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Ramsey Pricing on Airport Landing: An Empirical Study in Taiwan

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***Abstract*—The total revenue of the airport authority is divided into aeronautical and non-aeronautical ones. Landing fees are the main sources of aeronautical revenue. Therefore, it is essential to formulate a suitable charging mechanism for landing fees. Traditionally, pricing methods for airport landing fees are based on the maximum takeoff weight or maximum landing weight, which has little theoretical rationale. Airports landing fees charged in Taiwan are also based on the aircraft weight. There are various pricing methods in academic research, such as average-cost pricing, marginal-cost pricing and Ramsey pricing. Ramsey pricing is suitable for uncongested airports or any airports in its off-peak periods, while marginal-cost pricing is appropriate for congested periods. Due to the increase in traffic volume and its hub operation, Taiwan Taoyuan International Airport (TPE) suffers from congestion in peak periods. Thus, TPE is thinking to differentiate its landing fees in different periods. This research aims at developing a charging mechanism that applies the Ramsey pricing model. The pricing mechanism is then validated at TPE and Taipei Songshan Airport (TSA). Although price elasticity is essential to Ramsey pricing, it is difficult to directly calculate this elasticity of airline demand in landing. The ordered probit model is used to find the price elasticity from different passenger groups, and then the estimation results are put in the Ramsey pricing model in order to substitute the price elasticity of airline's landings. In empirical research, the results indicate that in most of the case, as the aircraft is larger and the distance is longer, the landing fees are higher. Additionally, calculation results reveal that in every case the current charge at TPE and TSA is less than the land fees based on the Ramsey pricing mechanism.**

***Keywords*—Landing Fee, Ramsey Pricing, Airport Pricing, Ordered Probit Model.**

I. Introduction

Traditionally, pricing methods for airport landing fees are usually adopted by the maximum takeoff weight (MTOW) or maximum landing weight (MLW). However, these pricing standards have few theoretical bases to back them up. The economic theory is that the price is affected by supply and demand factors. The airport landing fees charged in Taiwan are also based on the MTOW and thus are not entirely determined by the supplies and demands of the market. There are various pricing methods in the academic field such as average-cost pricing, marginal-cost pricing and Ramsey pricing etc. The Ramsey pricing is more appropriate when airports are in off-peak periods. Due to the increasing volume and usage frequency of the airports in Taiwan, peak and off-peak hours become more and more obvious. Therefore, the landing fees should be set in different rates according to peak and off-peak hour pricing. In theory, this will allow the airport operations become more efficient.

This study aims to calculate the landing fee of the two airports in Taiwan during off-peak hours with the Ramsey pricing model. There are two main airports in Northern Taiwan. One is the Taipei Songshan Airport (TSA), which locates at the center of Taipei city. The other is the Taiwan Taoyuan International Airport (TPE) that locates in Taoyuan. The distance between the two airports is 41 kilometers, which is approximately 40 minutes by car. TPE is the busiest international air entry point in Taiwan and is also an important East Asia transit hub. TSA on the other hand, is smaller than TPE. TSA does not serve continental-flights yet, such as North America routes, Europe routes, and Oceania routes etc. TSA mainly serves chartered flights, most of which are to and from China, domestic flights, and some short-haul flights in Asia. As a result, TSA is set to be a "business airport", and many of the flight destinations departing from Songshan are major business centers. Aircraft types adopted in this research are Boeing 747-400, Boeing 777-300ER and Airbus 330-300 in TPE, which holds the top three highest landing frequencies. TSA on the other hand, Airbus 330-300, Airbus 321-200 and Boeing 737-800, which holds the three highest landing frequencies in TSA.

The structure of the Ramsey pricing model has 4 variables, the marginal cost of landing to the airport, the price elasticity of the airline's demand in landing of different aircraft types, the different costs of different aircraft types, and the multiplied Lagrange. Due to the difficulty of calculating the price elasticity of the airline's demand in landing, it is dealt with as a function of the price elasticity of passenger demand, under the theory of output effect. The price elasticities of passenger demand with respect to different aircraft types and distances are

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calculated with the ordered probit choice model and the aggregate passenger air travel demand function. The distance is divided into short-haul, regional, and continental. Short-hauls are the flights between Taiwan and China. Regional flights are from Taiwan to Japan or Korea. Continental flights are to America, Europe and Australia. Specifically, flights from TPE to Shanghai Pudong (PVG), Tokyo Narita (NRT), Los Angeles (LAX), San Francisco (SFO) and Brisbane (BNE) as well as from TSA to Shanghai Pudong (PVG), Shanghai Hongqiao (SHA), Gimpo (GMP), Tokyo Haneda (HND) and Tokyo Narita (NRT) are investigated.

