European Transport \ Trasporti Europei n. 32 (2006): 114-135

Evaluating different pricing policies on social welfare: an application to Madrid Barajas

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Abstract

In this paper, we assess the potential impacts of different airport charges schemes that can be applied in Madrid Barajas airport. We use a model that has already been applied in the literature to calculate the social welfare of the different price regimes. The term social welfare refers to the social welfare generated from only aeronautical services, while the social welfare created from non-aeronautical activities will not be discussed here. We define, as is common in the literature, that the social welfare is the sum of consumer surplus and producer surplus. We analyze the potential impact of different pricing policies using the values obtained on social welfare, and using the concept of 'potential loss of social welfare' when the lack of adequate capacity preclude the potential demand from using the airport. Thus, we evaluate the "losses" or "gains" of each alternative pricing policy. Our results may contribute to the on-going debate in Madrid and around Europe about the merits of adjusting airport charges to different scenarios, e.g. congestion or lack of capacity or excess of capacity, in which airports are usually involved.

Keywords: Airport regulation; Social welfare; Airport pricing policies.

Introduction

Barajas airport is the principal gateway of the Spanish airport system. In 2003 it moved a total of 35 million passengers, and accounted for 27% of air traffic between the EU and South America. Some analysts have foreseen that future air deregulation in Europe, the United States of America and Asia will continue to put pressure on the Spanish airport system. In the face of this situation, the government has given high priority to airport infrastructure expansion plans. The capacity expansion programme for Barajas airport will change the present capacity of 80 air traffic movements per hour up to 120 air traffic movements in two different phases. The first one will increase the capacity up to 100 movements and it is expected to be finished at the beginning of winter 2005, the second one will definitely increase the capacity up to 120 movements and new aircraft could land and take-off at the beginning from the winter 2006. At the

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opening of the new facilities, Barajas airport will have a design capacity of 80 million passengers per year with four runways and four passengers' terminal buildings.

A brief characterization of the air traffic at Madrid airport would read as follows: strong domestic linkages with simultaneous concentration of passenger volume on the main routes, primarily the routes to and from Barcelona, and other domestic routes to some industrial or tourist cities of Spain being Iberia the principal incumbent airline; strong European Union traffic less concentrated than the domestic one but with important linkages with the principal capital cities of Europe, in which Iberia share its incumbent role with other former flag carriers such as British Airways, TAP, KLM and Air France; and finally the densest intercontinental traffic is highly specialized in the trans-Atlantic routes to the United States and Latin America, with Iberia again the principal incumbent airline in this market. It is against this background that the airport authorities of Spain (AENA) have planned the most ambitious expansion programme that would allow the airport to double its present capacity.

In this paper, we study the impacts of slot allocation and slot pricing. We study these issues applying a model that has already been used in the literature (Starkie (1998), and Zhang and Zhang (1997)). We define, as is common in the literature, that social welfare is the sum of consumer surplus, producer surplus, government revenue and externalities, and we analyze the potential impact of different pricing policies using the values obtained on social welfare, and using the concept of 'potential loss or gains of social welfare' developed by Lu and Pagliari (2004) when the lack of adequate capacity preclude the potential demand from using the airport.

We compare distinct pricing policies, such as the optimal airport charge ("first best prices"), "second best prices" in which the financial constraint of cost recovery is considered for each period, and the "market clearing prices", in which airport capacity is used at its maximum levels, and actual prices. Our results should contribute to the on-going debate in Madrid and around Europe about the merits of adjusting airport charges to each situation in which airports may be involved.

Slot allocation and pricing

Insufficient runway capacity cause major airports delay problems around the world. Disequilibrium between capacity and demand has been explained by failure to properly price runway use. Charges at most airports are proportional to aircraft weight and invariant with respect to time of day. This practice disincentives airlines to consolidate traffic onto large planes, and also ignores the loss in capacity that comes from the greater in-trail separation requirements and slower approach speeds of small aircraft.

Airport slot allocation is necessary when demand for airport's services exceeds its capacity. This may be resolved in different manners, through congestion causing important economic inefficiencies, or through more efficient mechanisms to allocate the scarce capacity, such as slot auctions. Slot allocation issues have been discussed greatly in the literature, while these issues are really important it is necessary to take into account the strong links that exist between slot allocation and slot pricing mechanisms. Many airports have been privatised and subsequently disposed to regulation to avoid the exertion of monopoly power. Price regulation restrains the levels of prices an airport may charge, and for this reason it may not be possible to rely entirely on price mechanisms to ration the airport capacity.

Levine (1969) argues that pricing is a better means of allocating scarce airport capacity than other mechanisms being considered at the time, such as slot allocation. Carlin and Park (1970) estimated the marginal delay costs at various airports, concluding that in many cases these exceed actual charges by a factor of 10. Morrison (1983) computed optimal landing charges and investment levels at several US airports, finding similar disparities between actual charges and short-run marginal costs, but somewhat smaller ones when long-run marginal costs (which assume optimal runway capacity) are considered.

Doganis (1991) examines the impacts of peak pricing at London Heathrow Airport on airline schedules, finding that changes in the time period when peak charges were in effect resulted in the anticipated shift in flight schedule. Barret et al. (1994) considers the effect of a hypothetical peak-period pricing scheme –in which all capacity-related airline costs are allocated to peak period operations- on airline schedules for Boston's Logan Airport. They argue that effects on jet airline schedules would be negligible because the cost differences would be less than $1.00 per passenger. Commuter flights, on the other hand, would face substantial increases in cost per passenger during peak periods, which would in some cases lead to flight cancellations. Altogether, they estimate that the proposed pricing scheme would decrease peak period flights by 7 percent but peak period seats by only 3 percent. Daniel (1995), focusing on hub airports where flight schedules of arrivals and departures are more complex, proposes a bottleneck model (as originally proposed by Vickrey (1969)) in which airlines trade delay against the cost of scheduling flights away from peak times. The model assumes that, in the absence of differential pricing, the sum of delay and schedule deviation cost is equal throughout the peak. Adding a fee that reflects external congestion costs (as estimated using a stochastic queuing model with time-dependent demand) induces a more even schedule and a 50 percent reduction in delays. Hansen (2002) analyzed runway delay externalities at Los Angeles International Airport (LAX) using a deterministic queuing model. The model estimates the delay impact of each specific arriving flight on each other specific arriving flight. He found that, despite being only moderately congested (average queuing delay only 4 min per arriving flight), individual flights can generate as much as 3 aircraft-hours of external delay impact on other flights, with an average impact of 26 aircraft-minutes and 3400 seat-minutes. About 90 percent of this impact is external to the airline as well as the flight, a consequence of the lack of a dominant airline at LAX. He also compared the delay impact of each individual flight to its contribution to schedule convenience by determining the amount of ''schedule delay'' that would result if the flight were eliminated and its passengers forced to use the previous flight flown by the same airline from the same origin, finding that a number of commuter flights serving high density, short-haul segments generate much more queuing delay than they save in schedule delay, with the ratio exceeding 10 in several cases. Thus, he argued that social welfare would increase if such flights were eliminated, upsizing others as necessary to accommodate the displaced loads.

