11. The economics of airports' pricing

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11.1 INTRODUCTION

Airports play a central role in urban development by connecting individuals, businesses, and governments, and spurring economic activity; multiple studies have demonstrated a positive effect of air transport on the economy, such as employment, trade, and GDP (Brueckner, 2003; Gibbons and Wu, 2020; McGraw, 2020). Aviation boosts productivity by expanding markets, facilitating competition, and giving access to a wider pool of skilled labor (Carbo and Graham, 2020). The exchange of knowledge and networking, all facilitated by air-link connections and face-to-face communication, is crucial for scientific collaboration and patenting activities (Hovhannisyan and Keller, 2015) and international financial investments (Chen and Lin, 2020).[1]

Over the past few decades, airports have accommodated increasing operations to support such regional and national growth. Before the COVID-19 pandemic, air traffic had grown significantly in the United States and Europe, even more rapidly in Asia and Oceania, and, more recently in Africa and Latin America. This growth has developed despite local contractions following 9/11 and the economic downturn in 2008 and 2009. It is also expected to grow again and reach pre-COVID-19 levels in 2024 (IATA, 2020). The need to connect remote regions (Fageda et al., 2019) as well as an increased focus on tourism (supported by national and international travel promotion, millennials' higher propensity to fly, higher living standards and income in major developing economies) and the emergence of low-cost carriers have also contributed to stimulate the traffic growth.

At the same time, airport throughput is limited by the existing infrastructure and operational capabilities. At many of the world's busiest airports – and despite several capacity expansion projects – traffic growth has outpaced capacity increases. According to pre-pandemic estimates provided by Eurocontrol, 1.5 million flights (8% of the forecasted demand) would not be accommodated in Europe by 2040 due to an imbalance between demand and capacity (Eurocontrol, 2018). London's Heathrow Airport is probably the best well-known case. According to pre-pandemic ACI forecasts (ACI, 2018), around 16 Heathrow-like airports will operate at capacity by 2040.

At airports where airline access is restricted (for example, the overwhelming majority of the busiest European airports), the restrictions can result in demand losses or displacement, e.g., to less preferred times of the day or other airports. At airports with largely unconstrained access (e.g., the vast majority of US airports), this often results in very costly delays.[2] While a significant cause of delays is traffic volume relative to airport capacity, other causes vary across countries. For example, the weather is a major source of delays in the United States. In contrast, limited aerospace for civil aviation (versus military aerospace) is a major source for China (see Zhang and Czerny, 2012, for a survey).

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Indeed, airports are associated with several externalities, with congestion, pollution, and noise being the most important. The nationwide impact of flight delays in the United States has been estimated at over $30 billion in 2007 (Ball et al., 2010). Recently, the Federal Aviation Administration (FAA) estimates that the airline cost for an hour of delay ranges from about $1,400 to $4,500 and that passenger time valuations range from $35 to $63 per hour (FAA, 2020), with delays affecting ticket prices too.[3] These figures confirm that air transport delays are costly, highlighting the importance of airport congestion policies.

Other than congestion, air traffic is also associated with environmental externalities. While the aviation industry is getting more fuel-efficient, overall emissions have risen as air travel volume has increased. Excess airplane idling, i.e., residual daily taxi time due to delays, has significantly impacted emissions levels (Schlenker and Walker, 2016). Despite dramatic reductions over the years in the noise produced by individual aircraft, airport noise also remains a critical public policy issue today. Real estate could be negatively affected by noise exposure (McMillen, 2004), justifying measures such as government economic compensation for households (Mense and Kholodilin, 2014).

In this chapter, we review the literature about pricing and regulation concerned with dealing with these negative externalities. The literature has devoted significantly more attention to congestion than to other externalities, and, consequently, we focus more on congestion. There are two types of measures to deal with congestion: supply-oriented measures such as expanding airport capacity and demand-oriented measures. Furthermore, demand-oriented policies can be classified as price-based (e.g., congestion tolls) and quantity-based policies (e.g., slot control).

Supply-oriented measures include adding infrastructure to existing airports, implementing operational and technological innovation in air traffic control and management, and constructing new airports. The latter involves many stakeholders, often having conflicting objectives. Moreover, airport capacity investments take a very long time from gestation to implementation, and tend to be expensive, lumpy, and subject to significant budget and environmental constraints. As a result, they are less of a solution for decreasing externalities.

In the following section, we discuss the literature about demand-oriented price-based measures. We focus on congestion pricing, understood as the welfare-maximizing pricing of the negative externality between flights. We also discuss second-best pricing and other issues related to pricing, such as private airports' pricing, airport competition, capacity investments, regulation, and the role of non-aeronautical operations. The airport pricing literature is vast, yet the congestion tolls have not been implemented.

Section 11.3 discusses the literature on quantity-based approaches to airport congestion management. Unlike pricing, slot control, which is a direct way of limiting the number of flights, has been implemented in several countries. We also briefly summarize the current practice, including slot control, trade, and auctions. Section 4 complements the review by examining how externalities other than congestion, such as environmental externalities (noise, emissions), could be incorporated into airports' pricing schemes. As this chapter focuses on airports, we do not discuss relevant topics such as airline pricing, price discrimination, yield management, the economics of baggage fees, and network pricing. We conclude in Section 11.5 by providing what we think should be the lines of future research.

11.2 PRICE-BASED DEMAND-ORIENTED MEASURES

The current practice of levying takeoff and landing fees based on the aircraft's weight that are constant throughout the day has been criticized since early contributions by Levine (1969) and Carlin and Park (1970). Since then, several theoretical and empirical analyses have investigated efficient runway pricing policies and their potential benefits and have argued in favor of their implementation.

The difference with the extensive congestion pricing literature developed for road traffic lies in that airlines usually control large shares of traffic at some airports and have market power, in contrast to road drivers who control a single vehicle. Airlines are large players in the aviation markets and, therefore, are expected to internalize the congestion imposed on themselves and their passengers and react differently from road users when facing congestion charges.