II. Research Related to Landing Charges

A. *Average-cost pricing*

Average-cost pricing is a regulatory policy used for public utilities (especially those that are natural monopolies) in which the price received by a firm is set equal to the average total cost of production. The advantage of average-cost pricing is that the firm is guaranteed a normal profit. Chang and Yen (2014) develop a mechanism based on the costs incurred from airside services. Costs considered in the research include the value of land, the depreciation and operations costs of related equipment and the compensation of staff involved in providing the services. The average-cost pricing method is applied in this study to allocate the costs on TPE and TSA. The result indicates that the location of airports should be considered when determining their landing fees.

B. *Marginal-cost pricing*

Marginal-cost pricing is one of the pricing methods which the price received by a firm is set equal to the marginal cost of production. When the price is set equal to the marginal cost of production, the sum of consumer surplus and producer surplus would be maximum. Therefore, marginal-cost pricing is also called “first best pricing”. Morison (1979) presents the theoretical model of optimal runway pricing to solve the problem of congested airports. The model is assumed to determine landing fee that maximize a weighted sum of airline consumers’ surpluses subject to a revenue requirement. Thus, optimal landing fee with a revenue constraint are made up of a component based on total flight costs (including congestion cost and the value of passengers’ time) and external congestion costs (marginal runway maintenance cost). The model is applied to San Francisco international Airport, and the main result is that commuter airlines are much more favored than others.

C. *Ramsey pricing*

While economics suggests setting monopoly prices according to marginal costs in order to maximize social welfare (optimal solution), marginal-cost pricing will result in deficits if average total costs are above marginal costs (Mankiw, 2008). As the airport is uncongested, Ramsey pricing is suitable for charging the landing fees. Morrison (1982) developed the landing fees of Ramsey pricing model. The model is derived by maximizing the difference between social benefits and costs, given a constraint on profit. Ramsey pricing is considered to be quasi-optimum pricing (second best pricing) scheme designed for a natural monopolist. Unlike current weight-based fees, the landing fees of Ramsey pricing model vary with aircraft type and distance. Thus, Ramsey pricing would result in increased fees for small planes on long flights and decreased fess for large planes on short flights. Martín-Cejas (1997) establishes an airport pricing structure for landing fee which reflects the overall costs that air transport operators impose on others. This paper analyzes one application of Ramsey Pricing on uncongested Spanish airport by considering the CO_2 emission costs as a valuable input. The results present that the landing fee for each type of aircraft increases with distance, and as the aircraft size increases the landing fee increase. Ramsey prices are optimal for airports with cost recovery problems, but are inefficient for busy airports (Hakimov and Muelle, 2014).

III. Methodology

A. *Ramsey pricing model*

Ramsey pricing provides a solution when landing fees based on marginal costs do not generate enough income to cover costs, a common situation for an uncongested airport. Ramsey pricing is derived by maximizing the difference between social benefits and costs, given a constraint on profit (Morrison, 1982), as illustrated in equations 1 and 2.

The objective function and constraint are

$$\max_{Q_1,\ldots,Q_n} \ \mathrm{NSB} = \mathrm{SB} - \mathrm{SC} \tag{1}$$

$$\mathrm{s.t.} \quad TR - \mathrm{TC} = 0 \tag{2}$$

where $Q_1,\ldots,Q_n$ = numbers of landing by category 1 to category n

NSB = net social benefits, the difference between social benefits and costs

SB = social benefit of the demand functions for the different aircraft types of the landings

SC = social cost of the landings

TR = total revenue to the airport authority of the landings

TC = total cost to the airport authority (including total variable cost and total fixed cost)

Social benefit (SB) is the demand functions for the different aircraft types of the landings. That is the sum of the demand from aircraft individual demand of category 1 to category n.

$$SB = \int_0^{Q_1} P_1(Q_1)dQ_1 + \cdots + \int_0^{Q_n} P_n(Q_n)dQ_n \tag{3}$$

where

P_i = the landing fee charged to aircraft in category *i* (a category is given by an aircraft type and length of flight).

