Title: **Landing fee including CO_2 emission cost: an application to Spanish Airport**

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Abstract

The rapid growth in the air transport required to satisfy the increased air travel demand makes the upgrading of airport infrastructure around the world crucial however this also poses a serious environmental problem. Due to the expansion in air transport, the required additional airport capacity may in the near future be unsustainable at a global level. Thus, there is the need to establish an alternative to the traditional airport pricing structure for landing fees, which reflects the true cost that air market operators impose on others. Airport pricing policies must provide a sound guide for future investments, and at the same time they must reflect whether additional facilities are needed and at what price, by taking into account all the generated costs including environmental costs. This paper analyses one application of Ramsey Pricing on uncongested Spanish airport, by considering the CO_2 emission costs as a valuable input.

Keywords: airport, carbon dioxide emissions, landing fees, environmental costs.

1. Introduction

In the near future air travel will grow fast, and it seems necessary to introduce mechanisms to internalize CO_2 emission costs, if climate change is to be managed. Drastic reductions in air travel would be needed to mitigate emissions worldwide, and might be achieved by applying an airport price structure that reflects all cost, related to air travel. The distance travelled and the types of aircraft are the two key dimensions that should be included in the price of this external cost. The users' willingness to pay depends on the distance of the flight, and also determines the type of aircraft. Hence, an emission charge that allows those two elements to be included is required. The paper is organised as follows. Section 2 describes the Ramsey pricing formula in context of external costs. In Section 3 the landing fee structure, including the emission cost as an application of Ramsey Pricing, is estimated for Spanish airports. Finally, Section 4 provides some conclusions.

2. Ramsey pricing rule in presence of external costs

The basic pricing structure for landing in airports in different continents is a weight-based landing fee. The similarity in landing structures around the world has occurred because most countries have adopted the recommendations made by ICAO and IATA to standardize airport charges. However, current weight-related charge may lead to poor utilization of resources, and airport users gaining at the expense of the rest of society. Those who use airport infrastructures impose high environmental costs, in terms of pollution upon others, and they should be charged accordingly. An alternative price structure such as the Ramsey approach allows for the inclusion of external emission costs on the basis of airport users' willingness to pay (Oum and Tretheway, 1988).

Any efficient allocation of airport resources requires the price paid by any user to reflect the costs they impose on others. If the prices reflect the cost, then the level of demand will represent the true demand. However, if the established price is below this cost, it may stimulate extra demand and induce investment in facilities that do not cover their full costs; and at the same time the external cost generated would not be optimal. A key issue in assessing the suitability of airport pricing structures is the degree to which they reflect all the costs. The Ramsey pricing structure is a quasi-optimal solution, since it permits the costs to be covered, but without forgetting the principle of the efficient allocation of an airport's available capacity. It also permits the costs generated by externalities such as congestion, noise and pollution to be included in the tariff structure. Oum and Tretheway (1988) derived the normal inverse elasticity mark-up rule for the Ramsey prices when marginal social costs and marginal private costs differ:

$$\frac{P_i - \lfloor MPC_i + (1/1+\lambda)MEC_i \rfloor}{P_i} = (\frac{\lambda}{1+\lambda}) \cdot \frac{1}{\varepsilon_i} \qquad (1)$$

The mark-up was established by adding marginal private costs (MPC) to a fraction of marginal externality costs (MEC) and it is equal to an inverse function of the elasticity of demand for landing (ε_i). Following on from Morrison (1982) this formula can be rearranged to yield a Ramsey pricing landing fee. The elasticity of demand for landing with respect to the landing fee, is equal to $\varepsilon_i = \eta_i [P_i/(P_i + TC_i)]$; e.g. the absolute value of the elasticity of demand for passenger trips in the *i*th flight multiplied by the fraction of the landing fees that make up the total cost of the *i*th flight, exclusive of the landing fee. By substituting the above expression of ε_i into formula 1, the solution for the price is:

