

Airport Charges

- Interactions between airlines and airports

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Abstract

A substantial part of airports’ revenues relate to charges covering the costs of services supplied by the airport. Charges are imposed on carriers, which in turn pass them or a percentage of them, on to passengers. In the present chapter special attention is given to regional airports characterized by low traffic volumes, enabling only one or a few carriers to serve each destination. A classic economic model is presented to analyse how the pass-on rate depends on supply and demand characteristics and market structure. Some illustrative examples assuming combinations of common specifications for market characteristics are also presented, showing pass-on rates ranging from 50% to more than 100%. Consequently, market structure and characteristics of carriers and passengers are decisive for how passengers experience changes in airport charges. The differences between the optimal charge from the perspectives of the airport and the welfare of society are specifically addressed. It is demonstrated that knowledge of the pass-on rate in the monopoly cases may be sufficient to infer how the mark-up will be affected by a change in marginal costs. Consequently, the understanding of the pass-on rate is relevant for airport owners and for decision-makers when considering the welfare of passengers and other politically stated goals.

Keywords: Airport charge, pass-on rate, carrier, passenger, regional airport, competition, airlines

1. Introduction

Whether airports are public or private bodies, they have revenues as part of their objective (e.g. Zhang and Czerny, 2012). In large part, revenues can be generated by either aeronautical revenues, commercial revenues or subventions (Losada et al., 2012). Airports often act to maximize profit from

commercial activities. As a part of the general public infrastructure, airport charges are often regulated by central governmental authorities, both for publicly and privately owned airports.

Traditionally, airport charges relate to air traffic movements (ATM) with landing fees based on the weight of aircraft (MTOW) and passenger (PAX) fee per departing passenger.¹ Airports throughout the world tend to have both per-passenger charges and per-flight charges, and indeed they collect as much revenue from one as from the other (Czerny and Zhang, 2015). Silva and Verhoef (2013) show that airports require both per-passenger charges and per-flight charges to maximize welfare, which they define as the sum of consumer surplus, airlines' profits and airport's profit.

The International Air Transport Association (IATA) aims for standardization of airport charges (Martin-Cejas, 1997), which are fair and cost-efficient² and the International Civil Aviation Organization (ICAO, 2012, point 13.II) emphasizes that public policy objectives should include ensuring 'non-discrimination and transparency in the application of charges'. However, some attempts on charges based on the ability to pay have been addressed in the literature. Studying private airports, Hakimov and Mueller (2014a) introduced the use of Ramsey pricing at uncongested airports with Germany as a case study. Mathisen et al. (2014) discussed distribution problems of strictly following the Ramsey rule by raising charges most aggressively at rural airports characterised by generally less elastic demand due to few alternative modes of transport.

The design of passenger fees varies between countries (e.g. Gordijn, 2010). In Germany the *Air Travel Tax* was introduced in 2011 to promote environmental friendly travel behaviour. In the UK, the *Air Passenger Duty* is a fiscal charge without environmental arguments, but rather based on its distributional effects, charging higher rates for more expensive ticket categories. In The Netherlands, the *Air Passenger Tax* was introduced in 2008 with the argument of making polluters pay. The introduction of this charge coincided with the financial crisis which, in combination with leakage to Belgium and Germany (Gordijn and Kolkman, 2011), resulted in a decline in passenger volume and discontinuation of the charge. In 2011, the (former) British Midland International (BMI)³ complained to the UK Civil Aviation Authority, about London Heathrow discriminating against short-haul airlines by charging them the same fees it charged long-haul ones (Zuidberg, 2014). In July 2016, a fiscal fee was introduced in Norway and it is unclear whether environmental impacts were part of the argument (Haanshuus and Jodalen, 2016). Also, in this case, the introduction coincided with a period of developing economic problems. It got much attention when Ryanair used the introduction of this fee to justify their leaving a private airport, which in turn resulted in a decision by the owners to close down the airport.

A change in the level of airport charges naturally has direct impacts on carriers' costs. However, carriers do not necessarily pass on all charges to passengers. Jørgensen and Santos (2014) discuss theoretically how transport firms pass on output taxes to passengers under different types of competition and goals, using a model of differentiated services dating back to Singh and Vives (1984). In their review of airport charging, Zhang and Czerny (2012) discuss the welfare optimizing airport charge, considering external costs such as congestion not internalized by passengers.

¹ While charges put on PAX and ATM are collected by the carriers on behalf of the airport, the other charges either cover expenses such as for example, security, or are out of airports' control, such as for example, en-route fees imposed by Eurocontrol.

² <http://www.iata.org/policy/infrastructure/Pages/index.aspx>

³ BMI was acquired from Lufthansa by International Airlines Group and integrated into British Airways in 2012.

The aim of this chapter is to provide a discussion on how characteristics of cost and demand and type of competition influence the extent to which airport charges are passed on from carriers to passengers. Moreover, attention is given to how optimal charges from the airport perspective, deviate from what could be preferable from a welfare point of view. Even though taxation in different types of markets has been widely studied in the literature, this study stands out for two reasons. First, in contrast to many earlier studies using general relationships, we introduce specific functional forms. Evidently, the choice of function influences both the optimal charge and the pass-on rate. By operationalizing the functions, we are able to capture common relationships relevant for air transport. Second, we focus on low traffic airports where few or only one transport firm operate(s). Knowledge on how carriers and passengers respond to changes in the charge scheme is important for both public authorities and airport owners when deciding upon charge policies and the actual charge. They should be aware of market structure when designing charges to meet their objectives.