Q_i = the number of landings of category *i*

Social cost (SC) is total variable cost to serve aircraft from category 1 to category n landing at the airport.

$$\mathrm{SC} = \mathrm{C}(\mathrm{Q}_1, \dots, \mathrm{Q}_n) \qquad (4)$$

Total revenue (TR) is landing charges collected from landing aircraft of category 1 to category n.

$$\mathrm{TR} = \sum_{i=1}^{n} P_i Q_i \qquad (5)$$

Total cost (TC) includes total variable cost and total fixed cost incurred by the airport authority to serve all types of aircraft.

$$\mathrm{TC} = \mathrm{C}(\mathrm{Q}_1, \dots, \mathrm{Q}_n) + \mathrm{F} \qquad (6)$$

where F = the fixed costs which must be covered.

The above objective function and constraint can be expended in detail as follows.

$$\max_{\mathrm{Q}_1,\dots,\mathrm{Q}_n} \int_0^{\mathrm{Q}1} \mathrm{P}_1(\mathrm{Q}_1)\mathrm{dQ}_1 + \cdots + \int_0^{\mathrm{Qn}} \mathrm{P}_n(\mathrm{Q}_n)\mathrm{dQ}_n - \mathrm{C}(\mathrm{Q}_1, \dots, \mathrm{Q}_n) \qquad (7)$$

$$s.t. \qquad \sum_{i=1}^{n} P_i Q_i - [\mathrm{C}(\mathrm{Q}_1, \dots, \mathrm{Q}_n) + \mathrm{F}] = 0 \qquad (8)$$

Forming the Lagrangean, we have

$$\max_{\mathrm{Q}_1,\dots,\mathrm{Q}_n,\lambda} \mathcal{L} = \int_0^{\mathrm{Q}1} \mathrm{P}_1(\mathrm{Q}_1)\mathrm{dQ}_1 + \cdots + \int_0^{\mathrm{Qn}} \mathrm{P}_n(\mathrm{Q}_n)\mathrm{dQ}_n - \mathrm{C}(\mathrm{Q}_1, \dots, \mathrm{Q}_n) + \lambda\left[\sum_{i=1}^{n} P_i Q_i - \mathrm{C}(\mathrm{Q}_1, \dots, \mathrm{Q}_n) - \mathrm{F}\right] \qquad (9)$$

The first-order conditions are

$$\frac{\partial \mathrm{L}}{\partial Q_i} = P_i - \frac{\partial C}{\partial Q_i} + \lambda\left(P_i + Q_i \frac{dP_i}{dQ_i} - \frac{\partial C}{\partial Q_i}\right) = 0 \qquad i = 1, \dots, n \qquad (10)$$

Solving equation 10 results in

$$\frac{P_i - \dfrac{\partial C}{\partial Q_i}}{P_i} = \left(\frac{\lambda}{1+\lambda}\right)\frac{1}{\varepsilon_i} \qquad i = 1, \dots, n \qquad (11)$$

where ε_i is the (absolute value) elasticity of demand for landings with respect to the landings fee. And, $\partial C/\partial Q_i$ is the marginal cost of category i (MC_i) This is the standard Ramsey pricing result, which indicates that the percentage markup of price over marginal cost should be inversely proportional to the price elasticity of the demand (Baumol and Bradford, 1970). In other words, as ε_i is less, the difference in P_i and MC_i (mark-ups) is greater. That is also called inverse elasticity rule.

As the elasticity of the demand for landings (ε_i) is difficult to get, Morrison reformulated formula 11 to be able to estimate each component. According to output effect in microeconomic theory (Layard and Walters, 1978), when the proportion of production factors is fixed (1 aircraft plus 1 landing equals 1flight), the airline's demand elasticity for landings is equivalent to the passenger's demand elasticity of trips with respect to ticket prices multiplied by the fraction of landing fees to total flight costs. The detailed description of output effect is in equations 12 to 19. (5)

Output effect is the change which would occur if factor proportions were held constant, but output changed in response to changes in its price (Layard and Walters, 1978). Now we will illustrate why the elasticity of demand for landings can be replaced by the product of the elasticity of demand for passenger trips. The explicit explanation can be seen in the following.