$$p_i = \frac{\left[MPC_i + (1/1+\lambda)MEC_i \right] + (K/\eta_i) \, . \, TC_i}{1 - K/\eta_i} \qquad (2)$$

$$K = \lambda/(1+\lambda)$$

Equation (2) indicates that the landing right depends on the resulting marginal private cost (MPC_i) and a fraction of the marginal external cost (MEC_i) for the *i*th flight. It also depends on the price-elasticity of passenger demand, which is the absolute value for η_i, and on the total cost of the flight (TC_i). The total cost of a flight depends on the size of the aircraft, as well as the flight distance; this is the key to reflecting the true value of the service lies in the size of the aircraft and distance[1]. This is a valuable result, because external costs such as air emission depend on the flight distance and the type of aircraft. So, this price formulation allows us to understand the dimensions of aircraft emission problem. Next, a Ramsey pricing model for uncongested tourist airports is implemented, in order to include air emission costs into the airport pricing structure.

3. Ramsey price estimation including CO_2 emission cost

This section provides an example of a Ramsey pricing model including emission costs for Spanish airport. Formula (2) shows that we need to estimate some of the parameters related to the activity of air travel; they are the marginal private cost of landing at the airport, the total cost of the flight, the external cost, the airfare elasticity and the constant K.

The total cost of the flight for a given type of aircraft and distance can be estimated by multiplying the total operating cost per block hour for that type of aircraft by the number of block hours for the flight:

Total Cost = (cost per block hour) x (number of block hours per flight)

The number of block hours per flight was modelled as a function of the flight distance in the following way. The number of block hours per flight is equal to the average taxiing time plus cruising time. Average taxiing time was estimated by multiplying 0.141[2] with the runway length, and cruising time was calculated by dividing the flight distance by the aeroplane's average cruising speed.

The operating cost per block hour in 2007 for the different types of aircraft that usually fly the tourist routes to Spain from the source countries, and other information subsequently used are presented in table 1.

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[1] The users´ willingness to pay depends on the flight distance.

[2] The constant 0.141 is taken from a study of the average taxiing time for British airport. http://www.dft.gov.uk/consultations/archive/2002/fd/scot/tr/raedb/appendixeappendix2aircrafttil524

Table 1: Aircraft Characteristics (year 2007)

Specifications/aircrafts	**A320**	**A310**	**A340-600**	**B737-700**	**B767-300ER**	**B747-400**
€/block hour	4,032	5,222	7,911	3,740	6,177	11,153
Seats	150	220	380	126/149	269/350	416/524
Maximum take-off weight (tonnes)	73.5	150	368	70.1	186.9	396.9
Average cruising speed (Km/h)	840	850	900	853	851	913
Range (Km)	4,800	8,050	14,360	6,230	11,070	13,450
Maximum fuel capacity (litres)	23,860	61,070	195,881	26,020	90,770	216,840
Fuel efficiency (Litres/Km)	4.97	7.59	13.64	4.17	8.20	16.12

Source: Compiled by the author using data from the Association of European Airlines (AEA) and Airbus and Boeing web pages.

The cost of delay is often used as a proxy for the marginal cost of an air carrier landing at any airport. It also is frequently used in the cost benefit analysis of air traffic management projects, which are expected to increase capacity and therefore reduce the levels of delay in the system[3] (Simakova, 2008). According to AENA[4], the recommended value for marginal private cost to be used in this study was €72. Although the analysis was carried out for different values of marginal costs, there were no significant changes in the pattern of results. The value of K depends on the extent to which the revenue constraint is binding, and in the following analysis we used a value of 0.045. This value was chosen because the fees generated were the same order of magnitude as the weight based fees that are currently charged at Spanish airports. A variety of values of K were used, but the general pattern of results remained the same.

