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Can private airport competition improve runway pricing? The case of San Francisco Bay area airports[☆]

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ABSTRACT

Travelers and airlines are frustrated by long and costly travel delays at public airports that are attributable to runway charges that do not account for aircraft congestion. Because the inefficient charges are likely to persist, we explore whether private airport competition could lead to more efficient charges that improve travelers' welfare, increase airlines' profits, and enable the airports to be profitable. We use the San Francisco Bay Area for our assessment and identify important conditions to achieve those outcomes, including competition among separately owned airports, bargaining between airports and airlines, and the ability of airports to differentiate prices and service.

1. Introduction

Public airports have failed to curb the increasingly long and costly travel delays that have frustrated both air travelers and airlines. The heart of the problem is that aircraft pay for runway landings—takeoffs are not charged—based on their weight subject to guidelines set by the Federal Aviation Administration (Van Dender, 2007). Weight-based landing fees do not vary with the volume of traffic, which affects congestion and delays, and are therefore inefficient. In principle, runway charges could be reformed to improve efficiency, but political resistance to reforming FAA policies (Winston, 2013) and the logistical challenges confronting a government authority that attempts to regulate prices for different airports in a metropolitan area suggest it would be more fruitful to explore whether private airport competition could improve airport runway pricing with government regulation, such as price caps, imposed only if it could enhance welfare. The U.S. Congressional airport privatization program and, for example, London's airport privatization experiment, where its major airports, Heathrow, Gatwick, and Stansted, have been sold to different owners, indicate that policymakers have a serious interest in the issue.

The purpose of this paper is to explore the potential effects of private airport competition on runway prices and the welfare of travelers, airlines, and airports for the San Francisco metropolitan area by developing an empirically tractable model of competition among Oakland, San Francisco, and San Jose airports. Previous literature has not modeled airport competition in this manner, but it has identified possible outcomes of privatization on runway pricing. Starkie (2001) and Zhang and Zhang (2003) pointed out in the stylized case of a monopoly airport that the rents from leasing space to other businesses such as retail shops induce the airport to set runway charges much closer to social marginal costs—to increase passenger throughput—than if the airport had no concessions. Basso (2008) provided a theoretical and numerical analysis that showed the welfare effects of airport privatization vary with competitive conditions. And empirical studies of European airports have indicated that privatization's effect on prices is debatable as Bel and Fageda (2010) found in a cross-section data analysis that runway charges are higher at private airports than at public airports and at private airports subject to regulation, while Bilotkach et al. (2012) found in a panel-data analysis that charges are lower at privatized airports.

Our main finding is that private airport competition could increase commercial travelers' welfare and airlines' profits and enable the airports to be profitable. The key conditions are that policymakers privatize all three Bay Area airports and sell them to different owners. In this environment, airports compete for airline operations by setting aircraft charges that reduce delays (*upstream competition*), aircraft charges are determined through negotiations between each airport and commercial carriers, which are organized as a bargaining unit (*bargaining between upstream and downstream firms*), and different classifications of users, commercial airlines and general aviation, face different charges (*upstream price differentiation*). We indicate how those conditions could be met in practice, thereby providing general guidance to policymakers who may want to institute private airport competition.

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Table 1
Summary statistics for SF airports.

	SFO	SJC	OAK
Total passengers in 2007[a]	34,346,413	10,653,817	14,533,825
Average trip distance of commercial travelers (miles)[b]	2084 (577)	1993 (603)	1996 (614)
Average flying time of commercial travelers (hour)[b]	4.93 (1.27)	4.78 (1.29)	4.70 (1.32)
Total commercial flight operations in 2007:3 [c]	69,331	31,257	44,991
Average commercial aircraft size (seats)[d]	146 (45)	126 (42)	134 (26)
Total general aviation (GA) flight operations in 2007:3 [c]	29,588	17,610	23,901
Percent of GA operations that are air taxis in 2007:3 [c]	84.1	42.1	31.6
Average number of commercial flights in a 15 minute interval in 2007:3 [e]	11 [1, 27]	6 [1, 15]	6 [1, 17]
Average departure delay in 2007:3 (min) [f]	15 (13)	9 (11)	10 (11)
Average arrival delay in 2007:3 (min) [f]	5 (4)	3 (3)	3 (3)

[a] Source: annual reports of the airports.
[b] Source: DB1B. Numbers in parentheses are standard errors.
[c] Source: http://aspm.faa.gov/opsnet/sys/Airport.asp.
[d] Source: Back Aviation Solutions database. Numbers in parentheses are standard errors.
[e] Source: ASPM data base. Numbers in parentheses are minimal and maximal values.
[f] Source: ASPM database. Numbers in parentheses are standard errors.

2. Modeling framework

Modeling private airport competition is challenging because consumer welfare and the profitability of the downstream firms, air carriers, and upstream firms, airports, is affected. We construct an appropriate network of air transportation routes to study and then model competition among private San Francisco Bay Area airports as a sequential-moves game given the network. The model and our findings account for horizontal airport competition, the vertical relationship between airports and airlines, and horizontal airline competition where airlines compete in both price and capacity.

2.1. The air transportation network

We confine our assessment to the San Francisco Bay Area airports, San Francisco Airport (SFO), Oakland Airport (OAK), and San Jose Airport (SJC), because those airports comprise a plausible market where competition is feasible and may be beneficial to travelers and airlines. As shown in the summary of the airports' operations in Table 1, SFO is the largest of the airports in terms of passengers, commercial flights, and general aviation operations, especially air taxi operations that use larger planes than other general aviation operations do. SFO also has longer departure and arrival delays but the average trip distances, flying times, and size of commercial aircraft serving the airports are similar.

The basic unit of observation of our analysis is round trip airline activity involving one of the three San Francisco Bay Area airports as the origin or destination and another U.S. domestic airport to complete the route. Our network of routes excludes international routes because data are not publicly available for the fares and service quality variables of all the carriers, domestic and international, which serve those routes and for the delays at the foreign airports that comprise the routes. This omission does not appear to be important for OAK and SJC airports because the share of international passengers at those airports is less than 2%, but the share of international passengers at SFO is roughly 20%.[1] We therefore discuss later how our findings may be affected by international airline operations and we also indicate how we account for any effects of international airline travel on travelers' demand and carriers' supply.

As noted, we are interested in whether private airport competition can improve pricing efficiency and reduce delays; thus, we distinguish takeoff and landing runway charges set by private Bay Area airports from (regulated) weight-based landing fees at public airports in other metropolitan areas by defining airline markets by directional city-pairs, so San Francisco → Los Angeles is a different market than Los Angeles → San Francisco. Airlines offer multiple products that we define as the combination of an airport itinerary, air carrier, and a ticket class (price range).[2] We capture private airport competition's effect on delays by including the 71 airports (including the SF airports) with sufficient congestion that their traffic delays are monitored by the Federal Aviation Administration (FAA). As a result, our analysis covers 120 city-pair markets.

We simplify our analysis by making the following assumptions.

Assumption 1. Pricing policy changes at SF airports will not affect congestion in non-SF markets.

Let A denote the set of the 71 airports in city-pair markets comprised by a San Francisco Bay Area market. For each airline f we restrict our analysis to its sub-network denoted by $H_f \equiv (\Phi_f, A)$, where Φ_f is the set of spoke routes that are used by airline f to provide non-stop and connecting service to and from SF airports. Thus, $\Phi_f = \{\Phi_f^{SF}, \Phi_f^{NSF}\}$, where Φ_f^{SF} is the set of the carrier's spokes connected to the three SF airports and Φ_f^{NSF} contains non-SF spokes that are used by the airline to provide connecting services.[3]

Assumption 2. Pricing policy changes at SF airports will not affect the structure of an airline's sub-network.

