比する呼び名です。
このアンケートでは全日本空輸（ANA）、日本航空（JAL）（日本トラストオーシャン航空を含む）を指します。

- ○ 運賃
- ○ 信頼性
- ○ 時刻、予定通りの運航
- ○ 快適さ
- ○ サービス、品質
- ○ パッケージ、ポイント、マイルプログラム
- ○ 乗り継ぎ
- ○ その他 [ ]

Q4.
LCCの利用を控える理由は安全性ですか。

（ひとつだけ）【必須】
※LCCとは格安航空会社（ローコストキャリア）の略語です。
このアンケートではジェットスター・ジャパン、ピーチ・アビエーション（Peach）、バニラ・エア、春秋航空日本を指します。

- ○ はい
- ○ いいえ

Q5.
FSAの運賃の増加がどの程度であれば、LCCを利用しますか。

（ひとつだけ）【必須】
※FSAとはフルサービスエアラインの略語で、LCCに対比する呼び名です。
このアンケートでは全日本空輸（ANA）、日本航空（JAL）（日本トラストオーシャン航空を含む）を指します。
※LCCとは格安航空会社（ローコストキャリア）の略語です。
このアンケートではジェットスター・ジャパン、ピーチ・アビエーション（Peach）、バニラ・エア、春秋航空日本を指します。

○ 10%の増加
○ 25%の増加
○ 50%の増加
○ LCCは利用しない

■Q1で過去1年間の中で直近で利用した国内線の航空会社はジェットスター・ジャパン、ピーチ・アビエーション（Peach）、バニラ・エア、春秋航空日本とお答えの方にお伺いします。

Q6.
LCCを選ばれた主な理由は何ですか。

（ひとつだけ）【必須】
※LCCとは格安航空会社（ローコストキャリア）の略語です。
このアンケートではジェットスター・ジャパン、ピーチ・アビエーション（Peach）、バニラ・エア、春秋航空日本を指します。

○ 運賃
○ 信頼性
○ 時刻、予定通りの運航
○ 快適さ
○ サービス、品質
○ パッケージ、ポイント、マイルプログラム
○ 乗り継ぎ
○ その他 [ ]

Q7.
LCCの運賃の増加がどの程度であれば、FSAをご利用しますか。

（ひとつだけ）【必須】
※FSAとはフルサービスエアラインの略語で、LCCに対比する呼び名です。
このアンケートでは全日本空輸（ANA）、日本航空（JAL）（日本トラストオーシャン航空を含む）を指します。
※LCCとは格安航空会社（ローコストキャリア）の略語です。
このアンケートではジェットスター・ジャパン、ピーチ・アビエーション（Peach）、バニラ・エア、春秋航空日本を指します。

○ 10%の増加
○ 25%の増加
○ 50%の増加
○ FSAは利用しない

■全員にお伺いします。

Q8～Q10は【[Q1]】での直近のフライトについてお答えください。

Q8.
フライトを予約される前に、他の航空会社の利用を検討されましたか。

（ひとつだけ）【必須】

○ はい
○ いいえ

Q9.
フライトの目的は何ですか。

（ひとつだけ）【必須】

○ ビジネス
○ ビジネス以外

Q10.
自費でのフライトでしたか。

（ひとつだけ）【必須】

○ はい
○ いいえ

Q11～Q13は引き続き【[Q1]】についてお答えください。

Q11.
次に示す内容について、あなたはどの程度同意しますか。
次の選択肢からあてはまるものをそれぞれお選びください。

（横にそれぞれひとつずつ）【必須】

	全く同意する	どちらかと同意する	どちらでもな	どちらかと同意しない	全く同意しな

		えば	い	えば	い
航空会社にはオンライン予約のための効率的で使いやすいウェブサイト／アプリがある	○	○	○	○	○
航空会社は役に立つ予約のフォローアップの連絡をしている（オンラインチェックインが利用可能なとき、出発日が近づいたら、航空便の変更に関する警告をする）	○	○	○	○	○
航空会社は空港の便利な場所にある	○	○	○	○	○
ターミナルとゲートに簡単にアクセスできる	○	○	○	○	○
航空会社は効率的なチェックインサービス／手荷物サービスを提供している	○	○	○	○	○
地上スタッフは理解力があり役に立つ	○	○	○	○	○
効率的でスムーズに乗り降りができる	○	○	○	○	○
航空会社の手荷物許容量／制限に満足している	○	○	○	○	○

Q12.
次に示す内容について、あなたはどの程度同意しますか。
次の選択肢からあてはまるものをそれぞれお選びください。

（横にそれぞれひとつずつ）【必須】

	全く同意する	どちらかといえば同意する	どちらでもない	どちらかといえば同意しない	全く同意しない
航空機の内装は良好である	○	○	○	○	○
座席と脚のスペースは快適である	○	○	○	○	○
客室乗務員は理解力があり役に立つ	○	○	○	○	○
従業員は、身なりがきちんとしている	○	○	○	○	○
航空機は、清潔できちんと整っている	○	○	○	○	○
航空会社は、時間を厳守している（飛行機は時間通りに出発／到着する）	○	○	○	○	○
フライトがキャンセルになった場合、運賃の払い戻し、宿泊施設、再予約に関して安心である	○	○	○	○	○
航空会社のマイレージ・サービスの恩恵を受けている	○	○	○	○	○