The chapter is structured as follows. In section 2 the model is presented, with attention to the interaction between airlines and airports. In section 3 the conditions for transfer of fares are derived for common cost and demand specifications, and the model is then set to the duopoly case with price competition. In section 4 the results are discussed and summed up. Finally, in section 5 some conclusions and implications are presented.

2. Models for airlines and airports behaviour

Both in the US and EU airline markets have been subject to deregulation (Janic, 1999), and markets are increasingly being considered as oligopolies with imperfect competition (Zhang and Czerny, 2012). This is the case for studies of airports at the network level. However, when studying airports at route level, travel demand may be sufficient for only one carrier serving the different destinations. This is particularly prominent at small airports where Public Service Obligation (PSO)⁴ subsidies are more frequently used (see e.g. Williams and Pagliari, 2004).

Let us assume an airline market including a value chain consisting of four bodies as illustrated in Figure 1. The State (represented by the national government, including parliament or equivalent), decide on public policy regarding airports, including charges. Airports then instruct airlines to collect the charges from the passengers.

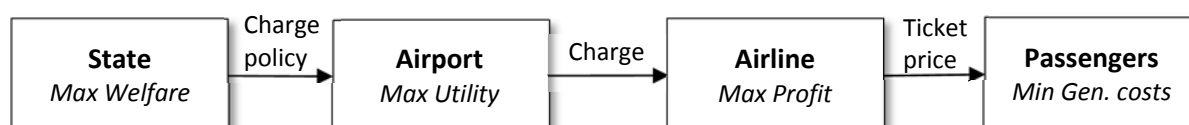


Figure 1. The value chain in the airline market.

⁴ In order to keep appropriate scheduled air services, PSOs are imposed by Member States on routes which, although not commercially viable, are 'vital for the economic development of the region they serve'. When no air carrier is interested in operating such route(s), the Member State in question may restrict the access to the route to a single air carrier and compensate its operational losses with a PSO subsidy. The selection of the carrier is made by public tender at Community level (https://ec.europa.eu/transport/modes/air/internal-market/public-service-obligations-psos_en)

In the simple principal-agent model illustrated in Figure 1, the state authority cares about overall welfare and subsidy needs when designing public policy for the part of air transport infrastructure costs financed through airport charges. Moreover, within the limits of this national policy, an airport maximises a goal function depending on profit, revenues and welfare (see section 2.2) when deciding upon the actual airport charge.⁵ For the airlines, the airport charge is a given variable when they choose the profit maximizing ticket price. Finally, passengers choose their optimal demand for flights by minimizing generalized travel cost, which, needless to say, includes all monetary and time costs. In our model we particularly focus on the relationship between the bodies in the three boxes to the right (“Airport”, “Airline” and “Passengers”). Hence, we do not explicitly look into the details of designing and implementing an optimal policy from the perspective of the state.

2.1 Airlines response to airport charges – a general model

Suppose an airline faces the following demand function for passenger transport to and from an airport

$$(1) \quad X = X(P) \text{ where } \frac{dX}{dP} < 0, \frac{d^2X}{dP^2} \geq 0$$

where X is the number of passengers transported and P is ticket price (fare). Moreover, let the airline’s total costs of using the airport facilities be given by the following function

$$(2) \quad C(X, t) = C_o(X) + tX \text{ where } \frac{\partial C(X, t)}{\partial X} > 0, \frac{d^2C(X, t)}{dX^2} \geq 0, \frac{\partial C(X, t)}{\partial t} = X > 0$$

In Eq. (2), parameter t is a per unit tax imposed by the airport on each passenger travelling to and from it. C_o represents all costs excluding airport fees and depends on the number of passengers (PAX). PAX is widely used as output indicator for transport activity and related to airline cost either alone, through Work Load Units (WLU) or in combination with other indicators such as Air Traffic Movements (ATM) (Martín and Voltés-Dorta, 2011). Empirical studies show that PAX relates closely to other production measures. According to Carlsson (2003), PAX accounted for 96% of the variation in costs at Swedish airports when used as a single independent variable. In the case of no airport charges ($t = 0$), then $C = C_o(X)$. The airline profit (π) is given by

$$(3) \quad \pi = P \cdot X(P) - C(X, t)$$

When the airline maximises profits, optimal price (P) is implicitly given by the following first order condition (e.g. Pindyck and Rubinfeld, 2013)

$$(4) \quad P \cdot \frac{dX(P)}{dP} + X(P) = \left(\frac{dC_o(X)}{dX} + t \right) \cdot X(P)$$

Equation (4) can be rephrased to $P = \frac{\frac{dC_o(X)}{dX} + t}{\frac{1}{1 + EL_P X(P)}}$ where $EL_P X(P) = \frac{dX}{dP} \cdot \frac{P}{X}$ represents price elasticity

of demand and where $EL_P X < -1$. The value of $EL_P X$ decreases (becomes more negative) when

⁵ From theory of industrial organization it is well-known that vertical integration of two monopolies in a value chain, as the airline and airport in our model, produces the problem of double marginalization (see e.g. Lipczynski et al., 2009; Pepall et al., 2014). This could considerably increase producers’ profits, and possibly also, consumers’ welfare. However, our model assumes an airport deciding upon the optimal charge, being aware of the market situation in the airline market, which eliminates the problem of double marginalization.

passengers have more substitutes, such as better access to other airports or better surface transport alternatives.⁶ Equation (4) implicitly defines the optimal price, P^* , as a function of t , i.e. $P^* = P^*(t)$.