Assumption 2 states that Φ_f is fixed in our analysis for any airline f. We restrict airlines' entry and exit behavior because modeling those dynamic decisions would significantly complicate the complex network equilibrium that we are trying to solve. On the one hand, this restriction may not be particularly strong in our case because SFO is a United Airlines hub and close to the main city in the metropolitan area, while OAK and SJC are smaller airports dominated by Southwest Airlines, which is a low-cost carrier serving point to point routes. Thus, in response to higher airport charges, United Airlines, for example, might not be willing to move its hub-and-spoke operations by shifting a large share of its flights from SFO to OAK and SJC. On the other hand, United could adjust its overall network to effectively play off its SFO hub against its other hubs in the west, including LAX and Denver, to serve certain routes that face higher airport charges at SFO. For example, it could reduce its service to Santa Barbara from SFO and provide more service to Santa Barbara from LAX. Oum et al. (1995) show that by adjusting their hubbing activity at hub airports, airlines could gain a competitive advantage.

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[1] Those figures are from Airports Council International.

[2] For example, the San Francisco Bay Area to New York City metropolitan area market may consist of the following set of products: 1) A $300 non-stop United Airlines (UA) flight from SFO to EWR (Newark); 2) A $300 connecting (one-stop) UA flight from SFO to EWR through ORD (Chicago); 3) A $300 non-stop UA flight from SJC to EWR; 4) A $300 non-stop UA flight from SFO to JFK (New York); 5) A $300 connecting UA flight from SFO to EWR through DEN (Denver); and 6) A $300 non-stop American Airlines (AA) flight from SFO to EWR.

[3] For example, the spoke connecting ORD and BOS is used by United to provide connecting service between SFO and BOS.

We discuss later how the restriction associated with Assumption 2 affects our main conclusions about the possible benefits of private airport competition; but it is worth previewing here that the effect is to limit the gains to travelers from airlines' adjusting their operations to generate both more airport product differentiation and a higher airline demand elasticity that would lower charges by privatized airports.[4] In addition, the capability of United to play off its SFO hub against its other hubs implies that the three SF airports compete with each other and, to a certain extent, with other airports like Denver and LAX; thus, airport competition among hub airports is another possible way that airlines can limit private airports' market power.

Assumption 3. Pricing policy changes at SF airports will not affect airlines' aircraft sizes on the routes that they serve.

Assumption 3 recognizes that it may be difficult for airlines to adjust aircraft sizes quickly by shifting aircraft between routes because pilots on those routes have to be certified to fly specific aircraft, union rules have to allow such changes, maintenance facilities at certain airports may have to be adjusted to service specific aircraft, and the like. We subject this assumption to sensitivity analysis by varying aircraft sizes to assess the effects on our conclusions.

2.2. A three-stage game

Currently, public airports receive weight-based landing fees from aircraft and passenger facility charges from travelers. We assume that a private airport would replace those charges with both takeoff and landing runway charges; charges to travelers for parking, to retail stores for rental space and advertising displays, and to airlines for renting terminal counters and gates, which are unrelated to government policy, would not change. We then make the following assumption to analyze private airport competition as a sequential-moves game on the preceding air transportation network.

Assumption 4. A three-stage game of private airport competition

Stage 1: The three airports simultaneously and independently choose their aircraft landing and takeoff charges.
Stage 2: Airlines simultaneously and independently announce capacities (total number of seats) on their spoke routes that are connected to the three airports.
Stage 3: Airlines simultaneously announce the prices of the products they offer on the 120 city-pair SF markets and passenger demand is allocated among products subject to the constraint that SF spoke passengers cannot exceed the spoke capacities announced in the second stage.

Given a fixed aircraft size (Assumption 3), airlines' capacity decisions in the second stage determine the flight frequency for the products they offer.[5] Travelers value greater flight frequency because it reduces the difference between their desired departure time and the closest available departure time. That difference was termed *schedule delay* by Douglas and Miller (1974) and is distinct from *scheduled delay* that is included by the airlines in their schedule to account for congestion at the origin, enroute, and at the destination.

The Bertrand–Nash equilibrium of airline price competition in the third stage of the airport privatization game allocates seats to products across markets, thereby simplifying the revenue management techniques adopted by airlines to address uncertain demand. Another simplification is that we allow spoke capacity to be added marginally when, in fact, it is added in a lumpy manner. Finally, we assume that airlines do not incur costs from committing to provide spoke capacity; costs are incurred only when capacity is actually used to transport passengers.

The three-stage private airport competition game provides only a static analysis by not accounting for airlines' dynamic entry and exit behavior, which is extremely difficult to model in our context. But, given our purpose, we can assess whether private airport competition would enhance social welfare in a static setting and then consider how that assessment would be affected in a dynamic setting.

2.2.1. Specifying airline behavior

Taking airport runway charges as given, airlines engage in price and service competition, where flight frequency, which influences schedule delay, is the key service variable. A product j in a market m is an airport–airline-routing combination. The number of travelers choosing product j in market m is denoted by $q_{jm}(\mathbf{p_m}, \mathbf{d_m})$, which is a function of a vector of prices ($\mathbf{p_m}$) and a vector of schedule delays ($\mathbf{d_m}$) for all products in market m. For a given aircraft size, schedule delays are determined by the spoke capacities chosen by the airlines in the second stage of the game; we use T_{sf} to denote the total number of seats of airline f on spoke route s. In the last stage of the game, given spoke capacities, airlines engage in Bertrand competition as each airline simultaneously chooses prices for the products it offers on SF markets by solving the following constrained profit-maximization problem:

$$\begin{aligned} &\underset{\{\mathbf{p_{fm}}\}_{m=1}^{M}}{\text{Max}}\ \pi_f = \left\{\sum_m \left[\sum_{j\in J_{fm}} p_{jm} q_{jm}(\mathbf{p_m}, \mathbf{d_m})\right]\right\} - C_f \\ &s.t. \sum_{m} \sum_{j\in\Psi_{sf}} q_{jm} \le T_{sf}, \text{ for all } s \text{ and } f \end{aligned} \tag{1}$$

where Ψ_{sf} denotes the set of products offered by carrier f using spoke s and J_{fm} denotes the set of products offered by carrier f in market m; $\mathbf{p_{fm}} = \left\{p_{jm}\right\}_{j\in J_{fm}}$ where p_{jm} is the price of product j in market m; and C_f is the airline's total variable cost function. Unlike total revenues, which are obtained by aggregating revenue from the products in each market that an airline serves, total costs for those products cannot be defined because products in different markets may share the same spoke route. Thus, similar to Berry et al. (2007), we specify an airline's total variable costs of providing services that are connected to the SF airport market as the sum of the total costs of each spoke served by the airline plus product-specific costs:

$$C_f = \sum_{s\in\Phi_f} C\left(Q_{sf}\right) + \sum_{m=1}^{M} \sum_{j\in J_{fm}} q_{jm} \cdot \left(W_{jm}\omega + \eta_{jm}\right), \tag{2}$$

where $C(Q_{sf})$ denotes the carrier's operating costs on spoke s; Q_{sf} denotes the spoke passengers; $q_{jm} \cdot (W_{jm}\omega + \eta_{jm})$ denotes product-specific costs; W_{jm} is a vector of observed exogenous market and product characteristics including airline and airport dummies; ω is a vector of parameters; and η_{jm} is a random component capturing unobserved product characteristics.

A carrier's spoke-route operating costs $C(Q_{sf})$ include aircraft operating costs (AOC_{sf}) that are affected by airport delays, aircraft take-off and landing fees (LF_{sf}), and an additional component capturing other spoke-route operating costs such as scheduling and maintenance costs (SC_{sf}). The specification of total variable costs implies that the marginal cost of product j in market m is

$$MC_{jm} \sum_{s\in\Phi_f(j)} \left(\frac{\partial AOC_{sf}}{\partial Q_{sf}} + \frac{\partial LF_{sf}}{\partial Q_{sf}} + \frac{\partial SC_{sf}}{\partial Q_{sf}}\right) + W_{jm}\omega + \eta_{jm}, \tag{3}$$

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[4] Airline entry at public airports is currently limited by exclusive-use gates (Morrison and Winston, 2000). Private airports are unlikely to maintain that entry barrier.

[5] For a given period of time, flight frequency on a spoke route is the ratio of the total number of seats to average aircraft size.

where $\Phi_f(j) \equiv \{\Phi_f^{SF}(j), \Phi_f^{NSF}(j)\}$ is the set of carrier f's spokes associated with product j.

