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DESIGNING A PRIVATIZED MARKET:

THE CASE OF SAN FRANCISCO BAY AREA AIRPORTS

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Abstract. *Privatization has gained attention throughout the world but less so in the United States. We explore the possibility of designing a privatized market in a vertical industry, commercial airports, which would improve consumers' welfare and enable firms to be profitable. Using the San Francisco Bay Area as the setting for our assessment, we identify important factors that would make it possible for privatization to achieve those goals, including competition among upstream firms (airports), bargaining between upstream and downstream firms (airlines), and the ability of upstream firms to differentiate prices. We call for experiments to explore privatizing U.S. commercial airports.*

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1. Introduction

The policy of converting state-owned assets into privately managed assets gained worldwide attention following the United Kingdom's privatization program that was initiated by the Thatcher government in the early 1980s. The United States has lagged behind most other countries in privatizing its public facilities; but it is not clear whether the nation's welfare has been adversely affected. As pointed out by Roland (2008), general equilibrium theory and industrial organization say little about the effect of firm ownership on economic welfare.

Welfare economics suggests that privatization could improve the performance of facilities where government failure is a more serious problem than market failure. For example, commercial airports in the United States, which are operated by local governments or through public airport authorities, do not have access to sources of private capital during a time when the federal aviation trust fund, which is used to support airport improvements, is running a large deficit that has been covered by general taxpayer funds, fewer of which will be available for transportation infrastructure in the coming years. In addition, public airports have failed to address travelers' frustrations with long travel delays because Congress has been unwilling to change federal aviation charges to reduce delays by allowing them to vary throughout the day in accordance with traffic levels. Even modest proposals, such as Secretary of Transportation Mary Peters' plan to reduce delays by auctioning up to 10 percent of the takeoff and landing slots at the three major New York-area airports, Kennedy, LaGuardia, and Newark, have been rejected by elected officials.

Of course, the shortcomings of public airports are not sufficient to justify airport privatization. In theory, privatized airports in major metropolitan areas could compete to improve air travel because they are not natural monopolies (passenger volumes at the Bay Area airports that we study here appear to exhaust any scale economies (Jeong (2005)), their catchment areas overlap (Starkie (2008)), and they are served by different airlines that serve different markets (Pels, Nijkamp, and Rietveld (2001), Ishii, Jun, and Van Dender (2008)). In practice, cities such as London have privatized their airports, but they initially sold their three major airports, Heathrow, Gatwick, and Stansted, to the same owner, Ferrovial SA, which raised concerns that the privatized airports possessed considerable market power.[1] We therefore explore whether it is possible to design a market for airport competition that would improve travelers' welfare and that would enable the airports to be financially viable. The setting for our analysis is the San Francisco metropolitan area because privatized Oakland, San Francisco, and San Jose airports could compete with each other. Given the complexity of the analysis, we focus on pricing behavior, which we find is sufficient to reveal critical differences between public and private airport operations.[2]

Because we provide a prospective assessment of airport privatization, we do not claim that our analysis characterizes how airport privatization would actually evolve in practice—it is obviously difficult to verify whether such a characterization is correct—rather we seek to indicate the conditions, if any, under which privatization could achieve certain goals. We make simplifying assumptions to facilitate an empirically tractable model and to make an initial assessment of whether airport privatization is socially desirable. We then explore whether our conclusions are affected by those assumptions. In the process, we provide policy guidance by indicating whether airport privatization could be justified, whether the essential conditions are theoretically plausible, and how those conditions could be satisfied in practice.

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[1] Facing pressure from the UK Competition Commission, Ferrovial SA sold Gatwick airport and subsequently sold Standsted airport.

[2] Starkie (2001) and Zhang and Zhang (2003) assess privatization in the case of a monopoly airport and point out 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) provides a theoretical and numerical analysis that shows the welfare effects of airport privatization vary with competitive conditions.

We find that airport privatization could be designed so that commercial travelers' welfare and airlines' profits increase and that the airports are profitable. The key conditions are that policymakers coordinate privatization such that all three Bay Area airports are privatized and not sold to the same operator, and that 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*). Our findings have important implications for considering how the performance of other industries with a vertical structure could be improved. We also show that relaxing our most important modeling assumptions would tend to strengthen the possibility that a market for private airport competition could be designed that enhances social welfare.

2. Modeling Framework

Modeling privatization in a vertical industry is challenging because the change in policy affects the profitability of the downstream and upstream firms—in the case of airport privatization, both airports' and air carriers' profits are affected—and the welfare of consumers. In this section, we construct an appropriate network of air transportation routes to study and then model privatization of the San Francisco Bay Area airports as a sequential-moves game given the network. We take a structural approach by using economic theory to develop a model and run counterfactual experiments on the potential effects of airport privatization because there are no large private airports in the United States that we could use as a control group in a reduced form approach. We assess later how changes in the simplifying assumptions that we use to develop our model affect the conclusions.

The Air Transportation Network

We confine our assessment of privatization 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 has the most passengers, commercial flights, and general aviation operations, especially air taxi operations that use larger planes than other general aviation operations do. SFO also has greater departure and arrival delays but the average trip distances, flying times, and size of commercial aircraft serving the airports are similar.

Our network includes only domestic airline markets where a Bay Area airport is the origin or destination city; international markets are excluded because they may be subject to fare and frequency regulations established by U.S. and foreign governments. Because we wish to distinguish takeoff and landing runway charges set by privatized Bay Area airports from (regulated) weight-based landing fees at public airports in other metropolitan areas, we define 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). 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); 6) A $300 non-stop American Airlines (AA) flight from SFO to EWR.

We are particularly interested in how airport privatization affects travel delays; thus, we include 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.

Because we consider only those markets that are comprised by a San Francisco Bay Area airport (hereafter SF airport) at the origin or destination, 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 services to and from SF airports.

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 explore later how this admittedly strong assumption affects our main conclusions about the possible benefits of privatization.

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 be designed 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.

A Three-Stage Game

Currently, public airports raise revenues to cover the costs of their terminals and runways by charging passengers for facility use and parking, retail stores for rental space and advertising displays, airlines for renting terminal counters and gates, and aircraft for runway landings based on their weight subject to guidelines set by the Federal Aviation Administration. Recently, general taxpayer funds have supplemented airport revenues to cover costs.

Under privatization, we assume that a private firm would purchase a commercial airport from the local government or authority if the present discounted value of lifetime operating profits from airport operations covered the initial cost of acquiring the airport. Because we have no way of knowing in advance what the purchase price would be for any of the Bay Area airports, we further assume—without invoking a particular pricing mechanism—that the appropriate government authority sets the sale price of each airport to exhaust the private airport operator's excess operating profits. Of course, the government may err in setting the sale price; we discuss the implications of that possibility on private airports' pricing behavior in the concluding section.

We assume that a private airport would replace the public airport's weight-based landing fees and passenger facility charges with both takeoff and landing runway charges; other airport charges that are unrelated to government policy would not change. We then make the following assumption to analyze airport privatization as a sequential-moves game on the preceding air transportation network.

Assumption 4: *A three-stage game of airport privatization*

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 and passenger demand is allocated among products subject to the constraint that spoke passengers cannot exceed the spoke capacities announced in the second stage.

Assumption 4 captures the features of horizontal airport competition, the vertical relationship between airports and airlines, and horizontal airline competition where airlines compete in both price and service quality. Given a fixed aircraft size (assumption 3), airlines' capacity decisions in the second stage determine the flight frequency for the products they offer.[3] Travelers value greater flight frequency because it reduces schedule delay; namely, the difference between their desired departure time and the closest available departure time.

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 airport privatization 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 airport privatization is justified in a static setting and whether that justification would be affected in a dynamic setting.

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. The number of travelers choosing product j is denoted by $q_j(p_m, d_m)$, which is a function of a

[3] Flight frequency on a spoke route is the ratio of the total number of seats to average aircraft size.

vector of prices (p_m) and a vector of scheduled delays (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 on the products it offers by solving the following constrained profit-maximization problem:

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

where J_{sf} denotes the set of products offered by carrier f using spoke s and J_{mf} denotes the set of products offered by carrier f in market m; $p_{mf} = \{p_j\}_{j\in J_{mf}}$ therefore $p_m = \{p_{mf}\}_{f\in\Omega_m}$ with Ω_m denoting the set of airlines in market m; finally, 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, Carnall and Spiller (2007), we specify an airline's total variable costs of providing services connected to the SF airport market as the sum of the total costs of each spoke served by the airline plus product-specific costs:

$$C_f = \sum_{s\in\Phi_f} C(Q_{sf}) + \sum_{m=1}^{M}\sum_{j\in J_{mf}} q_j \cdot (W_{mj}\omega + \eta_j), \tag{2}$$

where $C(Q_{sf})$ denotes the carrier's operating costs on spoke s; Φ_f is the set of spokes that are connected to the SF airports and are served by the carrier; $Q_{sf} \equiv \sum_{j\in J_{sf}} q_j$ determines the spoke passengers; $q_j \cdot (W_{mj}\omega + \eta_j)$ denotes product-specific costs; W_{mj} is a vector of observed exogenous market and product characteristics including airline and airport dummies; ω is a vector of parameters; and η_j 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

$$MC_j = \sum_{s \in \Phi_f^j} \left(\frac{\partial AOC_{sf}}{\partial Q_{sf}} + \frac{\partial LF_{sf}}{\partial Q_{sf}} + \frac{\partial SC_{sf}}{\partial Q_{sf}} \right) + W_{mj}\omega + \eta_j \tag{3}$$

where Φ_f^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 segments it serves $\left(\{T_{sf}\}_{s \in \Phi_f}\right)$ 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 equation (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.[4] In practice, airlines

[4] 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.

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 that are connected to the SF airports to achieve target load factors on those spokes.*

An airline's target load factor on a spoke can never be greater than 100%.[5] 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.

Specifying Airport Behavior. We construct an airport's profit equation, which is optimized with respect to its takeoff and landing charges.[6] Let n denote a San Francisco Bay Area airport; Φ_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

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

[5] 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.

[6] 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.