Using Eqs. (1) and (3) in combination yields the airline's optimal number of passengers transported (X) as a function of the tax (t) in Eq. (5).

$$(5) \quad X(t) = X(P^*(t)) = X\left(\frac{\frac{dC_0}{dX} + t}{\left(1 + \frac{1}{EL_P X(P)}\right)}\right)$$

The per unit tax pass-on rate from the airline to its passengers $\left(\frac{dP}{dt}\right)$ can be defined as the ratio between the change in price and the change in tax. In other words, it measures the impact that an infinitesimal change of a per unit tax, t , imposed on each passenger, has on the equilibrium price, P^* . The lower (higher) the value of $\frac{\partial P^*}{\partial t}$, the less (more) of the tax increase is paid by travelers to and from the airport and the more (less) is paid by the airline operating at the airport. When $\frac{dP^*}{dt} \geq (<)1$ the final price (tax inclusive) to passengers goes up by more than, the same as or less than the amount of the tax. Consequently, the magnitude of the increase in the travelers' fare, after introducing the airport charge (t), is $\left(\frac{dP^*}{dt} \cdot t\right)$.

Differentiating the first order conditions for profit maximization in Eq. (4) with respect to tax (t) we get, after some mathematical manipulation (see Bulow and Pfleiderer, 1983; Kate and Niels, 2005):⁷

$$(6) \quad \frac{dP^*}{dt} = \frac{X_P(P)}{2X_P(P) + X_{PP}(P)(P^* - C_X(X) - t) - C_{XX}(X)X_P^2(P)} > 0$$

It should be noted that the second order condition for maximization of the airline's profits (π) implies that the denominator in Eq. (6) is negative. Hence, $\frac{dP^*}{dt} > 0$, meaning that increasing the charge will always lead to higher fares for passengers. Moreover, by parameterizing the general expressions we can discuss in more detail how functional forms of demand and cost influence the relationship between tax and optimal price. Such operationalization of the functions are given in section 3.

Using Eq. (1) in combination with Eq. (6) gives the effect of a tax increase on the number of passengers

$$(7) \quad \frac{dX}{dt} = X_P \cdot \frac{dP^*}{dt} < 0$$

2.2 Airport charging under different objectives

Let the airport cost function of serving the airline be $K(X)$ and revenues be given by the number of passengers to and from the airport multiplied by the airport fee (t). We here isolate revenues from airport charges and do not consider commercial revenues. Then profit for the airport (ρ) can be written as

$$(8) \quad \rho = t \cdot X^*(t) - K(X^*(t)), \text{ where } \frac{dK}{dX} > 0 \text{ and } \frac{d^2K}{dX^2} \geq 0$$

⁶ For a discussion of different operational measures of the level of competition of individual airports, we refer to Merkert and Mangia (2014).

⁷ In Eq. (6) we denote $X_P = \frac{dX}{dP}$, $X_{PP} = \frac{d^2X}{dP^2}$ etc.

2.2.1 Profit maximizing airports

When airports want to maximize profit, they will set the level of charge (t^*) according to the first order conditions for profit maximization, as follows

$$(9) \quad \frac{d\rho}{dt} = X^*(t) + \left(t - \frac{dK(X^*(t))}{dX^*} \right) \frac{dX^*(t)}{dt} = 0$$

Equation (9) can be reformulated to $t^* = \frac{\frac{dK(X^*(t))}{dX^*}}{\left(1 + \frac{1}{EL_t X^*(t)}\right)}$ where $EL_t X^*(t) = \frac{dX^*}{dt} \cdot \frac{t}{X^*}$ is the elasticity of X^*

with respect to t . It follows from Eq. (9) that $t > \frac{dK(X^*(t))}{dX}$, meaning that the charge (t^*) is greater than the marginal cost of serving the passengers. Whether such pricing procedure is welfare optimal or not depends on the level of social costs imposed by each passenger that the airport authorities ignore (Δ). Examples of this include carbon emissions and noise caused by aircraft (European Commission, 2014; Martín-Cejas, 2010). If $\Delta \geq (<)(t^* - \frac{dK(X^*(t))}{dX})$, the airport sets too low, correct and too high a charge, respectively. Consequently, if all social costs are internalized in the airport's calculations ($\Delta = 0$), passengers are charged above the welfare optimal level.

2.2.2 Welfare maximizing airports

When the airport is owned or regulated by the state, it is likely, at least to some extent, that it will pursue other goals rather than pure profit maximization. One frequently discussed goal within the transport sector is the maximization of social welfare when the loss of revenues is financed by the state (e.g. Button, 2010). In line with the literature dating back to Ramsey (1927) we formulate this problem as maximizing social welfare subject to a subsidy restriction (budget). When solving the Lagrangian function, the optimal charge can be written as

$$(10) \quad t^{**} = \frac{\frac{dK(X^*(t))}{dX^*}}{\left(1 + \frac{\tau}{EL_t X^*(t)}\right)}$$

where $0 \leq \tau = \frac{\gamma}{1+\gamma}$ is the social cost of raising public funds by 1 Euro (see e.g. Mathisen et al., 2014).

By comparing Eqs. (9) and (10) it can be verified that $t^* > t^{**}$ but t^{**} will increase and tend to t^* when γ increases (t^{**} increases with τ). If the social cost of raising public funds is 0 ($\gamma = 0$) then $\tau = 0$ and the optimal charge will be equal to the airport's marginal costs $\left(\frac{dK(X^*(t))}{dX^*}\right)$.