Brueckner (2002), the first to formally model congestion and Cournot competition together, shows that welfare-maximizing congestion tolls should only account for the congestion cost imposed on other carriers. This became known as the self-internalization hypothesis, which implies that an airline's congestion charge should be proportional to the aggregate market share of the other airlines, excluding its own flights. This result remains valid under several different settings, including networks, when airport capacity investments are included and when airlines offer differentiated products and schedule delay costs are considered (e.g., Basso, 2008; Brueckner, 2005; Pels and Verhoef, 2004; Zhang and Zhang, 2006). For a more detailed review of the airport pricing literature offering these insights, we refer the reader to Zhang and Czerny (2012).[4]

On the empirical side, the issue has been more contentious. Daniel (1995) offers the first analysis on the potential for self-internalization by investigating the dynamic scheduling behavior of Northwest Airlines at the Minneapolis-St. Paul airport in 1990. Daniel and Harback (2008) follow a similar approach but consider a much broader database, including traffic patterns and delays from 27 major US airports. These analyses provided evidence against the hypothesis of the internalization of self-imposed delays. Empirical evidence in contradiction to the theory on self-internalization is also offered by Van Dender (2007). Based on a dataset from 55 US airports from 1998 to 2002, he found that delays increase when markets become more concentrated. The argument is that dominant airlines behave as Stackelberg leaders and the rest as a competitive fringe, i.e., a group of aircraft that adjust their operations to fill the capacity and keep the delays constant. Given this behavior, the leader has no incentive to internalize delays. The argument is analytically further developed in Brueckner and Van Dender (2008).

Moreover, Brueckner (2002) and Mayer and Sinai (2003) find empirical evidence of the inverse relationship between delays and airline market concentration at an airport and hence internalization of self-imposed congestion effects. Rupp's (2009) findings are mixed. The analysis shows that excess travel times are reduced by carrier market power, which indicates that self-internalization exists and is in line with the results derived by Mayer and Sinai (2003). He also finds that punctuality is reduced by carrier market power, which may stand in contrast to self-internalization. Ater (2012) finds that periods of high flight volume are more extended when the share of flights operated by the hub-airline is greater, and these more extended periods exhibit shorter delays. These results imply that hub-airlines consider the impact of their scheduling decisions on the congestion that they bear.

The internalization of delays is central as it determines the scope and efficiency of congestion pricing at an airport. While the evidence may seem contradictory, Brueckner and Van Dender (2008) were the first to reconcile the two sets of evidence theoretically. They show that a Stackelberg leader's degree of internalization depends on the substitution pattern between leader and fringe, and it can be anywhere between full self-imposed delay internalization and no internalization at all. Silva and Verhoef (2013) complement the analysis by pointing out that results may be reconciled even in the absence of a competitive fringe or a leader firm.

They argue that airline behavior is more consistent with a Bertrand competition model with differentiated products. In this case, airlines always internalize less than the self-imposed delays. Also, the equilibrium congestion levels approach the levels consistent with no internalization at all, the closer the airlines' products are. For example, for a medium degree of substitutability, airlines may internalize less than half of their self-imposed delays, a result consistent with empirical tests that reject internalization and fail to reject no internalization (Daniel, 1995; Daniel and Harback, 2008). However, despite being low, the share of internalized delays always increases with market concentration, validating the empirical findings that support internalization (e.g., Mayer and Sinai, 2003).

The airport pricing literature has moved past the internalization debate to develop new ideas and policy insights in the last ten years. The first strand that we review builds on Daniel (1995) and studies the dynamics of airport runway congestion over time. Daniel (2009) and Silva et al. (2014a) study the interaction between a Stackelberg leader and a competitive fringe using the deterministic Vickrey bottleneck model.[5] They show that the overall internalization pattern is consistent with results that use static models of congestion, such as Brueckner and Van Dender (2008). Nevertheless, the pricing implications are different. The optimal congestion charges are the same for both leader and fringe and do not depend on the degree of internalization of delays in the untolled equilibrium.

Theoretical advances in other models of competition in the dynamic congestion strand of the literature are scarce. According to Silva et al. (2017), the main problem is that the workhorse structural model of dynamic congestion, the Vickrey bottleneck model, cannot be easily extended to simultaneous competition. Indeed, Silva et al. (2017) show that a pure strategy Nash equilibrium (PSNE) does not exist in the simplest bottleneck model in which two identical firms schedule vehicles.[6]

11.2.1 Second-Best Pricing

A second strand of the literature deals with second-best congestion pricing. Among the many second-best problems that exist, we focus here on the existence of financial constraints, limitations on differentiating tolls over firms, and limitations on the number of instruments used.

Regarding the financial constraints, it is well known that the self-financing theorem that holds for road pricing (Mohring and Harwitz, 1962) does not hold for airports because of the presence of airline market power. As an alternative, Basso (2008) shows that welfare maximization subject to cost-recovery performs quite well, achieving congestion levels similar to a private unregulated airport without inducing such significant traffic contraction. Verhoef (2017) proposes a regulatory scheme that restores self-financing under specific technical conditions. Importantly, unlike in the original case for road provision, self-financing holds when airport capacity provision exhibits increasing returns to scale, which is most likely the case for airports. We discuss this topic further in the following subsection, where non-aeronautical revenues are considered. Also, Basso and Zhang (2010) show that if airport revenues matter, the choice of price versus quantity-based congestion management mechanisms is material.

One of the main contributions of uniform pricing is Morrison and Winston (2007). They develop a simple structural model to estimate the welfare effects of congestion tolls and calibrate it with US national trip data. They simulate the impact of charging the (uniform) marginal congestion damage to all airlines as if they did not internalize congestion at all, the so-called atomistic toll. Their main result is that the atomistic and the optimally differentiated congestion tolls achieve similar benefits as the share of internalized delays is small. However, the main simplifying assumptions, absence of airline market power, intertemporal substitution, and substitute products are too strong to overlook when generalizing the results.