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

To determine costs (Λ), 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 equation (4), we specify the short-run operating cost function for airports as $\Lambda_n(Q_n, F_n)$. 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 $\underset{\varsigma_n^A}{Max}\,\pi_n = R_n - \Lambda_n$. Their runway charges affect the equilibrium outcomes of airline price and service competition by affecting airlines' marginal spoke costs in equation (3).

Equilibrium Concept. The equilibrium concept for the three-stage airport privatization game is the subgame perfect equilibrium (SPE), which is characterized in this section by backward induction. Because airlines' target load factors on their spokes are less than 100%, we restrict our discussion of the equilibrium of the airline price subgame given airport runway charges and airlines' spoke capacities to the equilibria at which the capacity constraint in equation (1) is not binding. Thus, 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,[7] then equilibrium prices satisfy the first-order conditions:

$$\frac{\partial \pi_f}{\partial p_k} = q_k + \sum_m \sum_{j \in J_{mf}} \frac{\partial q_j}{\partial p_k}\left(p_j - MC_j\right) = 0, \; for\, all\, k \tag{5}$$

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

where $\frac{\partial q_j}{\partial p_k} = 0$ when products j and k are not in the same market.

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 airport privatization game, each airline chooses 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 and $BE(\mathbf{T})$ denote the set of Bertrand-Nash equilibrium prices in all markets given the spoke capacities. A function $P(\cdot)$ exists that maps the space of spoke capacities to the space of product prices and $P(\mathbf{T}) \in BE(\mathbf{T})$ for all $\mathbf{T}$. The demand for products given the spoke capacities and the associated equilibrium prices can then be denoted by $q_j(P(\mathbf{T}), \mathbf{T})$ for all j, because spoke capacities affect product demand both directly by determining flight frequency and indirectly by determining equilibrium prices. Let θ_{sf} denote the target spoke-route load factor, the capacity of a spoke-route given $\mathbf{T}$ and $P(\mathbf{T})$ is determined by:

$$T_{sf} = Q_{sf} / \theta_{sf} = \sum_{j \in J_{sf}} q_j(P(\mathbf{T}), \mathbf{T}) \Big/ \theta_{sf} = \mathrm{H}_{sf}(\mathbf{T}) \text{ for all } s \text{ and } f . \qquad (6)$$

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. 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. The definition of a SPE to the two-stage game of airline price and service competition given airport runway charges under Assumption 5 can then be stated as follows.

Definition 1: *A SPE to the two-stage game of airline competition constitutes a vector* $(\mathbf{T}^*, \mathbf{P}^*)$ *that satisfies the following conditions:*

1. $\mathbf{T}^*$ *is a fixed-point of* $\mathbf{H}(\cdot)$*, that is,* $\mathbf{T}^* = \mathbf{H}(\mathbf{T}^*)$*; and*

2. $\mathbf{P}^* = P(\mathbf{T}^*) \in BE(\mathbf{T}^*)$ *such that* $\mathbf{P}^*$ *satisfies equation (5) given* $\mathbf{T}^*$.

Moving backward to the first stage of the game, the three airports engage in Bertrand competition with the expectation of the equilibrium outcomes of airline competition given airport charges. The SPE to the airport privatization game is defined as follows.

Definition 2: *Let* $\boldsymbol{\varsigma}^* \equiv \left(\varsigma_{SFO}^{A\ *}, \varsigma_{SJC}^{A\ *}, \varsigma_{OAK}^{A\ *} \right)$ *denote a vector of airport charges;* $\mathbf{P}^*$ *denote a vector of product prices in city-pair markets connected to SF airports with the size of the vector* l *;* $\mathbf{T}^*$ *denote a vector of airline capacities on the spoke routes they serve that are connected to the three SF airports with the size of the vector* k *; and* $\Xi(\varsigma)$ *denote the set of equilibria to the service-price subgame of airlines given a set of airport charges* ς *as in Definition 1. The vector* $\left(\boldsymbol{\varsigma}^*, \mathbf{T}^*, \mathbf{P}^*\right)$ *is a SPE to the oligopoly airport price competition if* $\Psi^* \equiv \left(\mathbf{T}^*, \mathbf{P}^*\right) \in \Xi\left(\boldsymbol{\varsigma}^*\right)$ *and there exists a function* $\Psi : R_+^3 \to R_+^{l+k}$ *such that* $\Psi(\varsigma) \in \Xi(\varsigma)$ *for all* $\varsigma \geq 0$ *and for all* n *,*

$$\pi_n^A\left(\varsigma_n^{A^*}, \boldsymbol{\varsigma}_{-n}^{A\ *}, \Psi^* \right) \geq \pi_n^A\left(\varsigma_n^A, \boldsymbol{\varsigma}_{-n}^{A\ *}, \Psi\left(\varsigma_n^A, \boldsymbol{\varsigma}_{-n}^{A\ *} \right) \right) \ \forall \varsigma_n^A \geq 0$$

in which $\boldsymbol{\varsigma}_{-n}^{A\ *}$ *is the subset of* $\boldsymbol{\varsigma}^*$ *by excluding airport* $n \in \{SFO, OAK, SJC\}$.

Oligopoly airport Bertrand competition amounts to price competition with substitute products among single-product firms. 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 least and the greatest equilibrium points exist in the set of equilibrium points.

3. Parameterization and Estimation of the Model

Given the preceding framework, we provide a quantitative assessment of airport privatization by specifying and estimating empirical models of air travelers' airline and airport demand and airlines' and airports' operating cost functions to parameterize their profit functions.

Before describing those models, we note that we use the Generalized Method of Moments (GMM), as in Berry, Levinsohn, and Pakes (1995) hereafter BLP, to jointly estimate the demand parameters and some of the airline cost parameters. Applying this approach in air transportation normally faces difficulties because it estimates separate product costs for different markets when, as we indicate in equation (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 additional aircraft operating cost data to first estimate airlines' spoke costs and then use the BLP approach to estimate the product-level costs. 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. As a further refinement, we define markets as city-pairs, instead of as airport pairs, because, as noted, multiple airports in major metropolitan areas could compete to improve air travel.[8]

An Empirical Model of Air Travelers' Airport and Airline Demand

We develop an aggregate discrete choice model to analyze San Francisco Bay Area travelers' airline and airport choices. Although it would be preferable to estimate the model using disaggregated data to include detailed characteristics of those travelers, such as how much time it takes them to drive or take transit to each SF airport, such data are not publicly available and they would be difficult and expensive to collect. The traveler's utility function is assumed to include the price of travel alternatives, all of the components of service time for those alternatives that encompass the traveler's desired departure time from the origin and actual arrival time at the destination, and exogenous attributes of the alternatives. Assuming a linear functional form, the utility of traveler i choosing air travel product j in market m is given by:

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

where

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[8] Examples include but are not limited to the three airports in the San Francisco Bay Area (SFO, OAK, SJC) that we study here, the three airports in the Los Angeles metropolitan area (LAX, BUR, and LGB), and the three airports in the New York metropolitan area (JFK, LGA and EWR).

X_j is a vector of observed exogenous product attributes, including airline dummies to capture preferences for specific airlines and airport dummies to capture preferences for 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. Schedule delay is the difference between the traveler's desired departure time and the closest available departure time and is a function of the carrier's flight frequency and load factor;

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); the random component 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;

α_i, β, ϕ, γ^f, γ^a, and γ^l are parameters. The subscript i for the price coefficient indicates that the coefficient is modeled to vary across travelers to capture the heterogeneity of their preferences for air travel. The coefficients of other product attributes, such as the components of travel time, can also be modeled to vary across individuals; but, as we discuss shortly, data limitations prevented us from estimating those sources of preference heterogeneity. We later argue that our treatment of preference heterogeneity had little effect on our conclusions.

We specify the choice of an outside product (for example, not traveling or traveling by car) with subscript 0. The mean utility of the outside product is normalized to zero such that

$$u_{i0} = \varepsilon_{i0} \quad . \tag{8}$$

The joint distribution of the errors $\varepsilon_i \equiv \left(\varepsilon_{i0}, \varepsilon_{i1}, \ldots, \varepsilon_{iN_m}\right)$ is specified as a General Extreme Value (GEV), which results in a choice probability with the nested-logit form such that 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. We argue that the assumption is plausible because we are able to significantly capture the attributes of those products by including both airline and airport dummies to capture preferences for specific airlines and airports as well as including price and service quality measures. Moreover, following BLP, our specification explicitly models the unobserved product attributes ξ_j that may be correlated with the price and service time components. Finally, we allow for a less restrictive substitution pattern by capturing preference heterogeneity for the price of air travel products.

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. We therefore characterized travelers' preference heterogeneity by specifying the price variable in terms of a simple discrete 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. We expect that leisure travelers have a greater sensitivity to price than do business travelers. Formally, we specify a two-point distribution denoting a parameter for business travel as B and for leisure travel as L:

$$\alpha_i = \begin{cases} \alpha^B & \text{with the probabilit y } \rho \\ \alpha^L & \text{with the probabilit y } 1-\rho \end{cases} \tag{9}$$

This specification of demand implies that the market share of product j in a given market is

$$S_j = \rho \cdot S_j^B + (1-\rho)\cdot S_j^L \quad , \tag{10}$$

where S_j^B and S_j^L are the market shares of business and leisure travelers and for *g= B or L*

$$\begin{aligned} S_j^g &= \frac{\exp\left(\dfrac{X_j\beta + \alpha^g p_j + \phi d_j + \gamma_f t_j^f + \gamma_a t_j^a + \gamma_l t_j^l + \xi_j}{\lambda}\right)}{\exp(I^g)} \cdot \frac{\exp(\lambda \cdot I^g)}{1+\exp(\lambda \cdot I^g)} \\ &= S_{j|A}^g (1 - S_0^g) \end{aligned} \tag{11}$$

and

$$I^g = \ln \sum_{j'=1}^{J} \exp\left(\frac{X_{j'}\beta + \alpha^g p_{j'} + \phi d_{j'} + \gamma_f t_{j'}^f + \gamma_a t_{j'}^a + \gamma_l t_{j'}^l + \xi_{j'}}{\lambda}\right); \tag{12}$$

λ is the nested-logit parameter measuring the correlation of unobserved components of utility across air travel products. It must have a value between 0 and 1 for the choice model to be consistent with utility maximization. In the second equality in equation (5), the term $S_{j|A}^g$ is the market share of product j for air travel products denoted A for type g travelers (for example, $S_{j|A}^B = 0.05$ if 5% of business air travelers choose air product j); the second term is the total share of air travel in the market (S_0^g is the market share of the outside product in a given market for type g travelers). Because the market shares of the air travel products respond differently in the business and leisure segments to a change in an air travel product's attributes, those shares are not constrained by the conventional logit model's IIA property. The demand for product j is then $q_j = S_j \cdot \mathrm{O}_m$ with O_m denoting the market size.