It is relevant to mention that current slot allocation schemes are really controversial, and airport charges that cleared the market for landing slots are frequently invoked as a better mechanism to promote more efficient outcomes.

However this issue is not exempt from criticisms, because it is not necessarily true that airport operators are the best option to reap the scarcity rents, and other important facts are not analyzed in this context, such as, congestion externalities and revenue complementarities for non-aeronautical activities.

Madrid Barajas airport

This section discusses recent traffic trends at Madrid Barajas International Airport (MAD) and their implications both for the role that slot pricing could have played in the year 2004 and the potential for changes in social welfare due to different price policies or scenarios. The section first addresses the overall trends in traffic by type of carrier, then it examines three specific markets in more detail (domestic markets served predominantly by national airlines, Iberia and Spanair, traffic in the European Union, and the rest of international air traffic markets). These markets have been selected for more detailed examination because of their importance for different types of regulation.

The national airlines operate the smallest aircraft, and a relatively small proportion of the total passenger traffic at the airport is carried by large aircraft operations. Clearly, a significant change in average aircraft size by regional airlines could have a big impact on the total number of operations. Spanish domestic markets are characterized notably both for the high volume of traffic and the high frequency of service. At the same time, they are typically operated with relative small aircraft, of the order of 91 passengers per air traffic movement. Accommodating traffic growth in these markets through increases in average aircraft size would still provide frequent service while reducing the growth in aircraft operations, especially at certain hours of the day. Finally, there is considerable discussion in the industry about the future prospects for new large aircraft, with seating capacity greater than the current Boeing 747-400 (e.g. Franke, 2004; O'Connor, 2003). Such aircrafts are most likely to be deployed on very long haul international services, such as the trans-Atlantic markets, where stage lengths favour larger aircraft and time-zone differences create limited time windows for efficient service, which reduces the frequency advantages of using smaller aircraft[1]. In fact, it is also important to recognise that a small number of global gateway cities will remain the dominant feature of this trans-continental market. For the year 2000, the airports in three city-regions, London, New York and Chicago, accounted for more than 30% of the total passenger movement through the trans-Atlantic market. The continued role of these big city regions will keep the development and management of airport infrastructure at the forefront of airport planning in the immediate future. However, the introduction of large capacity planes, like new Airbus 380, may break this observed trend. In this sense, the Spanish airport authority AENA considers that Madrid Barajas may play an important role in the near future.

The growth in passenger traffic at MAD, since 1970, shows that all market segments have experienced traffic growth including international, European Union and domestic

[1] Franke (2004) sustains that for the short and medium term future, it would seem impossible for a reasonable intercontinental destination portfolio to be served without a hub. To fill an Airbus 380 and benefit from its huge unit cost advantages, a carrier still needs to bundle demand for one destination from several origins. Furthermore, passengers accept transfers on intercontinental rather than continental trips. Since major carriers can operate intercontinental routes on a profitable basis, hubs (and thus hub-and-spoke carriers) will remain. Nonetheless, the author also anticipates that down-sizing and reshaping of the hub-and-spoke landscape is probable.

traffic. Less obvious perhaps is the fact that different patterns of growth are observed through this period of time, for example some passenger traffic of new entrant domestic airlines, such as Spanair and Air Europa have also grown faster than the domestic traffic of the incumbent large airline Iberia. For convenience in discussion, and to conform to common industry terminology, the large airlines will be referred to as air carriers (Iberia, Air France, Spanair and Air Europa), as distinct from the regional airlines, such as Air Nostrum.

As expected, the average number of passengers per air carrier and regional airline operation varies significantly between the different markets (domestic, European Union and international operations), as shown in Table 1. International operations include both long-haul flights to other European countries not included in the European Union and flights to Canada, Asia, the United States, Africa and Latin America, which typically use similar aircraft to those used in some European Union operations. In consequence, the average number of passengers per international operation lies between 140 and 200, and are above 200 for trans-oceanic international flights. The average number of passengers per operation for Madrid-Barcelona for Iberia has been 105 for the year 2002. The average number of passengers per operation for other domestic traffic has shown figures between 93 for the pair Madrid-Bilbao for Iberia and 160 for the pair Madrid-Las Palmas for Iberia.

Table 1: Average Passengers per Operation (APO) from/to Madrid (2002).

Airline	*Airport*	*APO*
Iberia	**New York**	**207**
Iberia	**Havana**	**305**
Iberia	**Buenos Aires**	**286.8**
Iberia	**Tenerife**	**194.33**
Iberia	**Bilbao**	**93.71**
Air Europa	**Barcelona**	**112.41**
Iberia	**London**	**133.38**
Iberia	**Paris**	**108.56**
Air France	**Paris**	**92.46**
Iberia	**Las Palmas**	**160.53**
Iberia	**Malaga**	**131.36**
Spanair	**Barcelona**	**92.61**
Iberia	**Barcelona**	**105.21**

Source: Martín J.C. and Betancor, O. (2004).

If we examine the results for the year 2002, in terms of traffic for the ten largest airline markets for each type of traffic (see Tables 2-4), it can be seen that all but three of the largest thirteen markets, are domestic markets, connecting Madrid with Barcelona, Las Palmas, Bilbao, Malaga, Palma de Mallorca, Alicante and Vigo. The three exceptional markets are routes to important European Union markets such as Paris and London. Therefore, it can be seen that location in these transport market matters. Table 2 shows the largest domestic markets in the year 2002. It can be seen that Iberia dominates most of this densest markets, and Air Europa and Spanair serve three of the largest domestic markets that connect Madrid with Barcelona and Palma de Mallorca. Another remarkable element of Table 2 is the level of importance that the domestic market between Madrid and Barcelona represents. In total, this route represents more than 25 per cent of the total domestic traffic in Spain[2].

Table 2: Domestic Airline Traffic and Market Share in the Largest Domestic Airline Markets from/to MAD.

Airline	Airport	Passengers	Market Share
Iberia	**Tenerife**	**382849**	**2.6%**
Iberia	**Valencia**	**386820**	**2.6%**
Iberia	**Vigo**	**401379**	**2.7%**
Air Europa	**Palma de Mallorca**	**414050**	**2.8%**
Iberia	**Alicante**	**437884**	**2.9%**
Iberia	**Palma de Mallorca**	**450122**	**3.0%**
Iberia	**Bilbao**	**459821**	**3.1%**
Air Europa	**Barcelona**	**464125**	**3.1%**
Iberia	**Las Palmas**	**601843**	**4.1%**
Iberia	**Malaga**	**693033**	**4.7%**
Spanair	**Barcelona**	**809327**	**5.4%**
Iberia	**Barcelona**	**2112845**	**14.2%**

Source: Martín and Betancor, (2004).