In stage 2 of the airport privatization game, armed with an accurate prediction of the equilibrium outcomes of the price subgame given spoke capacities and runway charges, each airline chooses capacities on the SF segments it serves $\left(\{T_{sf}\}_{s\in\Phi_f^{SF}}\right)$ to maximize total profits from the markets that are connected to the SF airports. The capacity decisions affect the equilibrium outcomes of the price subgame by affecting product demand through flight frequency, the capacity constraint in Eq. (1), and aircraft operating costs through airport delays.

It is difficult to fully analyze the airline price and service subgame for a number of reasons. Given spoke capacities, airlines' pricing decisions may be interdependent across markets through the capacity constraints because products in different markets may share the same spoke route. Similarly, capacity decisions on different spokes may have complex interdependencies. And the pricing and capacity interdependencies may be exacerbated by airport congestion externalities.[6] In practice, airlines can hardly optimize spoke capacities for their entire network. In a survey paper, Barnhart and Cohn (2004) indicate that airlines use models of flight scheduling that establish rules to determine incremental changes to the existing schedule for a limited number of segments. Belobaba et al. (2009, p. 159) found that airlines generally assume a target load factor—the widely adopted industry measure of capacity utilization defined as the percentage of seats filled by paying passengers—in their fleet planning process. We therefore simplify our analysis of airline price and service competition by making the following plausible assumption:

Assumption 5. Airlines choose capacities on their spoke routes to achieve target load factors on those spokes.

An airline's target load factor on a spoke can never be greater than 100%.[7] Although U.S. carriers have become more disciplined about controlling the growth of their capacity, the industry-wide average load factor in U.S. domestic markets has been roughly 80% for the last several years, suggesting that carriers operate with excess capacity because the demand for air travel is stochastic and because carriers still compete on service quality by offering more frequent flights. Assumption 5 implies that the capacity constraint in Eq. (1) is always non-binding. Given a targeted spoke-route load factor, which is denoted by θ_{sf}, the capacity of a spoke-route is determined by $T_{sf} = Q_{sf}/\theta_{sf}$ for each $s \in \Phi_f$. Thus, the marginal cost of an airline's product, given by Eq. (3), includes the marginal spoke costs (the terms that are summed) even if the capacity constraint is not binding because the spoke costs, which are functions of T_{sf}, increase when Q_{sf} increases.

2.2.2. Specifying airport behavior

We construct an airport's profit equation, which is optimized with respect to its takeoff and landing charges.[8] Let n denote a San Francisco Bay Area airport; Ξ_n denote the set of spokes originating from or terminating at the airport; and Q_n denote the total number of departure and arrival passengers at airport n. We define an airport's operating revenue function as

$$R_n = \varsigma_n^A \cdot \sum_{s\in\Xi_n} \left\{ \sum_f T_{sf} \right\} + \varsigma_n^{NA} \cdot Q_n, \tag{4}$$

where ς_n^A denotes the takeoff and landing charges in dollars per seat at airport n and ς_n^{NA} denotes the dollar expenditures per passenger on concessions and parking.

To determine costs (Δ), we note that the outputs of an airport include the number of passengers, the number fights (F_n) which is determined by airlines' spoke capacities, and non-aeronautical activities (parking and concessions), which are measured by the revenues they generate. Because we model those revenues as a linear function of passengers as in Eq. (4), we specify the short-run operating cost function for airports as $\Delta_n(Q_n, F_n)$. Publicly-owned airports set landing charges based on current weight-based rules at U.S. commercial airports. When the airports are privatized and sold to different owners, each airport engages in Bertrand competition and solves $\underset{\varsigma_n^A}{Max}\,\pi_n = R_n - \Delta_n$. Their runway charges affect the equilibrium outcomes of airline price and service competition by affecting airlines' marginal spoke costs in Eq. (3).

2.2.3. Equilibrium concept

The equilibrium concept for the three-stage private airport competition game is the subgame perfect equilibrium (SPE), which is characterized in this section by backward induction. Because of the non-binding capacity constraint in Eq. (1), the airline price subgame can be investigated market-by-market as firms with multiple products engage in price competition. If a Bertrand–Nash equilibrium for the price subgame exists,[9] then equilibrium prices satisfy the first-order conditions:

$$\frac{\partial \pi_f}{\partial p_{jm}} = q_{jm} + \sum_{k\in J_{fm}} \frac{\partial q_{km}}{\partial p_{jm}} (p_{km} - MC_{km}) = 0, \text{ for all } j \in J_{fm} \text{ and } m. \tag{5}$$

Note that given the spoke capacities, $\frac{\partial q_{km'}}{\partial p_{jm}} = 0$ when $m' \neq m$.

We now characterize the SPE to the two-stage game of airline price and service competition given airport runway charges. In stage 2 of the private airport competition game, each airline chooses SF segment capacities such that it achieves its target load factor at the price equilibrium given its competitors' chosen capacities. Let $\mathbf{T} \equiv \{T_{sf}\}_{s,f}$ denote a vector of carriers' spoke capacities. The demand for products given the spoke capacities and the associated equilibrium prices can then be denoted by $q_{jm}(P(\mathbf{T}), \mathbf{T})$ for all j and m, because spoke capacities affect product demand both directly by determining flight frequency and indirectly by determining equilibrium prices by affecting marginal spoke costs. The capacity of a spoke-route given $\mathbf{T}$ and $P(\mathbf{T})$ is determined by:

$$T_{sf} = Q_{sf}/\theta_{sf} = \sum_{j\in\Psi_{sf}} q_j(P(\mathbf{T}), \mathbf{T})/\theta_{sf} = H_{sf}(\mathbf{T}) \text{ for all } s \text{ and } f. \tag{6}$$

Thus we can define a vector-valued function $\mathbf{H}(\mathbf{T}) \equiv \{H_{sf}(\mathbf{T})\}_{s,f}$ such that $\mathbf{H}(\cdot)$ is a self-map on the space of spoke capacities.[10] The fixed-point of the self-map along with the equilibrium air product prices, which are determined by Eq. (5) given the fixed-point of carriers' spoke capacities, constitute the SPE to the airline competition game given airport runway charges.

Moving backward to the first stage of the game, the three airports engage in Bertrand competition, which amounts to price competition with substitute products among single-product firms, with the expectation of the equilibrium outcomes of airline competition given airport charges. As summarized in Vives (2005), such a game is supermodular under general conditions and the results in Topkis (1979) show that pure-strategy equilibra exist for a supermodular game and that the

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[6] An example of the interdependencies of a carrier's decisions is that its capacity decision on a segment affects congestion at the airport and therefore affects the costs of all other products that are connected to the airport as well as travelers' choices in different markets.

[7] This does not imply that we assume specific flights are never sold out. Such events do occur because of the stochastic nature of air travel demand regardless of the target load factor.

[8] Airport charges can be complex and include add-ons for check-in counters and so on. However, negotiated charges at some airports (for example, in Europe) consist of one charge based on departing passengers.

[9] The existence and uniqueness of airline price competition equilibrium in a market depend on the specification of travelers' demand function. Detailed discussions of this issue based on our empirical demand specification are contained in the appendix.

[10] It is plausible to assume that there is an upper bound on capacity for each of the spoke routes. $\mathbf{H}(\cdot)$ is therefore a self-map on a closed, bounded, and convex space and according to Brouwer's fixed-point theorem its fixed-points exist if $\mathbf{H}(\cdot)$ is continuous. Moreover, the fixed-point is unique if $\mathbf{H}(\cdot)$ is monotonic.

least and the greatest equilibrium points exist in the set of equilibrium points. The Bertrand equilibrium airport charges, along with the SPE to the airline competition game given the airport charges, constitute the SPE to the overall game.

3. Parameterization, estimation, calibration and validation of the model

Given the preceding framework, we provide a quantitative assessment of private airport competition by using data from the SF airports in the 3rd quarter of 2007 to estimate empirical models of air travelers' airline and airport demand and airlines' and airports' operating cost functions. We then validate the empirical models by simulating the equilibrium of airline competition under the current policy that the SF airports are publicly owned. We outline the specification of the models and empirical procedures in the text and present the details of estimation, identification, and simulation in the technical appendix.