2.2.3 Utility maximizing airports

It could also be argued that airports' managers have particular interests in running a big airport and that they have some power to pursue other goals (see for example Button (2010) and Jørgensen and Mathisen (2014) and the literature dating back to Baumol (1962) and Williamson (1966) for discussions of this issue). If the goal were to maximize utility, the goal function (U) could be described as a weighted sum of profits and revenues, as follows

$$(11) \quad U = \rho + \beta \cdot R \text{ where } 0 \leq \beta < 1 \text{ and } R = t \cdot X^*(t) \text{ are the airport's revenues.}$$

The restriction imposed on β implies that airports may put some weight on size, but they always put a higher weight on profits. After some mathematical manipulation, the optimal charge, t^{***} , when U is maximized, can be written as

$$(12) \quad t^{***} = \frac{1}{1+\beta} \frac{\frac{dK(X^*(t))}{dX^*}}{\left(1 + \frac{1}{EL_t X^*(t)}\right)}$$

It can be seen from Eq. (12) that the higher the weight the airport places on revenues (given by β) the lower the charge, t^{***} , will be.

3. Pass-on rates under different market characteristics

We will now discuss in more detail how different specifications of market characteristics (i.e. the demand- and costs functions) influence the pass-on rate $\left(\frac{dP^*}{dt}\right)$. Furthermore, we will pay attention to the difference between the level of airport charge and the airport's marginal cost of serving airlines and their passengers $\left(t - \frac{dK(X^*(t))}{dX}\right)$. In the present discussion we focus purely on the profit maximizing airports of section 2.2.1. This mark-up indicates how the profit maximizing airport charge (t^*) deviates from the welfare optimal situation, most easily described by the marginal cost pricing rule. In all cases we assume linear cost functions for both the airline (13) and the airport (14), as follows

$$(13) \quad C = (c + t)X + F \text{ where } c, t, F > 0$$

$$(14) \quad K = qX + H \text{ where } q, H > 0$$

In Eq. (13), the airline's total costs and fixed costs of operating at the airport are given by C and F , respectively. The element $(c + t)$ represents the extra cost of carrying one more passenger to/from the airport. The marginal costs $\left(\frac{dC}{dX}\right)$ are, thus, constant and equal to $(c + t)$. In Eq. (14), the airport's total costs, fixed costs and marginal costs of serving the airline are given by K , H and q , respectively. Even though linear specifications are less flexible than more advanced cost functions, they are often used in the literature as an approximation to the cost structures for both transport modes and transport infrastructure (see e.g. Pels and Rietveld, 2008). Moreover, such functions give often mathematically tractable solutions that are easy to interpret (Blauwens et al., 2008).

The demand functions considered are standard in transport economic textbooks and in econometric analyses – namely linear functions, power functions and exponential functions (see for example Hensher and Brewer, 2001; McCarthy, 2001). Additionally, we introduce a two firm case (duopoly) competing on price assuming linear functions only. Our approach is similar to that in Bulow and Pfleiderer (1983), using constant marginal costs in combination with Power and Exponential demand functions when analysing the effect of cost changes on prices in a monopoly market. However, in our four cases, described below, we extend on the reasoning by Bulow and Pfleiderer (1983) in three ways. First, we address additional cases by including the linear demand function often found in the transport industry and duopoly price competition. Second, we study the interactions in vertical integration between airports and airlines when designing charges. Finally, we briefly comment on the monopoly case when airlines' cost functions are convexly increasing.

The variation in number of suppliers and the proposed demand functions in combination with the linear cost function produces the following four cases:

- I. Linear demand – monopoly
- II. Power demand – monopoly

- III. Exponential demand – monopoly
- IV. Linear demand – duopoly

For the sake of simplicity, when presenting the model results we use the same symbols for optimal values and parameters in the different cases. Alternatively indexing of all parameters to match the case in question could have been used, but it would have made the algebra heavy-handed.

Therefore, in the sections that follow it should be borne in mind that, for example, even if a and b represent aspects of demand conditions by market size and price sensitivity, respectively, in all cases, the strict interpretation of the parameters depends on each specification (I, II, III and IV).

3.1 Case I - Linear demand

The relationship between the number of passengers (X) traveling to and from an airport and average ticket price (P) is given by

$$(15) \quad X = a - bP \text{ where } a, b > 0 \text{ and } EL_p X = \frac{-bP}{a-bP}$$

The value of a indicates the size of the market, while b represents the price sensitivity of demand; the value of b increases when passengers get better access to other transport alternatives. The demand curve in Eq. (15) implies that price elasticity of demand, $EL_p X$, decreases convexly with price.

Inserting (13) and (15) into (3) and deriving the first order conditions for maximization of the airline's profits lead to the following equilibrium

$$(16) \quad P^* = \frac{a+b(c+t)}{2b} \text{ and } X^* = \frac{a-b(c+t)}{2}$$

Eq. (16) enables us to derive the influence of the charge imposed on the airline, as shown by Eq. (17).

$$(17) \quad \frac{dP^*}{dt} = \frac{1}{2} \text{ and } \frac{dX^*}{dt} = -\frac{b}{2}$$

The results in Eq. (17) show that an increase in airport charges (t) by 1 Euro will always increase the ticket price by 0.5 Euro, at the (optimal) equilibrium. In other words, the airline passes on to passengers' ticket price half of the change in the airport's charge. Hence, the change in ticket prices due to an increase in airport tax is independent of the demand conditions the airline faces, its productivity and the initial level of the tax. This implies equal pass-on rates across all airports. Consequently, the relative changes in ticket price will be greater for passengers at airports where prices are lowest.