Suppose 1 unit of x requires a units of K (fixed factor) and b units of L (variable factor). Then, under perfect competition the price of x is

$$P_x = a \cdot w_K + b \cdot w_L \qquad (12)$$

We suppose production function in short- run (within a certain period of time, at least one factor is fixed while others are variable) and let w_L rise but assume that the price of the other factor (w_K) is constant. The proportional increase in price of x is (8)

$$\frac{\mathrm{d}P_x}{P_x} = \frac{\mathrm{d}(b \cdot w_L)}{P_x} = \frac{b \cdot w_L}{P_x} \cdot \frac{\mathrm{d}w_L}{w_L} = \upsilon_\mathrm{L} \cdot \frac{\mathrm{d}w_L}{w_L} \qquad (13)$$

$$\mathrm{d}\log P_x = \upsilon_\mathrm{L} \cdot \mathrm{d}\log w_L \qquad (14)$$

where υ_L is the share of L in costs.

The demand elasticity of consumer (η^D) is

$$\eta^\mathrm{D} = \frac{\mathrm{d}Q_x / Q_x}{\mathrm{d}P_x / P_x} = \frac{\mathrm{d}\log Q_x}{\mathrm{d}\log P_x} \qquad (10) \qquad (15)$$

But the price (P_x) increase reduces output (Q_x)

$$\mathrm{d}\log Q_x = \eta^\mathrm{D}\, \mathrm{d}\log P_x = \eta^\mathrm{D} \cdot \upsilon_\mathrm{L} \cdot \mathrm{d}\log w_L \qquad (16)$$

And, since production is by fixed proportions, the proportional fall in each factor is the same as the proportional fall in output. (11)

$$\mathrm{d}\log L = \mathrm{d}\log Q_x \qquad (17)$$

$$\mathrm{d}\log L = \eta^\mathrm{D} \cdot \upsilon_\mathrm{L} \cdot \mathrm{d}\log w_L \qquad (18)$$

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Hence, the firm's demand elasticity of *L* (variable factor) is share of *L* in costs multiplied by demand elasticity of consumer.

$$\frac{d \log L}{d \log w_L} = \varepsilon_{LL} = \eta^D \cdot \upsilon_L \qquad (19)$$

In summary, we assume each flight requires one landing (variable factor) and aircraft operation for a flight (fixed cost) in this study. In the short-run, the aircraft operating cost is constant. υ_L is the share of landing in aircraft operating costs. And, since airline's short-run production is by fixed proportions, the proportional fall in the number of landings is the same as the proportional fall in output (flights). Therefore, the elasticity of demand for landing is equal to share of landing in total flight cost multiplied by the elasticity of demand for passenger. Thus, equation (11) results in

$$\varepsilon_i = \eta_i \left(\frac{P_i}{P_i + TC_i} \right) \qquad i = 1, \ldots, n \qquad (20)$$

where η_i = the (absolute value) price elasticity of demand for passenger trips of the i category.
TC_i = the cost of the flight for the i^{th} category exclusive of landing fee.

Finally, combing equations 11 and 20, the result of landing fee of Ramsey pricing for category *i* is

$$P_i = \frac{MC_i + \frac{k}{\eta_i} TC_i}{1 - \frac{k}{\eta_i}} \qquad i = 1, \ldots, n \qquad (21)$$

where
k = λ/1+λ
MC_i = the marginal cost to the airport authority of the landings.

Equation (21) shows that the landing fee charged to aircraft in category i is related to marginal cost of a landing to the airport authority, the elasticity of passenger, and the cost of the flight. Since this model is concerned with uncongested airports, the marginal costs are borne only by the airport authority; that is, there are no congestion externalities.

