Pass-through with Endogenous Quality: An Empirical Study of Per-passenger and Per-flight Airport Charges

Naoshi Doi
Sapporo Gakuin University
March 13, 2019

Abstract

This study empirically investigates the pass-through rates and incidence in the airline industry to understand how airport charges affect airfares, service quality (flight frequency), and welfare. It estimates a structural model endogenizing airfares and flight frequency by using data on Japanese domestic routes and conducts simulation analyses. It is found that while per-flight charges hardly affect airfares, an increase in per-passenger charges significantly raises airfares with the average pass-through rate of 97.5 percent. The pass-through rates are overestimated when flight frequency is treated as exogenous. Both types of charges decrease flight frequency. In addition, on nearly 80 percent of the routes in the sample, while per-passenger charges are superior to per-flight charges from the viewpoint of airline profits, the order is reversed from the viewpoints of the passenger and social surpluses.

Keywords: Pass-through; Airport pricing; Airline industry; Structural estimation; Endogenous product characteristics

JEL classification: L1; L5; L9; H2

*I am grateful to Achim I. Czerny and seminar participants at Sapporo Gakuin University, University of Tokyo, the Summer Workshop on Economic Theory (Otaru University of Commerce), the International Workshop on Competition and Public Policy in Network Industries (Kwansei Gakuin University), the Air Transport Research Society World Conference (University of Antwerp), and Hokkaido University. This work was supported by Sapporo Gakuin University Research Support Grant Numbers SGU–BS15–212004–01 (2015) and SGU–AS2016–02 (2016) and by a Grant-in-Aid for Young Scientists (B) Grant Number 17K13735 from the Japan Society for the Promotion of Science.
1 Introduction

Pass-through rates measure the proportion of a change in costs or taxes that is passed through to prices. They are closely related to incidence, namely how the burden of costs or taxes is divided between buyers and sellers. Previous studies report widely spread estimates of pass-through rates in different industries, market structures, and tax systems. This study empirically investigates the pass-through rates and incidence in the airline industry, focusing on those of airport charges.

The airline industry is an infrastructure for long-distance transportation. In Japan, air transport is used in more than 60 percent of travel over distances of 750–1,000 kilometers and 90 percent for distances of over 1,000 kilometers. Given the economic importance of both business and leisure travelers, prices (i.e., airfares) and service quality in the airline industry may thus have a widespread influence on the economy. Airfares and service quality are affected by airport charges, which are usually paid by airlines to airports and account for a relevant share (about 6–7 percent) of the operating costs of airlines.

While airport charges are somewhat complicated, their main two charges are broadly categorized as per-passenger charges (e.g., passenger service facility charges, PSFCs) and per-flight charges (e.g., landing fees). Per-passenger charges are usually collected by airlines at the time of sale and then paid to airports. Other types of charges include charges for parking, check-in counters, and boarding bridges, which all have lower shares. For example, the Ministry of Land, Infrastructure and Transport (MLIT) reports that landing fees and per-passenger charges account for 67.4 percent and 16.4 percent, respectively, for a type of airplane (B767-300) in 2013 at five major airports in Japan. Choo (2014) also reports that for 59 airports in the United States in 2002–2010, landing fees and terminal fees accounted for 44 percent and 50 percent, respectively.

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1Pass-through rates above 100 percent have been reported in the cases of televisions (Karp and Perloff, 1989), alcohol tax (Kenkel, 2005), fuel tax (Marion and Muehlegger, 2011), and soft drinks (Bonnet and Réquillart, 2013), while pass-through rates have been estimated to be below 100 percent in the cases of cigarette tax (Delipalla and O’Donnell, 2001), processed cheese (Kim and Cotterill, 2008), potato and fluid milk (Richards et al., 2012), electricity (Fabra and Reguant, 2014), and butter and margarine (Griffith et al., 2018).

2The latest data available from the Ministry of Land, Infrastructure and Transport (MLIT) are for 2007: 61.3 percent for 750–1,000 kilometers and 93.7 percent for over 1,000 kilometers (http://www.mlit.go.jp/k-toukei/17/17x0excel.html, in Japanese, accessed December 26, 2018). The mode share of air transport for all distances is 6.0 percent in Japan relative to 10.9 percent in the United States, 1.2 percent in the United Kingdom, 2.1 percent in France, and 0.7 percent in Germany (http://www.mlit.go.jp/statistics/pdf/23000000x026.pdf, in Japanese, accessed December 26, 2018).

3ICAO DATA+ Air Carrier Finances reports the operating costs of airlines, which are categorized into five items: aircraft fuel and oil; maintenance and overhaul; user charges; ticketing, sales, and promotion; and other operating expenses. For airlines globally, these categories accounted for 33.5, 8.8, 5.9, 4.7, and 47.1 percent in 2012, respectively. For Japanese airlines, for which the latest available data are for 2008, these proportions are 25.9, 9.6, 7.1, 9.5, and 47.8 percent, respectively. Other operating expenses are presumed to include labor costs, which account for about 20 percent according to the financial statements of Japanese airlines (e.g., Doi, 2015).

4This is from: http://www.mlit.go.jp/common/000996147.pdf (in Japanese, accessed March 12, 2019). According to the report, the share of landing fees in Japan is higher than at airports in Western and Asian countries except China.
The International Air Transport Association (IATA), the trade association for the world’s airlines, has proposed moving away from per-flight charges in favor of per-passenger ones (IATA, 2010). The IATA stresses that charging on a per-passenger basis increases the visibility of the charges that passengers pay and also makes it possible to share the risks and benefits of changes in passenger traffic between airports and airlines. IATA (2010), however, does not discuss the extent to which the change in the basis of charges affects airfares and service quality, which are important topics of discussion for the passenger and airport surpluses as well as airline profits.

As a first step to examining the best combination of per-passenger and per-flight charges, this study empirically investigates how these two categories of charges affect airfares and service quality. It also analyzes the incidence of per-passenger and per-flight charges, namely the degree to which each type influences airline profits, passenger welfare, and the social surplus. Clarifying the incidence of airport charges reveals why airlines have asked to move away from per-flight charges to per-passenger ones and whether changing the airport charge system in accordance with this request contributes to the social surplus.

To investigate the incidence of airport charges, we must estimate the passenger surplus. To do this, an empirical structural model in which airlines decide both airfares and flight frequency is used. Previous studies that estimate structural models of the airline industry usually endogenize only airfares and treat flight frequency as exogenous (e.g., Peters, 2006; Berry and Jia, 2010). Flight frequency is an important indicator of service quality in the airline industry, especially given that air passenger demand depends on it. Indeed, the higher flight frequency, the higher is the possibility that passengers can travel on flights with departure and arrival times that suit their schedules (Douglas and Miller, 1974); furthermore, changes to flight reservations are easier. Because airport charges plausibly influence airlines’ flight frequency and airfare decisions, it is thus more desirable to endogenize flight frequency than to treat it as exogenous when investigating the extent to which airport charges influence passenger welfare.

In this study, the effects of airport charges are estimated in the context of the 2004–2005 airport charge revision in Japan’s domestic airline market. In Japan, the country’s first ever per-passenger charge, the security charge of 100 JPY (equivalent to 4.7 percent of the mean of airfares in the dataset of this study), was introduced at national airports in October 2004. Over the next year, landing fees, a major per-flight charge, at national airports were reduced by about 7.7 percent. The effects of the revision are estimated by using the estimated structural model to simulate counterfactual scenarios in which the revision had not been realized and comparing the simulation results with the actual data.

Richard (2003) uses a model that endogenizes both airfares and flight frequency for monopoly or duopoly routes and investigates the effects of an airline merger. The model of this study is applicable to routes on which more than two airlines compete.
From the simulation analyses, it is found that increases in both per-flight and per-passenger charges significantly reduce flight frequency; it is also revealed that per-passenger charges are mostly passed through on airfares, while per-flight charges have insignificant effects on these. The introduction of the 100 JPY per-passenger charge is found to increase airfares by nearly the same amount as a pass-through rate of 97.5 percent on average. It also decreases flight frequency by 1.6 percent on average, which is evaluated to be equivalent to 186.5 JPY based on the estimated demand parameters. These estimates imply that passenger utility is reduced more by decreases in flight frequency than by increases in airfares. This result suggests that when the effects of airport charges are evaluated, it is important to consider changes in flight frequency as well as those in airfares. While the per-passenger charge raises the airport surplus by about 480 million JPY (per month), it reduces the consumer and producer surpluses by about 1,300 million JPY and 470 million JPY, respectively. The reduction in landing fees is found to have a negligible effect on airfares, increase flight frequency by 1.0 percent (equivalent to 106.5 JPY), reduce the airport surplus by roughly 220 million JPY, and raise the consumer and producer surpluses by about 610 million JPY and 330 million JPY, respectively.

It is also found that the pass-through rates of per-passenger charges tend to be overestimated when flight frequency is treated as exogenous. This is because the model with exogenous flight frequency does not consider the decrease in airfares that follows the decrease in flight frequency caused by per-passenger charges. This result suggests that endogenizing flight frequency is relevant to estimate the pass-through rates of airport charges.

The estimates of the effects on the surplus make it possible to investigate which types of airport charges are desirable to raise airport revenue by the same amount. It is found that on nearly 80 percent of routes in the analyzed market, per-passenger charges are more desirable than per-flight ones from the viewpoint of airline profits, while the order is reversed from the viewpoint of the consumer and social surpluses: the increase in per-passenger charges to raise the airport surplus by 1 JPY causes less reduction in airline profits but more reduction in the consumer and social surpluses than the increase in per-flight charges to raise airport revenue by the same amount. This result is consistent with the fact that airlines have asked to replace per-passenger charges with per-flight charges (IATA, 2010). However, it also implies that the social surplus may decrease if airports change airport charge system in accordance with the airlines’ request.

The rest of this section describes the literature related to this study. Following it, the remainder of this paper is organized as follows. Section 2 describes the system of airport charges in Japan’s domestic market and the data used in the present study. Section 3 introduces the structural model to be estimated. Section 4 presents the estimation results. Section 5 conducts a simulation analysis to quantify the impact of the 2004-2005 revision of the charge system. Section 6 concludes, and
this is followed by the Appendix.

**Related literature**  This study relates to the literature on airport charges as well as builds on three broader strands of research described later. Some recent studies have investigated airport charge systems in the context of the theory of multi-sided platforms, which regards an airport as a platform used by airlines and passengers (Flores-Fillol et al., 2015; Ivaldi et al., 2016). These studies have analyzed the combination of aeronautical prices such as landing fees and non-aeronautical prices for parking services (Ivaldi et al., 2016) or retail concessions in terminal buildings (Flores-Fillol et al., 2015). Although these issues across aeronautical and non-aeronautical prices are not negligible, even within aeronautical prices, the role of prices to airlines (per-flight charges) and to passengers (per-passenger charges) is not yet fully understood.

Some theoretical studies have investigated the different effects of per-passenger and per-flight charges. Some of them are motivated by airport congestion and investigate the roles of these charges at congested airports (e.g., Silva and Verhoef, 2013; Silva et al., 2014; Lin and Zhang, 2016). Other recent studies have been motivated by the proposal of IATA (2010). Czerny and Zhang (2015) and Czerny et al. (2017) compare the optimal combination of per-passenger and per-flight charges from the viewpoints of both carriers’ profits and social optimality. They point out, under the airport cost recovery constraint, a trade-off between low airfares achieved by low per-passenger charges and high frequency achieved by low per-flight charges.