3.1. Demand

We develop an aggregate discrete choice model in the spirit of Berry et al. (1995) hereafter BLP, to analyze San Francisco Bay Area travelers' airline and airport choices. Assuming a linear functional form, the utility of traveler *i* choosing air travel product *j* in market *m* is given by (for simplicity, we suppress the market subscript *m*):

$$u_{ij} = X_j\beta + \alpha_i \cdot p_j + \phi \cdot d_j + \gamma^f \cdot t_j^f + \gamma^a \cdot t_j^a + \gamma^l \cdot t_j^l + \xi_j + \varepsilon_{ij}, j = 1, \ldots, N_m \tag{7}$$

where X_j is a vector of observed exogenous product attributes, including the distance from the origin to the destination, airline dummies to capture travelers' preferences for specific airlines, airport dummies to capture travelers' preferences for specific airports, a carrier's origin and destination airport presence, defined as the number of domestic and international cities served by the carrier from the origin and destination airports, and interactions between the airline and airport dummies to capture travelers' preferences for specific airlines at specific airports; p_j is the price of product *j* (the passenger-fare listed in the itinerary); d_j is the schedule delay associated with product *j*; t_j^f is the airborne time associated with product *j*; t_j^a is the total airport delay, which includes departure and arrival delay at the origin and destination, as well as departure and arrival delay at the connecting airport for connecting flights, associated with product *j*; t_j^l is the layover time associated with product *j* (layover time is zero for non-stop flights); ξ_j is a random component representing unobserved attributes of product *j* (for example, travel restrictions associated with the fare) and it is allowed to be correlated with price and flight frequency; ε_{ij} is a random component representing measurement error; N_m is the total number of products in market *m*; and α_i, β, ϕ, γ^f, γ^a, and γ^l are parameters.

Three comments about the specification are in order. First, for a given traveler, the airline and airport dummies included among the exogenous product attributes capture the effect of such variables as the attractiveness of an airline's frequent flier program and the convenience of an airport's location. Second, although we do not include international routes in our sample, carriers' fares, flight frequency, and other service variables in the demand specification reflect the presence of international travelers on domestic routes. In addition, as noted, the specification includes the number of international cities that an airline serves from the Bay Area airports and includes airline and airport dummy interactions, which capture travelers' preferences for a specific carrier serving a specific Bay Area airport, which may be partly related to the carrier's more extensive international operations at that airport. Third, the subscript *i* for the price coefficient α indicates that the coefficient is modeled to vary across travelers to capture the heterogeneity of their preferences for air travel.[11] Because of data limitations, we specify the price variable in terms of a simple binary random distribution, which enables us to broadly capture the difference between those travelers who are primarily traveling for business and those who are primarily traveling for leisure.

The mean utility of the outside product, which is indexed by the subscript zero, is normalized to zero. We specify the joint distribution of the errors $\varepsilon_i \equiv (\varepsilon_{i0}, \varepsilon_{i1}, \ldots, \varepsilon_{iN_m})$ as Generalized Extreme Value (GEV), which results in a choice probability with the nested-logit form where the outside product is in one nest and the air travel products are in another nest. As is well known, the GEV distributional assumption yields a tractable model but it also restricts the substitution pattern among alternatives within the nest for air travel products by treating the errors as independent. Our empirical specification seeks to minimize that restriction by including price and various service quality measures as well as both airline and airport dummies to capture unobserved preferences for specific airlines and airports; by explicitly modeling the unobserved product attributes ξ_j that may be correlated with the price and service time components; and by capturing preference heterogeneity for the price of air travel products.

3.2. Operating costs

Because the observed air product prices, which are determined by Eq. (5), capture both demand and airline cost information, we can use the Generalized Method of Moments (GMM) to jointly estimate the demand and airline cost parameters. However, applying this approach to an air transportation network faces difficulties because it estimates separate product costs for different markets when, as we indicate in Eq. (2), airline costs are determined in a hub and spoke network such that products in different markets share the same spoke route. We therefore use aircraft operating cost data to first estimate airlines' spoke costs and then use the BLP GMM approach to estimate the product-level costs jointly with the demand side parameters. In the appendix, we argue that this two-step procedure is robust and causes little bias to the standard errors in the BLP GMM estimator.

Airlines' spoke operating costs in Eq. (2) include aircraft operating costs, take-off and landing fee expenditures, and the scheduling cost on a spoke. Let $z_f(K_{sf})$ be the unit aircraft operating cost function (in dollars per block hour for an aircraft) of carrier *f* on spoke *s*; K_{sf} denotes the average aircraft size (number of seats) of the carrier on the spoke. We parameterize $z_f(K_{sf})$ as Cobb–Douglas and estimate the parameters by OLS using the U.S. Department of Transportation's Form 41 (from Data Base Products), which records aircraft operating cost per block hour (including pilot costs) for the major and national carriers.[12] The coefficients are plausible, precisely estimated, and presented in the technical appendix.

In equilibrium, the total number of flights operated by the carrier on the spoke route is $\frac{T_{sf}}{K_{sf}} = \frac{Q_{sf}}{\theta_{sf} \cdot K_{sf}}$. Let h_{sf} be the average scheduled operating time (hours per aircraft) of the carrier on the spoke and δ_s be the average delay (hours per aircraft) at airports on the spoke. We can express total aircraft operating costs (AOC) of the carrier on the spoke as

$$AOC_{sf} = \frac{Q_{sf}}{\theta_{sf} \cdot K_{sf}} \left(h_{sf} + \delta_s\right) \cdot Z_f\left(K_{sf}\right). \tag{8}$$

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[11] Initial specifications and estimations attempted to also capture travelers' preference heterogeneity for the service times offered by the air travel products; but we were not able to estimate those taste parameters with much precision because identification from market level data only can rely on the variation in substitution patterns among similar products as the mix of products varies across markets. Because we analyze a network that includes only markets that originate or terminate in the San Francisco Bay area, we apparently did not have sufficient variation to estimate the service time taste parameters.

[12] We included airline fixed effects to control for variables such as pilots' and flight attendants' average wages in the estimation.

Total delay on a spoke route includes delay at both the departure and arrival airports; thus, in Eq. (8) $\delta_s = \textit{departure delay} + \textit{arrival delay}$. Delays at non-SF airports are held constant in our analysis (Assumption 2) and delay at each of the three SF airports is modeled as a function of the ratio of the total traffic volume to the number of active runways at each airport. We parameterize the function by a translog form and use traffic delays recorded in the FAA's Aviation System Performance Metrics (ASPM) database, which contains scheduled operations every 15 min for 23 specific airlines (22 U.S. network and commuter airlines plus Air Canada) plus one composite "other" category for all other commercial airlines, to estimate the parameters for departure and arrival delays for each of the SF airports. The parameter estimates and the plots of the estimated delay functions are shown in the technical appendix.

The three SF airports and other U.S. airports charge aircraft weight-based landing fees, with a representative value of \$2 per 1000 lb of landing weight. We estimated landing fee charges by using data on aircraft manufacturer websites to calculate the average aircraft landing weight per seat (details can be found in the technical appendix). If $\tau(K_{sf})$ is the average aircraft landing weight per seat (as a function of aircraft size K_{sf}) of carrier f on spoke s, then the carrier's total landing fee expenditures (LF_{sf}), including fees paid at a connecting airport, are

$$LF_{sf} = \frac{Q_{sf}}{\theta_{sf} \cdot K_{sf}} \cdot \left(0.002 \cdot \tau\left(K_{sf}\right) \cdot K_{sf}\right) = 0.002 \cdot \tau\left(K_{sf}\right) \cdot \frac{Q_{sf}}{\theta_{sf}}. \tag{9}$$

The final component of airlines' spoke-route costs is scheduling costs; we specify those as a linear function of spoke distance such that

$$\frac{\partial SC_{sf}}{\partial Q_{sf}} = \kappa_0 + \kappa_1 Dist_s, \tag{10}$$

where $Dist_s$ is the distance of spoke route s and the κ's are parameters to be estimated.[13]