With respect to European Union traffic handled by the air carriers (see Table 3), two characteristics are of importance: first there are no secondary airports in the largest routes, and second Iberia is still the incumbent airline but other former flag carriers and new entrants, such as Virgin Express compete fiercely with it in some markets. Table 3 also shows that the importance of these largest routes is inferior to the one observed for in the domestic traffic, that is the domestic traffic is more concentrated around the largest routes than the European Union traffic. It also seems less convincing that HSTs could compete in these markets in the near future. Another important feature that can be noted is the loss of competitive force as a consequence of the formation of the Oneworld alliance. Tap, Iberia and British Airways are under the development of code-

[2] The European high-speed train network is currently at a medium stage of development, with a limited number of mainly unconnected lines, but a number of new links are planned in order to complete an European high-speed train network as part of the trans-European Transport Network. One of these planned links is the Madrid–Barcelona–French border line, which is currently under the last phase of construction. In fact, the new line is nowadays operative between Madrid and Lleida. Madrid–Barcelona services will run at up to 350 km/h, so that travelling times between the main cities on the corridor will be significantly reduced. It is difficult to anticipate the effects of the opening of this new line in the modal split between these two important cities of Spain. The potential for high speed trains (HST) modal shift was first demonstrated by France's TGV, which reportedly captured as much as 90% of the Paris–Lyon market. In Spain, the AVE service has over 80% of the Madrid–Seville market, compared to the 33% share held by conventional rail in 1991 (CAA, 1998).

sharing agreements that can affect the consumers' surplus in these ten largest markets in the European Union.

Table 3: EU Airline Traffic and Market Share in the Largest EU Airline Markets from/to MAD.

Airline	*Airport*	*Passengers*	*Market Share*
TAP	**Lisbon**	**222573**	**2.4%**
Virgin Express	**Brussels**	**232363**	**2.5%**
Air Europa	**Paris**	**236901**	**2.6%**
Iberia	**Amsterdam**	**275152**	**3.0%**
Iberia	**Brussels**	**287067**	**3.1%**
Iberia	**Lisbon**	**294199**	**3.2%**
British Airways	**London**	**333755**	**3.6%**
Iberia	**Rome**	**343940**	**3.8%**
KLM	**Amsterdam**	**344228**	**3.8%**
Iberia	**London**	**482173**	**5.3%**
Iberia	**Paris**	**513705**	**5.6%**
Air France	**Paris**	**526761**	**5.8%**

Source: Martín and Betancor, (2004).

Table 4 shows that the largest international markets by far are related to the trans-Atlantic routes to the United States or to Latin America. The same patterns observed for the above markets are still present, that is, Iberia is by far the incumbent airline on these markets and the international traffic is less concentrated in these largest routes. The figures that appear in Tables 2-4 are usually referred to as segment traffic. The distinction between market traffic and segment traffic is usually important when figures of connecting passengers are not negligible. Market traffic counts passengers boarding at some origin airport and alight at some destination airport, irrespective of how many stops passengers have made. In this way, it is possible to count passengers that have made the trip directly, or with one or more stops. Segment traffic counts passengers on board nonstop flights, and includes passengers who are traveling on the same flight but perhaps with different origin or destination. Connecting passengers traveling to/from MAD represent an insignificant proportion of the total of passengers for most of the routes except for some long distance routes in Latin America.

In summary, a brief characterization of the air traffic at MAD would read something like this: strong domestic linkages with simultaneous concentration of passenger volume on the main routes, primarily the routes to and from Barcelona, and other domestic routes to some industrial or tourist cities of Spain being Iberia the principal incumbent airline; strong European Union traffic less concentrated than the domestic one but with important linkages with the principal capital cities of Europe, as the airport is highly congested no secondary European airports present dense routes and Iberia share its incumbent role with other former flag carriers such as British Airways, TAP, KLM and Air France; and finally the densest intercontinental traffic is highly specialized in the trans-Atlantic routes to the United States and Latin America being Iberia again the principal incumbent airline in this market. It is against this background that the Spanish airport authorities (AENA) have planned the most ambitious expansion programme that would allow the airport to double its present capacity.

Table 4: International Airline Traffic and Market Share in the Largest International Airline Markets from/to MAD.

Airline	*Airport*	*Passengers*	*Market Share*
Air Europa	**Havana**	**123892**	**2.1%**
Continental	**New York**	**129460**	**2.2%**
Iberia	**Lima**	**132360**	**2.3%**
Iberia	**New York**	**144659**	**2.5%**
Iberia	**New York**	**145800**	**2.5%**
Iberia	**Miami**	**152079**	**2.6%**
Iberia	**Mexico**	**182976**	**3.1%**
Iberia	**Havana**	**185736**	**3.2%**
Aerolineas Arg.	**Buenos Aires**	**198173**	**3.4%**
Iberia	**Buenos Aires**	**206215**	**3.5%**

Source: Martín and Betancor,(2004)

Different pricing policies at Madrid Barajas

Doganis and Nuutinen (1983) classified the services provided by an airport into two broad categories: aeronautical and non-aeronautical activities. The revenues from aeronautical services mainly encompass aircraft landing, parking and passenger charges, while revenues from all other sources are classified as non-aeronautical. The single-till approach takes not only aeronautical but also non-aeronautical revenues and costs into account to determine the level of aeronautical charges. The corresponding asset base comprises all airport assets regardless of their functions and characteristics. There may be cross-subsidies by revenues from non-aeronautical activities to cover the deficits from aeronautical services if a single-till approach is adopted. In other words, aeronautical charges could be set at a relatively lower level because of the existence of such cross-subsidies.

Conversely, the dual-till approach separates aeronautical activities from non-aeronautical ones. It determines the level of aeronautical charges by considering aeronautical revenues and costs only. Consequently, the corresponding asset base includes aeronautical assets only. Cross-subsidies are not permitted under this regulatory scheme. Aeronautical charges will be set at a relatively higher level under a dual-till approach than under a single-till approach.

There is a large body of literature on airport pricing and cost recovery. Useful references include Levine (1969), Carlin and Park (1970), Walters (1973), Morrison (1983, 1987), Gillen et al. (1987), Oum and Zhang (1990), Oum et al. (1996), Zhang and Zhang (1997), Zhang and Zhang (2001) and Zhang and Zhang (2003).

Morrison (1983) showed that if capacity is divisible and costs are homogeneous in volume/capacity ratio, then social-marginal-cost pricing leads to exact cost recovery for the airports. Oum and Zhang (1990) showed that if capacity is lumpy, then social-marginal-cost pricing would not guarantee cost recovery for the airport. Zhang and Zhang (1997) considered the effects of concession operations by the airports in a setting where capacity is divisible but social costs are not homogeneous in volume/capacity ratio. Zhang and Zhang (2001) obtained the optimal Ramsey prices, i.e., the mark-up of airport charge over the social-marginal-cost as a percentage of the full price that is inversely related to the demand elasticity[3].