On the other hand, the studies that have looked into the efficiency of atomistic congestion tolls without such strong assumptions are theoretical (as opposed to empirical) and use stylized settings. For example, Silva and Verhoef (2013) consider only one market with symmetric airlines and calibrate the model to reflect as much as possible realistic values. Lin (2019) studies welfare-maximizing uniform airport pricing for asymmetric airlines, but with similar simplifications as Silva and Verhoef (2013).

Finally, regarding the limitations of the pricing instruments, Zhang and Zhang (2006) noted that the common assumption of constant load factors implies that per-passenger and per-flight tolls are equivalent. Silva and Verhoef (2013) are among the first to depart from this assumption and study the implications of using one instrument over the other. Intuitively, distortions caused by flight congestion should be corrected through per-flight charges, and the inefficiency caused by airline market power exertion must be corrected with per-passenger subsidies. Naturally, the latter is practically impossible and the relevant question is how well per-flight tolls perform when market power effects are not corrected directly. They find that if the airport is not too concentrated, the relative efficiency of per-flight tolls relative to the first-best with subsidies can be significant. For example, with five symmetric firms with equal market shares, the relative efficiency is between 20% and 60%. Importantly, they show that charging atomistic tolls reaches at least 75% of those benefits. This result is in line with Morrison and Winston (2007), implying that the differentiation of congestion tolls may not be of crucial relevance.

Czerny and Zhang (2015) and Czerny et al. (2017) contribute to the topic of per-passenger versus per-flight charges by studying under which conditions airlines and welfare-maximizing airports under a cost-recovery constraint prefer to increase per-passenger charges and decrease per-flight tolls. Their analysis suggests that the current trend of increased per-passenger tolls and reduced per-flight tolls should not concern regulators, as long as congestion delays are relatively unimportant. Finally, several articles deal with airport pricing considering airlines' networks and route structure choice (e.g., Flores-Fillol, 2010; Silva et al., 2014b; Lin and Zhang, 2017). Although these are outside the scope of this review, a few of them show how the optimal per-flight and per-passenger charges should account for the route structure choice.

11.2.2 Pricing of Private Airports, Airport Competition and Capacity Investments

Airports have traditionally been owned and managed as government entities. Yet, starting with the privatization of some UK airports in 1987, more and more airports worldwide have been (partially) privatized. The rationale behind the privatization of airports is that they would implement more efficient congestion pricing schemes and better invest in capacity. The main concern has been that privatized airports are essentially local monopolies and will utilize their market power. But it has been argued that regulation may be unnecessary because a private unregulated airport would not induce large allocative inefficiencies, since price elasticities are low, and because potential collaboration between airlines and airports – or airline countervailing power – would put downward pressure on market power.

The theory shows that an unregulated profit-maximizing airport would overcharge for the congestion externality and, compared to the first-best, would induce large allocative inefficiencies and deadweight losses. Accordingly, the private airport charge is excessive from a social viewpoint (Zhang and Zhang, 2003, 2006; Basso, 2008).[7] As for the effects of privatization on capacity decisions, Oum et al. (2004) show that the capacity investment rule of a private airport is the same as the first-best rule when carriers are atomistic. This is that capacity is added until the marginal costs equate to the marginal benefits due to reduced delays to passengers and airlines. However, Basso (2008) and Zhang and Zhang (2010) show that in the general case of non-atomistic carriers, a private airport, for a given traffic volume, will overinvest in capacity, whether unregulated or regulated. The intuition is that an expansion in the capacity that reduces congestion raises the passengers' willingness to pay and cuts the carriers' ticket prices due to the decline of the marginal congestion cost that is internalized by the airlines. Both effects can contribute to a higher airport charge without changing the total demand. Consequently, when carriers have market power, reducing congestion is an effective way to increase the airport's revenue. For this reason, the result also holds for a public airport under a cost-recovery constraint, as Zhang and Zhang (2010) show.

Nonetheless, the growth of air transport demand and low-cost carriers have contributed to increased competition for passengers and carriers between airports. Indeed, there are several multi-airport regions such as Greater London, New York, and the San Francisco Bay Area where airports cannot be considered as monopolies. Basso and Zhang (2007b) are among the earliest theoretical studies on the topic. Using a Hotelling-type model, they show that duopoly facilities have lower charges and invest less in capacity than a monopolist when the facilities first decide on capacities and then on prices.[8] This is important as both the airport charge and the capacity investment move toward the socially optimal ones.

However, the extent to which competition in multi-airport regions reduces the need for regulation is ultimately an empirical matter. Yan and Winston (2014) study the potential effects of privatization on airport prices and welfare for the San Francisco metropolitan area. They develop an empirically tractable model of competition that considers the three airports (Oakland, San Francisco, and San Jose) and the network of domestic flights. Their main result is that competition can lead to large welfare gains: if there is a competitive environment for airports (i.e., privatized to different owners), this allows airlines to negotiate with airports to prevent excessive airport charges, which stimulates differentiated services by larger and smaller airports. Nevertheless, the gains come at the expense of consumers whose welfare decreases in all studied privatization scenarios.

Another relevant strategic interaction between private airports occurs when they are complements in international markets. Early studies by Mantin (2012) and Matsumura and Matsushima (2012), later extended by Lin and Mantin (2015), analyze the pricing decision of international airports that connect two countries and serve as hubs for local markets. There are three types of passengers (national, international hub-to-hub, and international one-stop) and two types of airlines, regional carriers, and hub-airlines. Moreover, they derive the pricing decisions of local welfare-maximizing and private airports and study the governments' incentives to privatize them. The main insight of the analysis is that a country may benefit from privatizing the hub-airport (alone or together with the local airport) if the international hub–hub market size is sufficiently large with respect to the domestic hub–local market size. The intuition is that airports cannot price discriminate and that the country benefits from extracting surplus to foreign passengers in the international hub–hub market. When the international hub–hub market is large and the other country privatizes its hub, privatizing its own hub-airport is a dominant strategy. Furthermore, they show that when countries privatize, governments are in a Prisoners' Dilemma type of equilibrium as both would be better off by keeping all airports under public ownership.[9]