We use the BLP GMM approach to jointly estimate the discrete choice demand parameters and the remaining parameters in the airlines' marginal cost equation, ω in Eq. (3) and the two parameters in Eq. (10). Combining the first-order condition in Eq. (5) with the marginal cost in Eq. (3), we obtain an estimable price-residual (supply) equation:

$$\begin{aligned} p_{jm} - \sum_{s \in \Omega_f(j)} \left(\frac{\partial AOC_{sf}}{\partial Q_{sf}} + \frac{\partial LF_{sf}}{\partial Q_{sf}} \right) + \left(\Delta^j_{mf}\right)^{-1} \mathbf{q_{mf}} \\ = \kappa_0 \times \text{Number of Segments} + \kappa_1 \times \sum_{s \in \Omega_f(j)} Dist_s + W_{jm}\omega + \eta_{jm} \end{aligned} \tag{11}$$

where $\Delta^j_{mf} = \left\{\partial q_{km}/\partial p_{jm}\right\}_{k \in J_{fm}}$ and $q_{mf} = \{q_k\}_{k \in J_{fm}}$ contain unknown demand parameters. In the regression Eq. (11), the number of segments and segment distances capture additional spoke-related costs after excluding aircraft operating costs and landing fee expenditures, which we estimate separately from detailed aircraft operating data. The exogenous regressors in W_{mj} enrich the specification by including both airline and airport-pair dummies to account for cost differences across airlines and for cost differences of a given airline operating at different airports. The specification captures the density economies in airline operations because both the marginal aircraft operating costs and the marginal landing fee charges are decreasing functions of the spoke-route load factor.

Our approach also captures the effects of international operations on airlines' costs. First, our construction of airline operating costs in Eq. (8) includes a carrier's flight frequency and other operations, such as average aircraft size, which reflect the presence of international travelers on domestic routes. Second, our specification of supply in Eq. (11) includes the number of international cities that an airline serves from the Bay Area airports and includes airline and airport dummy interactions, which capture cost shocks that a specific carrier experiences serving a specific Bay Area airport. For example, such shocks may result from the carrier's international operations at that airport that are coordinated with its domestic operations (namely, delays in UA's international flights at SFO may cause delays to some of its domestic flights and vice-versa).

3.3. Identification

When Eq. (11) is evaluated at the "true" values of the demand and marginal cost parameters, the difference between the observed and predicted product prices depends entirely on η_{jm}, which captures the unobserved product characteristics that affect the marginal cost of a product. Similarly, when the discrete choice demand is evaluated at the "true" values of the demand parameters, the difference between the products' observed and predicted market shares depends entirely on ξ_{jm}, which captures unobserved product attributes that affect travelers' choices. Thus we can identify the discrete-choice demand and supply equations with two vectors of instruments, Z^D_{jm} and Z^C_{jm}, such that

$$E\left(\xi_{jm} \middle| Z^D_{jm}\right) = E\left(\eta_{jm} \middle| Z^C_{jm}\right) = 0. \tag{12}$$

Variables in Z^D_{jm} include exogenous product attributes and instruments for the endogenous variables in the demand model, price and schedule delay. Variables in Z^C_{jm} include exogenous regressors in Eq. (11) and exogenous instruments for demand that affect the markup $(\Delta^j_{mf})^{-1}\mathbf{q_{mf}}$. We closely follow the literature (Nevo, 2000; Berry and Jia, 2010) to choose the instruments. A detailed summary and discussion of the validity of the instruments and of BLP GMM estimation is presented in the appendix.

3.4. Data

We use the Department of Transportation's DB1B data set, a 10% random sample of airline tickets reported by U.S. carriers, to perform BLP estimation. As noted, our analysis is based on airline travel during 2007:3; we include only domestic trips that originate or terminate in one of the three San Francisco Bay area airports (SFO, OAK, SJC); and we include the 71 airports with traffic delays that are monitored by the FAA; excluding airports whose delays are not monitored by the FAA eliminates less than 10% of the passengers in all markets that are connected to SF airport markets.[14] The travel time components associated with each product include airborne time, airport delays, airport transfer time, and schedule delay. Carriers' airborne or flying times between the origins and destinations in our sample were obtained from the U.S. Department of Transportation T-100 Domestic Segment Data. Traffic delays at the 71 airports are recorded in the ASPM database. Flight frequency for each travel product is constructed from Back Aviation Solutions' schedule data, which also record the size (number of seats) of each of the scheduled flights on a segment.

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[13] The marginal scheduling cost may depend on route distance in a nonlinear form, but when we included a quadratic distance term in the specification it did not have a statistically significant effect and its exclusion did not change the simulation results.

[14] Although additional airline ticket data are available over time, it was not necessary for us to collect that data because our static demand and cost models were appropriate for our purposes of analyzing the effects of private airport competition. We follow the standard empirical strategy of estimating BLP static demand and cost models to explore cross-market variation in behavior and construct appropriate instruments for the endogenous demand variables. Lagged price and flight frequency are not valid instruments because they are correlated with unobserved product attributes. Finally, as noted, our models are identified (further discussion of identification is contained in the appendix) and, as reported below, the estimated parameters were generally statistically significant.

Table 2
Demand elasticities and value of time components based on demand coefficients.

Variables	Heterogeneous preferences: BLP GMM estimates
Aggregate price elasticity of demand for air travel	
Overall	−1.54
Business travelers	−1.35
Leisure travelers	−2.10
Value of airborne time ($/h)	
Overall	24
Business travelers	33
Leisure travelers	16
Value of airport delay ($/h)	
Overall	104
Business travelers	144
Leisure travelers	71
Value of flight frequency ($/flight)	
Overall	16
Business travelers	22
Leisure travelers	11
Willingness to pay for non-stop flights ($)	
Overall	212
Business travelers	295
Leisure travelers	144
Willingness to pay for connecting flights with a connection that is less than 1.5 h ($)	
Overall	17
Business travelers	24
Leisure travelers	12

In sum, our sample encompasses an air transportation network consisting of 120 city-pair markets and 20,830 air travel products provided by 16 specific airlines, which serve a set of spoke routes connected to the SF airports.[15] OXR (Oxnard) → SF and SF → OXR offer the fewest products (8) and SF → NYC offers the most products (674). If we define an SF spoke as a combination of a carrier and route where one of the SF airports is an origin or destination, then the sample contains 292 SF spokes. Further details about the data sources and the sample, including construction of and summary statistics for the demand variables can be found in the technical appendix.

3.5. Key estimation results

We present the individual parameter estimates obtained from BLP GMM estimation in the technical appendix and the most important demand and cost measures based on those parameters in the text. Table 2 summarizes air travelers' price elasticity of demand and values of travel time components.[16] The overall aggregate price elasticity of demand for air travel in the 120 markets in our sample, −1.54, is broadly consistent with Gillen et al.'s (2003) comprehensive survey of price elasticity estimates of the demand for air travel that report a median elasticity of −1.33. As expected, leisure travelers are more responsive to fare changes than business travelers are because they usually pay for their air travel and their travel schedule in more flexible. In contrast, business travelers place a higher value on all of the travel time components, obtained as the ratio of a travel time coefficient and the business or leisure traveler price coefficient. We find that the overall value of airborne time is $24/h, with business travelers valuing that time at $33/h and leisure travelers valuing it at $16/h. This is aligned with previous estimates of the value of travel time that cluster around $30/h (e.g., Morrison and Winston, 1989). In all likelihood, travelers' high willingness to pay to avoid airport delays and connections indicate that those disruptions could result in late arrivals that force meetings to be canceled, hotel and other travel reservations to be lost or significantly altered, and the like. The estimates also suggest that the main source of disutility from connecting flights is the actual stop before reaching the destination rather than the length of the stop per se, while the fact that our sample consists of dense markets with many flight alternatives may explain why the marginal value of an additional flight is modest.[17]

Table 3
Summary of marginal costs from BLP GMM estimates.