First of all, it has already been discussed that there are only two groups of airport services: aeronautical and non-aeronautical services, each of which has specific aggregate demand and cost functions, and it is not difficult to anticipate that there are important complementarities between both activities[4]. In this section, we are going to follow a model that has already been used in the literature (Starkie (1998), and Zhang and Zhang (1997)). The term social welfare refers to the social welfare generated from aeronautical services only, while the social welfare created from non-aeronautical activities will not be discussed here. We define, as is common in the literature, that the social welfare is the sum of consumer surplus and producer surplus. We will analyze the potential impact of different pricing policies using the values obtained on social welfare, and using the concept of 'potential loss of social welfare' developed by Lu and Pagliari (2004) when the lack of adequate capacity preclude the potential demand from using the airport. Social welfare generated from aeronautical services during hour i can be calculated as:

$$SW_i = \begin{cases} \int_0^{q_i} P_i(q) - P_i \, dq + P_i q_i - c q_i - r K_i & if \quad q_i \le K_i \\ \int_0^{K_i} P_i(q) - P_i \, dq + (P_i - c - r) K_i & if \quad q_i > K_i \end{cases} \qquad (1)$$

Where

- $P_i(q)$ is the willingness to pay (or utility) of airlines using aeronautical services when q units of aeronautical services are consumed during hour i;
- P_i is the price charged for a flight using aeronautical services during hour i;
- q_i is the demand (the number of flights) for using aeronautical services when price is set at P_i during hour i;

[3] The authors also considered the situation where the demand for air traffic has a positive trend in the long run, and showed that the average airport charge will decline as the traffic increases over time in the long run. However, they argued that this situation is undesirable. The reason is clear: as the demand is low and the airport has excess capacity, airport charges are high while as demand increases and congestion builds up, airport charges are low. Putting it simple, they showed that when there is an excess capacity in the airport, the airport charge is above the social marginal cost, which would discourage an optimal use of the airport. However, when demand is approaching capacity, the airport charge will be below social marginal costs, which would encourage additional traffic that creates economic inefficiencies. In a sense, the users of the under-utilized airport are subsidizing the users of the congested airport.

[4] In fact, Beesley (1999) argued that the existence of important complementarities between aeronautical and non-aeronautical activities at major airports provides an adequate incentive for dominant airports to increase their output beyond the level that one would expect from profit-maximization behaviour obtained only from aeronautical services.

- c is the unit operating costs of providing each unit of aeronautical services;
- K_i is capacity of aeronautical services during hour i; and
- r is the capacity costs of providing each unit of aeronautical services.

We assume that total capacity of airport aeronautical services for the economic life is fixed for each hour i. It is clear that due to externality constraints, the majority of airports impose some capacity limitations during the night hours and for this reason capacity may depend on the hour i considered. If we do not regard K_i as a fixed capacity (e.g., when a new runway is built), unit operating costs and capacity costs, c and r, may not be regarded as parameters of the model. If the number of flights using aeronautical services during hour i is less than capacity, the airport still has to spend capacity costs, r times K_i, to provide (and maintain) a certain level of quantity and quality of aeronautical services. Capacity costs may include fixed costs to build runways, passengers' terminal buildings and taxiways, their depreciation and interest costs.

Below, we will develop alternative airport pricing schemes that are linked to different conceptualizations of the objectives of the aeronautical services function. First, we will consider the case of a publicly owned airport whose objective is to maximize social welfare without any financial constraint[5]. Second the conceptualization of the "second-best" situation will be developed. In this case, the airport is subject to a short-run break-even financial constraint, i.e., the airport cannot receive any subsidies of the regional economy or they are not allowed to exploit profits beyond reasonable returns on aeronautical services. So the financial break-even situation is achieved period by period. And finally we will also employ the concept of the 'market-clearing price', where the airport tries to reach a situation where capacity is fully utilized. Thus, the market-clearing price is the price at which demand is equal to the level of available airport capacity (CAA, 2002a). Setting aeronautical price at the market-clearing level ensures that airport users who are willing to pay the market-clearing price will obtain access to aeronautical capacity[6], and that all capacity will be consumed.

We will calculate the prices for each period of time for the different alternative pricing schemes and compare their gains (losses) in social welfare with respect to the pricing policy that was applied in the year 2002 by the Spanish airport authorities of MAD. We will also try to anticipate if some pricing policies based on single-till or dual-till approaches may be possible under each scenario.

In Fig 1-3, we represent the different situations that can be obtained when we calculate the market-clearing prices. D is the demand curve for aeronautical services, the x-axis and y-axis are the output level (the number of aircraft movements) and the price level of aeronautical services respectively. We have obtained the charts of the notice of airport capacity for the different days of the week for MAD during the summer season of the year 2002, thus we have obtained 168 pairs (P_t, Q_t) corresponding to the seven days of the week and the 24 hours of each day. For the majority of the hours of the weekdays, we have seen that the potential demand is higher than the capacity. This situation is shown in Fig. 1, where slots are allocated following IATA guidelines. Under this allocation, there is no guarantee that slots are used by those airlines that value them most. The lower the aeronautical price, the more scarcity will prevail and it is more

[5] This is the well-known situation called "first-best", where price is equal to operating marginal cost.

[6] We will see below that this 'market-clearing price' may imply airport-subsidies to airlines due to the position of the demand curve for some periods of time.

likely that low-slot-valuation airlines could prevent high-slot-valuation airlines from obtaining slots implying some potential loss of social welfare. This outcome can result in substantial allocative inefficiency and subsequently reduce the level of social welfare. An efficient allocation of airport resources requires the price paid by any user to reflect the costs. In this situation, prices are not reflecting the "scarcity costs", some airlines are purchasing particular airport services because they have obtained some privilege but they do not value them as highly as the opportunity cost of this scarce slots reveal[7].

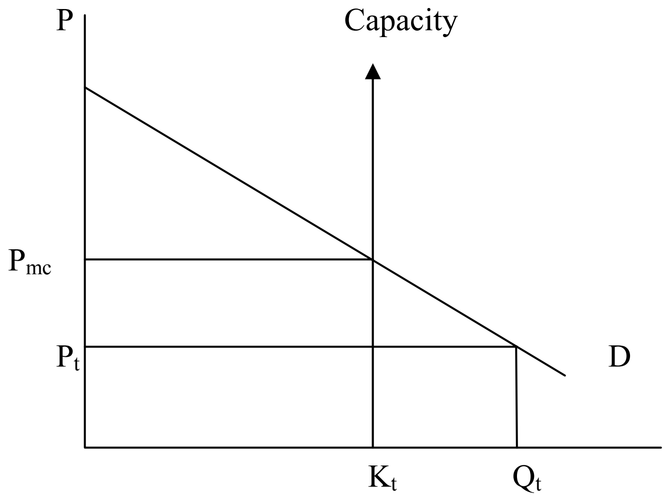

Figure 1: Market Clearing Prices. Situation of Scarcity in MAD.