Based on this specification, we calculate the change (denoted as *Pre* to *Post*) in consumers' surplus due to airport privatization using the "log-sum" rule for a nested-logit demand model given by Choi and Moon (1997):

$$CS = \sum_{g=B,L} \mathrm{O}^g \frac{\rho^g}{\alpha^g} \left(\log\left[1 + \lambda \cdot \exp\left(I^g_{\mathrm{Post}}\right)\right] - \log\left[1 + \lambda \cdot \exp\left(I^g_{\mathrm{Pre}}\right)\right] \right) \tag{13}$$

where O^g is the size of type g travelers; ρ^g equals ρ if $g = B$ and equals $1-\rho$ otherwise; and I^g_{Post} and I^g_{Pre} are values of equation (12) based on the product attributes after and before airport privatization.

Data to Estimate the Demand Model

We use the Department of Transportation's DB1B data set, a 10% random sample of airline tickets reported by U.S. carriers, to estimate the demand model based on airline activity during the third quarter of 2007. As noted, we include only domestic trips that originate or terminate in one of the three San Francisco Bay area airports (SFO, OAK, SJC). The 71 airports with traffic delays that are monitored by the FAA, which we include in our analysis, are mainly located in medium to large metropolitan areas; 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.

We include only roundtrip itineraries and exclude the following observations:

- Itineraries that involve tickets from multiple carriers
- Itineraries with fares that are less than $25 or that are unreasonably high
- Itineraries that require more than one connection.

We follow Berry and Jia (2010) and define ticket classes by using the following fare dispersion bins to avoid having an excessive number of products: increments of $50 are used for all tickets under $500; increments of $100 are used for all tickets above $500 and under $1000; and increments of $500 are used for all tickets above $1000. We explored the robustness of the demand estimates by using larger and smaller sizes for the fare bins.

Using the DB1B data, we determine the price (passenger-fare) and market share of each air travel product $\left(S_{j|A}\right)$. The market size, which is used to determine the share of the outside product, is estimated as the geometric mean of the populations at the end-point cities.

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 FAA's Aviation System Performance Metrics (ASPM) database, which contains scheduled operations every 15 minutes for 23 specific airlines (22 U.S. network and commuter airlines plus Air Canada) plus one composite "other" category for all other commercial airlines. Because the data do not include general aviation operations, we do not include that airport user classification in our initial assessment of the effects of airport privatization but we later extend our framework to include general aviation to complete our assessment. We calculated average departure delay and average arrival delay for each airport in the third quarter 2007 (obtained by averaging across all carriers for each of the 15-minute segments and then averaging across all time segments). Flight frequency for each travel product is constructed from Back Aviation Solutions' schedule data. For nonstop flights, we aggregate all departures over all ticketing carriers. For connecting flights, we follow Berry and Jia (2010) and restrict the range of connecting time (transfer time) from 45 minutes to 4 hours; we include only the shortest layover time when multiple feasible connections exist. To measure schedule delay, we need flight frequency, aircraft size, and load factor. The flight frequency data from Back Aviation Solutions also records the size (number of seats) of each of the scheduled flights on a segment. The aircraft size of a non-stop product is then the average aircraft size of the carriers on the segment. The aircraft size of a connecting product is constructed by averaging the average aircraft sizes of the carriers on the two segments. Given the flight frequency and aircraft size for each product, we calculate schedule delay by assuming an 80 percent load factor.[9]

In addition to the preceding variables, we include a dummy variable indicating a long transfer time (defined as 1 if the transfer time of a connecting flight exceeds 1.5 hours; 0 otherwise), a dummy variable indicating whether a product involved a connecting flight (to capture the "fixed costs" of a transfer such as switching departure gates, having luggage transferred to a different plane, and so on), a carrier's airport presence (cities served) at both the origin and destination airport, and unobserved product attributes, such as the time it takes to travel to an airport from various residential locations and the quality of an airline's frequent flier program, which are captured by airline and airport dummies. Finally, the market characteristics in the demand specification include a vacation destination dummy for Florida or Nevada cities, the distance of the origin from the destination, and a dummy indicating whether a flight involves a slot-controlled airport (Chicago O'Hare, New York Kennedy and LaGuardia, and Washington, DC Reagan National). Data sources and summary statistics for the demand variables are presented in Table 2.

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[9] The most recent functional expression that we are aware of to calculate schedule delay is from Douglas and Miller (1974). Our assumption of an 80 percent load factor is based on recent average industry load factors and reflects the fact that observed schedule delay is affected by all traffic. Assuming a somewhat higher or lower load factor did not affect our findings. We plugged the values of the relevant variables in our sample into Douglas and Miller's functional expression, which is given by:

$$d_j = 92 \cdot \text{Daily Departures}^{-0.456} + \left(\frac{12010}{\text{Daily Departures}}\right) \cdot (\text{Aircraft Size} \times \text{Load Factor})^{0.5725} \cdot [\text{Aircraft Size} \times (1 - \text{Load Factor})]^{-1.79}$$

In sum, our sample encompasses an air transportation network consisting of 120 city-pair markets and 20830 air travel products provided by 16 specific airlines, which serve a set of spoke routes connected to the SF airports.[10] 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.

Empirical Models of Airlines' Spoke Operating Costs and Airports' Operating Costs

Airlines' spoke operating costs in equation (2) include aircraft operating costs, take-off and landing fee expenditures, and the scheduling cost on a spoke. Aircraft operating costs depend on the type of aircraft, the duration of the flight, and the carrier operating the flight and can be estimated from 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.

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 $z_f(K_{sf})$ in Cobb-Douglas form and obtain the following OLS regression results:

$$\ln z_{if} = \underset{(0.2821)}{4.4715} + \underset{(0.0566)}{0.6982} \ln(K_i) + \varepsilon_{if}^{z}, \quad \text{Adj. } R^2 = 0.55 \tag{14}$$

where z_{if} is the operating costs per block hour for aircraft type i operated by carrier f and K_i is the number of seats of aircraft type i. We also included airline fixed effects to control for variables such as pilots' and flight attendants' average wages.

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

[10]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.

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

$$AOC_{sf} = \frac{Q_{sf}}{\theta_{sf} \cdot K_{sf}}\left(h_{sf} + \delta_s\right) \cdot \exp\left(4.5715 + 0.6982 \cdot \ln\left(K_{sf}\right) + \varepsilon_{if}^{z}\right). \qquad (15)$$

Total delay on a spoke route includes delay at both the departure and arrival airports; thus, in equation (15) $\delta_s = departure\ \ delay + arrival\ \ delay$. 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 total traffic volume (number of flights) at each airport. Total traffic volume at airport n is then

$$V_n = \sum_{s \in \Phi_n} \left\{ \sum_{f} \left(\frac{\sum_{j \in J_{sf}} q_j}{\theta_{sf} \cdot K_{sf}} \right) \right\} . \qquad (16)$$

Airport delay is specified as a function of the volume-capacity ratio, $\delta_n = D_n\left(\frac{V_n}{RW_n}\right)$, where RW_n is the number of active runways at airport n. We parameterize the function by a translog form and use traffic delays recorded in the FAA's Aviation System Performance Metrics (ASPM) database noted previously to estimate the following regression equation

$$\ln \delta_n = b_{0n} + b_{1n} \ln\left(\frac{V_n}{RW_n}\right) + b_{2n}\left(\ln\left(\frac{V_n}{RW_n}\right)\right)^2 + \varepsilon_n^{\delta}, \qquad (17)$$

where the dependent variable is the log of average aircraft departure or arrival delay (minutes per aircraft) in a 15-minute interval on a representative day of travel in 2007 and the explanatory variables are the log of the volume-capacity ratio and its square in the 15-minute interval. Table 3 presents the parameter estimates of this equation for the SF airports and we plot the estimated delay functions in figure 1, which indicate that for a given number of flights, departure delays tend to exceed arrival delays at each of the airports and that SFO has the largest departure delays and OAK has the largest arrival delays. The shape of the curves can be convex and then concave because in response to an increase in flights above a certain threshold, an airport may vary the number of active runways and the allocation of runways for departures and arrivals.

U.S. airports charge aircraft weight-based landing fees, with a representative value of $2 per 1,000 pounds of landing weight. We estimated landing fee charges by using data on aircraft manufacturer websites to calculate the average aircraft landing weight per seat for aircraft with fewer than 100 seats (940 lbs/seat), 101–199 seats (940 lbs/seat), 200–299 seats (1,240 lbs/seat), 300–399 seats (1,350 lbs/seat), and greater than 400 seats (1,580 lbs/seat). (Note an aircraft is not charged when it takes off from an airport.) 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

$$LF_{sf} = \frac{Q_{sf}}{\theta_{sf} \cdot K_{sf}} \cdot \left(0.002 \cdot \tau\left(K_{sf}\right) \cdot K_{sf}\right) = 0.002 \cdot \tau\left(K_{sf}\right) \cdot \frac{Q_{sf}}{\theta_{sf}} \ . \tag{18}$$

The final component of airlines' spoke-route costs is scheduling costs; we specify those as a polynomial function (with degree 2) of spoke distance such that

$$\frac{\partial SC_{sf}}{\partial Q_{sf}} = \kappa_0 + \kappa_1 Dist_s \, , \tag{19}$$

where $Dist_s$ is the distance of spoke route s and the κ's are parameters.