Despite the foregoing, it remains unclear how each type of airport charge quantitatively affects market outcomes, which is important for addressing airport congestion as well as understanding the proposals of the IATA. In particular, the trade-off is closely related to the extent to which passengers value flight frequency relative to airfares and how flight frequency is affected by a change in airport charges, both of which are empirical issues. To my knowledge, this study is the first to empirically investigate the issue of airport charges and provides an empirical framework within which to examine the effects of airport charges on airfares, flight frequency, and welfare.

In addition to the literature on airport charges, this study builds on three broader strands of research. First, it contributes to the literature on the estimation of pass-through rates. Previous studies estimating pass-through rates by using structural models usually treat product characteristics (such as quality) as exogenous (e.g., Kim and Cotterill, 2008; Richards et al., 2012; Bonnet and Requillart, 2013; Fabra and Reguant, 2014; Griffith et al., 2018). This study uses a model with endogenous quality and shows that not only pass-through on prices but also changes in quality are important to evaluate the welfare effects on consumers. It is also revealed that pass-through rates may be overestimated when using a model with exogenous quality.

Second, this study relates to the literature on public finance that compares the efficacy of taxation across its various forms. In the literature, the focus has traditionally been placed on
the comparison of a specific and ad valorem tax (e.g., Delipalla and Keen, 1992; Skeath and Trandel, 1994; Anderson et al., 2001; Delipalla and O’Donnell, 2001; Colombo and Labrecciosa, 2013; Griffith et al., 2018). This study compares a specific tax (per-passenger charges) and a tax on quality (per-flight charges), finding in the analyzed market that producers tend to prefer the specific tax, while consumers prefer the tax on quality.

Third, this study also relates to the literature on endogenous product characteristics. When a characteristic variable (such as quality) is discrete, the empirical methods to analyze the choice facing firms resemble those from the entry literature (e.g., Mazzeo, 2002; Seim, 2006; Draganska et al., 2009; Sweeting, 2013; Eizenberg, 2014). Previous studies also construct structural models endogenizing continuous characteristics variables and investigate the effects on the prices and qualities of mergers (e.g., Gandhi et al., 2008; Fan, 2013; Doi and Ohashi, 2019) and entries (Chu, 2010). They reveal that if product characteristics are treated as exogenous, the estimated effects of mergers and entries may be biased. This study uses a structural model endogenizing a continuous quality variable, which is similar to previous studies, to analyze pass-through rates. The results reveal that endogenizing quality is also relevant in this context, correcting the overestimation of pass-through rates.

2 Market and Data

This section explains the analyzed market and data. Subsection 2.1 describes airport charges in the domestic airline market in Japan. Subsection 2.2 presents the dataset and its summary statistics. Subsection 2.3 explains the preliminary analyses that explore how changes in airport charges affect airfares and flight frequency in the dataset.

2.1 Airport Charges in Japan

Airport charges in Japan consist of landing fees, facility usage fees for aids to navigation, a security charge, PSFCs, and other charges. Landing fees and facility usage fees for aids to navigation are categorized as per-flight charges, while the security charge and PSFCs are per-passenger charges. Other charges include those for the use of boarding bridges and oil supply facilities as well as parking charges that are levied according to how long an airplane stays at an airport.

Charge rates differ across airports, depending mainly on the airport administrators. In 2005, 26 of 97 Japan’s airports were managed by the national government. The remaining 71 were managed by local governments or companies. The charges at national airports are set by the national government and are basically uniform, as shown in Figure 1. As for the other airports, the charges are set by each local government or company.
In Japan, up to 2004, airport charges consisted primarily of per-flight charges. In October 2004, the first per-passenger charge, a security charge of 100 JPY per landing passenger (equivalent to 4.7 percent of the mean of airfares in the dataset of this study), was introduced at national airports. Since then, per-passenger charges have been introduced at several airports. For example, Haneda Airport set a PSFC of 100 JPY in April 2005; this charge was increased to 170 JPY in October 2008 and to 290 JPY in April 2014. By contrast, landing fees at national airports have tended to decrease. Figure 1 shows the system of landing fees at Japan’s national airports. Landing fees depend on the maximum takeoff weight (MTOW) and noise level of an aircraft and are discounted by 10–80 percent according to time period and route. The landing fee system has been changed several times. In October 2005, the part based on the MTOW was reduced by about 9 percent. This study empirically investigates the effects of this revision of the airport charge system in 2004–2005, which raised the weight of per-passenger charges instead of per-flight charges.

2.2 Data

This study uses monthly data by route and airline for 2000 to 2005. Throughout this paper, a route is defined as a pair of airports and does not consider the direction of the journey, following the definition in the Annual Report on Air Transport Statistics (Koku Yuso Tokei Nempo in Japanese), from which the data on the number of passengers, number of seats per flight, and flight frequency are obtained.

The airfare data by route are primarily obtained from the timetables published monthly by JTB Publishing, Inc. Because these airfare data are normal fares and do not take into account discounts, they may be somewhat different from the actual fares paid by passengers. Unfortunately, there are no publicly available data on actual fares for Japanese domestic routes before 2002. I therefore adjust the normal fares by using the discount rate following the Travel Survey for Domestic Air Passengers (Koku Ryokyaku Dotai Chosa in Japanese) for 2003 and 2005. The Survey provides data on actual fares for a couple of days and is conducted basically once every two years. Details of the adjustment are explained in the Appendix.

Calculating the landing fee needs information on the MTOW and noise level of an aircraft. The data on such aircraft characteristics are obtained from Suiji de Miru Koku (in Japanese) and Nihon Kokuki Zenshu (in Japanese). The timetable reports the type of aircraft making each flight.

Table 1 presents the summary statistics. Panel (A) shows the statistics for the full sample, in which the observation unit is defined by airline, route, and month. The number of airlines operating a route is 1.6 on average. In the market, three large airlines (All Nippon Airways, ANA;
Japan Airlines, JAL; and Japan Air system, JAS) accounted for more than 98 percent of domestic passengers in 2001. Two of these airlines (JAL and JAS) merged in 2002.

The main airport charges in the analyzed market are per-flight ones. The total of per-flight charges is 191.9 thousand JPY per flight on average, roughly divided half and half into landing fees and the facility usage fees for aids to navigation. Landing fees by airline, route, and month are calculated by using the MTOW and noise level values. The average landing fee is 97.7 thousand JPY. The proportion based on the MTOW accounts for about 85 percent of the total (82.7 thousand JPY). Accordingly, the 9-percent reduction in the rates of the MTOW-based part in October 2005 resulted in a 7.6 percent reduction in the total landing fee (the sum of the MTOW- and noise level-based parts) and a 3.9 percent reduction in the total per-flight charge. Landing fees may differ according to the direction of a flight, as the calculation formula of the arrival (not departure) airport is used to set them. Throughout this paper, since a route is defined by its endpoint airports without regard for the direction of travel, the landing fees of a route are defined as the mean of the landing fees of both directions of the route.

2.3 Preliminary Analyses

Before the simulation analyzes based on a structural model described in the next section, this subsection presents two sets of preliminary analyses to investigate the effects of airport charges on market outcomes that appear in the dataset. First, changes before and after the airport charge system revision are simply examined. Second, the effects are estimated by using a reduced form estimation.

Changes before and after the revision Table 2 reports the changes in airfares, flight frequency, and the number of passengers from October 2003 to October 2005, during which the security charge was introduced and landing fees were reduced at government-managed airports. The table shows the changes by route type, which is defined by the administrators of the endpoint airports of a route. Routes are classified into three types: routes between two national airports ("NN routes"), routes between a national airport and an airport managed by a local government or company ("NO routes"), and routes between two airports managed by a local government or company ("OO routes"). Panel (B) of Table 1 presents the summary statistics of the variables by route type.

Fares increased for all route types during 2003–2005. A possible explanation for this trend is the rise in fuel prices: for example, the kerosene jet fuel spot price in the U.S. Gulf Coast doubled during this period. The increase in fares on NN and NO routes (260 JPY) was, however, larger than that on OO routes (180 JPY), which suggests that the security charge of 100 JPY was passed through to fares.
Flight frequency decreased by an average of 0.17 round trips per day on OO routes partly because of the rise in fuel prices. Flight frequency decreased less on NO routes (by an average of 0.07) and rather increased on NN routes (by an average of 0.01), which suggests that the reduction in landing fees played a role in increasing flight frequency.

While the number of passengers decreased on all types of routes, the decreases on NN or NO routes were larger than that on OO routes. The discussion in the previous two paragraphs implies that the revision in 2003–2005 increased both airfares and flight frequency. The fact regarding the number of passengers implies that the airfare-increasing effect exceeded the frequency-increasing effect and that the revision reduced the passenger surplus.

Here, OO routes are treated as the control group to examine the effects of the airport charge revision at national airports. However, it may be unsuitable to do so because Panel (B) of Table 1 shows that the route, airline, and airport characteristics differ across route types. In addition, these changes during the revision period reflect the effects of both per-passenger and per-flight charges as well as other demand and cost shocks in the market, especially a drastic increase in fuel prices after the outbreak of the Iraq War. Therefore, it is difficult from simply looking at the statistics of the changes to identify which part of the changes is caused by the introduction of per-passenger charges, by the reduction in per-flight charges, or by other shocks. Accordingly, the rest of this section presents the results of a reduced form analysis to estimate separately the effects of per-passenger and per-flight charges on airfares and flight frequency.

**Reduced form analysis** To examine whether the effects of the airport charge system revision appear in the data, a reduced form model is estimated. Airfares and flight frequency are regressed on per-passenger charges, per-flight charges, airline-specific dummy variables, and route-specific dummy variables. The data after July 2003 are used for the estimation. This is because from October 2002 and June 2003, which is immediately after the JAL–JAS merger in October 2002, the airfares of the merged airlines were constrained as a remedial action and because the airport charge system was not revised in the period before the merger (see Figure 1).

Table 3 shows the results. Columns (3-1) and (3-3) are the results for the log-log models. The first row shows that per-passenger charges increase airfares significantly and decrease flight frequency (albeit insignificantly with p-value of 0.21). Column (3-2) corresponds to the estimation of the level-level model of airfares, which is used to estimate the pass-through rates. The coefficient of per-passenger charges is significant and implies that the pass-through rate is 74.6 percent. The null hypothesis of complete pass-through (100 percent) is not rejected because of the large standard error of the coefficient, which is plausibly due to the small variation in per-passenger charges in

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7For further details of the remedies, see Arai (2004) and Doi and Ohashi (2019).
the sample. Per-flight charges have insignificant effects on airfares. They, however, significantly
decrease flight frequency.

In the subsequent sections, the effects of airport charges are investigated by simulation analyses
using an estimated structural model. By doing so, the mechanisms behind the above results of the
reduced form estimation are expected to be revealed. The structural model also makes it possible
to estimate the passenger surplus and analyze the incidence of airport charges.

3 Model

This section describes the structural model used to explain the Japanese air travel market. Sub-
section 3.1 introduces a supply model in which both airfares and flight frequency are treated as
endogenous variables. Subsection 3.2 introduces a discrete choice model of demand for air trans-
port services on each route. Subsection 3.3 describes the procedures used to estimate the structural
model.