11.2.3 Regulation and Non-Aeronautical Operations

Given the growing pressure on airports to self-finance their operations, airports have increasingly depended on revenues generated by non-aeronautical businesses, including side activities like terminal concessions, advertising, car rentals, car parking, and land rent. For the last three decades, non-aeronautical revenues have grown faster than aeronautical ones; thus, they have become the primary income source for many airports (Zhang and Czerny, 2012). Commercial operations tend to be more profitable than aeronautical operations, owing partly to the "locational rents" enjoyed by an airport and partly to prevailing regulations and charging mechanisms (Starkie, 2021). While aeronautical operations are subject to various forms of regulation – either explicitly or implicitly – commercial operations are usually unregulated. One consequence of this profit disparity is that the profits made from commercial activities may be used to cross-subsidize aeronautical operations, diminishing the need for government aid (see, e.g., Zhang and Zhang, 1997; Zhang and Zhang, 2003).

Traditionally, the demand for side services is complementary to the demand for aeronautical services, in that the more people use the airport, the higher the non-aeronautical revenues are. Moreover, most consumers' decision to fly is based on the full price of the aeronautical service only; they do not consider the price of side activities in their travel decisions.[10] With atomistic airlines, Zhang and Zhang (1997) find that the first-best optimal solution (for an unconstrained public airport) involves marginal cost pricing on side services. Since a smaller aeronautical charge increases the demand for aeronautical and non-aeronautical services, the social marginal cost pricing on core activities would have an additional markdown. Conversely, the second-best optimal price (for a budget-constrained public airport) of non-aeronautical services would be higher than the related marginal cost, showing that profits would be made in the non-aeronautical business. Therefore, non-aeronautical operations would subsidize aeronautical operations. If the airport were not allowed to make profits from its non-aeronautical operations but were still asked to self-finance its operations, this would lead to a smaller level of social welfare. The downward pressure on the aeronautical charge elicited by non-aeronautical services is also confirmed in the presence of airline market power (Zhang and Zhang, 2010) and has been discussed in the case of different passenger types (Czerny and Zhang, 2014; D'Alfonso et al., 2013) and terminal congestion (Wan et al., 2015). Notably, in the absence of passenger-type-based price discrimination by airlines, it can be useful to increase the airport charge to protect passengers with a great relative time value. For example, to protect business passengers from excessive congestion caused by passengers with a low relative time value, e.g., leisure passengers. Extensions include price discrimination between business and leisure passengers when operating costs are the same for all passengers (Czerny and Zhang, 2014). Zhang et al. (2010) and Fu and Zhang (2010) deal with the issue of non-aeronautical revenue sharing with multiple airlines and airports and its effects on social welfare, but they focus on non-congested airports. Bracaglia et al. (2014) and D'Alfonso and Bracaglia (2017) discuss the role of service consumption and how it could be considered independent of traveling. This is relevant because it implies that a markdown would not be appropriate.

Zhang and Zhang (2003) and Oum et al. (2004) find that, while private airside prices diminish, they decrease less than the prices in a public airport with non-aeronautical activities, and that this is the case for both the first-best pricing and second-best pricing. Therefore, non-aeronautical revenues would not be a valid argument for deregulation once an airport is privatized. The intuition of the result is simple: a private airport would care about the extra profits it can make from side activities; a public airport maximizing social welfare, however, would care about non-aeronautical profits and the consumer surplus induced. Consequently, the decrease in the aeronautical charge would be more significant in the public case: non-aeronautical revenues would increase the gap between private and public airside charges.

Czerny (2006), Oum et al. (2004), Lu and Pagliari (2004), Yang and Zhang (2011), and Kidokoro et al. (2016) analyze the effects of alternative mechanisms of regulation on the performance of private airports, with a particular focus on how revenues from non-aeronautical services should be dealt with. Oum et al. (2004) conclude that the dual-till rate of return (ROR) induces the airport to invest optimally in capacity, while a price cap (either single-till or dual-till) induces underinvestment in capacity, worsening the congestion problem.[11] Indeed, the airport cannot recoup fully from its investment in capacity – which reduces congestion and increases the users' willingness to pay – because the price is capped. Lu and Pagliari (2004) and Czerny (2006) argue that single-till price-cap regulation is socially more desirable than a dual-till approach at non-congested airports, while the dual-till scheme dominates at congested airports. In principle, under the single-till price-cap regulation, the problem is that the more profit the airport makes from concessions, the smaller the allowed aeronautical charge would be in future revisions of the cap, even if traffic grows and congestion builds. Yang and Zhang (2011) demonstrate that when airport congestion is not a major problem, single-till price-cap regulation dominates dual-till price-cap regulation concerning social welfare. However, they identify that dual-till regulation performs better than single-till regulation when significant airport congestion occurs. Kidokoro et al. (2016) confirm that dual-till regulation yields higher welfare than single-till regulation, as long as the profit from non-aeronautical services is positive.

11.3 QUANTITY-BASED DEMAND MANAGEMENT MECHANISMS: SLOTS

An airport slot is an authorization to either take off or land on a particular day during a specified period (usually 15 minutes). The granting of a slot means the airline may use the full range of elementary infrastructure services (both airside and groundside) necessary for operating a flight at a given time. The use of slots to manage airport congestion has been gaining support due to the constraints on airport expansions and the lack of backing for congestion pricing. Currently, around 350 airports are slot coordinated, most being in Europe. The main events related to slot regulation and usage are displayed in Figure 11.1 as a timeline, and Table 11.1 summarizes the use of slot coordination worldwide by region as of January 2022.