Moreover, it follows from Eq. (17) that the impact of a change in the airport charge on demand is greater if price sensitivity is higher (greater b). This means that reduction in travel demand will be greatest at airports where passengers have many alternative means of transport (presence of substitutes). It is also worth noting that the change in demand resulting from a change in the airport charge is independent of the airline's productivity (c -value).

When the airport maximise profits (ρ) we can derive optimal airport charges (t^*) using Eqs. (9), (14) and (16), as follows

$$(18) \quad t^* = \frac{a-bc+bq}{2b} = \frac{a-b(c-q)}{2b}$$

Keeping in mind Eq. (17), the part of the tax (t^*) passed on to each passenger is just half ($\frac{1}{2} \cdot t^*$). From Eq. (18) it follows that a higher market potential (greater a) and higher marginal costs at the airport (greater q) will always increase t^* , whilst increasing marginal costs for the airlines (greater c) and more price sensitive demand (greater b) lead to lower t^* .⁸

The difference (Δ) between the airport charge maximizing the airport's profits and the airport's costs of serving an extra passenger (q) is given in Eq. (19).

$$(19) \quad \Delta = t^* - q = \frac{a-b(c+q)}{2b} > 0$$

It follows from Eq. (19) that $\Delta > 0$. The value of Δ is reduced when the market potential declines, when passengers become more price sensitive and when the marginal costs of the airline and the airport increase.

3.2 Case II - Power demand function

Let us now address the situation where the demand curve for transport to and from the airport decreases convexly with price as in Eq. (20) and where the airline and airport cost functions are the same as those specified in Eqs. (13) and (14), respectively.

$$(20) \quad X = aP^{-b} \text{ where } a, b > 0 \text{ and } EL_P X = -b < -1$$

The demand curve in Eq. (20) implies that $EL_P X$, is constant and equal to the exponent ($-b$). Also, in this specification the parameter a indicates market size.

By inserting (13) and (20) into (3), the first order conditions for maximization of the airline's profits can be derived. This yields the following market solution

$$(21) \quad P^* = \frac{b(c+t)}{b-1} \text{ and } X^* = a \left(\frac{b(c+t)}{b-1} \right)^{-b} \text{ where } b > 1$$

Equation (21) implies the following changes in equilibrium solutions when the per unit tax increases:

$$(22) \quad \frac{dP^*}{dt} = \frac{b}{b-1} \text{ and } \frac{dX^*}{dt} = - \left[\frac{b(c+t)}{b-1} \right]^{-b-1} \frac{ab^2}{b-1}$$

It follows from Eq. (22) that $\frac{dP^*}{dt} > 1$ when $b > 1$. This implies that a monopolist facing constant marginal costs and a demand curve with constant price elasticity will always pass on to passengers more than the change in the charge. Evidently, $\frac{dP^*}{dt}$ will decrease when b increases. Hence, the pass-on rate from airlines to passengers is lower when airlines operate at airports with more elastic demand. For example, if the value of b is 1.5 and 2.0, passengers will experience an increase in ticket price of 3 Euros and 2 Euros, respectively, if the airport charge is increased by 1 Euro. In contrast to the case of a linear demand function, the pass-on rate now depends on the price sensitivity of the passengers, while airline marginal costs still do not influence the pass-on rate. Moreover, (22) shows that the magnitude of the impact of the charge on the number of passengers depends both on market- and cost conditions. Specifically, the reduction in the number of passengers is smaller if the charge (t) is higher to start with and if marginal costs (c) are high. The impact of price elasticity (b) on travel demand is not clear-cut.

⁸ Note that $t^* > 0$ when X^* in Eq. (18) is positive and $\frac{dt^*}{db} = \frac{-2a}{(2b)^2} < 0$.

Let us now pay attention to the airport owner tax setting again. From Eqs. (10), (14) and (22), we can derive the optimal airport charge for profit maximizing airports as follows

$$(23) \quad t^* = \frac{bq+c}{b-1}$$

It is clear from Eq. (23) that $t^* > 0$ when $b > 1$. Moreover, the charge that maximizes profit for the airport increases with marginal costs for the airport (q) and when demand is less price elastic (lower b). In contrast to the case of linear demand, we find that the optimal charge for the airport owner increases when marginal costs for the carrier (c) increase. Also, it should be noted that t^* is independent of the value of a , meaning that the size of the market does not influence the optimal charge. Eq. (22) in combination with (23) implies that the tax effect on ticket price is $(\frac{b}{b-1} \cdot \frac{bq+c}{b-1})$, implying a greater effect when the demand becomes less price sensitive.

The difference (Δ) between the airport charge maximizing profit for the airport (t^*) and its marginal costs of serving the passengers (q) is given in Eq. (24).

$$(24) \quad \Delta = t^* - q = \frac{c+q}{b-1} > 0$$

In contrast with Case I, it is clear from Eq. (24) that the difference between the airport's charge and its marginal costs is unaffected by the market potential of the airport (value of a). Moreover, it increases in c and q and decreases in b .