During certain hours of some days, especially during weekends, the situation is better reflected by Fig. 2 and Fig. 3. In these situations, the scarcity costs are low or important excess of capacity exists. However, these situations share one common feature; the prices are higher than the first best prices. In order to obtain social welfare gains, it would be necessary to reduce the prices in both cases. It can be said that there is a cross-subsidisation by revenues from these periods of time to cover the allocative deficits created in the situation discussed above, where the scarcity costs are really important because aeronautical charges have been set at a relatively low level. Accordingly, if the market mechanism based on demand and supply were at work, the equilibrium price of using the airport would need to be raised to the price needed to recoup the scarcity cost. In effect, as traffic exceeds the capacity of the airport, scarcity costs at the airport become an issue. This would allow many busy airports in the world to levy the so-called "peak-hour" surcharge. The purpose of this surcharge is twofold. Firstly, it would be possible to reduce the scarcity costs as the surcharge discourages demand for aeronautical services during busy hours when capacity has been reached. Secondly, the surcharge will produce extra benefits and reflect in a better way the real opportunity costs of slots, giving the correct signal to airport authorities for future expansions of airport capacity.

[7]Inefficient outcomes may be avoided if airlines who value the airport access the most get the scarce slots. For example, suppose that a Boeing 747 passenger jet operator values the right to land at 08:00 a.m. on Monday morning at €10,000 and some freight operator would also like to land at the same time values the access at €2000, then it would be socially more efficient to allow the B747 rather than the freight aircraft to land.

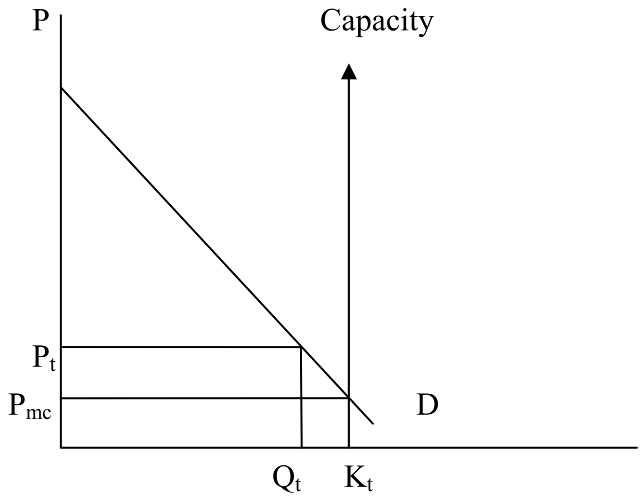

Figure 2: Market Clearing Prices. Situation of Moderate Scarcity in MAD.

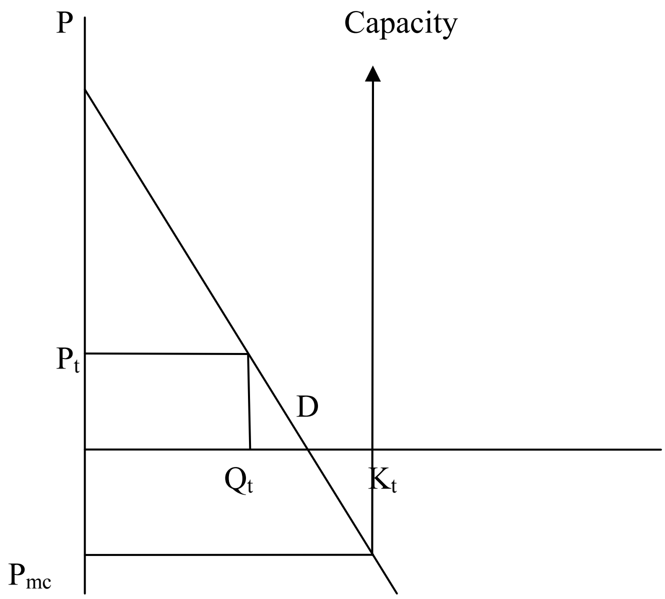

Figure 3: Market Clearing Prices. Situation of Excess Capacity in MAD.

In summary, we look at different airport charges schemes and cost recovery policies where the capacity divisibility is not assumed. In this more general setting, we will study the optimal airport charge ("first best prices") with other pricing policies, such as "second best prices" in which the financial constraint of cost recovery is considered for each period, comparing "market clearing prices" in which airport capacity is used at its maximum levels and actual prices. As discussed below, our results should contribute to the on-going debate in MAD and around Europe about the merits of adjusting airport charges to each situation in which airports may be involved. We will take into account the actual controversy about the merits of different price regulation with respect to the single-till or dual-till approaches.

The data

We have been assisted by the Directorate of Slots Coordination in MAD in terms of data collection. The Directorate of Slots Coordination is the main coordinator for Spanish airport authority AENA and is in charge of the allocation of airport slots in accordance with Council Regulation (EEC) 95/93. The data presented in this section are based on slots requested and allocated as part of the biannual schedule coordination process.

Capacity at MAD is reviewed twice yearly in advance of each scheduling season (winter and summer seasons). Capacity is assessed against an agreed average delay criterion. The process involves simulating the impact on average delays of adding additional slots at particular times of day. Where the additional slots do not result in a breach of the delay criterion, they are made available for allocation.

Table 5: Madrid Runway Capacity: Slots per Hour-Winter 2003.

Local time	*Arrivals*	*Departures*	*Total*
0:00	20	20	40
1:00	20	20	40
2:00	20	20	40
3:00	20	20	40
4:00	20	20	40
5:00	24	20	44
6:00	40	40	80
7:00	40	40	80
8:00	40	40	80
9:00	40	40	80
10:00	40	40	80
11:00	40	40	80
12:00	40	40	80
13:00	40	40	80
14:00	40	40	80
15:00	40	40	80
16:00	40	40	80
17:00	40	40	80
18:00	40	40	80
19:00	40	40	80
20:00	40	40	80
21:00	40	40	80
22:00	24	20	44
23:00	20	20	40
Total	808	800	1608

Source: Martín and Betancor, (2004)

This process has resulted in a declared runway capacity that can be seen on Table 5. During the winter season of 2003, the number of daytime (06:00 - 22:59) slots available each day achieved the figure of 1364. The same capacity has been declared since summer 2001. The number of slots per hour generally varies around 40 arrivals and 40 departures, with the following exceptions:

Arrivals in the 05:00 – 05:59 and 22:00 – 22:59 periods are limited to 24 slots. This is largely due to the fact that environmental constraints on aircraft arriving at this time are applied.

Departures in the 05:00 – 05:59 and 22:00 – 22:59 periods are limited to 20 slots. This is largely due to the same environmental constraints.

Arrivals and departures in the 23:00 - 04:59 period are limited to 20 and 20 slots respectively. This is partly due to lower demand at these times and the prevalence of the Night Quota Period (23:30 – 06:00). Significant increases in capacity in these hours are likely to result in an unacceptable increase in unplanned aircraft movements during this Night Quota Period due to neighbouring vicinities annoyance. The number of permissible movements at night is strictly limited by a task group and the quota is already proving very controversial.

Demand for MAD slots exceeds capacity by some variable margin for most part of a weekday. However, during weekends the demand does not usually exceed capacity. Over the 06:00 - 21:59 period, demand exceeded total capacity by 16% in a typical week for the summer 2002 season. Figure 4 below shows the detailed demand vs. capacity for a typical Tuesday. In this figure the extent of excess demand is clearly illustrated reinforcing the idea of MAD airport planners that the expansion capacity programme was required.