3.1 Supply

This study uses a supply model of airlines in which, on each route, single-product firms simultane-
ously decide their airfares and flight frequency to maximize their own profits. Previous studies that
estimate route-level structural models of the airline market usually assume that airlines only choose
airfares with exogenous flight frequency. This study uses an extended model that endogenizes flight
frequency as well as airfares, as in Doi and Ohashi (2019). In this model, airlines are assumed to
make decisions independently across routes, as in previous studies estimating structural models of
the airline industry (e.g., Richard, 2003; Peters, 2006; Berry and Jia, 2010). This assumption is
permissible for an approximation of the Japanese market. First, because transit passengers account
for a small proportion of the total number of passengers in Japan (4.7 percent in 2003 according to
the Travel Survey for Domestic Air Passengers), the airfares and flight frequency on a route hardly
affect demand on other routes through changes in the number of transit passengers. Second, the
sets of aircraft types used for two directions on a route are identical on most routes, implying
that aircraft utilization is primarily point-to-point. The small proportion of transit passengers

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8For example, of the 260 routes in October 2003, sets of aircraft differed according to directions on only nine
routes. All nine routes were related to airports on isolated islands, routes excluded from the sample used for the
estimation.

9In addition, the facts below imply that individual aircraft utilization and overall fleet utilization are not very
close to capacity and that increasing frequency on a route would not require a reduction in frequency elsewhere. The
number of aircraft held by large airlines in Japan are almost constant during the sample period. Nevertheless, there
are discrepancies between the number of routes with an increase and a decrease in flight frequency: the number of
routes on which flight frequency increased (decreased) compared with the previous year is 23 (16), 24 (18), 57 (29),
42 (29), 28 (32), and 27 (28) for 2000–2005, respectively.
also supports the assumption that an airline acts as a single-product firm providing a direct flight on a route rather than a multi-product firm providing different connecting flights to a destination.

The maximization problem of airline $j$ on route $r$ at time $t$ is thus assumed to be as follows:\footnote{This model treats flight frequency (the number of round trips per day) as a continuous variable. This is because the flight frequency variable in the sample takes the decimal values as well as integers. Flight frequency occasionally increases on only a few days of week (e.g., on Mondays, Wednesdays, Fridays, and Sundays on the Fukuoka–Aomori route in October 2003). In some cases, it increases for a limited number of the days in a month (e.g., 1–3, 6–10, 14–17, 20–24, and 27–31 in October 2003 on the Okadama–Hakodate route).} \vspace{-20pt}

$$\max_{p_{jrt}, f_{jrt}} \pi_{jrt} = (p_{jrt} - MC_{jrt}^Q - AFC_{jrt}^Q)q_{jrt}(p_{rt}, f_{rt}) - (MC_{jrt}^F + AFC_{jrt}^F)f_{jrt},$$ (1) \vspace{-20pt}

where $\pi_{jrt}$ denotes the profits of airline $j$ on route $r$ at time $t$, $p_{jrt}$ is airfares, $f_{jrt}$ is flight frequency, $q_{jrt}(\cdot)$ is the passenger demand function specified in the following subsection, $p_{rt}$ and $f_{rt}$ are the respective vectors of the airfares and flight frequencies of all the airlines that operate on route $r$ at time $t$, $MC_{jrt}^Q$ is the marginal cost with respect to the number of passengers, and $MC_{jrt}^F$ is the marginal cost with respect to flight frequency. Airport charges are represented by $AFC_{jrt}^Q$, the sum of per-passenger charges, including the security charge and PSFCs, and $AFC_{jrt}^F$, the sum of per-flight charges, consisting of landing fees and facility usage fees for aids to navigation.

As a first step to understanding the effects of airport charges on market outcomes, this study investigates the “short-term” effects on airfares and flight frequency. Aircraft characteristics such as aircraft size are treated as exogenous because the fleet of an airline rarely changes in the short term; a purchased aircraft is often used for more than 30 years, and an aircraft lease is also contracted for the long term. It can be confirmed that, in the sample of this study, a change in flight frequency is not accompanied by a change in aircraft size. In the dataset, there are 201 airline-route pairs on which flight frequency increased compared with the previous period by at least one round-trip per day. For these airline-route pairs, aircraft size, measured as the number of seats per flight, was 232.3 on average (with a standard deviation of 127.6), which was not significantly different from the average in the previous period, 240.6 (131.8). Similarly, for the 159 observations on which flight frequency decreased compared with the previous period, the average aircraft size was 218.0 (127.7), not significantly different from the average in the previous period, 211.5 (121.2). These insignificant changes in aircraft size before and after the changes in flight frequency suggest that the choice of aircraft is a longer-term decision than the choice of flight frequency, which is adjusted in accordance with the realized demand and supply shocks given aircraft sizes.

The supply model of this study assumes that an airline maximizes its profits as in previous studies estimating structural models of the airline industry (e.g., Richard, 2003; Berry and Jia, 2010). By using the same dataset of domestic routes in Japan, Doi and Ohashi (2019) conduct the statistical test proposed by Rivers and Vuong (2002) and show that this assumption is supported...
against another assumption that airlines maximize their joint profits.\footnote{The assumption of an airline maximizing its own profit is also supported against the alternatives that airlines colluded only during a part of the sample period, for example, the period after the JAL-JAS merger in 2002.}

The first-order conditions of maximization problem (1) are as follows:

$$q_{jrt}(·) + \left(p_{jrt} - MC_{jrt}^Q - AFC_{jrt}^Q \right) \frac{∂q_{jrt}(·)}{∂p_{jrt}} = 0,$$

(2)

$$\left(p_{jrt} - MC_{jrt}^Q - AFC_{jrt}^Q \right) \frac{∂q_{jrt}(·)}{∂f_{jrt}} - MC_{jrt}^F - AFC_{jrt}^F = 0.$$

(3)

Equations (2) and (3) are the first-order conditions with respect to airfares and flight frequency, respectively. In this supply model, airlines decide their frequency to equate the marginal revenues and marginal costs of frequency. In other words, this model abstracts the capacity aspect of frequency and focuses on its service quality aspect. Because the mean of load factors is 0.59 (standard deviation of 0.13 and 99th percentile of 0.91) in the dataset, it might be harmless to abstract the capacity constraint (i.e., the load factor should be no more than one) from models describing airlines’ month-by-month decisions.\footnote{In the literature, theoretical studies with endogenous flight frequency usually assume for analytical tractability that aircraft size is adjusted to always achieve a load factor of one. However, in reality, the load factor is often less than one. One study develops a theoretical model with a stochastic framework endogenizing fares, flight frequency, aircraft sizes, and load factors (Czerny et al., 2016). In this model, the load factors become less than one.}

From the implicit function theorem, the effects of airport charges on airfares and flight frequency can be derived analytically as follows:

$$\left( \frac{∂p_{jrt}}{∂AFC_{jrt}^Q} \frac{∂p_{jrt}}{∂AFC_{jrt}^F} \frac{∂f_{jrt}}{∂AFC_{jrt}^Q} \frac{∂f_{jrt}}{∂AFC_{jrt}^F} \right) = - \left( \frac{∂G_{jrt}}{∂AFC_{jrt}^Q} \frac{∂G_{jrt}}{∂AFC_{jrt}^F} \frac{∂H_{jrt}}{∂AFC_{jrt}^Q} \frac{∂H_{jrt}}{∂AFC_{jrt}^F} \right)^{-1} \left( \frac{∂G_{jrt}}{∂AFC_{jrt}^Q} \frac{∂G_{jrt}}{∂AFC_{jrt}^F} \right),$$

(4)

where $G_{jrt}$ and $H_{jrt}$ are the vectors of $\bar{G}_{jrt} = q_{jrt}(·) + \left(p_{jrt} - MC_{jrt}^Q - AFC_{jrt}^Q \right) \frac{∂q_{jrt}(·)}{∂p_{jrt}}$ and $H_{jrt} = \left(p_{jrt} - MC_{jrt}^Q - AFC_{jrt}^Q \right) \frac{∂q_{jrt}(·)}{∂f_{jrt}} - MC_{jrt}^F - AFC_{jrt}^F$, respectively, of all the airlines that operate on route $r$ at time $t$. Equation (4) shows that the effects of airport charges depend on the first and second derivatives of the demand function.

The first-order conditions suggest the channels through which airport charges affect airfares and flight frequency. It is obvious that as the per-passenger charge $AFC_{jrt}^Q$ works in the same manner as the marginal cost $MC_{jrt}^Q$, an increase in $AFC_{jrt}^Q$ is likely to increase airfares. The proportion of a change in $AFC_{jrt}^Q$ passed through on airfares is an empirical issue. The effect of $AFC_{jrt}^Q$ on flight frequency depends on the pass-through rate and curvature of the demand system. When the pass-through rate is less than 100 percent, an increase in $AFC_{jrt}^Q$ decreases the marginal revenue of flight frequency, the first term of (3). When the pass-through rate is more than 100 percent, a rise in $AFC_{jrt}^Q$ increases the marginal revenue of flight frequency. Marginal revenue may also be affected by a change in demand sensitivity to flight frequency, $\frac{∂q_{jrt}(·)}{∂f_{jrt}}$, following a change in airfares.
The second-order cross-derivative, \( \frac{\partial^2 q_{jrt}}{\partial p_{jrt} \partial f_{jrt}} \), is relevant to this effect.

We next turn to the effects of \( AFC^F_{jrt} \). From (3), it is obvious that since \( AFC^F_{jrt} \) plays the same role as the marginal cost with respect to flight frequency, \( MC^F_{jrt} \), an increase in \( AFC^F_{jrt} \) decreases flight frequency. Although \( AFC^F_{jrt} \) does not appear directly in the first-order condition with respect to airfares (2), it may affect airfares through the following two channels. First, a decrease in flight frequency negatively affects the number of passengers \( q_{jrt} \), which leads to an airfare decrease. Second, it may change demand sensitivity to airfares, \( \frac{\partial^2 q_{jrt}}{\partial f_{jrt} \partial p_{jrt}} \). The second-order cross-derivative, \( \frac{\partial^2 q_{jrt}}{\partial f_{jrt} \partial p_{jrt}} \), is relevant to this effect.

3.2 Demand

This subsection describes a discrete choice model of demand for air travel services on Japanese domestic routes. Each individual decides whether to travel by air on a route and, if travelling by air, the airline to use. The set of alternatives consists of operating airlines on the route and the outside option, i.e., not travelling by air. Individual \( i \) is assumed to maximize the following indirect utility on route \( r \) at time \( t \) by choosing airline \( j \) or the outside option (\( j = 0 \)):

\[
\begin{equation}
\begin{split}
u_{ijrt} &= \alpha p_{jrt} + \beta f_{jrt} + \mathbf{x}_{jrt}' \gamma + \xi_{jrt} + \nu_{jrt} + (1 - \sigma_r)\epsilon_{ijrt},
\end{split}
\end{equation}
\]

where \( p_{jrt} \) represents airfares, \( f_{jrt} \) represents flight frequency, and \( \mathbf{x}_{jrt} \) is the vector of the other control variables, including the route distance, its squared and cubed terms, the dummy variable taking one if one of the endpoint airports of route \( r \) is Haneda airport in Tokyo (the most utilized airport in Japan), a variable representing aircraft size (the number of seats per flight), and airline-specific and month-specific dummy variables. The utility function contains \( \xi_{jrt} \), the unobserved (by an econometrician) quality of airline \( j \) (e.g., passengers’ evaluation of the safety level) with \( E(\xi_{jrt}) = 0 \). Mean utility from the outside option is normalized to zero, as is typical in the literature.