3.3 Case III - Exponential demand function

Let demand be given by the general exponential function in (25).

$$(25) \quad X = ae^{-bP} \text{ where } a, b > 0 \text{ and } EL_P X = -bP$$

Similar to (20) the demand decreases convexly with ticket price, but the absolute value of price elasticity increases proportionally with P . Consequently, $(100 \cdot b)$ can be interpreted as the percentage change in X when P changes by 1 Euro. Inserting Eqs. (13) and (25) into (3) gives the following optimal values of price and the number of passengers transported to and from the airport

$$(26) \quad P^* = \frac{1+b(c+t)}{b} \text{ and } X^* = ae^{-(1+b)(c+t)}$$

Eq. (26) implies the following equilibrium effects of a marginal change of the airport charge

$$(27) \quad \frac{dP^*}{dt} = 1 \text{ and } \frac{dX^*}{dt} = -a(1+b)be^{-(1+b)(c+t)}$$

The fact that $\frac{dP^*}{dt} = 1$ implies that a profit maximizing airline acting as a monopolist with constant marginal costs and facing an exponential demand curve, will always pass on the entire change in the airport charge to the passengers. Hence, an increase in the charge of 1 Euro increases the ticket price for passengers by exactly 1 Euro. Under these conditions, passengers are, thus, treated similarly at all airports, but the relative value of a change in charge is highest at airports dominated by low fare tickets.

From Eq. (27) we can see that reduction in travel demand due to an increase in the charge is greater when the market is large (greater a), marginal cost low (lower c) and when the charge is lower to start with (lower t). Hence, there is a negative convex relationship between travel demand and the airport charge. A more price sensitive demand (greater b) will increase this effect if $(b+1)(c+t) > 1+2b$.

When still assuming a profit maximizing airport with cost structure according to Eq. (14), we can derive its optimal airport charge as follows

$$(28) \quad t^* = \frac{bq+1}{b}$$

Because airlines pass along the entire tax to passengers (see Eq. (27)), the increase in fares due to the tax will be exactly (t^*). It follows from Eq. (28) that the optimal charge increases when airport marginal costs (q) increase and when demand becomes less price elastic (lower b). In this case, the optimal charge for the airport owner is unaffected by the airline marginal costs (c) and the size of the market (a).

The difference (Δ) between the airport charge that maximizes airport profit (t^*) and the airport marginal costs (q) is

$$(29) \quad \Delta = t^* - q = \frac{1}{b} > 0$$

It follows from Eq. (29) that Δ decreases in b . In contrast to Case I and Case II, Δ is independent of both the marginal costs of the airline (c) and the airport (q).

3.4 Case IV – Linear demand – Duopoly

Even at small airports some routes are served by more than one company. Hence, it is relevant to study the interaction between airlines and airports under duopoly competition. Let two airlines (1 and 2) offer symmetrically differentiated services (X_1 and X_2) at an airport and compete simultaneously in prices (Bertrand competition).⁹ Moreover, we apply market conditions equal to Case I where both airlines face linear demand functions and identical linear cost functions. Their demand functions are

$$(30) \quad X_1 = a - bP_1 + sP_2 \text{ and } X_2 = a - bP_2 + sP_1 \text{ where } a, b > 0, 0 < s < b$$

In Eq. (30), parameter a indicates the market potential of the airport whilst parameter s measures the degree of substitutability between the services from the two airlines; the higher the value of s , the more intensely they compete. Their cost functions are

$$(31) \quad C_1 = (c + t)X_1 + F \text{ and } C_2 = (c + t)X_2 + F$$

where C_1 and C_2 are total costs of airlines 1 and 2, respectively.

Using Eqs. (30) and (31), profits for each airline ($\pi_i, i = 1,2$) are then given by

$$(32) \quad \pi_1 = (P_1 - (c + t))(a - bP_1 + sP_2) - F \text{ and } \pi_2 = (P_2 - (c + t))(a - bP_2 + sP_1) - F$$

When the airlines maximise their profits by choice of the fare variable we get the following common equilibrium prices (P^*) and quantity (X^*)

$$(33) \quad P^* = \frac{a+b(c+t)}{2b-s} \text{ and } X^* = \frac{ab+b(c+t)(s-b)}{2b-s}$$

⁹ Another possibility is that airlines move sequentially when choosing prices or compete in quantities simultaneously (Cournot) or sequentially (Stackelberg). For discussion on such model approaches in the transport literature see e.g. Pedersen (1999).

Based on Eq. (33), the influence on equilibrium values following changes in the per unit tax can be derived as follows

$$(34) \quad \frac{dP^*}{dt} = \frac{b}{2b-s} \text{ and } \frac{dX^*}{dt} = -\frac{b(b-s)}{2b-s}$$

Under the restriction placed on the b and s parameters it is easy to verify from Eq. (34) that $\frac{dP^*}{dt} > \frac{1}{2}$ and that it decreases with b and increases with s ; the less competition the airlines experience from other modes of transport and the more fiercely they compete the more of the tax is passed on to the passengers. The impact of the tax on the total number of passengers to and from the airport ($2 \cdot \frac{dX^*}{dt}$) will be higher when b increases and s decreases.

Let us now address the optimal charge from the airport perspective. By combining Eqs. (8), (14) and (33) it is clear that the optimal charge (t^*) for a profit maximising airport is

$$(35) \quad t^* = \frac{(b-s)(q-c)+a}{2(b-s)}$$

By comparing Eqs. (18) and (35) it can be verified that the airport charges a higher tax when it serves two airlines rather than one. Moreover, it follows from Eq. (35) that t^* increases when the market potential for the airlines increases (greater a), the airport marginal costs (q) increase and the airlines' marginal costs (c) decrease. Finally, better alternatives from other transport modes (greater b) and less fierce competition between the two airlines (lower s) will lower tax charged by the airport. From Eqs. (34) and (35) it follows that the effect on ticket price due to the tax is $(\frac{b}{2b-s} \cdot \frac{(b-s)(q-c)+a}{2(b-s)})$. As it can be seen, this effect is decreasing in b and increasing in s .