Turning to airports' operating costs, we specify the short-run operating costs of an airport n as Cobb-Douglas such that

$$\Lambda_n = \upsilon_{0n} \cdot \left(Q_n\right)^{\upsilon_{1n}} \cdot \left(\sum_{s \in \Phi_n} \sum_{f} \frac{T_{sf}}{K_{sf}} \right)^{\upsilon_{2n}} . \tag{20}$$

Based on Oum, Yan, and Yu's (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,[11] 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.[12] We found that varying the cost elasticities within plausible ranges had no notable effects on our findings.

BLP Estimation of the Demand Parameters and the Remaining Airline Marginal Cost Parameters

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 equation (3) and the two parameters in equation (19). This approach treats observed product prices as equilibrium outcomes that are generated from Bertrand airline competition—the last stage of the airport privatization game. Those prices therefore satisfy the first-order condition in equation (5), which can be combined with the marginal cost in equation (3) to obtain an estimable price-residual (supply) equation:

$$\begin{aligned} & p_j - \sum_{s \in \Omega_f^j} \left(\frac{\partial AOC_{sf}}{\partial Q_{sf}} + \frac{\partial LF_{sf}}{\partial Q_{sf}} \right) + \left(\Delta_{mf}^j \right)^{-1} q_{mf} \\ & = \kappa_0 \times \text{Number of Segments} + \kappa_1 \times \sum_{s \in \Phi_f^j} Dist_s + W_{mj}\omega + \eta_j \end{aligned} \tag{21}$$

where $\Delta_{mf}^j = \{\partial q_k / \partial p_j\}_{j \in J_{mf}}$ and $q_{mf} = \{q_k\}_{k \in J_{mf}}$ contain unknown demand parameters. In the regression equation (21), 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} include both airline

[11] We pointed out that airports tend to exhaust scale economies in the long run. The cost elasticities used here imply increasing returns in the short run.

[12] 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.

and airport-pair dummies to enable the airline marginal cost equation to account for cost differences across airlines and for cost differences of a given airline operating at different airports.

When equation (21) 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_j, which captures the unobserved product characteristics that affect the marginal cost of a product. Similarly, when the choice model equations (10)-(12) are evaluated at the "true" values of the demand parameters, the difference between products' observed and predicted market shares depends entirely on ξ_j, which captures unobserved product attributes that affect travelers' choices.

Thus we identify the discrete-choice demand and supply equations with two vectors of instruments, Z_j^D and Z_j^C, such that

$$E\left(\xi_j \middle| Z_j^D\right) = E\left(\eta_j \middle| Z_j^C\right) = 0. \tag{22}$$

Variables in Z_j^D include exogenous product attributes and instruments for the endogenous variables in the demand model, price and schedule delay. Variables in Z_j^C include exogenous regressors in equation (21) and exogenous instruments for demand that affect the mark-up $\left(\Delta_{mf}^j\right)^{-1} q_{mf}$.

Price and schedule delay are endogenous because they are likely to be correlated with an airline's unobserved product attributes. We use three sets of variables to obtain instruments for price. First, we follow the common strategy of using variables that capture rival product attributes and that indicate the competitiveness of the market environment, including the number of carriers in a market, the number of alternative routes offered by rivals in a market, the percentage of rivals' routes that are nonstop routes, and the average presence of rivals (number of connected cities) at the origin airport. Because those variables are largely determined by the size of a market and because they are unlikely to respond to the same shocks that affect prices, it is reasonable to assume that they are predetermined and uncorrelated with unobserved product characteristics.

Route characteristics constitute another set of variables that can be used as instruments, including a dummy if the origin or destination is a carrier's hub, the temperature difference between the origin and destination airports in January, and the temperature difference between January and July at the two endpoint airports. Given the other controls in the model, those variables affect the product price by affecting costs, such as time and money expenditures on de-icing, but not demand.

Finally, a third set of variables captures the extent of competition from low-cost carriers, including a dummy variable indicating if a low-cost carrier serves a route, a dummy variable indicating if Southwest Airlines serves the route, and a dummy variable indicating if Southwest Airlines is a potential competitor on the route, which occurs when Southwest serves the end-point airports but does not serve the route connecting the two airports.[13] Historically, low-cost carriers tend to enter markets with characteristics that are consistent with their operating "philosophy," such as Southwest's attraction to markets that do not have highly congested airports, and they are unlikely to react to the same shocks that affect prices. To be sure, low-cost carriers' growing market shares raise questions whether their operating philosophies have recently changed and whether it is appropriate to use them to construct instruments. We found that our parameter estimates were not affected very much when we did not include this third set of variables among the instruments.

Schedule delay is determined by an airline's flight frequency and aircraft size. We obtain an instrument for schedule delay by first regressing flight frequency and aircraft size on exogenous market characteristics, including flight distance, market size as defined previously, mean household income, the number of runways at the departure, arrival, and, if applicable, connecting airports, a dummy variable

[13] Goolsbee and Syverson (2008) provide evidence that incumbent carriers cut their fares on a route when Southwest Airlines serves the end-point airports that define the route but does not serve the route.

indicating whether the San Francisco Bay Area is the origin of a market, the temperature difference between the end-point cities in July and January, a vacation dummy variable defined previously, a dummy variable if the airports are subject to slot controls, a hub route dummy, and airline and airport dummies. The fitted frequency and aircraft size variables are then used as instruments for schedule delay in the final estimation.

The first stage regressions of endogenous price and schedule delay on their instruments, which are plausibly excluded from demand, produced high R-squares and statistically significant coefficients. Given those instruments, the parameters in the discrete choice demand and the supply equations can be estimated jointly using the BLP GMM approach based on the moment conditions in equation (22).

Identification of the demand and cost parameters relies on variation in the data both within and across markets, while identification of the demand parameter ρ, the share of traveler type, relies on the variation across markets in the substitution patterns among travel products and identification of the nested-logit parameter λ relies on the variation across market in the substitution pattern between air travel and the outside option. Details of the estimation approach are contained in the appendix. We note here that our findings were not particularly sensitive to the use of any specific instrument.

4. Estimation Results

BLP GMM estimation results of travelers' demand are presented in table 4. We allowed the price coefficient to vary to capture preference heterogeneity that is likely to arise for business and leisure travelers by drawing on the available evidence and assuming that the percentage of business travelers in our markets is 45%.[14] Generally, the coefficients are precisely estimated and have the expected signs:

[14] We are not aware of a recent estimate of the share of business travelers in the San Francisco Bay Area markets. Our assumed share is broadly consistent with Bay Area airport travelers' trip purposes that were reported in a 1995 survey conducted by the Oakland Metropolitan Transportation Commission and

market shares of leisure and business travelers are inversely related to price with business travelers attaching less disutility than leisure travelers attach to a price increase, market shares of all travelers are inversely related to the components of travel time, while they are positively related to airlines' presence at the origin and destination airports. The carrier dummies indicate that holding attributes such as price, frequency, and service time constant, travelers' carrier preferences relative to their preference for United Airlines are frequently negative, perhaps because of United's valued frequent flier program. The airport dummies indicate travelers' airport preferences in multi-airport cities, capturing the advantage of an airport's location among other considerations, with positive preferences for SFO, ORD (Chicago O'Hare), JFK (New York JFK), IAH (Houston George Bush Intercontinental), DFW (Dallas Fort Worth), IAD (Washington Dulles), and LAX (Los Angeles). Air travel demand increases with route distance because other travel alternatives such as driving become less attractive, but it does so at a decreasing rate. Air travel demand decreases because of airport slot controls and in markets with tourist cities, perhaps because of intermodal competition on routes connecting the Bay Area and Nevada cities, but the effect is statistically imprecise. The estimated value of λ, 0.74, is consistent with utility maximizing behavior and the value of $1-\lambda$ = 0.26 indicates the correlation of the unobserved utility of the air travel products.

As a robustness check, we followed Berry and Jia (2010) and explored how the demand estimates were affected by our assumption on airline price competition by dropping the cost-side moment conditions when we performed BLP GMM estimation. We did not find any notable changes to the parameter estimates.

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used by Pels, Nijkamp, and Rietveld (2001). It is also consistent with results contained in the 2001 National Travel Survey and national surveys periodically taken since the mid-1990s by the Gallup Organization. As a technical check, we found that the objective value of the moment function was smallest when we assumed 45% was the share of business travelers. Assuming smaller shares of business travelers, 35% and 25%, affected the deviation but not the weighted average of the price coefficients.

Based on the estimated coefficients, table 5 presents calculations of the price elasticity of demand and values of travel time components. For sensitivity purposes the table also includes calculations 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.

The first column of the table shows that OLS estimates that ignore price endogeneity produce implausibly small demand elasticities and an implausibly high willingness to pay for non-stop flights. The second and third columns indicate that the IV and GMM estimates of the overall demand elasticity are similar as are their estimates of the overall values of the travel time components. The GMM estimates, which account for travelers' heterogeneous preferences, are plausible. The overall aggregate price elasticity of demand for air travel in the 120 markets in our sample, -1.10, 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 $30/hour, with business travelers valuing that time at $40/hour and leisure travelers valuing it at $21/hour. This is aligned with previous estimates of the value of travel time that cluster around $30/hour (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 cancelled, 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.[15]

Table 6 presents the BLP GMM estimates of the unknown parameters in equation (21), which capture unobserved shifts in airlines' prices after controlling for the price mark-up, aircraft operating costs, and airport landing fees. The price residual is negatively related to the number of segments suggesting that airlines charge lower prices for products using connecting flights because travelers find those flights less desirable than non-stop flights. Because part of the impact of segment distance on the product marginal cost is already captured by aircraft operating costs, the price residual is negatively related to the segment distance. The estimates of the carrier dummies are plausible with UA and AA offering the most costly products and Southwest and JetBlue and other low-cost carriers offering the least costly products. Finally, products using OAK and SJC are less costly than products using SFO.

Using the estimates in table 6 along with equations (15) and (18), 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 7. The average marginal cost across the 20830 products is 8 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. 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, 12 cents per passenger mile, is greater than the average marginal cost of connecting flights, 7 cents per mile, possibly because airlines use larger more expensive aircraft and operate with

[15] 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.

somewhat lower load factors on non-stop flights.[16] Turning to airlines, Southwest's and JetBlue's marginal costs are, as expected, lower than the other (mainly legacy) carriers' marginal costs. Among the three airports in the SF market, air travel products that involve Oakland airport have the lowest marginal cost.