The last two terms of (5) represent the nest structure. I place airlines in one nest and the outside option in another nest. I assume that \( \epsilon_{ijrt} \) independently follows the Type I Extreme Value distribution and that \( \nu_{jrt} \) is distributed such that \( \nu_{jrt} + (1 - \sigma_r)\epsilon_{ijrt} \) also follows the Type I Extreme Value distribution.\(^{13}\) Cardell (1997) shows that such a distribution of \( \nu_{jrt} \) exists and is unique for each value of \( \sigma_r \in [0,1] \). The parameter \( \sigma_r \) is allowed to take a different value for long distance routes, namely \( \sigma_r = \sigma + longdist_{r} \sigma_{long} \), where \( longdist_{r} \) is a dummy variable that takes one if the

\(^{13}\)I tried random-coefficient discrete choice models by using the estimation technique proposed by Dubé et al. (2012). However, the estimation results seem unsuitable for the simulation analyses because some of the important parameters (e.g., the coefficient of airfares) have large standard errors as well as unexpected signs or values of the estimates. Therefore, this study adopts the nested logit-type model as in Doi and Ohashi (2019), who show that such a model predicts the data well.
distance of route $r$ is above 1,000 kilometers. The parameters $\sigma$ and $\sigma_{long}$ measure the correlation in unobserved individual-specific utility between airlines. When $\sigma_r$ is zero, the model is a standard logit model. As $\sigma_r$ approaches one, the substitutability among airlines becomes high.

The higher flight frequency, the higher is the possibility that passengers can travel on flights with departure and arrival times that suit their schedules (Douglas and Miller, 1974); furthermore, changes to flight reservations are easier. Hence, as flight frequency increases, a passenger’s utility is likely to increase. Therefore, it is expected that $\beta \rho > 0$. However, the utility rise from an increase in flight frequency is expected to gradually diminish (cf. Brueckner, 2004), namely $\rho < 1$ when $\beta \rho > 0$. Subsequently, both $\beta$ and $\rho$ are estimated.

An increase in flight frequency may also have a negative effect on passengers’ utility because it may make runways more congested and increase takeoff and landing delays. The coefficient and exponent of flight frequency represent the net effect of this negative effect and the positive effect discussed in the previous paragraph. In Japan’s airline market in the 2000s, however, takeoff and landing delays were negligible. FlightStats, a data service company focused on commercial aviation, reported that Japanese airlines and airports showed good on-time arrival performance, measured as the ratio of flights arriving within 15 minutes of their scheduled time (FlightStats, 2010). The two major airlines in Japan, Japan Airlines and All Nippon Airways, achieved the highest and second highest on-time performance (91.0 percent and 90.4 percent, respectively) of the world’s major airlines. The most utilized airport in Japan, Haneda Airport, also achieved the highest on-time performance (90.8 percent) of the world’s busiest airports.

The passenger demand function for airline $j$ on route $r$ at time $t$ is as follows:

$$q_{jrt}(p_{rt}, f_{rt}) = M_{rt} \frac{\exp \left( \frac{\alpha p_{jrt} + \beta f_{jrt}^0 + \alpha'_{jrt} \gamma + \xi_{jrt}}{1 - \sigma_r} \right)}{V_{rt}^{\sigma_r} \left( 1 + V_{rt}^{1 - \sigma_r} \right)}, \quad (6)$$

where $M_{rt}$ is the potential market size. The fraction multiplied by $M_{rt}$ represents the probability of a passenger selecting airline $j$, where $V_{rt} \equiv \sum_{k \in J_{rt}} \exp \left( \frac{\alpha p_{krt} + \beta f_{krt}^0 + \alpha'_{krt} \gamma + \xi_{krt}}{1 - \sigma_r} \right)$. Recall that the effects of airport charges are related to the second-order derivatives regarding flight frequency, $\left( \frac{\partial^2 q_{jrt}}{\partial f_{jrt}^2} \right)$ and $\left( \frac{\partial^2 q_{jrt}}{\partial p_{jrt} \partial f_{jrt}} \right)$, as shown in (4). These derivatives heavily depend on the exponent of it, $\rho$, which is a parameter to be estimated.

### 3.3 Estimation

Following Berry (1994), we derive a regression model for the nested logit model previously described:

$$\ln(s_{jrt}) - \ln(s_{0rt}) = \alpha p_{jrt} + \beta f_{jrt}^0 + \alpha'_{jrt} \gamma + \sigma_r \ln(\bar{s}_{jrt}) + \xi_{jrt},$$
where \( s_{jrt} \) denotes the market share of airline \( j \), \( s_{0rt} \) represents the market share of the outside option, and \( s_{jrt} \) denotes the share of the passengers choosing airline \( j \) among all individuals who choose to travel by air. The market share of airline \( j \) on route \( r \) is defined as the ratio of the number of passengers of \( j \) to the potential market size, \( M_{rt} \), which is assumed to be the geometric mean of the populations of the prefectures in which the endpoint airports of route \( r \) are located, as in previous studies (e.g., Peters, 2006). I estimate the demand parameters by using a generalized method of moments (GMM) approach with the population moment condition of a product of \( \xi_{jrt} \) and the exogenous variables.

The endogeneity problem for airfares, \( p_{jrt} \), flight frequency, \( f_{jrt} \), and the share within airlines, \( s_{jrt} \), should be addressed. In discrete choice demand models such as equation (5), the structural error term, \( \xi_{jrt} \), denotes the utility derived from the unobserved (by an econometrician) quality of the products. In this study’s context, \( \xi_{jrt} \) includes passengers’ evaluation of airline safety and security, in-flight offerings (such as meals and in-flight environment), and so on. If \( \xi_{jrt} \) is correctly perceived by passengers and airlines, then this unobserved quality is likely to be correlated with airfares and flight frequency: better-quality products may induce a higher willingness to pay, and sellers may be able to charge higher prices because of the higher marginal costs or oligopolistic market power and may profitably increase flight frequency. This also leads to an obvious correlation of the share within airlines \( s_{jrt} \) and \( \xi_{jrt} \).

To address this endogeneity problem, I use cost-related variables and airport charges as instrumental variables, which are expected to be correlated with airfares and flight frequency but uncorrelated with the unobserved quality of airline services. One set of instruments includes two variables of aircraft characteristics: operating weight and the engine compression ratio. These variables are expected to be correlated with marginal costs with respect to passengers (\( MC^Q_{jrt} \)) and/or flights (\( MC^F_{jrt} \)). A heavier airplane is expected to result in higher marginal costs with respect to flights (\( MC^F_{jrt} \)) because a flight consumes more fuel to fly. Because the compression ratio of an engine is positively related to fuel efficiency, it may have a negative correlation with both \( MC^Q_{jrt} \) and \( MC^F_{jrt} \).

Another instrument is an index of fuel prices: a three-month lag in the three-month moving average of the kerosene jet fuel spot price. This standard was used by Japanese airlines to determine their surcharges for international flights at that time. Each month’s fuel price is obtained from the U.S. Department of Energy website and converted into JPY by using that month’s exchange rate. The fuel price is expected to be positively correlated with marginal costs. The interaction terms between the fuel price and the aircraft characteristics are added into the set of instrumental variables because the impact of fuel price changes is likely to depend on the aircraft used. In addition, the

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14 The demand estimation results are robust to the definition of potential market size. For example, when the market size is multiplied by 0.6, 2, or 5, we obtain similar results.
interaction between the fuel price and the dummy variable that takes one if the route distance is above 1,000 kilometers is added because the increase in marginal costs caused by a rise in the fuel price is likely to be larger on longer routes. These cost-related variables are expected to correlate with airfares, flight frequency, and the share within airlines because they relate to marginal costs.

Airport charge variables are also added into the set of instruments. The rate of per-passenger charges $AFC_{jrt}^Q$ is expected to be positively correlated with airfares. As the rate of per-flight charges $AFC_{jrt}^F$ appears in (3), the first-order condition with respect to flight frequency $AFC_{jrt}^F$ is expected to be negatively correlated with flight frequency. To capture the possible non-linear impacts of $AFC_{jrt}^F$ on airfares and flight frequency, its squared term is also used as an instrument.

In the simulation analysis presented in the next section, the marginal cost values with respect to passengers ($MC_{jrt}^Q$) and flight frequency ($MC_{jrt}^F$) are required. Because data on marginal costs by route are not publicly available, their values are estimated by using the first-order conditions of the airlines’ maximization problem as in, for example, Peters (2006) and Berry and Jia (2010). Specifically, I solve $MC_{jrt}^Q$ and $MC_{jrt}^F$ by using the system of equations (2) and (3) into which the demand estimates and data on airfares and flight frequency are substituted.

4 Estimation Results

This section presents the estimation results of the structural model. Table 4 presents the estimation results of the demand model. In column (4-1), $p_{jrt}$, $f_{jrt}$, and $s_{jrt}$ are treated as exogenous variables. In column (4-2), these variables are treated as endogenous variables, and the parameters are estimated by using the GMM with the instrumental variables introduced in Subsection 3.3. The first-stage F-statistic for the explanatory power of the instruments conditional on the included exogenous variables is 86.7 on average, indicating that the instruments are not weak. The chi-squared statistic tests the validity of the instruments conditional on the existence of a set of valid instruments that just identify the model. The value of the chi-squared statistic is insufficiently large to reject the orthogonality condition at the 5 percent level. The estimates in column (4-2) are thus used in the subsequent analyses.

The coefficient of airfares is negative and significantly different from zero. The price coefficient moves from -0.002 in column (4-1) to -0.084 in column (4-2). This result is consistent with the successful elimination of the expected upward bias owing to the positive correlation between the

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15 Fuel costs can be estimated by route from the data on aircraft characteristics. Hence, if route-level data on labor costs and costs for aircraft maintenance can be obtained, the values of $MC_{jrt}^F$ can be directly calculated. Unfortunately, although airlines may have those data, they are not publicly available.

16 To estimate the exponent of flight frequency, $\rho$, the squared term of $f_{jrt}$ is added into the set of exogenous variables in the GMM estimation in column (4-1).

17 The finite size of the test in small samples is known to far exceed the normal size, that is the test too frequently rejects (Hayashi, 2000).
price measure and error term. The average of own-price elasticities, calculated by using the estimates in column (4-2), is -2.0. This result is similar to those reported by previous studies that have estimated air travel demand by using a discrete choice model. For example, the average of own-price elasticities is reported to range from -1.5 to -2.8 by Armanitier and Richard (2008), to approximately -2.0 by Berry and Jia (2010), and range from -3.2 to -4.0 by Peters (2006).

Both the coefficient and the exponent of flight frequency are significantly negative, suggesting a positive marginal utility from flight frequency. Because the exponent is less than one, marginal utility is decreasing. The average flight frequency elasticity is 0.96. Adding one daily departure to all airlines on all routes increases aggregate demand by 21 percent. From a similar analysis, Berry and Jia (2010) report that aggregate demand in the U.S. market has grown by 6–16 percent. The estimated coefficients and exponents of flight frequency also suggest the successful elimination of the endogeneity of involving the positive correlation of flight frequency with the error term; the average of the frequency elasticity of demand drops from 1.11 in column (4-1) to 0.96 in column (4-2).