B. *Aggregate demand function and elasticity*

According to Daganzo (1979), the estimated discrete choice model is a choice probability function of a vector of specified attributes **a** and a parameter vector θ. The choice function of alternative j can be stated as $P_j(\theta, \mathbf{a})$, j= 1, 2, …, J, with J as the number of alternatives. For a given vector of model parameters θ, the aggregate demand function of alternative j can be expressed as:

$$D_j = N \int_{a_1} \int_{a_2} \ldots \int_{a_K} P_j(\theta, \mathbf{a})\, f_A(\mathbf{a})\, d\mathbf{a} \qquad (22)$$

Where N is the population size, K is the number of attributes specified in the choice function, and $f_A(\mathbf{a})$ is the probability density of the attribute vector **a** across the population. By definition, $P_j(\theta, \mathbf{a})\, f_A(\mathbf{a})$ N represents the density of decision makers with an attributes vector **a** who choose alternative j. Therefore, the integral in equation (22) is the expected value of $P_j(\theta, \mathbf{A})\, f_A(\mathbf{A})$ N with respect to **A**, and aggregate demand function D_j can be written as $E_A[N\, P_j(\theta, \mathbf{A})]$ or $N\, E_A[P_j(\theta, \mathbf{A})]$, with E_A as the expectation function with respect to the vector of random variables **A**.

Theoretically the elasticity of the aggregate demand for choice alternative j with respect to attribute a is (Yen, 2000):

$$\varepsilon_a^{D_j} = \frac{\partial D_j}{\partial a} \frac{a}{D_j} = \frac{\partial\, \{E_A[P_j(\theta, \mathbf{A})]\}}{\partial a} \frac{a}{E_A[P_j(\theta, \mathbf{A})]} \qquad (23)$$

The standard approach to obtain the aggregate demand for a specific choice alternative is either taking the integral in equation (22) or weighting the individual probability across the population. The multiple integral is generally difficult to solve in practice. In some case when the choice probability is not a closed function such as the probit model, the weighting process is computationally intensive. Specifically, if the population is homogeneous, the expected aggregate probability for the population can be approximately by the probability of a representative individual whose values of the explanatory variables are respective mean values of the population. Consequently, equation (23) can be simplified as

$$\varepsilon_a^{D_j} = \frac{\partial\, P_j(\theta, \bar{\mathbf{A}})}{\partial a} \frac{a}{P_j(\theta, \bar{\mathbf{A}})} \qquad (24)$$

where $\bar{A}$ is the vector of the population mean values of the explanatory variables. Empirically, the partial derivative in equation (24) is approximated by a differentiation in equation (25).

$$\varepsilon_{a_K}^{D_j} = \frac{P_j(\theta, \bar{\mathbf{B}}) - \partial\, P_j(\theta, \bar{\mathbf{A}})}{\Delta a_K} \frac{a_K}{P_j(\theta, \bar{\mathbf{A}})} \qquad (25)$$

where the elements of vector $\bar{B}$ are the same as in vector $\bar{A}$ except that attribute a_K in the former is replaced by $a_K + \Delta a_K$. Equations 24 and 25 define the point elasticity of the demand for choice alternative j with respect to attribute a_K. If Δa_K is substantial, equation 25 is referred as an arc elasticity, with $P_j(\theta, \bar{A})$ in the denominator being replaced by the average of $P_j(\theta, \bar{A})$ and $P_j(\theta, \bar{B})$.

IV. Empirical Study

A. *Price elasticity of passenger demand* (η_i)

The derivation presented in section 3.1 shows that the airline's demand elasticity in landing (ε_i) is proportional to the price elasticity of passengers (η_i) as in equation (20). To calculate η_i, it is essential to develop the aggregate demand function as in equation 22. Additionally, the choice probability function, $P_j(\theta, a)$, is important to obtain the aggregate demand function and the demand elasticity of passenger for various aircraft types. The choice probability function, based on the ordered probit model, was estimated by Yen et al. (2015).

The data of this study and Yen et al. (2015) were collected from passengers in different aircraft types and to different destinations at TPE and TSA. The survey was conducted in May 1-24, 2015, collecting data by purposive sampling and interviewing travelers from the departure lounges at TPE and TSA. Among those 1,139 who completed the questionnaire, 18 respondents were excluded from the data set. Therefore, a total valid sample is 1,121. Among them 661 departed from TPE, and others from TSA.