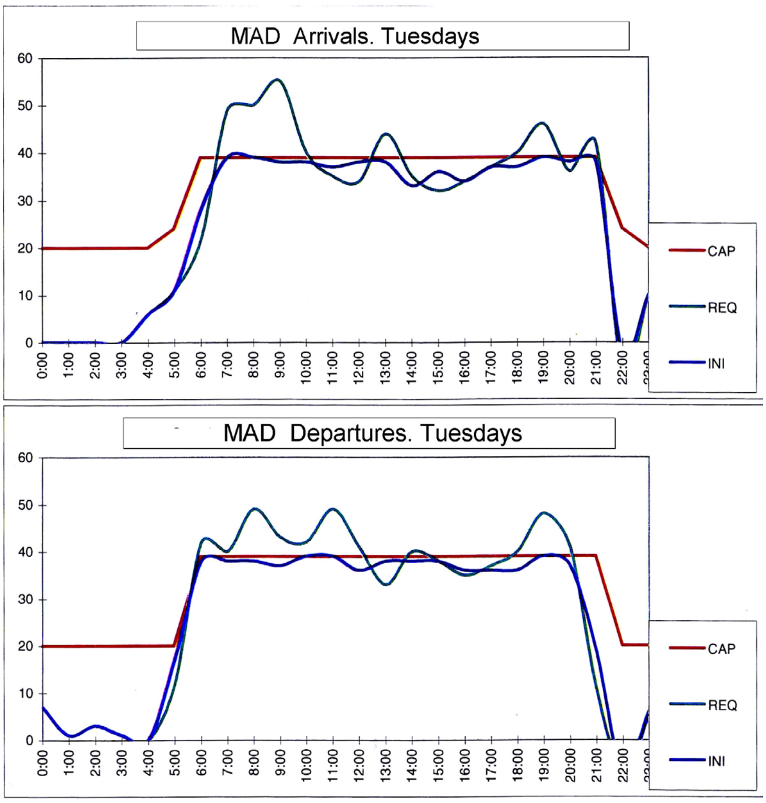

Figure 4. Slot Demand vs. Capacity by hour in MAD.

The degree of excess demand for runway slots results in a high level of capacity utilization during the 06:00 - 21:59 period. The allocation data used here is based on a typical week in the summer 2002 season after the industry slot return deadline of 31st January 2002. This is the date by which airlines finalize their planned schedules.

Based on the above analyses of capacity, patterns of demand and the resultant scarcity of runway slots at MAD, we will calculate the market-clearing prices for each period of time of the day. We will make some assumptions about the demand function for aeronautical activities. The functional form and the elasticity of the demand are the most critical points. There are not many studies analyzing the elasticity of the demand for aeronautical services. Kanafani and Ghobrial (1985) estimated that the elasticity of demand for flights was between -0.148 and -0.38, while in Australia, it was estimated to fall in the range of -0.1 to -0.225 for interstate flights in the early 1990s (CC, 2002). In our case, we will suppose that the demand function is linear and that the elasticity of the demand is -0.15.

Doganis (2002) points out two reasons why demand for aeronautical services is so inelastic. First, aeronautical charges represent only a small part of an airline's total operating costs (generally less than 8% for intra-European routes and 4% for trans-Atlantic routes). However, the ratio of aeronautical charges to total operating costs varies from 7.8% to 13.2% for low-cost carriers. For this reason, using price mechanisms to allocate scarce capacity may more strongly affect these new low-cost carriers. Therefore, such policies may have unanticipated consequences on competition. There can also be equity implications as this approach will affect consumer groups differently. It is more likely that some low-dense or leisure routes (that are serviced by low-cost carriers) suffer an increase in aeronautical charges differently from other routes that are serviced by global incumbent carriers.

A 50% reduction in aeronautical charges at one end of the route would cut only 2% of total operating costs for intra-European routes and 1% for trans-Atlantic routes. Secondly, airlines' decisions on operating a route from and into the airport are primarily dependent on the level of anticipated demand for that route but not on the level of aeronautical charges. Therefore, if the above two examples prevail, price mechanisms to allocate scarce capacity may not be an effective option. However, it may be a better option if funding is provided to invest in additional capacity in order to reduce the scarcity costs created for a highly busy airport.[8]

Crew et al. (1995) provide an interesting note about the fact that, in airports, peak and off-peak prices have not had the expected effects on demand shifting because of the level of persistence of non-price mechanisms, such as grandfather rights. These authors argue that the impact of the price mechanisms on demand shifts would be quite small as long as these rights prevail, and that only overall reforms on slot trading may provide a basis for applying efficiently any type of price mechanism. Their concerns certainly satisfy the equity considerations that have been explained above.

In order to calculate first-best prices and second-best prices, we also need some information about the aeronautical charges and costs of the airport. The model shown in equation 1 uses the aircraft movements as the output variable, and it considers that airports operate under constant returns to scale[9].

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[8] Funds for new airports expansion projects are provided by AENA.

[9] Pels et al. (2003) showed that if air traffic movements are considered as the output, then the average airport of a sample of European airports is operating under constant returns to scale and under increasing

MAD bases its charges on the IATA guidelines and applies a maximum take-off weight (MTOW) price, which classifies the aircraft according to the weight and the type of market. It distinguishes three different weights (small, medium and heavy) and three different types of market (Domestic, European and International). The airport discriminates by these groups but it applies a uniform price during the 24 hours of the day. There is not any surcharge by peak time or night time or noisy aircraft. There is a large range of charges for different services like parking, aerobridge use, etc., but movements and handling charges are the most important ones.

Aircraft characteristics have an important impact on aeronautical costs. The use of both the airport airside and landside facilities depend highly on operating characteristics of the aircraft that lands or takes-off at/from the airport. On the airside, the characteristics of the aircraft will determine the use of the runway and width, the minimum separation between runways and taxiways, the geometric project of taxiways, and the pavement strength. Additionally, environmental issues such as noise and air pollution are also based on the aircraft which will make use of the airport. On the terminal area, aircraft characteristics will influence the number and size of gates, and consequently the terminal configuration. Finally, the aircraft passenger capacity will influence the size of facilities within the terminal -such as passenger lounges and passenger processing systems -, and the size and type of the baggage handling system.

The differences observed between the different aircraft that have used MAD facilities during the year 2002 may help explain the difficulty that we have found in order to obtain an average aeronautical charge. The results on the side of costs are even worse, because there is not a separation of costs that can be assigned to aeronautical and non-aeronautical activities. For instance, runway length requirements range from 1,100 m (ATR-42) to over 4,400 m (DC-10-40), a difference of 300 %. The passenger capacity range is even wider: from 30 seats (EMB-120) to 400 seats (the capacity of B747-400). Finally, the maximum takeoff weight ranges from 11,500 kg (EMB-120) to over 362,871 kg (B747-X). It is very important to have in mind that these differences would have implications on different costs and prices of air traffic movements (ATMs), since they have a high influence on the cost function for aeronautical services. Runway length is highly limited by land availability and land costs; the amount of runway required by aircraft is therefore an important determinant for the airport cost. Wheel track and wingspan determines the runway and taxiway widths, and the separation between those ways. Additionally, wingspan and aircraft length rules the design of the apron area. Pavement strength determination is based on the aircraft weight. Passenger terminal facilities are sized to accommodate peak hour demand, which is highly influenced by aircraft passenger capacity.