The nest parameter \( \sigma_r \) is estimated to be 0.33 for long-distance routes. As \( \sigma_r \) approaches one, substitutability among airlines becomes high. The nest parameter is significantly less than one at the 1 percent level, suggesting that other transport modes are relevant substitutes for air transport in Japan, a small country that has a developed network of highways and high-speed railways. The transportation mode share for air passengers in Japan was 5.9 percent (based on passenger-kilo) in 2005, suggesting that airlines compete with other transport modes on many routes, especially short-distance ones. For example, the nest parameter for the U.S. market was estimated to be 0.41 by Peters (2006) and 0.42 by Wei and Hansen (2005).

Based on the estimates, the first- and second-order derivatives of the demand function with respect to airfares and flight frequency can be calculated. The first-order derivatives have the expected signs, namely negative for \( \frac{\partial q_{jrt}}{\partial p_{jrt}} \) and positive for \( \frac{\partial q_{jrt}}{\partial f_{jrt}} \). The second-order derivative with respect to flight frequency, \( \frac{\partial^2 q_{jrt}}{\partial f_{jrt}^2} \), is negative because the estimated value of its exponent, \( \rho \), is sufficiently less than one. The second-order cross-derivative, \( \frac{\partial^2 q_{jrt}}{\partial p_{jrt} \partial f_{jrt}} \), is negative for the entire sample, meaning that an increase in flight frequency enhances sensitivity to airfares, while a fall in airfares increases sensitivity to flight frequency.

For the estimated structural model, the second-order conditions are satisfied for 99 percent of the observations. By using a similar model estimated by using the same data, Doi and Ohashi (2019) confirm the validity of the marginal cost estimates obtained from the first-order conditions by comparing them with the marginal cost estimates using the method of Brander and Zhang (1990). Doi and Ohashi (2019) also show that the structural model predicts the data well with high correlation coefficients of the predicted and actual values.
5 Effects of Per-passenger and Per-flight Charges

This section describes the economic impacts of the per-passenger and per-flight charges estimated from the simulation analyses based on the structural model. Subsection 5.1 details the simulation analyses. Subsection 5.2 discusses the estimated effects on airfares and flight frequency. Subsection 5.3 investigates the incidence of airport charges and which types of charges are preferred by airlines, passengers, and social planners. Subsection 5.4 discusses the implications of assumptions of the structural model.

5.1 Simulation

The estimated structural model is used to quantify the economic impacts of the revision of the airport charge system of national airports in 2004–2005. To estimate the impacts, three counterfactual scenarios are simulated for October 2005. The first scenario assumes that the security charge was not introduced. In this scenario, the values of $AFC^{Q}_{jrt}$ are replaced with zero and the airfares and flight frequency in the equilibrium are calculated by numerically solving the simultaneous equations of the first-order conditions of the airlines’ maximization problem. Initial values are set to be the actual values of the data. Comparing the results of this simulation with the actual data reveals the effects of the introduction of the security charge. The second scenario assumes that the landing fees were not reduced in October 2005. In this simulation, the values of $AFC^{F}_{jrt}$ are replaced with the corresponding values and the airfares and flight frequency in the equilibrium are calculated. By comparing the results of this simulation with the data, the effects of the reduction in landing fees were estimated. The third scenario assumes that neither the introduction of the security charge nor the reduction in landing fees occurred. The difference between this scenario and the actual data can be interpreted as the net effect of the revision in 2004–2005. Because the revision was for national airports, the charges of the airports managed by local governments or private firms are fixed to those in reality in these simulations.

The numerical solution of the simultaneous equations of the first-order conditions is plausibly an equilibrium of the model for most routes. The second-order conditions for the profit maximization problem are satisfied for the 96 percent of the sample used for the simulations. The following discussions focus on the observation satisfying the second-order conditions. In addition, airfares, flight frequency, and the number of passengers take positive values at the solutions for the entire sample.

To address a concern about multiple equilibria, I tried to solve the equations numerically with initial values shifted by 5 percent from the actual values of the variables. The solutions do not change for this 96 percent of the sample. This result implies that other equilibria are unlikely to exist near the values in reality. Therefore, this study treats the equilibria obtained from numerically
solving by using the initial values of the actual values as the equilibria of the counterfactuals in which market conditions change a little (i.e., marginal costs change by only a few percent).

Throughout the paper, a route is defined non-directionally because of the limitation of data availability explained in Section 2.2. Hence, the structural model should be interpreted as one that predicts the average of the airfares of both directions (e.g., travel from Haneda to Fukuoka and that from Fukuoka to Haneda) on a route (e.g., Haneda–Fukuoka). The variables of airport charges are defined non-directionally as the average of the airport charges of both directions. In reality, a change in airport charges at an airport (e.g., Haneda) may affect only one of the directions (e.g., travel from Fukuoka to Haneda), as airport charges are usually levied when an aircraft lands at (not takes off from) an airport. The effects of airport charges on airfares, which are discussed in the following, should thus be interpreted as the average of the effects on airfares of the two directions on a route.

5.2 Effects on Airfares and Flight Frequency

This subsection discusses the effects on airfares and flight frequency. First, the effects averaged across routes are discussed. Then, differences across routes are focused on. Lastly, how the results change if flight frequency is treated as exogenous is discussed.

Average effects Table 5 shows the estimated effects of the revision. Because the charge system was revised for national government-managed airports (and not for airports managed by local governments or private firms), this table reports the effects calculated for the 153 routes involving national airports. The impact of the revision on the values of \( AFC^Q_{jrt} \) and \( AFC^F_{jrt} \) was twice as large on a route between two national airports (an NN route) as on a route with only one national airport as an endpoint (an NO route) since \( AFC^Q_{jrt} \) and \( AFC^F_{jrt} \) are defined as the average of the airport charges of both directions on a route. For the 86 NN routes, the introduction of the security charge increased \( AFC^Q_{jrt} \) by 100 JPY and the reduction in landing fees decreased \( AFC^F_{jrt} \) by 7.7 percent on average. The effects of the revision are estimated by airline and route, and Table 5 shows the averages across them.

As Table 5 shows, the introduction of per-passenger charges significantly increases airfares, by 72.5 JPY on average.\(^\text{18}\) The pass-through rate, which is defined as the ratio of the price change to the change in \( AFC^Q_{jrt} \), is 97.5 percent on average. Pass-through rates depend on both demand and supply structures (e.g., Weyl and Fabinger, 2013). For example, in the case of linear demand with a homogeneous product, the pass-through rate is 100 percent in the competitive case and 50 percent in the monopoly case. Even in the monopoly case, pass-through rates differ according to

\(^\text{18}\)On NN routes, a 100-JPY increase in \( AFC^Q_{jrt} \) raises airfares by 97.2 JPY. On NO routes, a 50-JPY increase in \( AFC^Q_{jrt} \) results in a 48.8-JPY rise in airfares.
the shape of the demand curve. For example, they are above 100 percent with constant elasticity and exactly 100 percent with level-log-type demand (Bulow and Pfeiferer, 1983). In addition, in price competition models of a differentiated product market, pass-through rates can be above 100 percent (Anderson et al., 2001).

The reduction in landing fees, one of the main per-flight charges, has both statistically and economically insignificant effects on airfares. This is because per-flight charges do not directly appear in the first-order condition with respect to airfares and have only indirect effects on airfares through the change in flight frequency, as shown in (2). In addition, the fare-increasing and fare-decreasing effects of per-flight charges cancel out. On the one hand, the increase in flight frequency caused by a reduction in per-flight charges may raise airfares because it shifts the demand curve upward. On the other hand, the increase in flight frequency may reduce airfares through the increase in demand sensitivity to airfares because the second-order cross-derivative of the demand function, \( \frac{\partial^2 q_{jrt} \left( \frac{\partial q_{jrt}}{\partial p_{jrt}} \right)}{\partial p_{jrt} \partial f_{jrt}} \), is negative. In the present analysis, the former overwhelms the latter, increasing airfares (albeit insignificantly).

We now turn to the effects on flight frequency. The introduction of the security charge decreases flight frequency on average by 0.04 return flights per day (1.6 percent) for two reasons. First, as the pass-through rate is below 100 percent, an increase in per-passenger charges decreases the marginal revenue of flight frequency, the first term of (3). Second, since \( \frac{\partial^2 q_{jrt} \left( \frac{\partial q_{jrt}}{\partial p_{jrt}} \right)}{\partial p_{jrt} \partial f_{jrt}} < 0 \), the increase in airfares caused by a rise in per-passenger charges decreases demand sensitivity to flight frequency, which then decreases the marginal revenue of flight frequency. The monetary values of the decreases in flight frequency can be derived as the decreases in \( \beta f_{jrt} \) divided by the coefficient of airfares (\( \alpha \)). They are 186.5 JPY on average and more than double the increase of 72.5 JPY in airfares. These estimates suggest the importance of taking into account changes in flight frequency as well as those in airfares when we consider the effects of airport charges.

The reduction in landing fees increases flight frequency. The reduction of 7.7 percent increases flight frequency by 0.04 return flights per day (1.0 percent) on average. The average of the monetary values of the increases is 106.5 JPY.

**Differences by route** So far, the averages of the effects have been discussed. However, as suggested by Table 5, these are widely distributed across routes. Figure 2 is a histogram of the estimates of the pass-through rates of per-passenger charges. While many observations are located around the average of 97.5 percent, the estimates range from 88 percent to 112 percent.

To obtain insights into the differences in the pass-through rates across routes, the pass-through rate estimates are regressed on the route and airline characteristics. The first two columns of Table 6 show the results. Column (6-1) corresponds to the estimation with the sample of all routes. The coefficient of the number of airlines operating on a route is significantly positive, implying
that the severer competition, the higher are the pass-through rates. This finding is consistent with those of previous studies investigating pass-through rates theoretically (H"ackner and Herzing, 2016), empirically (Kim and Cotterill, 2008), and experimentally (Konrad et al., 2014). Column (6-2) presents the results for the estimation using only the sample of monopoly routes, which are basically similar to those in column (6-1).

The other coefficients also mostly show the expected signs. The coefficient of market share is significantly negative. The second derivative of log-demand is known as a key factor determining pass-through rates (cf. Weyl and Fabinger, 2013). In the model estimated in this study, the higher market share, the higher is the second derivative (i.e., $\frac{\partial^2 \ln(q_{jrt})}{\partial p_{jrt}^2}$). The high value of the derivative means that a small change in airfares can lead to an adjustment in the first-order conditions, thus accompanying a lower pass-through rate. Route distance has a positive correlation (correlation coefficient of 0.28) with market share because demand for air travel relative to other transport modes rises on longer routes. This relationship between distance and market share might make the coefficient of distance negative by picking up some of the effects of market share in the simple linear regression model.

An interesting result is the significantly positive coefficient of flight frequency, which means that the pass-through rates tend to be higher on routes with higher frequency. This is plausibly because flight frequency relates to the degree of the effects that per-passenger charges decrease flight frequency. To understand this, recall that per-passenger charges decrease flight frequency as discussed above. A decrease in flight frequency weakens demand and places downward pressure on airfares, which reduces the pass-through rate. Hence, it is expected that the larger the effects decreasing flight frequency, the lower are the pass-through rates.