Median marginal cost per mile ($ per passenger mile)	
Overall	0.09
Non-stop products	0.16
Connecting products	0.08
By airlines	
American	0.10
United	0.11
Delta	0.07
US Airways	0.08
Continental	0.07
Northwest	0.09
Alaska	0.10
Southwest	0.05
JetBlue	0.06
Other non-low-cost carriers	0.13
Other low-cost carriers	0.07
By SF airports	
SFO	0.10
SJC	0.09
OAK	0.07

Using the BLP GMM estimates for Eq. (11) along with Eqs. (8) and (9), which are estimated separately based on aircraft operating data, we calculate the marginal costs of the air travel products and report the results in Table 3. The average marginal cost across the 20,830 products is 9 cents per passenger mile; Berry and Jia (2010) obtain a lower estimate of 6 cents per passenger mile but they do not restrict their sample to SF airport markets, which may have higher costs because they include a higher share of airline flights that experiences delays from operating in congested conditions. Moreover, our specification of airline marginal cost differs from theirs by explicitly accounting for airlines' costs based on hub and spoke operations. The average marginal cost of non-stop flights, 16 cents per passenger mile, is greater than the average marginal cost of connecting flights, 8 cents per mile, possibly because airlines use larger more expensive aircraft and operate with somewhat lower load factors on non-stop flights.[18] Turning to airlines, Southwest's and JetBlue's marginal costs are, as expected, lower than the other (mainly legacy) carriers' marginal costs. American's and United's costs may be the highest among the legacy carriers because they tend to serve the most congested routes in our network, while United's costs may slightly exceed American's costs because of its extensive international operations at SFO.[19] Among the three airports in the SF market, air travel products that involve Oakland airport have the lowest marginal cost.

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[15] The sixteen airlines are Air Tran, Alaska, Aloha, American, ATA, Delta, Continental, Frontier, Hawaii, Jet Blue, Midwest, Northwest, Southwest, Sun Country, US Airways, and United.

[16] The appendix presents calculations for sensitivity purposes based on coefficients obtained from OLS estimation, which treats preferences as homogenous and assumes price and schedule delay are exogenous, and from instrumental variables (IV) estimation as in Berry (1994), which treats preferences as homogenous and assumes price and schedule delay are endogenous. In general, ignoring the endogeneity of price and schedule delay leads to implausible results.

[17] The estimated value of flight frequency may also reflect imprecision from using an equation for schedule delay that needs to be based on more recent data. However, we obtained a similar value when we directly specified flight frequency instead of schedule delay in the demand model.

[18] Of course, large aircraft become economical at an airport when the airport can consolidate traffic on spoke routes. At the same time, recall that the landing weight (and cost) per seat increases with aircraft capacity.

The final task of the model parameterization is to specify the short-run operating costs of an airport n. We specify the function as Cobb–Douglas such that

$$\Delta_n = \upsilon_{0n} \cdot (Q_n)^{\upsilon_{1n}} \cdot \left(\sum_{s \in \Xi_n} \sum_f \frac{T_{sf}}{K_{sf}} \right)^{\upsilon_{2n}}. \tag{13}$$

Based on Oum et al. (2008) estimates of a short-run multi-output airport operating cost function, we set $\upsilon_{1n} = 0.60$ and $\upsilon_{2n} = 0.10$, which measure the cost elasticities with respect to passengers and aircraft operations respectively,[20] in the baseline simulations and calibrate υ_{0n} so that in equilibrium the ratios of operating expenses to operating revenues at the SF airports are equal to the ratios that were actually observed in 2007 given the applicable landing fees.[21] We found that varying the cost elasticities within plausible ranges had no notable effects on our findings.

3.6. Validation

To validate our empirical models, we compute the SPE of the airlines' service-price subgame given airport charges by simulating the baseline equilibrium (2007:3) under the current policy that the SF airports are publicly owned.[22] We show in the technical appendix that based on a comparison of simulated with actual outcomes, our model generates credible predictions of air travel activity at the SF airports as indicated by its close replication of the level of airport passengers and the distribution of product prices, demands, and spoke passengers. Our model tends to underestimate flight frequencies, but that is not surprising because we do not include connecting passengers whose flights do not originate or terminate at an SF airport.

4. The effects of private airport competition

We quantify the economic effects of private San Francisco Bay Area airports engaging in competition by comparing the base-case (public airport) equilibrium with equilibria generated under alternative scenarios characterizing private airport competition. Each scenario results in a three-stage sequential moves game and we describe our computational procedures for the different scenarios in the appendix. It is appropriate to characterize the scenarios as capturing the effects of private airport competition because the airports are independently setting runways charges to maximize profits without, at this point, any governmental regulatory constraints.

When a SF airport is privatized, we assume that a carrier's weight-based landing fee and passenger facility charges are replaced with the appropriate take-off charge indicated in a particular scenario. The carrier does pay a weight-based landing fee when it lands at a non-SF airport. When a carrier takes off from a non-SF airport it is not assessed a charge by that airport, but it is assessed the charge indicated in a particular scenario for landing at a privatized SF airport. The first column of Table 4 presents the base-case equilibrium outcomes generated from weight-based landing fee charges at the SF airports. We measure the welfare effects from alternative scenarios relative to the base case. In column 2, we present another benchmark based on runway charges that maximize social welfare—the sum of consumer surplus and airport and airline profits. Those charges confirm that current weight-based landing fees are inefficient by generating substantial welfare gains, $260 million per quarter, but the airports accrue all the benefits while both airlines and travelers are worse off.

4.1. Findings for different competitive environments

We now turn to scenarios that collectively have the potential to offer insights on designing both an efficient and feasible strategy of private airport competition. We first consider monopoly scenarios in which the three airports are privatized and acquired by one owner who sets charges for all three airports. One extreme case is that the owner behaves like an upstream monopolist and sets charges to maximize total airport profit (third column). Even in this case welfare improves over the base case. As expected, airport profits are the source of the welfare gain while travelers' and airlines' welfare declines sharply as airport charges are nearly double socially optimal charges and confirm the double marginalization problem in a vertical market structure: travelers pay excessive air fares because both the upstream monopolist (airports) and the downstream oligopolists (airlines) raise prices above their own marginal costs.

Economic theory suggests that the double marginalization problem can be ameliorated by bargaining between upstream and downstream firms. Negotiated or contract prices have also been an important feature of deregulated transportation markets with few competitors (Winston, 1998) and they were previously used by Winston and Yan (2011) to assess highway privatization in an oligopolistic setting. Bargaining between an airport and a large airline(s) could occur because such airlines are involved in terminal investments and may have a large share of airport operations (for example, United at SFO and Southwest at OAK). In the extreme case that the owner of the airports sets runway charges to maximize total airline profits, charges are much lower than in the preceding cases (fourth column), enabling airlines to gain from private airport competition and curbing travelers' losses with some sacrifice in social welfare.

The conflict between increasing social welfare and increasing each agent's welfare could be reduced by introducing market competition, where the three airports are privatized and acquired by different owners who set profit-maximizing charges independently. Allowing bargaining in that situation and a non-negative outcome for airlines compared with the base case results in a social welfare gain that is close to the upper bound, a gain instead of a loss for airlines, and only a modest loss for travelers (column 5). Finally, as shown in the sixth column, it is possible for airports, airlines, and travelers to be better-off from private airport competition if competition and bargaining generate airport charges that maximize airline profits subject to a non-negative change in airports' profits. Although that outcome greatly improves the political feasibility of private airport competition, it does so by reducing the overall welfare gain to a small fraction of the upper bound.

What do we learn from the experiments? First, allowing competition between airports with different owners and bargaining between airports and airlines are essential components of an efficient and politically feasible—in the sense of not generating intolerable losses to any agent—private airport competition policy. Otherwise, airports would exercise considerable market power to set runway charges that extract most if not all of the benefits. Second, the major obstacle preventing travelers from gaining is the high pass-through rate from airport charges to airline fares. Even a modest increase in airport charges (column 4), while increasing airports' and airlines' profits, harms travelers. At the same time, the intensity of bargaining that keeps travelers from being harmed drives airport charges to such a low level that the overall welfare gains are small (column 6). Accordingly, it would be desirable to reduce the high pass-through rate from airport charges to air fares in a more competitive airline market. We explored this possibility by computing the average fare increase in each market when the three airports increased their current charges to $50 per seat under private airport competition (roughly $70 per passenger given the 70% load factor). Fig. 1 shows that as the number of carriers in a market increases, the pass-through

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[20] Airports tend to exhaust scale economies in the long run when runway capacity is optimized (Morrison (1983)). The cost elasticities used here imply increasing returns in the short run.

[21] Based on their financial reports, the ratios in 2007 of real operating expenses to operating revenues are 0.86 at SFO, 1.34 at SJC, and 1.03 at OAK.