Due to the lack of data availability and for the sake of simplicity, we finally decided to calculate an average aeronautical charge per air traffic movement, and we obtained a figure of 4650 euros per operation. With respect to the cost side, we have already mentioned that we did not have any disaggregate information for both aeronautical and non-aeronautical activities, so we have supposed that the proportion of revenues obtained by aeronautical activities over the total of revenues of the airport would be the same as the one observed on the cost side (42%). Thus, we got a very rough estimate of

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returns to scale if passengers are considered as the output. This situation suggests that it is an optimal policy both to increase the load factor of airplanes or the size of the airplanes.

aeronautical costs of MAD[10]. Traditionally, airports have relied on revenues raised from aeronautical activities; whereas non-aeronautical revenues have grown rapidly in proportion and in magnitude over the past ten years, partly because non-aeronautical services have generally fallen outside the scope of economic regulation, and partly because airports tend to earn more from non-aeronautical activities after the new role that airports are playing being units with more commercial orientation. Behnke (2000) points out that the ratio of non-aeronautical revenues to total revenues for a sample of more than 1,400 airports by Airports Council International had grown from about 30% in the late 1980s to over 50% in 1998[11].

Many airports generate a much higher proportion of their revenues from concession activities rather than from aeronautical operations. Doganis (1992) has reported that in medium to large US airports, concession operations represent between 75 and 80% of the total airport revenue. Indeed, in 1990, more than 90% of the total revenue of Los Angeles airport resulted from commercial operations. Furthermore, concession revenues have grown faster than aeronautical revenues. For example, Hong Kong International Airport generated an equal amount of revenue from its aeronautical and commercial operations in 1979, while in the late 1980s and 1990s its concession revenue accounted for 66–70% of total revenue (Zhang and Zhang, 1997).

We have calculated rough estimates of operating and capacity costs for Barajas airport, and their respective unit costs *r* and *c* per aircraft movement when capacity is fully used, using the percentage of capital cost over the total costs and supposing that this percentage is invariant on the aeronautical activities. In the next section, we will show the results of the different pricing schemes and the relationships between the different price mechanisms and the social welfare obtained.

Social welfare implications

Turning to equation 1 again, we will find that if we have an aeronautical charge that produces important scarcity costs (excess of capacity), then the price charged is lower than the market-clearing price. This situation is shown in Starkie (1998). In order to calculate the airline surplus, an extreme case is assumed where the whole tail of the excess of capacity (but low value) demand displaces an equivalent quantity of high value demand. Thus, the airline surplus, producer surplus and social welfare from aeronautical services will all decrease significantly. If the average aeronautical charge was also below the average aeronautical cost, the airport would have deficits from

[10] It would be advisable to estimate a cost function separating aeronautical activities and non-aeronautical activities in order to obtain better estimation of unitary costs of aeronautical services. Lack of data precludes us from doing this exercise, so we finally use average operating costs (c=4200 euros) and average capital costs (r=1800 euros). In this last case, we make the assumption that airport is operating at full capacity.

[11] A number of airport operators, such as BAA, AENA and Schiphol Group, are attracted to become involved in the airport business all over the world due to the importance that the potential growth opportunities from non-aeronautical services present. This is usually reflected in the final bidding price paid. The operators need proper information about unexploited commercial potential in retail, trading, car parking, ground transport, and property development in order to bid with confidence. Retail operations, in particular, have become an important source of revenue for airports, and an area that airport operators have largely developed since privatisation.

aeronautical activities and would require cross-subsidization of these deficits by non-aeronautical activities or the State taxes. The airline surplus during hour t can be calculated as:[12]

$$CS(P_t) = \int_{0}^{2K_t - q_t} P_t(q) - P_t \, dq + \int_{K_t}^{q_t} P_t(q) - P_t \, dq \qquad (2)$$

It can be seen that if airport authorities set aeronautical prices as close to market-clearing level as possible, then the potential loss of social welfare will be minimized and the excess of demand will be reduced.

We proceeded to calculate the four alternative pricing schemes: first-best, second-best, market-clearing and actual average charges. The results can be seen in Figure 5.

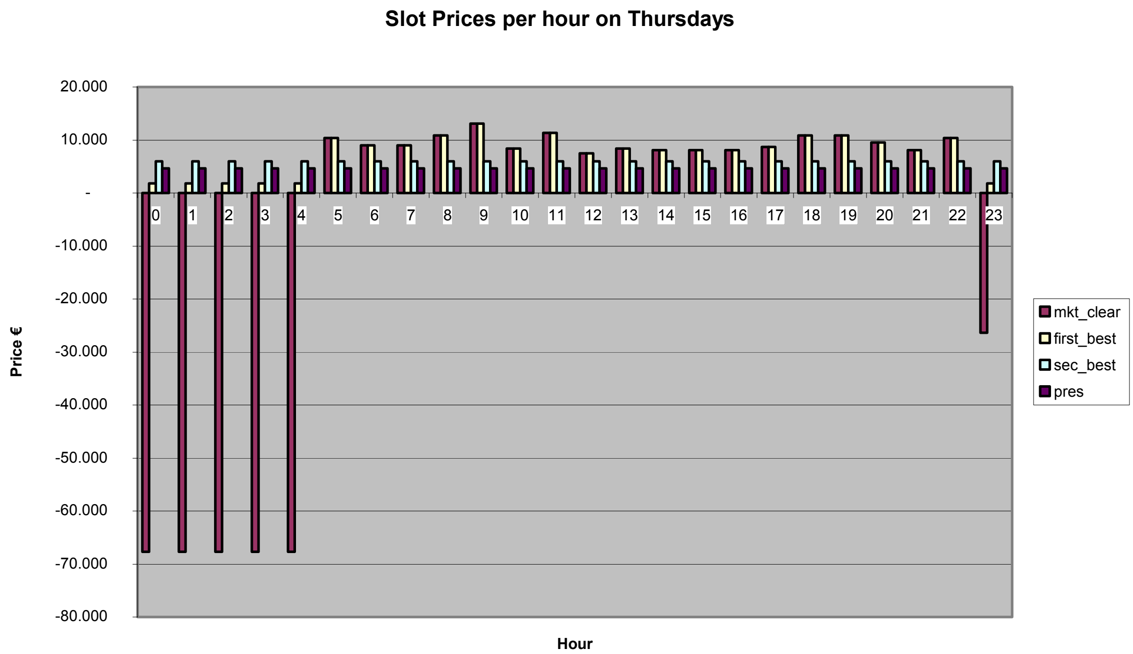

Figure 5: Alternative Pricing Schemes on Thursdays in MAD.