The frequency-decreasing effects become large on routes with low flight frequency. Figure 3 plots the change rates of flight frequency by the introduction of per-passenger charges on the vertical axis with flight frequency on the horizontal axis. The figure indicates a positive correlation (correlation coefficient is 0.49) and shows that when flight frequency increases, the change rates approach zero. The reason why the frequency-decreasing effects relate to flight frequency is as follows. Flight frequency is determined to equate its marginal revenues, the first term of equation (3), and marginal costs, the second and third terms of the equation. Per-passenger charges, as a first-order effect, decrease flight frequency by decreasing marginal revenues. As equation (3) suggests, for the same increase in per-passenger charges, the decrease in marginal revenues becomes small when the frequency sensitivity of demand ($\frac{\partial q_{jrt}}{\partial f_{jrt}}$) is small. On routes with high flight frequency, the sensitivity is small because of the decreasing marginal utility of flight frequency, which is estimated as the smaller exponent of frequency. Hence, on such routes, the decrease in marginal revenue by per-passenger charges is small and results in small effects on flight frequency.
Comparison with an exogenous frequency model  The rest of this subsection discusses how the pass-through rate estimates are biased if flight frequency is treated as exogenous. The pass-through rates estimated by using the structural model introduced in Section 3 are compared with those estimated by using a structural model modified to exclude flight frequency from the set of an airline’s strategy variables and treat it as exogenous. The results reveal that pass-through rates tend to be overestimated if flight frequency is treated as exogenous. The difference in the pass-through rate estimates of the two models is 1.6 percent on average and significantly different from zero (t-value is 8.0). The exogenous frequency model abstracts the frequency-decreasing effects of per-passenger charges, which places downward pressure on airfares, resulting in the overestimation of the pass-through rates.

Moreover, this overestimation tends to be serious on routes with low flight frequency. Columns (6-3) and (6-4) of Table 6 show the results for the regression of the differences in the pass-through rate estimates between the exogenous and endogenous frequency models. The coefficient of flight frequency is estimated to be negative, implying that when flight frequency is high, the degree of the overestimation becomes small. This is plausibly because the frequency-decreasing effect of per-passenger charges is small on routes with high flight frequency, and therefore so is the overestimation caused by ignoring this effect.

5.3 Effects on Welfare

This subsection discusses the effects of airport charges on welfare and consists of four parts. First, the revision in 2004-2005 is assessed. Then, the incidence of per-passenger charges and that of per-flight ones are compared. The argument on incidence is subdivided into three topics: the total values summed over all the routes, differences across routes, and how the results change when flight frequency is treated as exogenous.

Before presenting these arguments, the definitions of the surpluses that this study employs are clarified. It is reasonable to assume that the social surplus is the sum of the consumer surplus, producer surplus, and airport surplus. The consumer surplus on route $r$ can be represented as follows:

$$\text{CS}_{rt} = M_{rt} \frac{\ln(1 + V_{rt}^{1-\sigma})}{-\alpha},$$

where the definitions of the variables are the same as in Subsection 3.2. The producer surplus $PS_{rt}$ is defined as the sum of the profits $\pi_{jrt}$ of all the airlines on route $r$. Airport surplus $AS_{rt}$ is defined as follows:

$$AS_{rt} = \sum_j \left\{ AFC_{jrt}^Q q_{jrt} + AFC_{jrt}^F f_{jrt} - C_{rt}(q_{jrt}, f_{jrt}) \right\},$$

where $C_{rt}(q_{jrt}, f_{jrt})$ is a variable cost function of airports. Unfortunately, comprehensive cost data
for Japanese airports are not available. In this study, the variable costs are assumed to be zero because the additional costs generated by one extra passenger or one extra flight are likely to be very low relative to the fixed costs (e.g., for the construction of airport facilities).19

**Effects of the revision** First, the effects of the 2004–2005 revision, namely the net effects of the introduction of security charges and reduction in landing fees are discussed. Table 7 presents the simulation results about welfare. To take into account the fact that the simulations use the estimated demand parameters, a Monte Carlo method is adopted to calculate the standard errors of the averages. The simulations are conducted for 1,000 draws from the asymptotic normal distribution for the demand estimates.

Recall that as shown in Table 5, the 2004–2005 revision significantly increased airfares while having an insignificant net effect on flight frequency. The introduction of the security charge significantly increased airfares. The reduction in landing fees, however, had insignificant effects on airfares. The net effect on airfares was thus an increase of 71.7 JPY on average. The security charge decreased flight frequency significantly, while the landing fee reduction increased it significantly. As these effects cancel out, the net effect on flight frequency was insignificant.

Since the revision brought about an increase in airfares and an insignificant change in flight frequency, the consumer surplus decreased by 719.3 million JPY per month. The producer surplus also decreased by 129.5 million JPY, as the pass-through rate was estimated to be less than 100 percent. The net effect on the airport surplus was significantly positive, 255.5 million JPY, which suggests that the degree of the reduction in landing fees was small compared with that of the introduction of the security charge. The social surplus decreased by 593.3 million JPY. These results suggest that the revision decreased economic efficiency in exchange for raising the airport surplus.

The bottom of Table 7 reports the estimated changes in the airport surplus when we treat both airfares and flight frequency (and then the number of passengers) as exogenous variables. It shows that the effects of both the security charge and the landing fees are significantly overestimated. The increase in the airport surplus by the introduction of the security charge is overestimated by 38.6 percent. This is because, in the case of exogenous airfares and flight frequency, the estimate does not reflect the revenue-decreasing effects of the increase in airfares and the decrease in flight frequency, both of which then reduce the number of passengers because of the introduction of the security charge. The decrease in the airport surplus by the reduction in landing fees is overestimated

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19 The MLIT reports the operating costs of the airports managed by the national government. For the fiscal year of 2015, costs that are plausibly fixed (e.g., construction, depreciation, rent for land and buildings, and grants to local governments) accounted for 75 percent of the total operating costs of national airports. In addition, personnel costs and agency costs, some of which can be regarded as fixed costs, accounted for 5.2 percent and 18.3 percent of operating costs, respectively.
by 96.1 percent. In the case of exogenous airfares and flight frequency, the estimate does not reflect the revenue-increasing effects of the rises in flight frequency and the number of passengers due to the reduction in landing fees. These overestimated values are offset when calculating the net effect of the revision in 2004–2005. In this case, there is found to be an insignificant difference in the estimates of the net effect between the case of endogenous airfares and flight frequency and the case of exogenous ones.

**Incidence of airport charges: in total** The surplus estimates in Table 7 reveal the difference in the incidence of airport charges between the two types of charges. To clarify the difference, however, we cannot simply compare the quantities of the effects of the increase in per-passenger charges with the decrease in per-flight charges. Because the effect on the airport surplus of the increase in per-passenger charges (482.9 million JPY) is more than twice that of per-flight charges (218.4 million JPY), it is not surprising that the change in per-passenger charges affects the producer and consumer surpluses more than does the change in per-flight charges. To discuss the difference in incidences between the types of airport charges, the effects on the surplus are therefore divided by the effect of the airport surplus and standardized to the value per 1 JPY of the airport surplus change. Figure 4 visualizes the results.

The results imply that per-passenger charges are better than per-flight ones from the perspective of airlines’ profits. The introduction of per-passenger charges in 2004 increased the airport surplus by 482.9 million JPY, while it reduced the producer surplus by 467.5 million JPY. These figures imply that airlines bear a loss of 0.97 JPY to raise 1 JPY of the airport surplus with the use of per-passenger charges. The reduction in landing fees decreased the airport surplus by 218.4 million JPY and increased the producer surplus by 333.8 million JPY, implying that airlines bear a loss of 1.53 JPY to raise 1 JPY of the airport surplus with the use of per-flight charges. The difference of 0.56 JPY is statistically significant at the 1 percent level. One reason for this result is the differences in the effects on airfares: per-passenger charges are mostly passed through to airfares, while per-flight charges are not. This result is consistent with the fact that airlines have asked to raise the weight of per-passenger charges instead of that of per-flight charges (IATA, 2010).

From the viewpoint of the consumer surplus, the two types of charges result in similar impacts, the difference of which are statistically insignificant. The loss of the consumer surplus to raise 1 JPY of the airport surplus is 2.73 for per-passenger charges and 2.77 for per-flight charges.

These estimates suggest that per-passenger charges are superior to per-flight charges from the perspective of the social surplus. The reduction in the social surplus to raise 1 JPY of the airport surplus is 2.70 for per-passenger charges and 3.30 for per-flight charges. This result depends on the estimated demand parameters representing passengers’ evaluation of flight frequency. As discussed above, an increase in per-flight charges, which work similarly to marginal costs with respect to
flights, decreases flight frequency but does not affect airfares significantly. By contrast, an increase in per-passenger charges, which work similarly to marginal costs with respect to passengers, raises airfares. In other words, as pointed out in the theoretical study of Czerny and Zhang (2015), there is a trade-off between low airfares with low per-passenger charges and high frequency with low per-flight charges. If passengers do not value flight frequency, per-flight charges are expected to be better than per-passenger charges for raising airport revenue. In the market analyzed in this study, however, passengers value flight frequency sufficiently with the flight frequency elasticity of air travel demand estimated not to be small (0.96 on average). This makes the negative effects of per-flight charges relevant. It is also implied that the current trend toward the increased use of per-passenger-based airport charges requires no immediate regulatory corrections.

**Incidence of airport charges: by route**  The arguments so far focus on the total surplus over all domestic routes. However, which types of charges are desirable can depend on route characteristics. To compare per-flight charges with per-passenger ones, for each route, the loss of the surplus to raise 1 JPY of the airport surplus with per-flight charges is divided by that with per-passenger ones. If this value exceeds one, per-passenger charges are preferred to per-flight ones. Figure 5 plots the values of each route with flight frequency.

Panel (A) presents the results for airlines’ profits. For most routes, the values are more than one, implying that per-passenger charges are preferred by airlines. The panel also shows that the difference between the two types of charges tends to be larger on routes with higher flight frequency. This is plausibly because of the higher pass-through rates of per-passenger charges on such routes, as discussed in Subsection 5.2, which enables airlines to shift the more burden to passengers.

For the results for the passenger surplus in panel (B), the values are less than one on most routes. That is, passengers primarily prefer per-flight charges. However, as in the case of airlines’ profits, per-passenger charges tend to become preferable as flight frequency on the route increases. This is plausibly because the decreasing-frequency effects of per-passenger charges fall on routes with higher flight frequency, as discussed in Subsection 5.2.20 Although per-flight charges are preferred by passengers on most routes, the discussion in the previous part implies that per-passenger charges are no worse than per-flight ones from the perspective of the passenger surplus in total over all the routes. This is because per-passenger charges are preferred by passengers on routes with high frequency, which tend to have a large market size and account for a significant weight of the total passenger surplus.

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20For the effects of per-flight charges on flight frequency, the correlation of the size of the effect on a route with flight frequency is insignificant (correlation coefficient of 0.06).
Incidence of airport charges: comparison with an exogenous frequency model  The last part of this subsection discusses how the conclusions on the incidence of airport charges could change if flight frequency is treated as exogenous. Figure 6 shows the losses in the surplus to raise 1 JPY of the airport surplus calculated from the simulation results based on the model in which airfares may be changed by airlines but flight frequency is fixed at the actual level. As in the endogenous frequency cases, airlines prefer per-passenger charges to per-flight ones. When flight frequency is fixed, an increase in per-flight charges is perfectly born by airlines. Per-passenger charges can be passed through to passengers by increasing airfares.