[22] Under this policy, commercial carriers pay the 2007 weight-based landing fee, but they are not charged for taking off from an airport, and travelers pay passenger facility charges that are included in the fare.

Table 4
Welfare effects of privatizing SF airports.

	Base case	Social welfare maximizing charges	Airports' profit maximizing charges	Airlines' profit maximizing charges	Bertrand competition: charges are subject to a non-negative change in airline profits at each airport	Bertrand competition: charges maximize airlines' profits at each airport subject to non-negative airport profits
Airport charge ($/seat)[a]						
SFO	2.00	54	85	20	48	5
SJC	2.00	46	82	14	41	4
OAK	2.00	50	84	16	44	4
Airport delay (min)						
SFO						
Departure delay	15	8	4	13	9	15
Arrival delay	5	3	2	4	3	4
SJC						
Departure delay	9	4	1	8	4	9
Arrival delay	3	1	1	2	2	3
OAK						
Departure delay	10	4	1	8	4	10
Arrival delay	3	2	1	3	3	3
Change in airport profits (million $/quarter)						
SFO	0.00	114.93	131.59	54.07	108.31	3.52
SJC	0.00	66.05	75.15	22.75	61.68	0.00
OAK	0.00	87.84	100.73	34.33	82.31	0.00
Total	0.00	268.82	307.47	111.15	252.30	3.52
Change in airline profits by airport (million $/quarter)						
SFO	0.00	−3.49	−35.06	14.00	0.00	13.56
SJC	0.00	−0.24	−38.43	12.03	2.75	8.29
OAK	0.00	−0.90	−36.11	15.57	4.36	10.96
Total	0.00	−4.63	−109.60	41.60	7.11	32.81
Consumer surplus change (million $/quarter)[b]						
Business travelers	0.00	−2.66	−4.11	−0.83	−2.38	0.00
Leisure travelers	0.00	−1.15	−1.58	−0.41	−1.05	0.00
Total	0.00	−3.81	−5.69	−1.24	−3.43	0.00
Change in social welfare (million $/quarter)[b]	0.00	260.38	192.18	141.51	255.98	36.33

[a] The airport charge in the base case is the 2007 weight-based landing fee that is charged when a commercial carrier lands at an airport. The carrier is not charged when it takes off from an airport. Travelers pay passenger facility charges that are included in the fare. In the privatization scenarios, the weight-based landing charge and the passenger facility charges are replaced with the following charges. When an aircraft takes off from a San Francisco Bay Area airport, it is assessed the charge indicated in the column heading (e.g., airport profit maximizing charge) as well as the weight-based landing charge at the non-San Francisco Bay Area airport. When an aircraft takes off from a non-San Francisco Bay Area airport it is not assessed a charge by that airport but it is assessed the charge indicated in the column heading (e.g., airport profit maximizing charge) for its landing at a San Francisco Bay Area airport.

[b] Measured as the change from the base case.

rate decreases slightly from 88% to 84%, suggesting that airline competition is not an important ingredient for a successful private airport competition policy.

4.2. Accounting for general aviation

Another approach to benefiting commercial airline travelers is to recognize that some 20,000 to 30,000 general aviation (GA) operations per quarter use the San Francisco Bay Area airports (Table 1) and contribute to congestion and delays. GA travelers tend to have higher incomes and, in some cases, more pressing trip purposes than commercial airline travelers have and are therefore likely to have a greater willingness to pay for airport service. Thus differentiated airport prices, which cater to GA and commercial airline travelers' varying preferences, could increase airport profitability and overall welfare gains even if the charges for commercial airlines are not high.

We did not initially include general aviation (GA) in our model because data on unscheduled operations by origin–destination pair and by time of day are generally unavailable. But by making some reasonable assumptions about GA operations, we can obtain some illustrative findings to help design a market for private SF airport competition that would enhance both commercial airline travelers' welfare and the overall welfare gain. We adjusted the demand and operating cost functions that we developed for commercial airline travel to calibrate GA demand and operating cost functions at each of the SF airports, the values of different time components for GA travelers, and the delay functions accounting for GA operations at each of the SF airports. Details of those calibrations are contained in the technical appendix. We then incorporated those functions and parameters to analyze Bertrand oligopoly private airport competition scenarios that accounted for GA operations. We assumed that private airports are able to increase their charges for general aviation but that those charges are subject to a price cap, which prevents them from exceeding twice the current landing charge of $140 per flight at SFO. Thus we identify a potentially constructive role for government regulation. Given GA charges, airports compete on charges for commercial carriers to optimize their own objectives subject to negotiations.

We seek "win–win" oligopoly bargaining solutions where the welfare of travelers and commercial airlines does not decrease from the base case and airports make positive profits. Let $\varpi \in [0, 1]$ represent the bargaining power of an airport when it negotiates charges with the airlines; each airport is assumed to set charges to maximize:

$$\varpi \cdot \text{Airport Profits} + (1 - \varpi) \cdot \text{Airlines}' \text{Profits}.$$

We find that values of $\varpi \leq 0.17$ lead to the win–win outcome, which suggests that given the capped GA charge, airlines and airports have sufficient flexibility to negotiate charges that raise social welfare and benefit travelers because their gain from less delay offsets the loss from higher fares.[23] Table 5 presents results for $\varpi = 0.17$ and a solution that maximizes the sum of airlines and airports profits at each airport

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[23] Airlines' and airports' flexibility to negotiate charges that lead to a "win–win" situation is slightly reduced if we reduce the price cap for GA. For example, if the price cap for GA is $140 instead of $280, then the airline bargaining weight cannot be less than 0.085 to generate a bargaining outcome where the change in commercial travelers' welfare is non-negative.

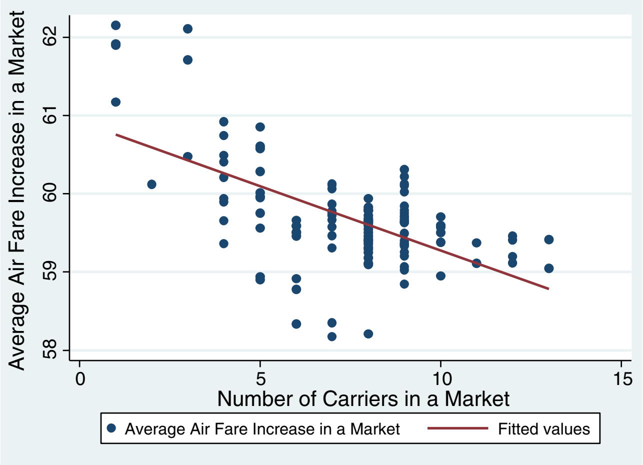

Fig. 1. The average increase in air fares and the number of carriers in a market. Note: This figure assumes that the privatized Bay Area airports charge \$50/seat. The regression line is $y = \underset{(0.17)}{60.92} - \underset{(0.01)}{0.16}\,x$, where y is the average price increase (in dollars) and x is the number of carriers.

subject to a non-negative change in commercial travelers' welfare and a \$280 price-cap on the GA charge. We obtain a sizeable welfare gain because GA's small current charge, which has little effect on its contribution to delays that increases airlines' and travelers' costs, is replaced by a greater and more efficient charge.[24]

Because the gains from private airport competition come at the expense of General Aviation, including recreational flyers and commercial air taxis, it is useful to consider how their welfare could improve. One approach is to stimulate competition among smaller private airports in the Bay Area. Currently, with the major exception of Branson Missouri Airport, hardly any private airports offer scheduled commercial service; in all likelihood because they face a significant disadvantage competing against public airports that receive federal and local government subsides.[25] GA's welfare could improve if smaller private airports, including newly privatized public airports, competed for (smaller) aircraft that provide scheduled commercial service and that have unscheduled operations by, for example, taking advantage of improvements in GPS technology that have enabled GA to have easier access to smaller airports, by upgrading runways and gates, and by offering van and rental car services to improve travelers' access to the central city and other parts of the metropolitan area. In sum, policymakers must resist the temptation to regulate the major SF airports to protect GA from higher charges, and should encourage all airports to engage in market competition for commercial passengers and recreational flyers so that all civilian aviation classifications could potentially gain from the policy.