Details of the questionnaire can be referred to Yen et al. (2015). To summarize, according to different aircraft types and different destinations, the questionnaire contains 9 versions at TPE and 6 versions at TSA. For TPE, 3 aircraft types were adopted in the survey, including Airbus 330-300, Boeing 777-300 ER and Boeing 747-400. Each aircraft type is further divided into short-haul, regional, and continental. The destination of short-haul is PVG. The destination of regional-flights is NRT. Furthermore, the destinations of continental-flights are BNE (A330-300), LAX (B777-300ER), and SFO (B747-400). For TSA, 3 aircraft types were adopted, including Airbus 321-200, Boeing 737-800 and Airbus 330-300. Each aircraft type is divided into 2 distances, short-haul and regional. The destinations of short-haul are PVG (A321-200 and B737-800) and SHA (A330-300). On the other hand, the destinations of regional-flights are GMP (A321-200 and B737-800) and HND (A330-300). TSA currently does not serve continental-flights. Therefore, the questionnaire for TSA just has 6 versions. All versions contain 6 questions on travel experiences, 5 questions on individual demographic characteristics and 3 different scenarios. In the questionnaire, each respondent was asked of their willingness of choosing this route for how many times in three different rating scenarios.

Data from TPE

Firstly, this research examines the passenger information of Boeing 747-400. There are 65 respondents in the short-haul with B747-400, 58% of which are male, 60% of the respondents traveled by air more than 2 times per year. Approximately 57% of the respondents travel with business purpose, and 51% of the respondents travel within 7 days. Secondly, there are 74 respondents in regional-flights with B747-400, 46% of them are male. Approximately 70% of the respondents hold a bachelor degree. More than 73% of the respondents travel for leisure, and 83% of the respondents travel within 7 days. Lastly, there are 74 respondents continental-flights with B747-400, among those 49% are male. Approximately 38% of the respondents hold a Master or Ph.D. degree and 51% of the respondents hold a bachelor degree. More than 60% of the respondents travel for leisure or to visit friends and relatives (VFR), and 47% of the respondents travel within 8-14 days.

Next is Boeing 777-300ER. In short-haul with B777-300ER, there are 62 respondents, in which 58% are male. Approximately 52% of the respondents travel less than 2 times per year by air. 76% of the respondents travel with business purpose, and 67% of the respondents travel within 7 days. In regional-flights with B777-300ER, there are 60 respondents, 42% of which are male. More than 70% of the respondents hold a bachelor degree. Approximately 83% of the respondents travel for leisure, and 75% of the respondents travel within 7 days. In continental-flights with B777-300ER, there are 95 respondents, 51% of which are female. 52% of the respondents travel for business purpose, and 51% of the respondents travel within 8-14 days.

Lastly, in short-haul with A330-300, there are 76 respondents, 51% of which are male. Approximately 39% of the respondents travel by air within 2 times per year and 32% travel by air within 3-5 times per year. Approximately 60% of the respondents travel with business purpose. In regional-flights with A330-300, there are 63 respondents, 52% of which are male. Approximately 62% of the respondents travel for leisure, and 68% of the respondents travel within 7 days. As for continental-flights with A330-300, there are 92 respondents and 38% of which are male. More than 66% of the respondents travel within 2 times per year by air. Approximately 33% of the respondents travel within 7 days and 28% of the respondents travel for 31 days or over.

Data from TSA

Firstly, the research observes the passenger information of A330-300. There are 99 respondents in the short-haul with A330-300, 59% of which are male, 63% of the respondents traveled by air more than 2 times per year. More than 68% of the respondents hold a bachelor degree. Approximately 87% of the respondents travel with business purpose, and 59% of the respondents travel within 7 days. Secondly, there are 98 respondents in regional-flights with A330-300, 56% of them are female. Approximately 69% of the respondents hold a bachelor degree. More than 52% of the respondents travel for leisure, and 74% of the respondents travel within 7 days.

Next is Airbus 321-200. In short-haul with A321-200, there are 60 respondents, in which 53% are male. Approximately 68% of the respondents travel is more than 2 times per year by air. 68% of the respondents travel with business purpose, and 75% of the respondents travel within 7 days. In regional-flights with A321-200, there are 73 respondents, 81% of which are female. Approximately 92% of the respondents travel for leisure, and 86% of the respondents travel within 7 days.