The marginal CO_2 emission cost was modelled as a function of the flight distance plus the emissions in the landing and takeoff cycle (LTO). First, the tonnes of CO_2 emission were estimated multiplying conversion factor, 0.00251 tonnes of CO_2/litres of fuel, to convert the aircraft efficiency in litres of fuel/km into the number of tonnes of CO_2 per km. By multiplying this figure by the flight distance we get the total tonnes of CO_2 per flight:

Tonnes of CO_2 = LTO cycle + [(Fuel efficiency) x (Conversion factor) x (Flight distance)]

The emissions for the landing and takeoff cycle (LTO cycle) were considered equal to 6.5 kg per passenger or alternatively to the available seats (Pearce and Pearce, 2000). To obtain the marginal CO_2 emission cost, the tonnes of CO_2 were converted into euros multiplying it by the marginal external cost of the CO_2.This marginal external cost ranges from €1.10 to €25.70 per tonne of CO_2 (Olsthoorn, 2001). All the papers on the cost of the damage caused by carbon dioxide emissions conclude that climate change is too uncertain to draw conclusions; nonetheless, the average marginal external cost of carbon dioxide emissions that emerges from all the studies is about €80 per tonne of CO_2. However, for practical purposes seems unlikely that the marginal external cost of carbon dioxide emissions exceeded 50% of this value (Tol, 2005).

The price-elasticity for air travel requires more detailed consideration. It has to be said that the values used were estimated by taking several considerations into account. From an economic point of view, the price sensitivity of air travel depends on several factors, such as mode-

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[3] http://www.eurocontrol.int/ecosoc/gallery/content/public/documents/CBA%20examples/Cost%20of%20delay.pdf

[4] Aeropuertos Españoles y Navegación Española.

substitution possibilities, level of income and the distance of the trip[5]. Those factors are correlated, while bearing in mind that a long-distance flight will generally show a smaller number of substitute modes than a short-distance one; this implies an inverse relationship between distance and price sensitivity. Nonetheless, a long-distance flight is more expensive than a short-distance flight, so any cost increase will require a larger share of a passenger's budget. The relationship between flight distance and price elasticity of demand for air travel appears to depend on a number of forces that counteract one another (Brons *et al*, 2002) [6]. The point here is whether the substitution effect prevails over the income effect, or vice versa. One the one hand, as air travel is generally considered to be a discretionary expenditure, and as airfares for long-distance flights form a substantial part of the total travel costs, it seems that the income effect prevails and travellers on long haul segment show higher absolute price elasticity with respect to the flight distance. On the other, for short distance flight substitution effect prevail. Thus, the values used in this study, in absolute terms, range from 1.14 for short haul flight (500 to 3000 Kms) to 1.17 for long haul flight (4000 to 10000 Kms) (Martín-Cejas, 1997; Tol, R. 2007; Pearce and Pearce, 2000).

The Ramsey pricing structure for landing at Spanish airports for different aircraft types flight distances and for marginal external cost per tonnes of CO_2 equal to €25.7 are presented in table 2. As it is apparent from the table, two basic patterns can be noted. First, the landing fees for each type of aircraft increases with distance. This is because all costs (flight and emission cost) rise with the flight distance. In addition, longer flights generate more greenhouse gases than shorter ones. Second, by looking through the rows, it can be seen that as the aircraft size increases the landing fees increase. This is due entirely to the flight-cost effect.

Table 2: Ramsey pricing including CO_2 emission cost (Euros)

Dist. (km)	**A320**	**A310**	**A340**	**B737-700**	**B767**	**B747**
500	386	431	504	376	486	797
1000	586	690	889	576	789	1,317
1500	786	949	1275	776	1,092	1,836
2000	945	1,157	1,588	935	1,335	2,253
3000	1,327	1,652	2,324	1,317	1,914	3,245
4000	1,709	2,147	3,060	1,699	2,492	4,237
5000	3,028	3,833	5,522	3,012	4,461	7,620
10000	5,824	7,455	10,906	5,805	8,695	14,880

The computation of the ratio of Ramsey prices with emission costs to Ramsey prices without emissions showed that by including these costs produce a price penalization ranging from 70% to almost 100% for all planes and distance. First, for any given type of aircraft, the ratio increases with distance. This indicates that the Ramsey prices with emission costs increase with distance more rapidly than the Ramsey prices without an emission cost. Second, for any given distance,

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[5] We can assume two hypotheses for η_i. The first is that it is a weighted average of the price-elasticity of passenger demand for different flight distances aboard the same aircraft. Secondly, the flight distance for all the passengers is identical to the flight distance of the aircraft.