From the viewpoints of the consumer and social surpluses, however, the results change. Per-flight charges are superior to per-passenger charges to raise airport revenue when flight frequency is fixed. A rise in per-passenger charges significantly increases airfares and decreases the consumer and social surpluses by 1.00 and 0.96 JPY, respectively to raise 1 JPY of the airport surplus. By contrast, per-flight charges do not change airfares because they affect airfares only through changes to flight frequency, which is fixed in this simulation. In other words, when flight frequency is fixed, per-flight charges only serve to transfer money from airlines to airports. Therefore, a change in per-flight charges does not affect the consumer surplus or social surplus and it decreases airline profits by the same amount as the increase in the airport surplus. In summary, treating flight frequency as exogenous results in a bias toward preferring per-flight charges from the viewpoints of the consumer and social surpluses. This result highlights the importance of endogenizing flight frequency to investigate the combination of per-passenger and per-flight charges.

5.4 Discussion on Model Assumptions

Thus far, the simulation analysis has been conducted by using the structural model introduced in Section 3. This subsection discusses the implications of the model’s assumptions. The issues include the timing of decision making, slot constraints at congested airports, and longer-term effects.

Timing of decision making  In the model, airfares and flight frequency are assumed to be determined simultaneously. The timing of decision making is relevant for the evaluation of airport charge structures, as pointed out by Czerny et al. (2017). In the sequential choice setting in which carriers first choose flight frequency and then decide airfares, flight frequency may be undersupplied because carriers have an incentive to soften price competition by reducing flight frequency (cf. Brueckner and Flores-Fillol, 2007; Czerny et al., 2017). In the setting with the simultaneous choice of airfares and flight frequency, this effect disappears. The negative effects of per-flight charges (decreases in flight frequency) may become larger in the sequential setting with the undersupply of flight frequency than in the simultaneous setting because of the estimated decreasing marginal
utility with respect to flight frequency. If a model with the sequential setting is used to conduct the simulation, the results may change toward preferring per-passenger charges to per-flight ones from the perspective of the consumer surplus.

This study uses a simultaneous setting model because the cycle for changes in the dataset differs little for airfares and flight frequency. In the data period, the number of airfare changes is 2.17 on average across routes (standard deviation of 1.58), while that of flight frequency is 2.20 (2.51). Here, incidents of change are counted when those changes are greater than 150 JPY (0.7 percent of the average airfare of 20,900 JPY) from the preceding period for airfares and greater than 0.5 flights per day (17.8 percent of the average of 2.8) for flight frequency. Therefore, contrary to our expectation that airfares should change more often than flight frequency, flight frequency changes no less often than airfares in the dataset.

Slot constraints The structural model assumes that airlines can freely choose their flight frequency as well as airfares. This is because airlines can change their flight frequencies even at Haneda Airport, which is the most congested airport in Japan and at which takeoff and landing slots are allocated to airlines, by reallocating their slots across routes. Here, the robustness of the assumption that airlines can freely choose their flight frequency is discussed.

The slot constraints are not explicitly included in the supply model presented in Subsection 3.1, as in previous studies estimating structural models of the airline market, which usually assume that routes are independent. This assumption may cause at least two problems. First, the marginal cost values derived from the first-order conditions may be biased. On the routes at Haneda Airport, the values of marginal costs with respect to flight frequency \( MC_{Fjrt} \) may include the shadow prices of slot constraints and be overestimated. This overestimation, if any, is not a serious problem for this study because airport charges per flight \( AFC_{Fjrt} \) are obtained from the data and \( MC_{Fjrt} \) itself is not the main objective of this study. Second, the simulated values of flight frequency may be biased. This may be a serious problem. If the slot constraints are binding in reality, changes in airport charges are likely to be accompanied by no change in flight frequency.

To ensure the robustness of the results to this possibility, I conducted a simulation analysis in which flight frequency is fixed at the actual level on the routes at Haneda Airport. As suggested by the argument in the last part of the previous subsection, the better type of airport charge from the viewpoints of the consumer and social surpluses depends on whether flight frequency is fixed, while airlines prefer per-passenger charges in both situations. When flight frequency is fixed, per-

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21The average cycle for changes is once every approximately 18.0 months for airfares and once every 17.8 months for flight frequency. The period before and after the JAL-JAS merger in October 2002 is omitted when the number of changes is counted because this unusual period witnessed a drastic change in market structure and some remedial measures constraining airfares.

22The results are available from the author upon request.
flight charges are better for passengers because these do not affect airfares and thus the consumer surplus (i.e., they are only a transfer from airlines to airports). By contrast, when flight frequency is adjusted by airlines, per-flight charges decrease flight frequency and thus the consumer surplus. In this case, per-passenger charges may be superior to per-flight charges. The reality is likely to be located between these two polar situations with frequency fixed and frequency freely adjusted because airlines often change their flight frequency, even at Haneda Airport, by reallocating their slots across routes.

**Longer-term effects** This study uses a static model and investigates the short-term effects of airport charges on airfares and flight frequency. Airport charges, however, impact investment and other decisions in the longer term. This part discusses possible impacts on decision making on the used aircraft and on entry into or exit from a route, which are treated as exogenous in this study.

Treating aircraft as exogenous may result in a bias toward preferring per-flight charges from the viewpoint of the consumer surplus. An increase in per-flight charges is expected to make airlines use larger aircraft to decrease flight frequency while maintaining the number of available seats. The shift to a larger aircraft raises the marginal costs of flights (e.g., fuel costs) and becomes itself a pressure to decrease flight frequency. This shift is therefore unfavorable for passengers. This negative effect of per-flight charges disappears by assuming exogenous aircraft.

Treating entry and exit as exogenous may also result in a bias toward supporting per-flight charges from the viewpoint of the consumer surplus. Recall that airlines tend to prefer per-passenger charges to per-flight ones. This implies that an airline is more likely to exit from a route when airport revenues are raised with per-flight charges than per-passenger ones. The exit would result in decreasing the consumer surplus. This negative effect of per-flight charges is excluded by treating exits as exogenous. In addition, an airline is more likely to enter a route when per-passenger charges replace per-flight ones, which would increase the consumer surplus. This positive effect of per-passenger charges disappears when entry is treated as exogenous, which also results in a bias toward preferring per-flight charges.

6 Conclusion

This study estimated the effects of airport charges on airfares, flight frequency, and welfare. It used a structural model that endogenizes airfares and flight frequency and estimated its parameters by using data on Japan’s domestic airline market. It then examined the extent to which per-passenger and per-flight charges affect market outcomes and evaluated the revision of the airport charge system in Japan in 2004–2005.

The main results of this study are as follows. First, per-passenger charges, including PSFCs
and the security charge, significantly increase airfares and decrease flight frequency. The pass-
through rate of the security charge of 100 JPY, which was introduced in 2004, on airfares is 97.5
percent, suggesting that per-passenger charges are almost completely passed through to airfares.
The security charge reduces flight frequency by 1.6 percent, which is equivalent to an increase in
airfares of 186.5 JPY. These results imply that per-passenger charges decrease the consumer surplus
by decreasing flight frequency no less than by increasing airfares. This can be revealed by using
the structural model with endogenous flight frequency.

Endogenizing flight frequency is also revealed to be important for estimating pass-through rates.
The simulation results show that when treating flight frequency as exogenous, the pass-through
rates of per-passenger charges tend to be overestimated. This is because the frequency-decreasing
effects of such charges, which weaken demand and thus decrease airfares, disappear in the model
with exogenous flight frequency. It is also revealed that this overestimation problem is severer on
routes with lower flight frequency.

Per-flight charges significantly decrease flight frequency, while having an insignificant effect on
airfares. The reduction in landing fees in 2005 by an average of 7.7 percent increases return flights
by 1.0 percent (equivalent to 106.5 JPY). This quantitative result implies that the sensitivity of
flight frequency to landing fees is relatively small and that if the government aims to affect market
outcomes by changing the system of landing fees, radical revision is needed.

It is also found that the revision of the airport charge system at national airports in 2004–2005
increased the airport surplus, while decreasing the consumer surplus, producer surplus, and social
surplus. It also increased airfares significantly and had insignificant effects on flight frequency.
These results imply that even a small increase (100 JPY) in per-passenger charges (equivalent to
0.4 percent of average airfares) had no smaller effects on market outcomes than the 7.7 percent
decrease in landing fees.

To investigate the incidence of airport charges, the loss of airline profits for a 1-JPY increase in
the airport surplus is compared between the two types of charges. The results reveal that from the
viewpoints of airline profits, per-passenger charges are more desirable to raise the airport surplus
than per-flight charges on nearly 80 percent of routes. This finding is consistent with the fact
that airlines have asked to replace per-passenger charges with per-flight charges (IATA, 2010). By
contrast, the loss of the consumer and social surpluses is smaller for per-flight charges than for
per-passenger charges on most routes in the sample.

There are some remaining questions. First, airport regulators must know the best combination
of these two types of airport charges and how this changes according to airport characteristics.
Moreover, which airport charge system might private (or profit-maximizing) airports choose after
the privatization of airports and how this differs from the optimal (or social surplus-maximizing)
system is also an important question. The long-run effects of airport charges on aircraft size and entry are other topics worthy of investigation.

**Appendix: Data on Airfares**

This appendix explains the data on airfares. As described in Subsection 2.2, the airfare data used in this study are primarily the normal fares obtained from the timetable published by JTB Publishing, Inc. There are no published data on the actual fares paid by passengers for domestic routes in Japan before 2003. Further, while publicly available data have been accessible since 2003, they are limited. The Travel Survey for Domestic Air Passengers (*Koku Ryokyaku Dotai Chosa* in Japanese) has offered data on actual fares for a couple of days in fall basically once every two years since 2003.

The normal airfares from the timetables were adjusted as follows. First, the actual fares for each route were obtained from the Surveys in November 2003 and October 2005. By comparing these actual fares with the normal fares obtained from the timetables, the “discount rates” on each route were calculated. The average discount rates were 10.01 percent on monopoly routes, 15.43 percent on duopoly routes, and 12.68 percent on routes with three or more airlines. These average values were then used to adjust the normal fares. Basically, they were simply applied as discount rates according to the number of airlines operating on the route (i.e., 10.01, 15.43, and 12.68 percent for monopoly, duopoly, and the other routes, respectively).

However, this simple adjustment would be unsuitable for the period before the merger between JAL and JAS in October 2002. Because the merging airlines had a market share of nearly 50 percent, the Japan Fair Trade Commission (JFTC) expressed concern that the merger would likely constitute a substantial restraint of competition. Based on that concern, the merging party proposed remedial actions to the JFTC. Given the remedy to be implemented, the JFTC approved the merger. As one part of the series of remedial measures, the discount fare on the routes on which the merger company competed with ANA (in other words, duopoly routes after the merger) was set as the same level as the routes on which the three airlines competed before the merger (JFTC, 2002b).

Therefore, the airfares in the period before the merger are adjusted as follows. For routes with three or more airlines before the merger, the discount rate is assumed to be at the same levels as on the duopoly routes after the merger (15.43 percent). For the duopoly routes in the pre-merger period, the discount rate of 12.72 percent, which is the average of the discount rate of the monopoly routes (10.01 percent) and that of the routes with three or more airlines (15.43 percent), is applied. This is because it is reported that the discount rates on the duopoly routes are in range of those of the monopoly routes and those of the routes with the three airlines in the period before the merger (JFTC, 2002a). For the monopoly routes, the average value for the post-merger monopoly routes
(10.01 percent) is simply applied.