Lastly, in short-haul with B737-800, there are 63 respondents, 63% of which are female. Approximately 38% of the respondents travel by air within 2 times per year and 46% travel by air within 3-5 times per year. Approximately 41% of the respondents travel with business purpose. As for regional-flights with B737-800, there are 67 respondents and 78% of which are female. More than 63% of the respondents travel within 2 times per year by air and 78% travel with leisure purpose. Approximately 88% of the respondents travel within 7 days.

To sum up, for short-haul from TPE, most passengers' purpose of traveling is for business. Passengers traveling for leisure mostly exist in regional-flights. For continental-flights, passenger's travel purposes are mainly for leisure, business or VFR. On the other hand, what's worth mentioning is that in all 3 aircraft types in short-haul from TSA, most respondents travel for business. Passengers traveling for leisure also mostly exist in regional-flights. In addition, the proportion of female is higher than male in regional-flights.

Price elasticity

According to equations 24 and 25, choice probabilities are necessary to calculate the elasticity of passenger air travel demand. This section used the estimated results of ordered probit model for TPE and TSA by Yen et al. (2015) to frame the aggregate passenger air travel demand function. To the extent that the aggregate demand elasticity is of interest, the aggregate probabilities are predicted with respect to each alternative. The approach labeled as classification is adopted in this paper to predict the aggregate choice probability and thus to calculate the various price elasticities of aggregate passenger air travel demand.

The population of each aircraft type for different distance is divided into several groups according to the dummy variables of those estimated results from the order probit models. Each group is assumed to homogeneous with respect to the explanatory variables and the "average individual" approach is adopted for aggregate forecasting within each groups. That is, the aggregate probability for each group is approximated by the probability of an average individual in the group.

The price elasticity of passenger demand is the percentage change of the number of expected choice due to one percent change in the price of ticket, all else being equal. If the differences between ticket prices that passengers pay in various scenarios are viewed as the changes in the prices of various flights, the predicted probabilities under different scenarios can be used to calculate the price elasticity of passenger demand. Table 1 lists the calculated results. The negative values for each group reflect that decreasing prices of ticket will increase passenger air travel demand. At TSA, the results indicate that the price elasticity of the passenger for small aircraft is greater (absolute value) than the one for large aircraft. This phenomenon merits special investigation. In addition, the price elasticity of the passenger for regional-flights is greater (absolute value) than the passenger for short-haul. This might reflect the situation that the competition in the regional market is higher than in the short-haul market.

B. Cost of flight (TCi)

As we concentrate on the cost for the landing of each flight the following formulation is used. The cost of flight during landing (TC_i) is equal to the operation cost per block hour for each aircraft type times the number of block hours per flight and times 2. Operating costs per block hour in 2014 were taken from the Bureau of Transportation Statistics (BTS). The aircraft characteristics are summarized in Table 2.

C. Parameter k

The value of k depends on the extent to which the revenue constraint is binding. If the constrain is not binding, then k=0 and Ramsey pricing reduces to marginal cost pricing $P=MC$. At the other extreme, when revenue requirements is at the maximum attainable level, the value of λ tends to infinity and we get k=1that reduces the Ramsey pricing formula to P=MR. Therefore, the value of k will be between 0 and 1.

The unknown k will be calculate and used because the fees generate with that value for k are of the same order of magnitude as current fees. According to the assumption of most of the authors in previous related studies, the landing fees of Ramsey pricing generated with that value for k are of the same order of magnitude as current fees. Therefore, in this research, we choose a level of weight-based fees as basis for estimation, which are the current rates of the smallest aircraft type in the short-haul at TPE and TSA. We assume the current rates of the smallest aircraft type in the short-haul as the landing fee (Pi), and then all of the estimated variables (including ηi, TCi, and MCi) are put in the Ramsey pricing model. Finally, the research gets the estimated values of k. At TSA, the estimated value of k is 0.0021. At TPE, the estimated value of k is 0.0093.

D. Marginal cost for airport authority (MCi)

This paper assumes that TPE and TSA are natural monopolists. A natural monopoly has economies of scale that the average cost is decreasing. Because it has a high fixed cost for a product, marginal cost of producing one more good is roughly constant and approximate to average cost. We use the estimation of Chang and Yen (2014) as the indicator of the average cost for landing at TPE and TSA. Table 3 shows the average costs of different aircraft types at TPE and TSA, which are used as marginal costs (MC_i) in equation 21.