[6] According to Brons et al (2002), the overall mean price elasticity found for a set of case studies analyzed was equal to 1.146, in absolute terms.

the ratio increase slightly as the aircraft sizes increase. This indicates that the Ramsey prices that include emission costs rise with aircraft size, which means that the Ramsey price rule captures the true dimensions of the emission problem; i.e. flight distance and type of aircraft.

The ratio of Ramsey prices to weight-based fees, both including CO_2 emission cost, for each aircraft type and distance, which is shown in table 3, will be used to analyse the relative structure of the Ramsey prices. The fee based on take-off weight was used, because the difference between the take-off and landing weights is fuel; hence the takeoff weight based fees incorporate the relevant dimensions of Ramsey prices, which are size and range.

Table 3: Ratio of Ramsey prices to price based on take-off weight

Dist. (km)	**A320**	**A310**	**A340**	**B737-700**	**B767**	**B747**
500	0.48	0.23	0.12	0.49	0.21	0.19
1000	0.65	0.35	0.19	0.67	0.32	0.30
1500	0.79	0.45	0.27	0.81	0.42	0.40
2000	0.88	0.52	0.33	0.91	0.49	0.47
3000	1.06	0.68	0.45	1.09	0.64	0.62
4000	1.20	0.80	0.55	1.22	0.77	0.74
5000	1.50	1.12	0.83	1.52	1.08	1.05
10000	1.76	1.46	1.19	1.77	1.43	1.40

According the results shown in table 3, two consistent trends are apparent. First, for any given aircraft type, the ratios increase with distance. This indicates that the Ramsey prices increase with distance faster than the weight-based fees. Second, for any given distance, the ratios decrease as aircraft size increases. This indicates that weight-based fees rise too rapidly with size (weight). The introduction of Ramsey pricing would result in decreased fees for small planes on short flight and increased fees for large planes on long flight. Overall, the weight-based fee mispriced the flights.

The welfare gain from the imposition of Ramsey prices will be due to include in landing price structure all cost that international aviation imposes on the rest of the society. The adjustments of the flights which are mispriced under current weight-based system without considering marginal external cost of emission would be higher. Thus, if a reasonable price for the tonnes of CO_2 is achieved and at the landing fee level is enough to restrict inefficient air travel demand then the welfare gains for society will be substantial.

4. Conclusion

Carbon emissions from aviation are an international issue that requires an international solution. An internationally accepted airport landing fee, such as Ramsey pricing structure, has been shown to be a reasonable approach to internalizing the aviation industry’s carbon emission costs. On the one hand, it is an unambiguous way to overcome the problem of allocating the responsibility for greenhouse gas emissions between the source and destination countries. On the other hand, it must be borne in mind that this is a progressive taxation system, because the air transport users who choose air transport to get to a distant destination are more willing to pay the cost they impose upon the rest of the society. Ramsey price structure has to be applied globally rather than regionally, as this would to avoid a situation whereby a taxed air market loses out to a non-taxed region.

Finally, it must be said that, without the imposition of carbon pricing to suppress demand for international flights, it is unlikely that greenhouse gas emissions from international aviation would have stabilized at the 2005 levels (this requires an average annual 1.9% reduction in emissions), or decreases to below 850 Mt of CO_2 by 2025. To stabilize international aviation emission at levels consistent with the targets for climatic change without restricting demand is an extremely difficult task.

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