The intuition and appeal of slot coordination at airports are that congestion externalities can be reduced to an optimal level by fixing a total desired flight volume. However, the practice of allocating slots has not been in line with this target. In the United States, slot administration at coordinated airports generally follows the process laid out by IATA in the Worldwide Slot Guidelines. The method relies heavily on "historical slots," or slots carriers have operated for a qualifying duration under the FAA rules. The carriers submit their schedules or slot requests, and the FAA responds to their proposal. In the European Union, the Slot Allocation

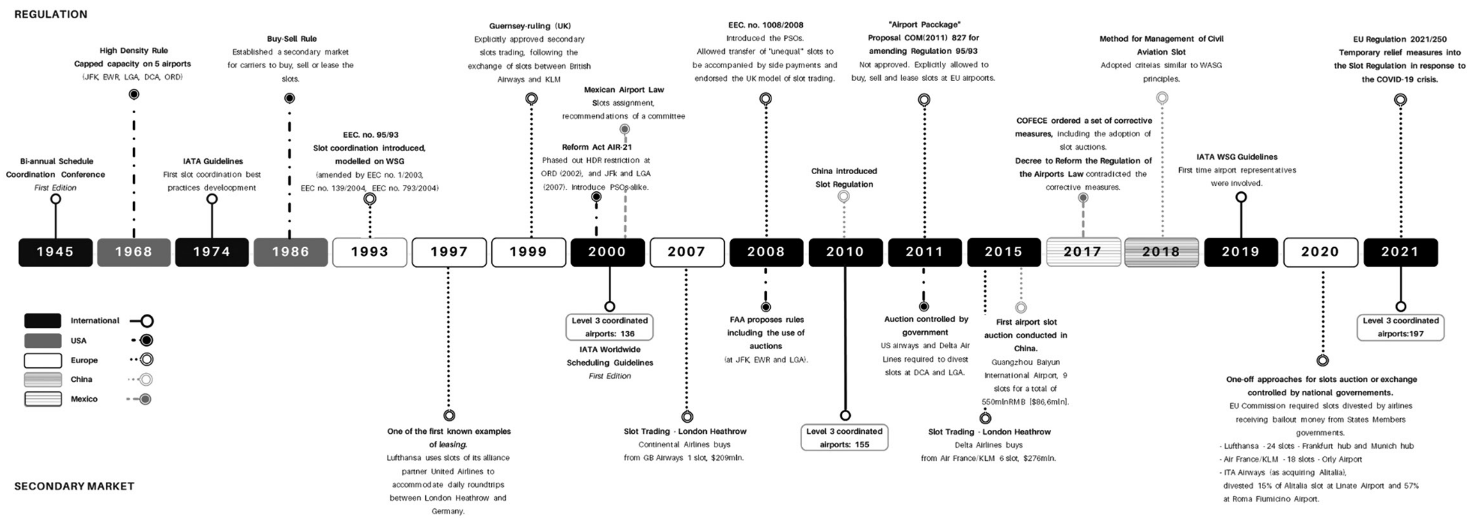

Figure 11.1 *Timeline of slot regulation main events*

Table 11.1 Countries with slot-coordinated airports by region (as officially declared to IATA). The number of airports per country is in parenthesis

Asia Pacific	Europe		Middle East and Africa	North Asia	The Americas
Australia (8)	Austria (6)	Kosovo (1)	Bahrain (1)	China, P.R. (22)	Bermuda (1)
Bangladesh (1)	Belgium (1)	Lithuania (1)	Egypt (6)	Chinese Taipei (2)	Brazil (13)
Cambodia (2)	Bulgaria (1)	Luxembourg (1)	Ghana (1)	Hong Kong (SAR), China (1)	Canada (5)
India (10)	Croatia (4)	Malta (1)	Kuwait (1)	Macau (SAR), China (1)	Cayman Islands (1)
Indonesia (2)	Cyprus (2)	Netherlands (3)	Morocco (2)		Colombia (1)
Japan (6)	Czech Republic (1)	Northern Macedonia (1)	Qatar (2)		Cuba (4)
Malaysia (1)	Denmark (2)	Norway (14)	Republic of Cape Verde (3)		Mexico (1)
New Zealand (4)	Faroe Islands (1)	Norway/Svalbard & Jan Mayen Islands (1)	Saudi Arabia (13)		Peru (1)
Pakistan (4)	Finland (1)	Poland (3)	Seychelles (1)		Turks & Caicos Islands (1)
Pakistan (4)	France (8)	Portugal (5)	South Africa (3)		United States (7)
Papua New Guinea (1)	Germany (15)	Russian Federation (4)	Sultanate of Oman (1)		
Philippines (1)	Greece (20)	Slovakia (1)	Tunisia (2)		
Republic of Korea (3)	Greenland (3)	Slovenia (1)	United Arab Emirates (3)		
Republic of Maldives (1)	Hungary (1)	Spain (27)			
Singapore (1)	Iceland (1)	Sweden (8)			
Sri Lanka (1)	Ireland (1)	Switzerland (2)			
Thailand (9)	Israel (2)	Turkey (8)			
Vietnam (2)	Italy (24)	Ukraine (2)			
		United Kingdom (18)			

Source: www.iata.org/contentassets/4ede2aabfcc14a55919e468054d714fe/wasg-annex-12.7.xlsx (last retrieved on January 27, 2022).

Regulation (EC Regulation 95/93, as amended by Regulation 793/2004) defines the mandatory rules for coordinated airports (EC, 2004). Although there are no property rights, there are grandfather rights in using slots. If an air carrier has used some slots for at least 80% of the time during a season, it is entitled to use the same slots in the next corresponding season; otherwise, slots become free and may be allocated to new entrants.

The outcome of slot allocation mechanisms based on historical rights can be far from economic efficiency. The use-it-or-lose-it rule may induce airlines to slot hoarding – being reluctant to cede slots for fear of a rival's entry – and inefficient use of slots. Examples are behaviors such as "slot babysitting," in which airlines only use them for the minimum required amount to retain their grandfather rights (Ball et al., 2018; Dempsey, 2001). In practice, few carriers hold many available slots and operate several flights merely to comply with the use-it-or-lose-it rule (Madas and Zografos, 2006, 2008). As a result, market concentration may increase, raising competition concerns.