Eq. (36) implies that the difference, Δ , between the charge set by the airport and the airport marginal cost (q) is

$$(36) \quad \Delta = t^* - q = \frac{(s-b)(q+c)+a}{2(b-s)}$$

Eq. (36) demonstrates that Δ increases when both the airlines and the airport marginal costs decrease and when the market potential for the airlines increases. Increasing competition between the airlines also leads to a greater value of Δ .

4. Discussion and numerical example

4.1 Main model results

The model presented in section 3 addresses an airport system where routes are served by a single airline or two airlines in duopoly competition. This is particularly relevant for smaller airports or low demand destinations. One of the main findings is that demand characteristics have a substantial influence on how changes in airport charges are passed on to passengers. Consequently, information on demand characteristics should be obtained and used as part of the decision making process when revising airport charges. This is particularly relevant for airport authorities pursuing political goals and taking into account distributional impacts between types of airports and groups of passengers. Table 1 summarizes the results for each of the four cases addressed in Section 3.

Table 1. Summary of impacts on pass on rates, demand, charges and mark-up in the four cases

Case	Demand function	$\frac{dP^*}{dt}$	Marginal impact on ticket price	Marginal impact on demand, $\frac{dX^*}{dt}$	Impact on airport mark-up, Δ
I	Linear (Monopoly) $X = a - bP$	= 0.5	Half of the charge is passed on to passengers. Independent of demand conditions and thereby equal pass-on rate for all airports. Relative change in ticket price is greatest where prices are lowest.	Reduction increases with b . Independent of a and c .	Δ increases with a and decreases with b , c and q
II	Power (Monopoly) $X = aP^{-b}$	> 1	Always pass on more than change in charge. Increase in price due to charge is reduced with elasticity value (b).	Reduction is smaller if charge is large to start with. Decreases with c . Uncertain influence of b .	Δ increases with c and q and decreases with b . Independent of a
III	Exponential (Monopoly) $X = ae^{-bP}$	= 1	Entire change in charge is passed on to passengers. Other consequences are similar to Case I.	Reduction increases with a . Other consequences are similar to Case II.	Δ decreases with b , independent of a , c and q
IV	Linear (Duopoly) $X_i = a - bP_i + sP_j, i = 1, 2, i \neq j$	> 0.5	Pass-on rate decreases with b and increases with s .	Reduction increases with b . Decreases with s .	Δ decreases with c and q and increases with a , b and s .

When the demand function facing the airline is linear or exponential the airline will pass on half ($\frac{dP^*}{dt} = \frac{1}{2}$) or all of the tax ($\frac{dP^*}{dt} = 1$) to passengers, respectively, regardless of how sensitive demand is (b value) and the levels of marginal costs for the airline (c) and for the airport (q). When fares are lower, the relative changes in ticket price will be higher. If fares are assumed to increase with distance travelled (e.g. Mathisen, 2015), passengers using airports that serve short distances will, thus, be more affected by increasing charges, relatively speaking.

When the airline serving an airport faces a power demand function, the pass-on rate decreases when demand becomes more price sensitive. This suggests that passengers at airports with few transport alternatives (few substitutes) will be hardest hit by the tax. The impact is, however, still independent of the size of the market and the airline's and airport's marginal costs (values of c).

In Case IV (duopoly) the charge is influenced by the degree of product differentiation (parameter s in Table 1) in addition to the parameters discussed in the first three cases. The pass-on rate is always larger than 0.5 and increases when airlines experience less competition from alternative modes of transport and when airlines compete more fiercely in the market.

A profit maximising airport serving an airline facing a linear demand function will increase the tax when the demand becomes less price elastic, when the marginal costs for the airport increase and when the marginal cost for the airline decrease. The same conclusions apply for a power demand function except that increasing marginal cost for the airline also increase the tax. Lastly, for the case of an exponential demand function, less price elastic demand and higher marginal cost of the airport of serving the passengers will increase the tax, but the airline's marginal cost does not affect the level of charge. It should be remarked that changes in the a , b and c parameters affect t^* (optimal tax) and

Δ (airport mark-up) in the same directions. Increasing q on the other hand, will always increase t^* but only increase Δ when assuming a power demand function.

The close relationship between pass-on rate and the impact on mark-up is demonstrated in the right column of Table 1. More specifically, knowledge of the pass-on rate in the monopoly cases may be sufficient to infer how mark-up will be affected by a change in marginal cost. For instance, when the pass-on rate is below 1, then an increase in airline or airport marginal cost will decrease the mark-up, while a pass-on rate equal to 1, implies that the mark-up is independent of these marginal costs.

It is well documented that firms could have other incentives than the owners and there is no reason to assume that airports differ from this reasoning (see sections 2.2.2 and 2.2.3). For example, managers at the airport could put some weight on revenues. Then the airport will set a lower charge the more weight it places on revenues. In a situation where the airport tax is designed by the government, it could be more relevant to assume social welfare maximization under budget restrictions. The optimal charge will then increase with stricter budget restrictions and the cost of raising public funds.

Admittedly, the model relies on restrictive assumptions regarding demand and costs. Despite producing a good approximation to practice and intuitive results that can be easily interpreted, the use of linear costs is not always suitable. Therefore, using Eq. (6) we now briefly focus on the special monopoly case of a convex specification where costs increase with traffic, raising to the power of two (quadratic). When assuming such a quadratic cost function ($\frac{d^2c}{dx^2} \geq 0$ with linearly increasing marginal cost), then the pass-on rate is less than a half ($\frac{dP^*}{dt} < 0.5$) and less than one ($\frac{dP^*}{dt} < 1$) when the demand function is linear and exponential, respectively. Also in the case of a power demand function the pass-on rate will be lower when employing a quadratic cost function compared to a linear one, but it is not straightforward to establish intervals for the values of $\frac{dP^*}{dt}$. Consequently, increasing marginal cost will for all three specifications of the demand function lead to lower pass-on rates compared to a situation with constant marginal costs. Future applications of such a standard model can be extended to include other specifications found of particular relevance to the air transport industry.