Thursday is typically very busy in Barajas airport, and it can be seen that for most part of the day, the market-clearing prices coincide with the first-best prices because the lack of adequate capacity to attend the excess of demand prevails. It is also interesting to remark that for this reason, the first best prices are higher than the present and second best prices. For example, if airport authorities in MAD applied a first-best pricing scheme, they would raise the aeronautical charge by about 143% on Thursdays from 11:00 to 11:59.

Forsyth (1976) showed that there are three possible reactions for airlines to an increase in aeronautical charges: to raise airfares, to cut flights, or to switch operation to another airport. In May 2001, the ACCC decided to permit Sydney Airport Ltd. to increase aeronautical charges by 97%. If these increases were passed on to passengers, the increase in air ticket fares would add around $3.0 to a domestic return flight and

[12] See Lu and Pagliari, 2004.

around \$14.0 to an international return flight (ACCC, 2001). It is believed that very few passengers, as a result of these price increases, would alter their travel choice to another airport or cancel their flight.

It can also be seen that when excess of capacity prevails, then first-best prices and market-clearing prices are lower than present average aeronautical charges. In this case, airport authorities would need to cut prices in order to reduce the potential loss of social welfare. This situation is common during the night hours. In the case of market-clearing prices, the airport authorities would even need to subsidize the use of the airport during these hours. This result would be difficult to implement due to the existing problems during the night hours with the surrounding vicinities. If airport authorities in MAD applied first-best pricing scheme, they would need to cut the aeronautical charge by about 68% on Thursdays from 00:00 to 04:59. This situation is not strange when there is extreme excess of capacity. Zhang and Zhang (2001) commented that Hong Kong airport charges were very high, but due to the severe under-utilization of the airport, the Airport Authority was obliged to review the charges in August 1999 and after lengthy negotiations with the airlines, the airport managers finally decided to cut the charges by 15%, making this cut effective from 1 January 2000.

In the following we will interpret and comment on the results of the different price schemes on the social welfare obtained from the application of the different pricing policies. The results for an average Thursday can be seen in Figure 6.

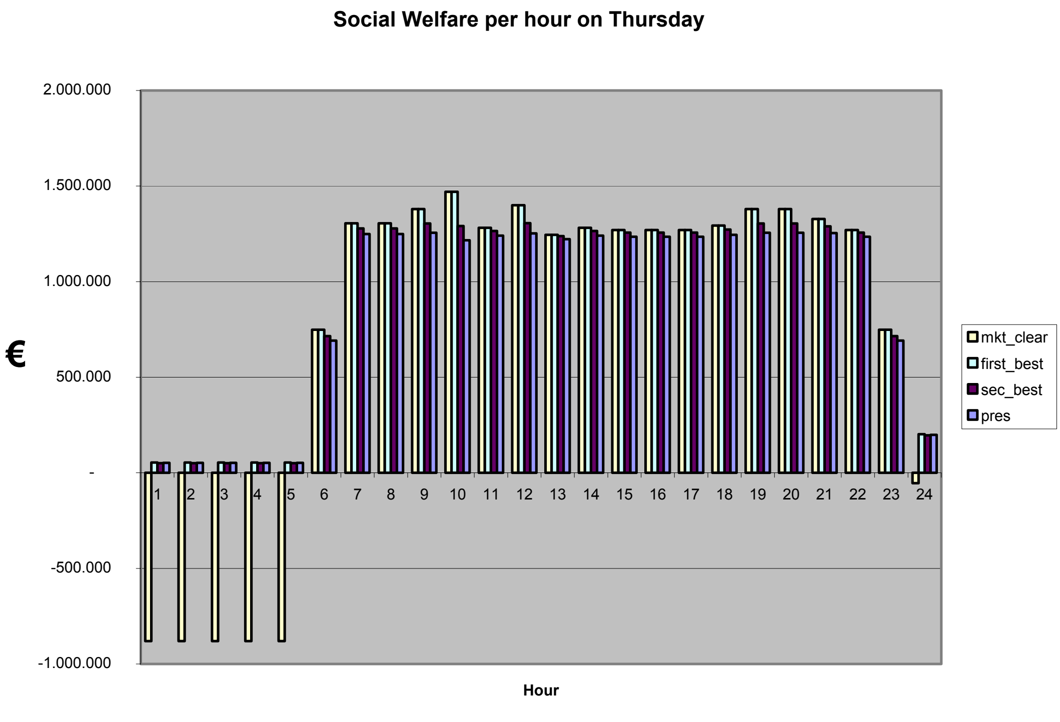

Figure 6: Alternative Pricing Schemes on Thursdays in MAD.

It is interesting to note that the gains in social welfare of first-best pricing policies with respect to the present situation show a range from 3 per cent during night hours to 11 per cent from 11:00 to 11:59. We have also obtained that if airport authorities set aeronautical prices to the first-price level, the average potential gains per year would be about 6 per cent. If a second-best policy is applied the potential gains would be about 2 per cent. Finally, if the use of the airport is expanded to its maximum declared capacity (market-clearing policy), the potential losses of social welfare would be about 17 per cent. It is also interesting to note that with the model assumptions, Barajas airport is being operated with cross-subsidization of non-aeronautical activities because the aeronautical prices are lower than the average aeronautical cost.

Final remarks and conclusions

Our results suggest that for the majority of the hours in the weekdays, potential demand is higher than capacity. For most parts of the day, the market-clearing prices coincide with the first-best prices because the lack of adequate capacity to address the excess of demand prevails. On the contrary, when there is excess of capacity, first-best prices and market-clearing prices are lower than present average aeronautical charges. In this case, airport authorities would need to cut prices in order to reduce the potential loss in social welfare. This situation is common during night hours. In the case of market-clearing prices, the airport authorities would even need to subsidize the use of the airport during these hours. Nevertheless, this result would be difficult to implement due to the existing problems during night hours with the surrounding vicinities.

In summary, the relationship between airport pricing schemes and social welfare from aeronautical activities has been clearly established. It is shown that social welfare from aeronautical services will increase by 6 per cent if a first-best pricing scheme (rather than the present pricing policy) is applied in MAD (where aeronautical demand usually exceeds capacity for most part of the day during all the weekdays). We have also shown that a policy pursuing a higher level of capacity use does not provide a higher social welfare and for this reason such a policy must not be encouraged.

However, it is clear that one of the caveats that this analysis presents is that the social welfare from non-aeronautical services has not been considered, and results can change significantly if there are strong complementarities between these two activities. The demand for non-aeronautical services is closely related to the demand for aeronautical services. An increase in the quantity consumed for aeronautical services will increase the potential demand for non-aeronautical services.

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Acknowledgements

This paper draws on some results from a case study prepared for the EU Commission (Research project SPECTRUM). We acknowledge support under the Growth specific programme of the 5th FP for RTD. We also want to express our gratitude to the director of Madrid Barajas Airport, Mr. M. A. Oleaga, for helpful comments and provision of necessary data. Special thanks for our colleagues C. A. Nash and J. Preston. Remaining errors are authors' sole responsibility, as all opinions expressed in this paper.