Product differentiation at airports that, for example, differentiated service between business and leisure commercial travelers would enhance both the efficiency and political feasibility of private airport competition. But modeling product differentiation is difficult in our analysis because airlines, not airports, are capable of segregating commercial travelers according to their travel preferences. Airport services could be differentiated through the entry and exit behavior of airlines; for example, such behavior has created a certain degree of product differentiation at the SF airports with Southwest, a low-cost carrier, playing a dominant role at OAK and United, a legacy carrier, playing a dominant role at SFO. Under private airport competition, an airport in a metropolitan area could differentiate its services further to cater to certain carriers; those carriers could adjust their networks to use that airport more frequently; and those travelers who prefer the airline and airport's differentiated service would benefit.

5. Discussion and qualifications

Our private airport competition empirical experiments based on air travel using the SF airports have identified the importance of: 1. policymakers creating a competitive environment for airports (upstream competition); 2. allowing airlines to negotiate with airports to prevent excessive airport charges (upstream and downstream bargaining); and 3. stimulating differentiated services provided by large and smaller airports (upstream product differentiation). Policymakers in other U.S. metropolitan areas that have the potential to benefit from private airport competition, such as Chicago, New York, Boston, Washington, DC, and Los Angeles, could also use those insights to guide their strategy. Based on our findings for the SF airports, the potential annual benefits from private airport competition nationwide could amount to billions of dollars.

Moreover, the assumptions that we used to enable the analysis to be empirically tractable tend to produce a downward bias in our estimates. First, we restricted commercial airlines' entry and exit behavior in response to airport charges (Assumption 2), which limits airports' product differentiation and enables them to face a less elastic demand from airlines. Relaxing the assumption would increase airlines' demand elasticity and make it more difficult for private airports to increase charges. It would also enable airlines, as noted earlier, to adjust their networks by playing other airport hubs off against the SF airports and therefore increase their bargaining power and airport competition. Our simulations indicate that an increase in airlines' bargaining power would increase the benefits of private airport competition. Second, we have assumed aircraft sizes are fixed (Assumption 3) although it is possible that airlines could respond to higher airport charges by increasing aircraft sizes and reducing flights, which would increase charges but reduce delays. As shown in the appendix table A1, we find that if, for example, airlines increase their aircraft sizes 50%, then the potential gains from private airport competition are increased because the airlines' gain from less delay exceeds their loss from higher charges, airports' profits increase, and the quarterly social welfare gains are an additional \$100 million. Third, we have assumed that airlines operate with a target average load factor (Assumption 5), which we assumed was 70% in our simulations because, as discussed in the appendix, it enabled us to most closely replicate observed outcomes based on our network of routes. Assuming a higher average load factor would be more aligned with industry-wide average load factors during the last several years and would cause airlines' profits to increase by reducing average costs and would cause travelers' welfare to increase by reducing average fares. Of course, average load factors vary across routes; but capturing this heterogeneity in an environment with higher load factors would generally show that the benefits to airlines and travelers from private airport competition are even greater.

We noted that data limitations prevented us from including international routes in our analysis, but we have discussed how we control for the effects of international air travel on air travel demand and supply. The presence of international passengers lowers the target load factor to some extent on certain domestic routes; hence, we set a 70% load factor in our simulations, which is lower than the 80% industry average in domestic markets, to account for international and connecting passengers. In addition, we have performed sensitivity analysis to explore the effects of assuming different load factors and we have found that the findings from our simulations were not particularly affected. International routes themselves do include congested domestic and international airports so travelers on those routes would also benefit from private airport competition that reduces travel delays. At the same

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[24] Morrison and Winston (1989) assessed the effects of congestion pricing at airports and contacted airport control towers to obtain data on general aviation operations based on tower logs. They found that setting congestion tolls substantially increased airport charges to GA, causing them to curtail operations at major airports which reduced delays experienced by commercial carriers and travelers.

[25] As part of its negotiations to operate privately, Branson Missouri Airport "gifted" some of its land to Taney County and agreed not to receive federal funds from the Airport Improvement Program. In rare cases, the Secretary of Transportation has funded private airports under the justification that they serve as "reliever" airports for congestion.

Table 5
Welfare Effects of Privatizing All Three SF Airports: Incorporating General Aviation.

	Base case	Bertrand competition: charges for commercial flights maximize the weighted sum of airlines and airport profits at each airport subject to a non-negative change in commercial travelers' surplus and a $280 price-cap on the GA charge[d]
Airport charge for commercial airlines($/seat)[a]		
SFO	2.00	11
SJC	2.00	4
OAK	2.00	3
Airport charge for general aviation ($/flight) [b]		
SFO	140	280
SJC	0	280
OAK	0	280
Airport delay (min.)		
SFO		
Departure delay	15	14
Arrival delay	5	4
SJC		
Departure delay	9	7
Arrival delay	3	2
OAK		
Departure delay	10	7
Arrival delay	3	3
Change in airport profits (million $/quarter)		
SFO	0.00	113.72
SJC	0.00	51.21
OAK	0.00	120.13
Total	0.00	285.06
Change in airlines' profits by airport (million $/quarter)		
By airports		
SFO	0.00	10.38
SJC	0.00	20.00
OAK	0.00	26.22
By type of airline		
Full cost carriers	0.00	23.68
Low cost carriers	0.00	32.92
Total	0.00	56.60
Consumer surplus change (million $/quarter)[c]		
Business travelers	0.00	0.01
Leisure travelers	0.00	−0.01
General aviation travelers	0.00	−6.53
Total	0.00	−6.53
Change in social welfare (million $/quarter)[c]	0.00	335.13

[a] The airport charge in the base case is the 2007 weight-based landing fee that is charged when a commercial carrier lands at an airport. The carrier is not charged when it takes off from an airport. Travelers pay passenger facility charges that are included in the fare. In the privatization scenarios, the weight-based landing charge and the passenger facility charges are replaced with the following charges. When an aircraft takes off from a San Francisco Bay Area airport, it is assessed the charge indicated in the column heading (e.g., airport profit maximizing charge) as well as the weight-based landing charge at the non-San Francisco Bay Area airport. When an aircraft takes off from a non-San Francisco Bay Area airport it is not assessed a charge by that airport but it is assessed the charge indicated in the column heading (e.g., airport profit maximizing charge) for its landing at a San Francisco Bay Area airport.

[b] The airport charge at SFO for general aviation in the base case is the current minimal charge when a general aviation aircraft lands at the airport. A general aviation aircraft is not charged when it takes off from SFO. In the privatization scenarios, the current charge is replaced by a charge that is applied to both take-off and landing.

[c] Measured as the change from the base case.

[d] In this scenario, each airport charges commercial flights to maximize: $\varpi \cdot \text{Airport Profits} + (1-\varpi) \cdot \text{Airlines ' Profits}$, where $\varpi \in [0,1]$ represents the bargaining power of an airport when it negotiates charges with the airlines. We can find a threshold ϖ^* and when $\varpi \le \varpi^*$, under the bargaining equilibrium of oligopoly airport competition, the airports and airlines are better off and the commercial travelers are not worse off from privatization. Results presented in the column are bargaining outcomes when $\varpi = \varpi^*$.

time, the pass through rate of higher airport charges to higher fares may be limited on those international routes where fares are still regulated.

Finally, we have considered airports' pricing behavior only. In the long run, competition among private airports would provide airports with the incentive to overcome regulatory hurdles to and to expedite construction of additional runways to expand capacity and reduce delays[26]; facilitate entry by allowing any carrier to provide service that was willing to pay the cost of terminal facilities; work with airlines to improve the efficiency of taxi and runway operations; improve operations to reduce costs[27]; implement advances in technology that could improve security and aircraft operations; and be more responsive to passengers by introducing new services such as short-stay hotels and relaxation areas. Although an analysis that incorporates those factors awaits further research, the findings that we have obtained for pricing behavior suggest by themselves that the benefits from private airport competition may be quite large if the policy is implemented properly.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.jpubeco.2014.04.013.

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[26] Private investors that have acquired foreign airports that have been privatized have made additional investments to expand runway and terminal capacity.

[27] In a worldwide comparison of airports, Oum et al. (2008) found that privatization has reduced airport costs by promoting competition.

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