Market mechanisms for slot allocation have been widely discussed in the economic literature (Brueckner, 2009; Button, 2008; Verhoef, 2010). In principle, well-designed auctions may ensure that the resource is assigned to those bidders that will generate the highest value from managing it. Secondary trading may improve efficiency by creating an opportunity cost for holding slots since airlines that use slots forego revenues from selling (the right to use) slots. Despite their benefits, market mechanisms also have some crucial drawbacks. Above all, high private valuations do not necessarily reflect the social value of the resource. While there is the need to achieve economic efficiency in allocating valuable resources (thereby maximizing a weighted sum of consumers' and producers' surplus), this goal can hardly be attained in practice as consumers do not participate in auctions. Thus, the outcome of an auction is primarily driven by bidders' profits rather than social welfare (Klemperer, 2002). Moreover, Hoppe et al. (2006) stress the importance of market structure as a determinant of bidders' valuations. Finally, potential buyers and sellers do not necessarily meet each other due to a lack of information (Aravena et al., 2019; Avenali et al., 2015).

Table 11.2 summarizes the use of secondary markets since their first use. As the last column of Table 11.2 reveals, slots are very valuable to airlines. However, the use of trading and leasing has been limited, and auctions have occurred very rarely. For example, in 2008, the US FAA initiated a proposal to auction off 10% of the slots at New York City's three major airports, which was met with criticism from airlines and IATA. In 2009, the Obama Administration rescinded the plans for slot auctions after the US Court of Appeals stayed the proposal in December 2008 (IATA, 2010). An obvious question is whether these two mechanisms, pricing versus slot policies, are equivalent. Brueckner (2009) shows that distributing slots and allowing free trade and a slot auction would achieve the first-best outcome in the absence of market power and information asymmetries. On the other hand, slot sales – which are treated as a uniform congestion toll – are inferior to congestion pricing and slot trading/slot auctions except when the airlines are symmetric in size. Brueckner's (2009) discussion parallels Verhoef's (2010) analysis, which finds that tradable slots may yield the first-best outcome if the congestion externality is relatively important and the market power distortion relatively unimportant. Conversely, Basso and Zhang (2010) show that the equivalence is lost under perfect information if the airport profits matter (either because it is privately owned or because it has to self-finance). If airport profits matter marginally, slot auctions will outperform pricing to achieve a higher objective function

Table 11.2 The use of secondary markets since their first use

Year	Type	Airport	Buyer/User	Seller/Leaser/Divested	Price, Number of slots
2007	Trading	London Heathrow (UK)	Continental Airlines	GB Airways	$209MM, 1 pair
2008	Trading	London Heathrow (UK)	Continental Airlines	GB Airways	$52.3MM each, 4 pairs
2008	Trading	New York LaGuardia (USA)	Southwest Airlines		$7.5MM, 14 slots
2014	Trading	London Heathrow (UK)	American Airlines	Cyprus Airways	$32MM, 2 slots
2015	Trading	London Heathrow (UK)	American Airlines	SAS Airlines	$60MM, 1 slot
2015	Trading	London Heathrow (UK)	Delta Airlines	Air France\KLM	$276MM, 6 slots
2016	Trading	London Heathrow (UK)	Oman Air	Air France/KLM	$75MM, 1 pair
2017	Trading	London Heathrow (UK)	American	SAS Airlines	$75MM, 2 slots
2020	Trading	London Heathrow (UK)	*Not disclosed*	Air New Zealand	$27MM, 1 pair
1997	Leasing	London Heathrow (UK)	Lufthansa	United Airlines	
2015	Leasing *Long-term*	New York John F. Kennedy (USA) New York Newark Liberty (USA)	Delta (JFK), United Airlines (EWR)	Delta (EWR), United Airlines (JFK)	$14MM, 14 slots (EWR) $14MM, 30 slots (JFK)
2020	Leasing	Amsterdam Schiphol (EU) London Heathrow (UK)	Delta Airlines	Air France\KLM	
2008	Auction *Attempt blocked*	New York John F. Kennedy (USA) New York LaGuardia (USA) New York Newark Liberty (USA)			
2011	Auction *Government-Controlled*	Ronald Reagan Washington National Airport (USA), New York LaGuardia (USA)	JetBlue for DCA and LGA, WestJet for LGA	US Airways Delta Airlines	$40MM, 16 slots at DCA $49.6MM, 32 slots at LGA

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2015	Auction *Executed*	Guangzhou Baiyun International Airport (China)	Air China, China Eastern, China Southern, Hainan Airlines		550 MM RMB, 9 slots
2016	Auction *Announced*	Shanghai Pudong International Airport (China)			
2016	Divest *Anti-trust*	New York John F. Kennedy (USA) Mexico City (MEX)		Delta Airlines Aeroméxico	
2020	Auction One-off approach,	Frankfurt hub (EU) Munich hub (EU)		Lufthansa	24 slots per day
2021	Controlled by	Orly Airport (EU)	Vueling	Air France\KLM	18 slots per day
2021	government	Milano Linate Airport (EU) Roma Fiumicino hub (EU)		ITA Airways, as acquiring Alitalia	15% of Alitalia slots at Linate airport, 57% at Roma Fiumicino hub

Source: own elaboration

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value. Pricing may be strongly preferred over slot auctions, especially when airlines are asymmetric.