5. Computing the Equilibrium and Validating the Model

We develop algorithms to compute the SPE to the three-stage airport privatization game and initially use them to validate the accuracy of our estimated and calibrated parameters by computing and assessing the predictions of baseline equilibrium outcomes of airline competition under current airport policy.

Given airport charges and airlines' spoke capacities in each of the 120 markets; we compute the equilibrium of the airline price subgame iteratively by allowing each carrier in a market to optimize the prices of its air travel products taking the other carriers' product prices as fixed. If F is the number of carriers in a market, then an iteration of the computational procedure requires solving F optimization problems using the first-order condition in equation (5). Starting from different initial prices, we found that the computed equilibrium airline prices were very close to the observed prices, which suggests that our parameter estimates are consistent with the existence of a unique airline price subgame equilibrium. In the appendix, we discuss in detail the existence and uniqueness of this equilibrium.

We compute the SPE (given in Definition 1) to the two-stage airline service-price subgame by iterating the fixed-point equation $\mathbf{T}^{\mathbf{t+1}} = \mathbf{H}\left(\mathbf{T}^{\mathbf{t}}\right)$ under an assumed spoke load-factor, which represents the target load factor in airlines' capacity decisions. We explored target load-factors of 60%, 70%, 80%,

[16] 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.

and 90% and found that 70% enabled us to most closely replicate observed outcomes; thus, we assume that load-factor in the baseline simulations and we later discuss the sensitivity of our conclusions to that assumption. In the appendix, we indicate that we had no difficulty determining a unique equilibrium from a fixed-point iteration except when we assumed the lowest load-factor 60%.

Because Bertrand competition among airports is supermodular, our algorithm computes the least equilibrium point, which corresponds to the upper bound of travelers' surplus in the set of the SPE to the three-stage airport privatization game (given in Definition 2). The algorithm starts from the lowest charge at the three airports, zero, and then each airport successively increases its charge $1 while the other airports' charges are fixed. Iterations stop when no airport can benefit from increasing its charge given the current charges at the other airports. Details of this algorithm are also in the appendix.

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. 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. We show in table 8 that based on a comparison of simulated with actual outcomes, that 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.

6. The Effects of Airport Privatization

We quantify the economic effects of privatizing the San Francisco Bay Area airports by comparing the base-case equilibrium with equilibria generated under alternative privatization scenarios including: 1.) only SFO is privatized and it maximizes profits given the landing fees at OAK and SJC; 2.) SFO, OAK, and SJC are privatized and acquired by one owner who sets charges for all three airports; and 3.) SFO, OAK, and SJC are privatized and acquired by different owners who set charges for the airports independently. Because privatization may enable airports to exercise considerable market power, we also consider bargaining solutions between airports and airlines to limit that power. Negotiated or contract prices have been an important feature of deregulated transportation markets with few competitors (Winston (1998)) and were previously used by Winston and Yan (2011) to assess highway privatization in an oligopolistic setting. Possible contract equilibria include airline takeoff and landing charges that maximize airlines' profits or that maximize airports' profits subject to constraints, such as a nonnegative change (compared with the base case) in airlines' profits or in travelers' consumer surplus.[17]

Each scenario results in a three-stage sequential moves game and requires us to modify the algorithm to compute the SPE. We describe our computational procedures for the different scenarios in the appendix. We compute equilibrium outcomes including airport charges, airport delays, and quarterly changes in airports' profits, airlines' profits, consumer surplus, and social welfare. (We report quarterly changes because our demand and cost models were estimated with data from the third quarter of 2007 and it may be misleading because of seasonality effects to simply multiply those changes by four to report annual changes.)

[17] Littlechild (2011) discusses independent dispute resolution as a possible approach to facilitate bargaining between airports and airlines.

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.

Privatize One Airport. We begin our analysis with the case where one of the airports in a metropolitan area participates in a privatization pilot program, in this case SFO, but the other airports are still owned and operated by the local government. Table 9 shows that privatizing SFO airport produces roughly an $80 million (quarterly) social welfare gain because SFO sets takeoff and landing charges that increase its profits and that greatly reduce departure and arrival delays. Airlines' profits decrease because their operating costs increase and because they cannot sufficiently raise their fares to offset the higher airport charges. Despite the increase in fares, travelers experience only a small loss in consumer surplus because they no longer pay passenger facility charges, benefit from much shorter delays, in some cases avoid the higher fares at SFO by switching to OAK and SJC airports and incurring only a modest increase in departure delays, and in some cases avoid both the higher fares at SFO and increase in departure delays at OAK and SJC by switching to the outside option of using an alternative mode or not traveling. As shown in the third and fourth columns of the table, SFO charges that maximize social welfare and airlines' total profit transfer some airport profits to airlines while having a modest effect on the social welfare gain and the loss to travelers. That loss is eliminated only if SFO sets no charge (fifth column), which produces a social welfare loss, or a small charge (sixth column), which produces a much smaller welfare gain. Thus airport privatization has the potential to improve social welfare but distributional concerns arise because travelers do not stand to gain from the policy.

Privatize All Airports: *Monopoly*. The basic findings are magnified to some extent when all the SF airports are privatized and purchased by a single owner. As shown in table 10, the quarterly welfare gain is on the order of $200 million, with most of the improvement coming from the increase in airport profits. Airlines' negotiations with airports over charges could result in airline profits (column 4) or losses (column 2). Note travelers pay excessive air fares when airports set charges to maximize their profits because of double marginalization; both the upstream monopolist (airports) and the downstream oligopolists (airlines) raise prices above marginal cost. Social welfare maximizing charges reduce the double marginalization problem and increase social welfare; although travelers continue to experience a small loss under any scenario except one that generates a much smaller welfare gain and has little effect on delays (column 5). Thus welfare gains expand when all the airports in a metropolitan area are privatized but the failure of travelers and possibly airlines to benefit is still a source of concern.[18]

Privatize All Airports: Oligopoly. Privatization of the SF airports does not have to result in a monopoly provider because the policy could require the airports to be purchased by different owners that set charges independently under oligopolistic competition.[19] Table 11 indicates that such an environment would increase the potential welfare gains. Airport profit maximization would generate quarterly social welfare gains that exceed $250 million (column 2) and negotiations would enable those gains to be increased while both full-cost and low-cost air carriers earn positive profits (column 3). Both outcomes come reasonably close to maximizing social welfare.[20] Somewhat larger gains in airline

[18] Travelers could be better off if, for example, airports invested their profits to expand runway capacity and reduce delays. But we are analyzing only pricing responses at this point; we discuss the effects of additional responses later.

[19] As noted, the privatized airports in London currently have separate owners.

[20] The welfare maximizing charges for the oligopoly case imply full coordination among the three airports, which would be equivalent to the monopoly welfare maximizing charges that generate a quarterly social welfare gain of $275 million.

profits and negligible gains to travelers would come at a considerable sacrifice to airports' profits and overall social welfare (column 4).

In sum, if private airports, the upstream firms in the vertical market structure, set prices to maximize profits, travelers' fares would be excessive because double-marginalization—a common feature of vertical market structures—would result in a high pass-through rate from airport charges to airfares. We have found, however, that the extent of double-marginalization—and the increase in fares—can be reduced if airports engage in price competition and set charges in a bargaining framework that enables airlines to increase their profits without airports sacrificing much of theirs. Could the high pass-through rate also be reduced by stimulating downstream competition among airlines? We explored this issue by computing the average fare increase in each market when the three airports increased their current charges to $50 per seat under privatization (roughly $70 per passenger given the 70% load factor). Figure 2 shows that as the number of carriers in a market increases, the increase in average fares attributable to higher airport charges decreases, but the effect is small. Thus airline market competition does not seem to have much effect in creating a competitive airport market.

The most effective way to generate measurable improvements in commercial travelers' welfare, which would increase the political feasibility of airport privatization, is for travelers to face differentiated prices and service that would cater to their varying preferences for service time and reliability. This appears difficult to accomplish in the vertical market structure that we are studying because airlines, but not airports, appear to be in a position to segregate commercial travelers according to their travel preferences. However, the existence of some 20,000 to 30,000 general aviation operations per quarter that use the San Francisco Bay Area airports (see table 1) and contribute to congestion and delays suggests airports could approach the problem by differentiating their prices for different classifications of users.

7. Airport Privatization Accounting for General Aviation Operations

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 privatized SF airports that would enhance commercial travelers' welfare.

We assume distinct GA demand functions for the SF airports take a simple constant-elasticity demand form

$$Q_n^{GA} = A_n \cdot \left(FP_n\right)^{-e} \quad , \qquad (23)$$

where FP_n is the full-price of using airport n, which includes aircraft operating costs, airport charges, and passengers' time costs**,** e is the demand elasticity, and A_n is a scale parameter. Because the full prices of landing and taking off are different, equation (23) implies that total GA demand for each of the SF airports is given by

$$Q_n^{GA} = A_n \cdot \left[\left(FP_n^T\right)^{-e} + \left(FP_n^L\right)^{-e}\right] \quad , \qquad (24)$$

where the superscripts T and L denote taking off and landing.