References


IATA, 2010, *Passenger Based Airport Charges*.

Ivaldi, Marc, Senay Sokullu, and Tuba Toru, 2016, “Airport Prices in a Two-Sided Market Setting,” manuscript.


### Table 1
Summary Statistics

(A) All [sample size: 7,779]

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<th>Variable (unit)</th>
<th>Mean</th>
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(B) By route type

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<td>77.9</td>
<td>75.5</td>
</tr>
<tr>
<td>Per-passenger charge</td>
<td>0</td>
<td>0.1</td>
<td>0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Note: Route type NN, NO, and OO denote routes between two national airports, routes between a national airport and an airport managed by a local government or a company, and routes between two airports managed by a local government or a company, respectively.
**Table 2**
Changes from 2003.10 to 2005.10

<table>
<thead>
<tr>
<th>Route type</th>
<th>Routes</th>
<th>Fare (1,000 JPY)</th>
<th>Flight frequency (round trip per day)</th>
<th>The number of passengers (1,000)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Sta. Dev.</td>
<td>Mean</td>
</tr>
<tr>
<td>NN</td>
<td>82</td>
<td>0.26</td>
<td>1.89</td>
<td>0.01</td>
</tr>
<tr>
<td>NO</td>
<td>142</td>
<td>0.26</td>
<td>0.74 ***</td>
<td>-0.07</td>
</tr>
<tr>
<td>OO</td>
<td>25</td>
<td>0.18</td>
<td>0.55</td>
<td>-0.17</td>
</tr>
</tbody>
</table>

Notes: Route type NN, NO, and OO denote routes between two national airports, routes between a national airport and an airport managed by a local government or a company, and routes between two airports managed by a local government or a company, respectively. The number of routes is for the value in October 2004. *** and * denote 1- and 10-percent significance, respectively.

**Table 3**
Reduced Form Estimation

<table>
<thead>
<tr>
<th></th>
<th>(3-1)</th>
<th>(3-2)</th>
<th>(3-3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ln(airfare)</td>
<td>0.002</td>
<td></td>
<td>-0.003</td>
</tr>
<tr>
<td>[0.001]***</td>
<td></td>
<td></td>
<td>[0.002]</td>
</tr>
<tr>
<td>Per-passenger</td>
<td>0.746</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[0.389]*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ln(Per-flight)</td>
<td>0.002</td>
<td></td>
<td>-0.064</td>
</tr>
<tr>
<td>[0.0029]</td>
<td></td>
<td></td>
<td>[0.027]**</td>
</tr>
<tr>
<td>Per-flight</td>
<td>-0.088</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[0.322]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td>0.97</td>
<td>0.98</td>
<td>0.92</td>
</tr>
</tbody>
</table>

Notes: Sample size is 2,350. All estimations include airline- and route-specific dummy variables. The numbers in brackets are standard errors. *** and * denote 1- and 10-percent significance, respectively.
### Table 4
**Demand Estimates**

<table>
<thead>
<tr>
<th>Variables / parameters</th>
<th>(4-1)</th>
<th>(4-2)</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instruments</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Airfare</td>
<td>0.002</td>
<td>-0.084</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.008)**</td>
<td></td>
</tr>
<tr>
<td>Flight frequency Coefficient ($\beta$)</td>
<td>-6.16</td>
<td>-3.63</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.62)**</td>
<td>(0.70)**</td>
<td></td>
</tr>
<tr>
<td>Exponent ($\rho$)</td>
<td>-0.17</td>
<td>-0.31</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.93)</td>
<td>(0.08)**</td>
<td></td>
</tr>
<tr>
<td>Nest parameter</td>
<td>0.38</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Base ($\sigma$)</td>
<td>(0.02)**</td>
<td>(0.12)</td>
<td></td>
</tr>
<tr>
<td>Additional for long routes ($\sigma_{\text{long}}$)</td>
<td>0.04</td>
<td>0.29</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.02) *</td>
<td>(0.06)**</td>
<td></td>
</tr>
<tr>
<td>Sample size</td>
<td>5,680</td>
<td>5,680</td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.64</td>
<td>0.52</td>
<td></td>
</tr>
<tr>
<td>Chi-square statistics [d.f.]</td>
<td>8.58 [4] *</td>
<td></td>
<td></td>
</tr>
<tr>
<td>First-stage $F$-statistics [d.f.]</td>
<td>86.7 [9, 5650]**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Own-price elasticity [Sta. dev.]</td>
<td>0.06 [0.02]</td>
<td>-2.00 [0.66]</td>
<td></td>
</tr>
<tr>
<td>Own-frequency elasticity [Sta. dev.]</td>
<td>1.11 [0.20]</td>
<td>0.96 [0.23]</td>
<td></td>
</tr>
</tbody>
</table>

Notes: In (3-1), the squared term of $f_{\text{jrt}}$ is added in the set of exogenous variables. The numbers in brackets are standard errors. All estimations include route distance, its squared and cubed terms, and airline- and month-specific dummy variables, which are not reported in the table. The Chi-square statistics are for a test of overidentifying restrictions. The First-stage $F$-statistics provide the average explanatory power of the instruments, conditional on exogenous variables. *** and ** denote 1- and 5-percent significance, respectively.
### Table 5
**Effects on Airfares and Flight Frequency**

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Sta. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Airfares</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The introduction of the security charge (JPY)</td>
<td>72.5</td>
<td>24.4</td>
<td>44.0</td>
<td>111.0</td>
</tr>
<tr>
<td>Pass-through rate (%)</td>
<td>97.5</td>
<td>3.0</td>
<td>88.0</td>
<td>112.0</td>
</tr>
<tr>
<td>The reduction of landing fees (JPY)</td>
<td>0.8</td>
<td>1.2</td>
<td>-7.0</td>
<td>7.0</td>
</tr>
<tr>
<td><strong>Flight frequency</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The introduction of the security charge (Round trip per day)</td>
<td>-0.04</td>
<td>0.03</td>
<td>-0.17</td>
<td>-0.02</td>
</tr>
<tr>
<td>Change rate (%)</td>
<td>-1.6</td>
<td>1.0</td>
<td>-5.7</td>
<td>-0.5</td>
</tr>
<tr>
<td>Monetary value (JPY)</td>
<td>-186.5</td>
<td>158.0</td>
<td>-812.4</td>
<td>-28.7</td>
</tr>
<tr>
<td>The reduction of landing fees (Round trip per day)</td>
<td>0.04</td>
<td>0.05</td>
<td>0.0001</td>
<td>0.35</td>
</tr>
<tr>
<td>Change rate (%)</td>
<td>1.0</td>
<td>0.6</td>
<td>0.01</td>
<td>3.2</td>
</tr>
<tr>
<td>Monetary value (JPY)</td>
<td>106.5</td>
<td>73.4</td>
<td>0.5</td>
<td>431.3</td>
</tr>
</tbody>
</table>

Notes: Sample size is 209 (route-airline). The monetary values of the effects on flight frequency are derived as the change in $\beta_f^{jrt}$ divided by the coefficient of airfare ($\alpha$).

### Table 6
**Regression of Pass-through Rates**

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>(6-1)</th>
<th>(6-2)</th>
<th>(6-3)</th>
<th>(6-4)</th>
<th>Difference: Frequency exo. model - end. model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Routes</td>
<td>All Monopoly</td>
<td>All Monopoly</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The number of airlines</td>
<td>0.853</td>
<td>[0.348]**</td>
<td>[0.339]**</td>
<td>-0.721</td>
<td></td>
</tr>
<tr>
<td>Flight frequency</td>
<td>0.22</td>
<td>0.431</td>
<td>-0.223</td>
<td>-0.494</td>
<td></td>
</tr>
<tr>
<td>Market share</td>
<td>-1.342</td>
<td>-2.675</td>
<td>0.602</td>
<td>1.895</td>
<td></td>
</tr>
<tr>
<td>Route distance</td>
<td>-1.205</td>
<td>-2.046</td>
<td>1.264</td>
<td>1.689</td>
<td></td>
</tr>
<tr>
<td>Income level around endpoint airports</td>
<td>0.196</td>
<td>0.238</td>
<td>-0.298</td>
<td>-0.531</td>
<td></td>
</tr>
<tr>
<td>Population around endpoint airports</td>
<td>-0.029</td>
<td>0.435</td>
<td>0.036</td>
<td>-0.228</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>97.019</td>
<td>98.167</td>
<td>2.918</td>
<td>2.613</td>
<td></td>
</tr>
<tr>
<td>Sample size</td>
<td>209</td>
<td>89</td>
<td>209</td>
<td>89</td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.16</td>
<td>0.74</td>
<td>0.12</td>
<td>0.62</td>
<td></td>
</tr>
</tbody>
</table>

Notes: The standard errors are in brackets. *** and ** denote 1- and 5-percent significance, respectively.
Figure 1
Landing Fees at National Airports

Based on the MTOW

<table>
<thead>
<tr>
<th>Standard charge</th>
<th>2001.4</th>
<th>2003.4</th>
<th>2009.7</th>
<th>2010.4</th>
<th>2013.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>-25t</td>
<td>1,100</td>
<td>1,000</td>
<td>1,000</td>
<td>950</td>
<td>850</td>
</tr>
<tr>
<td>26-100t</td>
<td>1,500</td>
<td>1,400</td>
<td>1,400</td>
<td>1,380</td>
<td>1,330</td>
</tr>
<tr>
<td>101-200t</td>
<td>1,700</td>
<td>1,550</td>
<td>1,650</td>
<td>1,650</td>
<td>1,650</td>
</tr>
<tr>
<td>201t-</td>
<td>1,800</td>
<td>1,650</td>
<td>1,800</td>
<td>1,800</td>
<td>1,800</td>
</tr>
</tbody>
</table>

Based on the noise level

-25t 1,100 JPY/t
26-100t 1,500 JPY/t
101-200t 1,700 JPY/t
201t- 1,800 JPY/t

3,400 JPY multiplied by the noise level minus 83

Rate of discount

“Second class” airports

<table>
<thead>
<tr>
<th>Rate of discount</th>
<th>1/3</th>
<th>3/10</th>
<th>2/5</th>
<th>1/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haneda Airport</td>
<td>1/3</td>
<td>1/10</td>
<td>1/4</td>
<td>1/2</td>
</tr>
<tr>
<td>(for routes connected to local airports)</td>
<td>3/10 or 1/2</td>
<td>1/4, 2/5</td>
<td>2/3, or 4/5</td>
<td></td>
</tr>
</tbody>
</table>

Notes: The noise level is in the Effective Perceived Noise Level (EPN) dB. The “second class” airports are the local airports managed by the national government. The rate of discount at Haneda Airport varies according to the endpoint airport of a route.

Figure 2
Histogram of Pass-through Rates

[Histogram showing pass-through rates with observations (airline-route) on the y-axis and pass-through rates (%) on the x-axis.]
Figure 3
Effects of Per-passenger Charges on Flight Frequency by Route

Figure 4
Welfare Loss for a 1 JPY Increase of Airport Surplus

Note: Vertical lines represent the 95-percent confidence intervals.
Figure 5
Comparison of the Two Types of Charges by Route

(A) Airlines’ profits

(B) Passenger surplus

Figure 6
Welfare Loss for a 1 JPY Increase of Airport Surplus:
Exogenous Frequency Model

Note: Vertical lines represent the 95-percent confidence intervals.