Another stream of literature presents variants of Weitzman's (1974) analysis and compares the performance of quantity and price mechanisms considering more complex information structures. Czerny (2008, 2010) shows that the social benefits of slots relative to congestion pricing depend on the functional forms of passenger demand and congestion cost when passenger demands are uncertain. Notably, Czerny (2010) shows analytically that airport networks (as opposed to single airports) increase the relative welfare benefits of quantity-based mechanisms. Aravena et al. (2019) compare tolls with slots under asymmetric information. In this setting, the equivalence between the two is lost: direct allocation is always *ex-post* inefficient, and, in some cases, tolls and subsequent quantity delegation is a better alternative social welfare wise. Auctions may be superior or inferior to tolls. [12]

The empirical evidence about the impacts of slot auctions and trade is mixed. In the UK, trading has had varied effects. It has helped a dominant carrier (British Airways) increase the share of slots at Heathrow airport and other strong carriers, such as Virgin Atlantic, emerge. The UK case study also suggests that the slot trades among partner carriers contributed to slightly increased competition measured in terms of the number of competitors per route. In contrast, the slot trades between rival carriers decreased the number of competitors at the route level (Fukui, 2014). The results suggest that carriers seem to have used the slots obtained from their rivals to strengthen their dominance on their existing routes. Mixed results have also been observed for the secondary trading of slots in the United States. Evidence shows that, while slot-holding carriers did sell their slots to other airlines, including new entrant carriers and rival carriers, the number of slots sold to them was too limited to allow these carriers to increase their presence at airports (Fukui, 2010, 2012). Focusing on the impact of slot restrictions as a determinant of scarcity rent (i.e., the markup on fares resulting from airport capacity shortages), slot restrictions have limited the effect of competition on airfare (Fukui, 2019). The scarcity rent is not transferred to passengers: the average fare at Newark, for instance, decreased by about 2.5–2.6% after the slot removal, and the key driver lowering airfares was carriers other than the dominant carrier (i.e., United Airlines).

11.4 AIRPORT PRICING CONSIDERING ENVIRONMENTAL COSTS

In addition to congestion, charges at airports could be set to account for environmental damages (e.g., emissions and noise). Excess airplane idling, i.e., residual daily taxi time due to delays, has been proven to significantly impact residents' health, primarily driven by increased levels of carbon monoxide (CO) exposure. For instance, Schlenker and Walker (2016) use the variation in daily airport congestion to estimate the population dose-response of health outcomes to daily CO exposure, examining hospitalization rates for asthma, respiratory, and heart-related emergency room admissions. They find a one standard deviation increase in daily pollution levels leads to an additional \$540 thousand in hospitalization costs for respiratory and heart-related admissions for the 6 million individuals living within 10 km of the airports in California. The circling in the air waiting for landing also burns extra fuel increasing greenhouse gas (GHG) emissions. Furthermore, the possibility of being held up induces airlines to carry extra fuel in their aircraft, increasing the aircraft's weight and, consequently, fuel consumption and GHG emissions (see The Economist, 2006).

Despite the dramatic gains in aircraft "quietness" over the jet age, evidence shows growing trends in various airport noise limits, such as operational curfews, noise quotas, and noise surcharges, in the United States. Such measures are even more widespread in Europe, as Girvin (2009) discussed. Indeed, aircraft noise is one, if not the most detrimental environmental effect of aviation, being associated with severe health effects, such as sleep disorders, cardiovascular disorders, and even low birth weight babies (Argys et al., 2020).

When charges at airports are set to account for environmental damages, in addition to the airport's marginal cost and the marginal cost of congestion, each aircraft would have to pay the marginal environmental damage it produces. This should consider that the extra delay a new flight imposes on existing flights increases all flights' average environmental cost (Carlsson, 2003). The optimal charge would depend on the aircraft types and times of the day.

In practice, optimal environmental taxation and regulation are complicated by several factors, such as network effects (Carlsson, 2002; Girvin, 2010; Nero and Black, 1998; O'Kelly, 2012). Higher flight frequency benefits passengers by reducing schedule delays (allowing departures at more convenient times) but generating greater environmental damage (Brueckner and Girvin, 2008). Along with the companion paper by Girvin (2010), Brueckner and Girvin (2008) explore the impact of airport noise regulation on airline service quality and airfares. They also characterize the socially optimal stringency of noise limits, taking both noise damage and the various costs borne by airlines and their passengers into account. They show how noise regulation harms airline passengers by raising fares and potentially reducing service quality. Brueckner and Zhang (2010) explore the effect of airline emissions charges on airfares, airline service quality, aircraft design features, and network structure by analyzing the impact of an increase in the effective fuel price, and the path by which emissions charges will alter airline choices.[13] The results show that emission charges will raise fares, reduce flight frequency, increase load factors, and raise aircraft fuel efficiency, not affecting aircraft size.

11.5 CONCLUDING REMARKS

We have reviewed the airport pricing literature of the last 10–15 years, emphasizing optimal congestion pricing. We revised the studies that focus on the dynamics of airport runway congestion and those that study second-best pricing problems. We have also provided an overview of the pricing of private airports, airport competition and capacity investments, regulation and the role of non-aeronautical operations. We have discussed quantity-based approaches and their equivalence with congestion pricing and the pricing of externalities such as noise and emissions.

We conclude by providing what we believe are the most relevant avenues for future research. First, the discussion on quantity-based regulation and its comparison with pricing abstracts away from the consideration that assigning slots via market mechanisms locally (i.e., at any given airport) cannot fully internalize interdependencies among slots at different airports (for each flight, an airline needs a feasible combination of slots at the origin and destination airports). Czerny and Lang (2019) and Lang and Czerny (forthcoming) analyze the subject and study the conditions under which quantities determined by a local authority can reach the first-best quantity, yet more research is needed. Moreover, the vast majority of the articles about airport pricing and regulation assume perfect information, with the few exceptions of Czerny (2010), Aravena et al. (2019), and de Palma and Lindsey (2020). The lack of studies with private information is most likely due to the added complexity given by the within and between-markets negative externality. Vickrey–Clarke–Grooves mechanisms seem to be a promising approach for solving the congestion problem when regulators are not perfectly informed.

Second, in most dynamic congestion models, congestion tolls must vary continuously over time to achieve the optimum. In practice, however, only tolls that take different values over discrete time intervals (but constant within each interval) have been implemented. Given the prevalence of these so-called step-tolling schemes, they have received surprisingly little attention in the airport pricing literature.[14]

Third, the problem of per-passenger-based versus per-flight-based airport charges is somehow under-investigated. Czerny et al. (2017) focus on the issue while extending the monopoly case in Czerny and Zhang (2015) to the oligopoly case. Further topics include discussing passenger types and price discrimination, including transfer passengers, and introducing the investigation in a hub–spoke network. An environment designed to study second-best pricing with endogenous load factors would also be a worthwhile avenue for future research. Studies only recently started to analyze more realistic and complex models with endogenous load factors (e.g., Czerny et al., 2016).