Consistent with the much larger percentage of GA operations at San Francisco airport (SFO) that are air taxi operations (table 1), GA aircraft that use Oakland (OAK) and San Jose (SJC) airports are assumed to have four seats and an average load factor of 60 percent and GA aircraft that use SFO are assumed to have eight seats and an average load factor of 60 percent. The GA aircraft operating cost function (in dollars per block hour) is assumed to be a linear function of total seats and we use the unit aircraft operating costs (dollars per block hour per seat) of small commercial aircraft as the basis for our estimate—that is, \$35 per seat for a 50 seat aircraft. Currently, GA aircraft using OAK and SJC are not charged landing fees and GA aircraft using SFO are charged a minimum of \$140 per landing.[21]

Turning to passengers' time costs, we assume that the predominantly business GA travelers who use SFO are airborne for two hours, on average, and that GA travelers who use OAK and SJC are airborne for one hour. We assume that GA travelers who use OAK and SJC have the values of airborne time and airport delay, \$40/hour and \$160/hour, which we obtained from our nested-logit model for business travelers using commercial aircraft, and we assume somewhat higher values, \$60/hour and \$200/hour, for GA travelers who use SFO. The full price elasticity of demand for GA travelers is assumed to be the same demand elasticity, -1.8, which we obtained for business travelers on commercial aircraft.[22] Finally, we set the values of A_n such that GA's predicted shares of total traffic at SFO, OAK, and SJC are consistent with their actual shares.[23]

Given the GA demand functions, we account for GA's effect on air travel delays by inflating the traffic volume in each of the 15-minute segments at the SF airports to include GA's traffic in accordance with its actual traffic shares and by re-estimating the translog delay function given in equation (17). Unfortunately, data are not available that indicate how GA's traffic shares vary throughout the day. Estimation results for the new arrival and departure delay functions presented in table 12 show that including GA operations mainly affects the constant in those functions. Figure 3 plots the previous estimated departure and arrival delay functions and the estimated delay functions that account for

[21] http://www.flysfo.com/investor/SummaryFY0910.pdf .

[22] We calculated the elasticity from the demand estimates in table 4 by increasing both price and travel times (airborne time and airport delay) by 1%.

[23] GA airport shares, obtained from http://aspm.faa.gov/opsnet/sys/Airport.asp, are 30% for SFO and 35% for SJC and OAK.

general aviation. The vertical distance between the two delay functions for a given airport indicates that GA does contribute to delays at all the SF airports.

We analyze Bertrand oligopoly privatization scenarios that account for GA operations by assuming private airports are able to increase their charges for general aviation but that those charges are subject to a price cap, which limits them to double the current landing charge of $140 per flight at SFO. Given GA charges, airports determine charges for commercial carriers to optimize their objectives subject to negotiations. The findings presented in table 13 indicate that it is now possible for airports, airlines, and commercial travelers to gain from airport privatization with general aviation incurring some cost, while overall annual welfare gains are larger than in the previous scenarios that do not account for GA.

Additional gains are generated because GA contributes to delays that increase airlines' and travelers' costs, while being charged little, if anything, for those social costs.[24] Quarterly welfare gains increase 50 percent if airports set profit-maximizing charges to carriers (column 2) and if those charges are subject to a non-negative change in airline profits at each airport (column 3). And if negotiations between airports and airlines generate charges that maximize airlines' profits at each airport, with each airport earning non-negative profits, then airports, airlines, and commercial travelers gain and quarterly welfare gains are still sizable (column 4). In this case, airports gain from charging GA and airlines and travelers gain from less delay without incurring airport charges and higher fares. The last column shows that there is some flexibility for airlines and airports to negotiate charges whereby commercial airlines pay some airport charges, social welfare increases over the previous scenario where they do not pay

[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.

charges, and the change in commercial travelers' welfare is non-negative because their gain from less delay offsets the loss from higher fares.[25]

Because the gains from airport privatization 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 extend privatization to stimulate competition among smaller 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.[26] 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 improved 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 increase the likelihood that all civilian aviation classifications could gain from airport privatization by encouraging all airports to engage in market competition for commercial passengers and recreational flyers.

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[25] As a matter of sensitivity, we found that reducing the price cap for GA slightly reduces the flexibility of airlines and airports to negotiate charges that lead to a "win-win" situation. At the current price cap of 280 for GA, bargaining between airlines and airports could lead to a "win-win" outcome when the airline bargaining weight ($1-\varpi$) satisfies $0.83 \leq 1-\varpi \leq 1$. If the price cap for GA is reduced 50% to 140, the airline bargaining weight cannot be less than 0.85 to have a bargaining outcome where the change in commercial travelers' welfare is non-negative.

[26] 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.

8. Does Airport Privatization's Possible Success Depend on Restrictive Assumptions?

We have found that it is possible for privatization of the San Francisco Bay Area airports to result in those airports being profitable and to improve the welfare of commercial carriers and travelers, provided separately-owned airports negotiate charges with airlines organized as a bargaining unit and general aviation faces higher charges to use those airports.

We have made a number of modeling assumptions to enable the analysis to be empirically tractable, so it is important to assess whether our positive conclusion about airport privatization's possibilities is robust to the most important assumptions. First, we have not accounted for commercial airlines' and general aviation's entry and exit behavior in response to higher airport charges (Assumption 2). But doing so would only increase the possibility that airport privatization could succeed by increasing the likelihood that airports and airlines could solve the problem of segmenting air travelers by offering them differentiated prices to cater to their varying preferences for travel time and reliability. In practice, airports could differentiate their services to cater to certain carriers, for example, some airports could offer much lower delays during peak travel periods by charging higher takeoff and landing fees and by reducing the diseconomies of scope that arise from providing long runways to serve both commercial jets and general aviation. Carriers could adjust their sub-networks to serve airports in metropolitan areas that are most closely aligned with the fares and service they wish to offer passengers. Travelers would then be better able to choose airlines and airports that optimize their preferred combination of fares and service.

A corollary of this discussion is that we have understated the benefits from airport privatization by capturing travelers' heterogeneity in our demand model that accounted only for business and pleasure travelers' different valuations of fares. As noted, product differentiation by private airports could increase benefits by catering to airlines' "preference" heterogeneity for fares *and* service and allow heterogeneous travelers to self-select in their choice of airlines.

Second, we have assumed aircraft sizes are fixed (Assumption 3) when 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 airport privatization 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 4), which we assumed was 70% in our simulations because 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 airport privatization are even greater.

In sum, our assumptions generally result in conservative estimates of the benefits from airport privatization. In addition, we have understated benefits because our analysis has considered airports' pricing responses only. Privatized airports would have the financial incentive to produce additional benefits to travelers and carriers by overcoming regulatory hurdles to and expediting construction of additional runways to expand capacity and reduce delays; facilitating entry by allowing any carrier to provide service that was willing to pay the cost of terminal facilities; working with airlines to improve the efficiency of taxi and runway operations; improving operations to reduce its costs[27]; implementing advances in technology that could improve security and aircraft operations; and being more responsive to passengers by introducing new services such as short-stay hotels and relaxation areas. Finally, a privatized airport would have an incentive to increase output because of the high margins from concessions that reflect locational rents.

9. Implications for Designing a Privatized Market for Airport Competition

We have found that it is possible that the benefits from airport privatization in the San Francisco Bay Area could be in the hundreds of millions of dollars for one quarter, which could amount to billions of dollars of annual benefits nationwide because the potential for airport competition exists in several U.S. metropolitan areas, including New York, Boston, Washington, DC, Chicago, and Los Angeles. Thus our analysis offers important policy guidance that airport privatization could be justified on welfare economics grounds and that the essential conditions for its success are, at least, theoretically plausible.[28]

We also identify some important considerations to help policymakers actually design a market for private airport competition. We have assumed that the government's sale price of an airport would be aligned with an efficient market outcome that would extract the excess operating profits that an airport obtains from its charges. Hence, the government must be very careful when setting that price because errors will affect an airport's charges to airlines and travelers, which seek to recover capital

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

[28] We have not assessed privatization of airports in smaller cities that could potentially operate as a monopoly. Starkie (2011) points out that airlines can reduce charges that they pay to such airports by playing one airport off against another as they decide which of the airports to include as their national network evolves.

costs. The government must also allow the most efficient market structure to develop by privatizing all the airports in a metropolitan area and by allowing airports and airlines to coordinate prices and service by engaging in negotiations. Failure to do so could significantly reduce travelers' welfare by creating a private monopoly airport and by resulting in a high pass through rate of higher airport costs to higher fares. Our findings that highlight the importance of upstream competition also suggest how the performance of other industries with a vertical structure could be improved whether they are potential candidates for privatization or they are being scrutinized because of antitrust concerns.

Because we suggest that it is only possible that airport privatization could raise social welfare, policymakers would be advised to conduct a major experiment to produce hard evidence that private airport competition could succeed in practice. The Congressional airport privatization pilot program could be used for that purpose; but the required approval of airlines that account for 65 percent of the landed weight at an airport may impede participation in the program. Moreover, because private oligopolistic competition among all the major airports in a metropolitan area would be essential to privatization's success, it is important to secure the participation of all the airports that could compete.[29] Public officials should therefore explore whether independent private investors would be interested in purchasing the major airports in a metropolitan area and participating in a major airport privatization experiment without necessarily securing the approval of airlines. Such an experiment may launch a major reform that could significantly improve the efficiency of the U.S. aviation sector and perhaps generate momentum that causes other parts of the public sector in the U.S. economy to explore privatization to improve their performance.

[29] In 2011, Senator Mark Kirk of Illinois introduced a measure that would remove the limit on the number of airports that could be privatized and eased other restrictions.

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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	1993	1996
	(577)	(603)	(614)
Average flying time of commercial travelers (hour)[b]	4.93	4.78	4.70
	(1.27)	(1.29)	(1.32)
Total commercial flight operations in 2007:3 [c]	69,331	31,257	44,991
Average commercial aircraft size (seats)[d]	146	126	134
	(45)	(42)	(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	6	6
	[1, 27]	[1, 15]	[1, 17]
Average departure delay in 2007:3 (min) [f]	15	9	10
	(13)	(11)	(11)
Average arrival delay in 2007:3 (min) [f]	5	3	3
	(4)	(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.