E. Estimation results of Ramsey pricing

By applying equation 21 and other parameters calculated in the previous sections, the landing fees based on the Ramsey pricing mechanism with respect to various selected aircraft types are calculated and shown in Table 4. The structure of the Ramsey pricing for landing fees is related to distances and aircraft types. In most of the case, as the aircraft is larger and the distance is longer, the landing fees are higher, which is similar to the results presented by Morrison (1982). For example, the calculated landing fees for B747-400 at TPE are US$ 1832, 2692, and 3174 with respect to flight distances from short-haul, regional, and continental, respectively. This phenomenon applies to other two aircraft types at TPE. At TPE, for each distance category the calculated landing fees of B747-400 is greater than the one of A330-300. However, the landing fee of B777-300ER is greater than the one of B747-400 due to the much higher average costs of B737-300ER.

Table 4 also lists the current landing fee for each aircraft type at both airports. Since neither airport charges landing fees according to flight distances, there is only one current charge for each aircraft type at every airport. The comparison between the calculation results and the current charge reveals that in every case the current charge is less than the land fees based on the Ramsey pricing mechanism. This finding is consistent with the fact that both TPE and TSA have deficits on their financial performances at airside.

Since A330-300 aircraft serves both TPE and TSA, it is interesting to compare the calculation results at both airports. The landing fees based on Ramsey pricing in both distance categories at TSA is greater than the ones at TPE, respectively, mainly due to the higher average costs at TSA. The current landing charges of A330-300 at both airports also show that same pattern.

V. Conclusion

In order to use Ramsey pricing mechanism to calculate landing fees, the price elasticity of passenger air travel demand for different aircraft types at TPE and TSA are estimated. The results indicate that the price elasticity of passenger demand is associated with flight distances and aircraft types. This elasticity for smaller aircraft is greater than the one for larger aircraft. In addition, this elasticity for regional-flights is greater than the one for short-haul, due to higher competition.

The calculation results of the landing fees at TPE and TSA demonstrate that the structure of the Ramsey pricing for landing is related to distances and aircraft types. At TSA, the landing fee is higher for larger aircraft in any distance range. TPE shares the same results except that the landing fee of B777-300ER is greater than the one of B747-400 due to the former's higher average costs incurred by the airport operator.

The comparison between the calculation results and the current charge reveals that in every case the current charge is less than the land fees based on the Ramsey pricing mechanism. This finding might give the reason that both TPE and TSA have deficits on their financial performances at airside. Although the empirical study was conducted using data from two airports in Taiwan, the mechanism can be applied to airports world-wide.

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Table 1: Price elasticity of passenger demand

Aircraft type / Distance	TPE			TSA		
	B747-400	B777-300ER	A330-300	A330-300	A321-200	B737-800
Short-haul	-1.24	-1.37	-1.58	-0.72	-1.21	-1.80
Regional-flights	-0.86	-1.34	-1.27	-1.65	-1.77	-3.13
Continental-flights	-1.56	-0.24	-1.35	-	-	-

Table 2: Aircraft Characteristics at TPE

Aircraft Characteristics	Aircraft Type				
	Boeing 747-400	Boeing 777-300ER	Airbus 330-300	Airbus 321-200	Boeing 737-800
USD per block hour	15,629	11,007	10,484	4,537	5,173
Seats(2-class)	524	451	335	185	162
MTOW(ton)	397	352	230	94	79

Table 3: Average costs of different aircraft types in 2012 (in US$)

Airport	TPE			TSA		
Aircraft Type	B747-400	B777-300ER	A330-300	A 330-300	A321-200	B737-800
Average Cost	810	2,107	1,370	1,913	687	467

Table 4: Calculation results of landing fees with Ramsey pricing (in US$)

Aircraft type / Distance	TPE			TSA		
	B747-400	B777-300ER	A330-300	A330-300	A321-200	B737-800
Short-haul	1,832	2,409	1,053	3,159	1,002	703
Regional-flights	2,692	2,710	1,408	2,960	1,007	735
Continental-flights	3,174	10,666	2,207	-	-	-
Current charge	1,970	1,743	1,053	2,283	830	703