Q13.
次に示す内容について、あなたはどの程度同意しますか。
次の選択肢からあてはまるものをそれぞれお選びください。

（横にそれぞれひとつずつ）【必須】

	全く	同意 どち	どち	同意 どち	全く

	同意する	らかといえばする	らでもない	らかといえばしない	同意しない
この航空会社を利用して安全に旅行できると思う	○	○	○	○	○
航空運賃は妥当である	○	○	○	○	○
運賃と追加料金が明確に示され、理解されている	○	○	○	○	○
航空会社には十分なフライトスケジュールとフライト頻度がある	○	○	○	○	○
この航空会社に良いイメージを持っている	○	○	○	○	○
この航空会社を再度利用したい	○	○	○	○	○
この航空会社を他の人に推薦したい	○	○	○	○	○

Q14は特定の航空会社に限らず、飛行機全般についてお答えください。

Q14.
次に示す内容について、あなたはどの程度同意しますか。
次の選択肢からあてはまるものをそれぞれお選びください。

（横にそれぞれひとつずつ）【必須】

	全く同意する	どちらかといえば同意する	どちらでもない	どちらかといえば同意しない	全く同意しない
飛行機での旅行は地球環境に著しい影響を及ぼす	○	○	○	○	○
飛行機は環境に悪い影響を与えるので旅客はもっと高い料金を払うべきだ	○	○	○	○	○
飛行機を利用することで得られる利益は自然資源を守ることよりも重要だ	○	○	○	○	○

Q15～Q16はあなた自身についてお答えください。

Q15.

あなたの最終学歴をお答えください。

（ひとつだけ）【必須】

○ 中学校
○ 高校
○ 短大、専門学校
○ 大学
○ 大学院

Q16.
あなたの個人年収をお答えください。

（ひとつだけ）【必須】

○ 200万円未満
○ 200万円以上500万円未満
○ 500万円以上1，000万円未満
○ 1，000万円以上1，500万円未満
○ 1，500万円以上

Appendix B.2

Analysis of User Perception of Airline Service in Japan (English) (Chapter Three)

SURVEY

Analysis of user perception of airline service

Part I. Flight experience and sociodemographic information

1. Have you used one of the following airlines in the past 12 months?

A. All Nippon Airways B. JAL

B. Jetstar C. Peach

D. Vanilla Air E. Spring Japan

F. Other _____ G. Not used in past 12 months

2. (If A) Is safety a reason why you would refrain from flying an LCC airline?

YES NO

3. (If B) Is price the main reason why you chose this airline?

YES NO

4. Did you look at other carriers before you booked your flight?

YES NO

5. What was your purpose of flying?

A. Business B. Non-business

6. Did you travel at your own expense?

A. Yes B. No

Part II. Assessment of perceived service value

Please assess your agreement to the following statements using the scale:

1 = Strongly Agree, 2 = Agree, 3 = Neither Agree nor Disagree, 4 = Disagree, 5 = Strongly Disagree

Booking

7. The airline has an efficient/easy-to-use website/app for online booking

1 2 3 4 5

8. The airline has good follow-up communication about reservations (alerts about changes in flight, as departure date approaches, when online check-in is available, etc.)

1 2 3 4 5

Ground service

9. The airline uses convenient airport locations

1 2 3 4 5

10. The terminal and gate are easily accessible

1 2 3 4 5

11. The airline has efficient check-in/baggage service

1 2 3 4 5

12. Ground staff are understanding and helpful

1 2 3 4 5

13. Boarding and deplaning are efficient and smooth

1 2 3 4 5

14. You feel satisfied with the airline's baggage allowance/restrictions

1 2 3 4 5

Flight

15. The aircraft interior is in good condition

1 2 3 4 5

16. In-flight entertainment is satisfactory

1 2 3 4 5

17. The airline provides quality food and beverages

1 2 3 4 5

18. Seats and leg space are comfortable

1 2 3 4 5

19. Cabin crew are understanding and helpful

1 2 3 4 5

20. Employees are neat and tidy

1 2 3 4 5

21. The aircraft is neat and tidy

1 2 3 4 5

Service reliability

22. The airline is punctual (flights depart and arrive in time)

1 2 3 4 5

You feel reassured in terms of fare refunds, accommodation or rebooking in the event of a flight cancellation

1 2 3 4 5

23. You benefit from the airline's frequent flyer program

1 2 3 4 5

Safety

24. You feel safe travelling with this airline

1 2 3 4 5

Airfare and schedule

25. Airfare price is fair

1 2 3 4 5

26. Fares and extra charges are clearly outlined and understood

1 2 3 4 5

27. The airline has enough flight schedules and frequency

1 2 3 4 5

Airline image

28. I have a good image of this airline

1 2 3 4 5

29. I would use this airline again

1 2 3 4 5

30. I would recommend this airline to others

1 2 3 4 5