On the modeling technique side, we believe structural and empirically tractable models that integrate airport decisions, the vertical relationship between airports and airlines, the competition between airlines, and congestion externalities should be at the center of future research. Some of the components we deem fundamental for future research on airport pricing and regulation include discrete choice models in the spirit of Berry et al. (1995), structural models of airport congestion such as Daniel and Harback (2009), and strategic choices of capacity and prices by airlines. To the best of our knowledge, the only study that incorporates some of these elements is Yan and Winston (2014), who study airport privatization and competition. The airport pricing and quantity regulation literature would greatly benefit from these approaches.

NOTES

1. Although the positive effects of aviation on the economy seem intuitive, the identification of such as a causal relationship is difficult because of the strong interdependence between the provision of aviation services and regional growth (Blonigen and Cristea, 2015). Campante and Yanagizawa-Drott (2018) confirm a causal link between long-haul non-stop flights and economic growth, but also show how the flow of investments tends to originate largely in the wealthiest countries towards medium income ones, with low-income countries partially shut out of this process.
2. Whether congestion leads to flight delays is largely under the control of the airlines since they are free to set scheduled flight durations. In other words, the congestion-related lengthening of flight times can be built into airline schedules through a practice known as "schedule padding," whose recent growth is documented by Forbes et al. (2019) and Brueckner et al. (2021). While airport congestion may make flights longer, this schedule adjustment prevents them from arriving late with respect to the schedule.
3. Forbes (2008) uses data from New York-La Guardia airport and finds an average price reduction per additional minute of delay of \$1.42 for direct passengers; this price decrease amounts to \$0.77 for connecting passengers. Britto et al. (2012), on a sample of US routes, find that a 10% decrease in delays implies a benefit of \$1.50–2.50 per passenger, while the gains for airlines of reducing delays are about three times higher. Recently, Bilotkach and Pai (2020) find that one additional minute of weather delay decreases average US fares by between \$4.46 and \$6.55, while an extra minute of carrier delay results in a \$2.70 to \$5.13 price decrease.
4. Before Brueckner's contribution, it was common to model airports as if they were selling directly a final product; Basso and Zhang (2007a) call this the "traditional approach" and review these papers.

This approach is different to the current common modelling setting of a vertical airport-airline-passengers structure. Basso and Zhang (2008) show analytically that the traditional approach is valid only if air carriers have no market power and have constant marginal operational costs.

5. The essence of the bottleneck model is that users trade off the costs of queuing delay at the bottleneck with the costs of schedule delay (i.e., arriving/leaving earlier or later than desired). Basso (2008), Brueckner (2004) and Flores Fillol (2010) do not consider a dynamic model of congestion but they include schedule delay costs as the expected gap between passengers' actual and desired departure time, which decreases with frequency.
6. The model assumes α-β-γ preferences. Lindsey et al. (2019) extend the result to multiple firms and shows that with sufficient heterogeneity PSNE can be restored.
7. Bel and Fageda (2010), using data for 100 large airports in Europe, provide evidence that unregulated private airports charge higher prices than public or regulated airports.
8. When the capacity and price decisions are made simultaneously, the duopolists provide the same service quality as the monopolist.
9. Lin (2020) analyzes uniform and discriminatory charges for local-welfare-maximizing international airports that benefit from extracting rents from foreign airlines. Unlike the papers we discuss above, they study capacity investments and show that each airport tends to overinvest under locally optimal pricing rules.
10. On the other hand, a second strand of the literature assumes that consumers may make decisions about buying flights and non-aviation services simultaneously rather than independently. In this case, passengers increase as the price for side services decreases. A reduction in the price for side services can be considered as an increase in airport "quality," which enhances consumer surplus and thus stimulates travel demand (Czerny, 2006; Flores-Fillol et al., 2018). In this setting, the provision of non-aeronautical services can increase or reduce the private aeronautical charge relative to a situation where side services not exist. Recently, Gomez and Tirole (2018) study the imposition a minimum price on for ancillary services in order to curb the incentive to increase prices for core services.
11. Under the single-till ROR, airport charges are set for cost recovery plus a return on the invested capital. Under the dual-till ROR, the return applies only to aeronautical operations. As of price cap regulation, under a single-till airport revenues from all services should cover the airport's total costs. Under dual-till price cap, the airport charge is set such that only the aeronautical services' revenues cover its costs, while keeping non-aeronautical services unregulated.
12. Basso et al., (2017) examine the optimal design of monopoly regulation in the presence of asymmetric information Under decreasing marginal cost and with the possibility of offering menus, a regulator would significantly improve welfare regulating through quantity. As long as the regulator can enforce the actual sale of the product, which is the case, for example, when airport slots are assigned, quantity seems an attractive regulatory instrument.
13. The Emission Trading System (ETS) generates a permit price that becomes part of an airline's cost structure. With the carrier's required outlay on emissions permits varying in step with its total fuel consumption, the permit price is effectively added to the price of fuel, even though most of the permits will be freely distributed. Thus, the planned trading system can be viewed as equivalent to a carbon-tax scheme applied to aviation, which would explicitly raise the price of fuel. As a result, regardless of whether policy interventions to limit aviation emissions follow the EU's cap-and-trade approach or rely on taxation, they can all be depicted as policies that raise the fuel price paid by airlines (Brueckner and Zhang, 2010).
14. Daniel (2009) develops a general step-tolling model for which the no-toll and continuously-varying toll equilibria are the limiting cases as the number of tolling steps goes from zero to infinity. This unified model of tolling demonstrates how the dominant-fringe equilibria interact with the tolling structures.

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