Table 2. Summary Statistics for the Demand Variables

Variable	Definition	Mean (std. dev.) or fraction in the sample
Fare ($100)	Fare paid by passengers for an itinerary. Source: DB1B	2.79 (1.60)
Airborne time (hour)	Total airborne time on a route. It is constructed by summing total airborne time for all segments. Source: T-100 Domestic Segment Data.	4.83 (1.29)
Airport delay (hour)	Total delays at airports on an itinerary. It is constructed by summing delays at origin and destination airports as well as departure and arrival delays at the connecting airport for connecting flights. Source: ASPM database.	0.58 (0.14)
Transfer time (hour)	Layover time at the connecting airport on an itinerary; zero for non-stop flights. Source: Back Aviation Solutions database.	1.34 (0.71)
Schedule delay (hour)	The difference between travelers' desired departure times and the closest available departure times. The expression to measure this difference is in footnote 8. Source: Back Aviation Solutions database.	3.98 (3.16)
Low cost carriers [a]	1 if the product is offered by a low cost carrier; 0 otherwise. Source DB1B	20%
Connecting flight	1 if the product is served by a connecting flight; 0 otherwise. Source: DB1B.	88%
Origin airport presence	Number of destinations served by the carrier from the origin airport (100s of cities). Source: Back Aviation Solutions database.	0.15 (0.25)
Destination airport presence	Number of destinations served by the carrier from the destination airport (100s of cities). Source: Back Aviation Solutions database.	0.15 (0.25)
OD Distance	Distance between the origin and destination airports (1000 miles)	2.04 (0.59)
Tourist city	1 if the city connecting to SF airports is located in Florida or Nevada; 0 otherwise	17%
Slot control	1 if the airport connecting to SF airports is under slot control; 0 otherwise. Airports under slot control are Chicago O'Hare, LaGuardia and Kennedy in New York, and National Reagan in Washington D. C.	18%
Hub route[b]	1 if the origin or destination airport is the carrier's hub airport (including the connecting airport for connecting flights); 0 otherwise.	66%
LCC route presence [a]	1 if the route connecting the origin and destination airports of a product is served by a low cost carrier (LCC); 0 otherwise	90%

Southwest route presence	1 if the route connecting the origin and destination airports of a product is served by Southwest; 0 otherwise	34%
Potential Southwest entry	1 if Southwest operates at the origin and destination airports but does not serve the route connecting the two airports; 0 otherwise.	0.01%
Market size (millions)	Geometric mean of the population of the end cities	4.36 (2.10)
Mean Income ($1000)	Geometric mean of income per capita of end cities	47.75 (3.16)
Number of observations	Number of products	20830

[a] Following Ito and Lee (2003), we classify the following carriers as low cost carriers: Air South, Access Air, Air Tran (FL), ATA (TZ), Eastwind, Frontier (F9), JetBlue (B6), Kiwi, Morris Air, National, Pro Air, Reno, Southwest (WN), Spirit, Sun Country (SY), ValuJet, Vanguard and Western Pacific.

[b]We include the following hubs in U.S. markets: Chicago-O'Hare (American. United), Cleveland (Continental), Newark (Continental), Atlanta (Delta), San Francisco (United), Dallas-Ft. Worth (American), Philadelphia (US Airways), Phoenix (US Airways), Detroit (Northwest), St. Louis (American), Houston (Continental), Washington-Dulles (United), Minneapolis-St. Paul (Northwest), Cincinnati (Delta), Salt Lake City (Delta), Denver (United), and Miami (American).

Table 3. Delay functions at the SF Airports

	SFO	SJC	OAK
Departure delay			
b_{0n}	-2.9886 (0.0312)	-2.2606 (0.0388)	-0.7956 (0.0314)
b_{1n}	4.2989 (0.0405)	3.8172 (0.0523)	3.0890 (0.0286)
b_{2n}	-0.7852 (0.0193)	-0.6731 (0.0446)	-0.5159 (0.0326)
Adj. R^2	0.45	0.22	0.27
Arrival delay			
b_{0n}	-2.4557 (0.0269)	-1.7537 (0.0343)	-0.4314 (0.0269)
b_{1n}	3.0804 (0.0349)	1.9147 (0.0463)	2.4513 (0.0245)
b_{2n}	-0.5915 (0.0167)	-0.1824 (0.0395)	-0.9372 (0.0279)
Adj. R^2	0.36	0.10	0.25
# of observations	31754	25961	32435

Note: The dependent variable is the log of average aircraft delay (minutes per aircraft) in a 15-minute interval on a representative travel day in 2007 and the explanatory variables include a constant and the log of the volume-to-capacity ratio and its square in the 15-minute interval.

Table 4. Demand estimation results

Variables	Model with preference heterogeneity: BLP GMM Estimates (standard errors)
Constant	-5.64 (0.45)
Price (hundred $):	
Leisure travelers	-1.01 (0.47)
Business travelers	-0.53 (0.13)
Connecting route dummy	-1.83 (0.11)
Airborne time (Hour)	-0.21 (0.03)
Airport delay (Hour)	-0.85 (0.23)
Long Transfer time dummy (> 1.5Hour)	-0.14 (0.03)
Schedule delay (Hour)	-0.06 (0.02)
Origin airport presence	0.20 (0.08)
Destination airport presence	0.14 (0.09)
Carrier dummy (United as the base)	
American	0.09 (0.04)
Delta	-0.24 (0.07)
Continental	-0.21 (0.07)
US Airways	-0.21 (0.06)
Northwest	-0.29 (0.08)
Alaska	0.15 (0.12)
Southwest	-0.33 (0.12)
Jet Blue	0.07 (0.11)
Other non-low-cost carriers	0.89 (0.17)
Other low-cost carriers	0.03 (0.10)
Airport dummy	
OAK dummy (SFO as the base)	-0.15 (0.04)
SJC dummy (SFO as the base)	-0.05 (0.03)
MDW dummy (ORD as the base)	-0.56 (0.11)
EWR dummy (JFK as the base)	-0.37 (0.10)
LGA dummy (JFK as the base)	-0.38 (0.11)
HOU dummy (IAH as the base)	-0.34 (0.10)
DAL dummy (DFW as the base)	-0.38 (0.22)
DCA dummy (IAD as the base)	0.24 (0.09)
LGB dummy (LAX as the base)	0.08 (0.64)
BUR dummy (LAX as the base)	0.28 (0.29)
Market characteristics	
OD distance (thousand miles)	0.77 (0.21)
Square of OD distance	-0.05 (0.04)
Tourist city dummy	-0.06 (0.04)
Slot controlled airport dummy	-0.21 (0.05)
Other parameters	
Lamda(λ)	0.74 (0.02)
Number of observations	20830

Table 5. Demand Elasticities and Value of Time Components based on Demand Coefficients

Variables	Homogeneous preference: OLS estimates [a]	Homogeneous preference: IV estimates [a]	Heterogeneous preference: BLP GMM estimates
Aggregate price elasticity of demand for air travel			
Overall	-0.19	-1.26	-1.10
Business travelers	--	--	-0.96
Leisure travelers	--	--	-1.33
Value of Airborne time ($/hour)			
Overall	70	27	30
Business travelers	--	--	40
Leisure travelers	--	--	21
Value of Airport delay ($/hour)			
Overall	160	93	118
Business travelers	--	--	160
Leisure travelers	--	--	84
Value of flight frequency ($/flight)			
Overall	79	16	17
Business travelers	--	--	22
Leisure travelers	--	--	12
Willingness to pay for non-stop flights ($)			
Overall	1030	241	255
Business travelers	--	--	345
Leisure travelers	--	--	181
Willingness to pay for connecting flights with a connection that is less than 1.5 hours ($)			
Overall	90	21	19
Business travelers	--	--	26
Leisure travelers	--	--	14

[a] When preferences are homogenous, the analytical solution of unobserved product attributes can be derived and the following regression equation can be estimated (Berry (1994)):

$$\ln\left(S_{jm}\right)-\ln\left(S_{0m}\right)=X_{jm}B+\alpha\cdot p_j+\phi\cdot d_j+\gamma^f\cdot t_j^f+\gamma^a\cdot t_j^a+\gamma^l\cdot t_j^l+\left(1-\lambda\right)\ln S_{jm|A}+\xi_{jm}$$

In this regression model, price, schedule delay, and the market share within travel products ($S_{jm|A}$) are endogenous. We report results from OLS estimation of this regression, which ignores endogeneity, in the first column, and report results for instrumental variables estimation of this regression in the second column. The IVs for price and schedule delay were presented in the text and the IV for the market share within travel products is the average airport presence of airline competitors.

Table 6. Marginal Cost Parameter Estimates

Variable	Model with heterogeneous preferences: BLP GMM estimates (standard errors)
Constant	2.97 (0.35)
Number of segments	-0.95 (0.07)
Segment distance (thousand miles)	-0.63 (0.06)
Carrier dummy (United as the base)	
American	-0.06 (0.05)
Delta	-0.54 (0.07)
Continental	-0.48 (0.06)
US airways	-0.43 (0.05)
Northwest	-0.31 (0.07)
Alaska	-0.64 (0.14)
Southwest	-0.72 (0.07)
Jet Blue	-0.74 (0.08)
Other non-low-cost carriers	0.15 (0.16)
Other low-cost carriers	-0.77 (0.08)
Airport dummy	
OAK dummy (SFO as the base)	-0.32 (0.03)
SJC dummy (SFO as the base)	-0.13 (0.03)
Non-SF airport dummies included	YES
Number of observations	20830

Table 7. Summary of Marginal Costs from BLP GMM estimates

Median marginal cost per mile ($ per passenger mile)	
Overall	0.08
Non-stop products	0.12
Connecting products	0.07
By Airlines	
American	0.09
United	0.09
Delta	0.07
US Airways	0.07
Continental	0.07
Northwest	0.08
Alaska	0.08
Southwest	0.05
JetBlue	0.06
Other non-low-cost carriers	0.12
Other low-cost carriers	0.06
By SF Airports	
SFO	0.08
SJC	0.08
OAK	0.06

Table 8. Comparison between Simulated and Observed Market Outcomes for 2007: 3

Market outcomes	**Observed**	**Simulated outcome with 70% load factor**
Product price ($)		
Mean	279	254
Median	242	215
Standard deviation	160	161
75%-ile	347	320
25%-ile	168	142
Product demand (number of passengers)		
Mean	311	314
Median	30	30
Standard deviation	1818	1850
75%-ile	70	84
25%-ile	10	13
Product frequency		
Mean	4.84	3.16
Median	4	2.79
Standard deviation	3.65	1.96
75%-ile	6	4.23
25%-ile	2	1.58
SF spoke route passengers[a]		
Mean	22,187	22,387
Median	16,095	15,536
Standard deviation	19,903	21,356
75%-ile	29,295	31,048
25%-ile	7,785	7,388
Airport passengers		
SFO	2,554,390	2,525,252
SJC	1,600,820	1,638,659
OAK	2,323,340	2,373,967
Number of Products	20830	20830
Number of SF spoke routes	292	292

[a] A SF spoke route is defined by a carrier and an airport pair, where the origin or destination is one of the three SF airports.