4.2. Numerical example

Let us now apply the model to a simple numerical example based on some empirical evidence from the regulated part of the Norwegian air transport industry. As mentioned in section 2, operations at these routes are licensed to one supplier by the PSO regime (e.g. Mathisen and Solvoll, 2012). Focusing on the Power function (Case II and discussed by Bulow and Pfleiderer (1983)), we need information on elasticity (b) and marginal costs for airports (q) and airlines (c). The study by InterVISTAS (2007) suggests an elasticity value for short trips at the route level in Europe at about -1.5 , which if plugged into Eq. (22) yields a pass on rate equal to 3.

Mathisen et al. (2014, p. 54) estimate the long-run marginal costs of handling an extra passenger at small and mid-sized Norwegian airports at 34 NOK, which is about 3.5 Euros at 2016 exchange rates. This is the value we assume for the example below. Whilst there are a number of studies that estimate airport marginal costs (e.g. Hakimov and Mueller, 2014b; Link et al., 2009; Martín et al., 2011; Martín and Voltes-Dorta, 2011; Voltes-Dorta and Lei, 2013) studies on airline marginal costs

are very rare, probably because costs are highly sensitive information for airlines. We do not know of any estimates on airline marginal costs for the routes in question. Given this uncertainty, we can only make arbitrary assumptions on c , which we allow to take two values, 5€ and 10€, in our numerical calculations.

Plugging these values in Eq. (23) renders $t^* = \frac{1.5 \times 3.5 + 5}{1.5 - 1} = \frac{10.25}{0.5} = 20.50\text{€}$ when $c = 5\text{€}$ and $t^* = \frac{15.25}{0.5} = 30.50\text{€}$ when $c = 10\text{€}$. Using Eq. (21) and the same parameter values it is evident that $P^* = 77\text{€}$ when $c = 5\text{€}$ and $P^* = 122\text{€}$ when $c = 10\text{€}$. These estimates are within the fare interval estimated by Mathisen (2015) for highly regulated air transport in Norway.

Currently, the airport owner Avinor charges passengers approximately 5 € (Mathisen et al., 2014). This suggests that the Norwegian airport authorities put some weight on goals other than profits. Additionally, a fiscal passenger seat fee amounting to about 9 € was introduced by the Norwegian government in 2016 producing a total fee of about 14€. When using the same parameter values in Eq. (21) it is evident that the 9 € environmental tax increased P^* from 30€ to 57€ when $c = 5\text{€}$ and from 45€ to 72€ when $c = 10\text{€}$. Summing up, the estimations above demonstrate clearly that the airport authorities' objectives can be of great importance for passenger fares.

5. Concluding remarks

Many interesting questions remain to be modelled, discussed and empirically tested when analyzing airport charges. In our approach we have restricted ourselves to analyzing airport charges and pass-on rates to passengers in a single airport and single flight route model. In a model describing a network of airports and several flight routes, possibly with differences in number of operating airlines and where costs and demand conditions might vary, the problem of designing airport charges and consequences for pass-on rates might be more complex.

Another issue that should be given more attention to when designing airport charges, is that the central government in reality has several political goals to consider. This is illustrated by the state owned Norwegian airports setting airport charges below profit maximizing level leading to lower ticket price. Securing overall welfare often means choosing a policy for airport charges where internal and external efficiency in the airport and airline markets should be seen in relation to possible private and public budget constraints, negative externalities from aviation and possible positive wider economic benefits on regional development and industries depending on the supply from airports and airlines. This means that in a more comprehensive analysis, the principal-agent relationship between the government (labelled State in the first box from the left in Figure (1)) should be discussed in more depth. It is also worth mentioning that whether airports charges are optimal from a welfare perspective does not only depend on their goal function, but also on to the degree to which they consider all social costs caused by airlines' activity. Finally, it is demonstrated that knowledge of the pass-on rate in the monopoly case may be sufficient to infer changes in the mark-up for the airport following a change in marginal cost.

As mentioned in the introduction, the Norwegian government and parliament introduced a new fiscal air charge as of 1 June 2016. The extra fee is about nine Euros per passenger. The new charge provoked an intense political and economic debate concerning possible negative effects on passengers and industries, especially in regions where few other transport alternatives exist.

However, preliminary data shows that traffic volume has increased, although it may be too early to say what the long-term effect will be. This increase in traffic volume may be the result of other favorable changes having nothing to do with (low or no) pass-on rates for passengers. This is indeed likely to be a suitable explanation, especially bearing in mind that often air tickets are purchased well in advance, and in this case, probably before the new air charge become effective. Future studies could use this case to uncover the pass on rate in the Norwegian air transport market.

Nevertheless, the relatively simple model provides two important lessons to be learned. First, we have clear conclusions on how market characteristics influence the pass-on rate when using the chosen specifications. Second, and more importantly, we have demonstrated the interrelations between carriers' fare setting, pass-on rates and airports' tax level on the one hand and demand and costs conditions for carriers and airports on the other hand. It is evident that market characteristics have a considerable impact on pass-on rates and should be part of the decision making process when designing airport charges.

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