Table 9. Welfare Effects of Privatizing SFO

	Base case	SFO profit maximizing charge	SFO social welfare maximizing charge	SFO charge that maximizes airlines' total profit	SFO charge that maximizes airlines' profit at SFO	SFO profit maximizing charge subject to non-negative consumer surplus change
Airport charge ($/seat)[a]						
SFO	2.00	85	59	24	0	5
SJC	2.00	2	2	2	2	2
OAK	2.00	2	2	2	2	2
Airport Delay (min.)						
SFO						
Departure delay	15	4	7	13	16	15
Arrival delay	5	2	3	4	5	5
SJC						
Departure delay	9	11	10	10	10	10
Arrival delay	3	3	3	3	3	3
OAK						
Departure delay	10	12	12	11	10	10
Arrival delay	3	3	3	3	3	3
Change in Airport Profits (million $/quarter)						
SFO	0.00	108.04	99.33	53.42	-14.73	2.87
SJC	0.00	0.44	0.33	0.13	-0.04	0.00
OAK	0.00	0.76	0.58	0.25	-0.07	0.00
Total	0.00	109.24	100.24	53.80	-14.84	2.87
Change in Airline Profits by airport (million $ / quarter)						
SFO	0.00	-61.29	-28.55	3.06	11.67	11.15
SJC	0.00	16.66	12.26	4.93	-1.21	0.13
OAK	0.00	19.65	14.66	6.07	-1.59	0.15
Total	0.00	-24.98	-1.63	14.06	8.87	11.43
Consumer surplus change (million $/quarter)[b]						
Business travelers	0.00	-1.39	-1.03	-0.43	0.12	0.00
Leisure travelers	0.00	-0.58	-0.46	-0.21	0.06	0.00
Total	0.00	-1.97	-1.49	-0.64	0.18	0.00
Change in social welfare (million $/quarter)[b]	0.00	82.29	97.12	67.22	-5.79	14.30

[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.

Table 10. Welfare Effects of Privatizing All the Three SF Airports: Monopoly Case

	Base case	Airports' profit maximizing charges	Social welfare maximizing charges	Airlines' profit maximizing charges	Airports' profit maximizing charges subject to non-negative consumer surplus change
Airport charge ($/seat) [a]					
SFO	2.00	106	66	22	0
SJC	2.00	97	55	14	8
OAK	2.00	103	59	19	8
Airport Delay (min.)					
SFO					
Departure delay	15	4	8	13	16
Arrival delay	5	2	3	4	5
SJC					
Departure delay	9	1	4	9	8
Arrival delay	3	1	1	2	2
OAK					
Departure delay	10	1	4	8	10
Arrival delay	3	1	3	3	3
Change in Airport Profits (million $/quarter)					
SFO	0.00	134.21	116.94	50.69	-14.69
SJC	0.00	83.34	72.18	21.05	8.42
OAK	0.00	121.61	105.71	42.11	12.10
Total	0.00	339.16	294.83	113.85	5.83
Change in Airlines' Profits by airport (million $/quarter)					
SFO	0.00	-40.76	-7.57	11.04	13.59
SJC	0.00	-41.93	-4.16	11.97	5.64
OAK	0.00	-49.34	-3.49	13.68	9.28
Total	0.00	-122.02	-15.22	36.69	28.51
Consumer surplus change (million $/quarter)[b]					
Business travelers	0.00	-4.06	-2.61	-0.76	-0.01
Leisure travelers	0.00	-1.91	-1.36	-0.44	0.01
Total	0.00	-5.97	-3.97	-1.20	0.00
Change in social welfare (million $/quarter)[b]	0.00	211.17	275.64	149.34	34.34

[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.

Table 11. Welfare Effects of Privatizing All Three SF Airports: Oligopoly Case

	Base case	Bertrand competition: charges maximize airports' profits	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	92	54	5
SJC	2.00	76	43	4
OAK	2.00	84	49	4
Airport Delay (min.)				
SFO				
Departure delay	15	5	9	15
Arrival delay	5	2	3	5
SJC				
Departure delay	9	2	5	9
Arrival delay	3	1	2	3
OAK				
Departure delay	10	2	5	10
Arrival delay	3	1	2	3
Change in Airport Profits (million $/quarter)				
SFO	0.00	130.02	106.19	2.84
SJC	0.00	82.87	62.62	0.00
OAK	0.00	119.18	95.08	0.00
Total	0.00	332.37	263.89	2.84
Change in Airlines' Profits by airport (million $/quarter)				
By airport				
SFO	0.00	-30.45	0.00	10.86
SJC	0.00	-18.58	4.38	7.44
OAK	0.00	-28.44	3.14	10.68
By type of airline				
Full cost carriers	0.00	-46.99	1.78	14.98
Low cost carriers [b]	0.00	-30.48	6.74	14.00
Total	0.00	-77.47	8.52	28.98
Consumer surplus change (million $/quarter) [c]				
Business travelers	0.00	-3.49	-2.17	0.01
Leisure travelers	0.00	-1.71	-1.16	0.01
Total	0.00	-5.20	-3.33	0.02
Change in social welfare (million $/quarter) [c]	0.00	251.41	269.08	31.84

[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] Low-cost carriers include Southwest, JetBlue, Air Tran, ATA, Frontier, and SunCountry. The other carriers are characterized as full cost carriers.

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

Table 12. Delay Functions at the SF Airports Accounting for GA Operations

	SFO	**SJC**	**OAK**
Departure delay			
b_{0n}	-4.6218 (0.0385)	-4.0299 (0.0508)	-2.2220 (0.0335)
b_{1n}	4.8590 (0.0532)	4.3971 (0.0833)	3.5335 (0.0407)
b_{2n}	-0.7852 (0.0193)	-0.6731 (0.0446)	-0.5159 (0.0326)
Adj. R^2	0.45	0.22	0.27
Arrival delay			
b_{0n}	-3.6297 (0.0332)	-2.6124 (0.0494)	-1.6613 (0.0287)
b_{1n}	3.5023 (0.0459)	2.0719 (0.0738)	3.2587 (0.0349)
b_{2n}	-0.5915 (0.0167)	-0.1824 (0.0395)	-0.9372 (0.0279)
Adj. R^2	0.36	0.10	0.25
# of observations	31754	25961	32435

Note: The dependent variable is the log of average aircraft delay (minutes per aircraft) in a 15-minute interval on a representative travel day in 2007; explanatory variables are the log of the volume-to-capacity ratio and its square in the 15-minute interval.

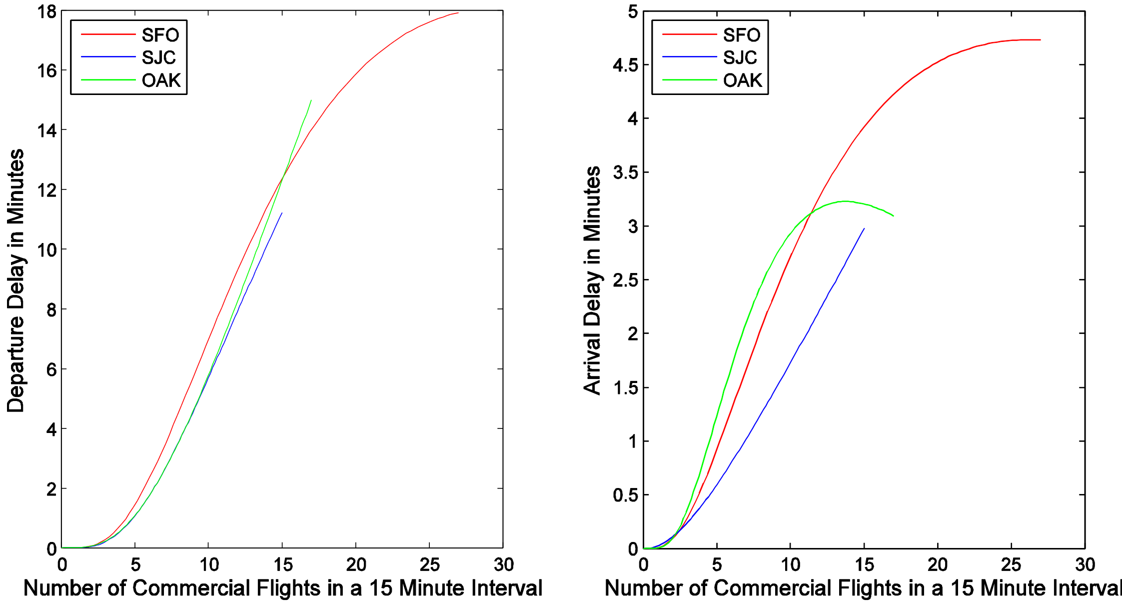
Table 13. Welfare Effects of Privatizing All Three SF Airports: Incorporating General Aviation

	Base case	Bertrand competition: charges for commercial flights maximize airports' profits given a price-cap on the GA charge	Bertrand competition: charges for commercial flights maximize airports' profits subject to a non-negative change in airline profits at each airport and given a price-cap on the GA charge	Bertrand competition: charges for commercial flights maximize airlines' profits at each airport subject to non-negative airport profits and given a price-cap on the GA charge	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 price-cap on the GA charge[d]
Airport charge for commercial airlines($/seat) [a]					
SFO	2.00	88	50	0	13
SJC	2.00	71	49	0	5
OAK	2.00	49	49	0	4
Airport charge for general aviation ($/flight) [b]					
SFO	140	280	280	280	280
SJC	0	280	280	280	280
OAK	0	280	280	280	280
Airport Delay (min.)					
SFO					
Departure delay	15	7	10	15	13
Arrival delay	5	3	3	4	4
SJC					
Departure delay	9	2	3	7	6
Arrival delay	3	1	1	2	2
OAK					
Departure delay	10	3	3	7	7
Arrival delay	3	2	2	3	3
Change in Airport Profits (million $/quarter)					
SFO	0.00	155.75	136.16	53.71	92.45
SJC	0.00	86.57	80.56	5.91	14.18
OAK	0.00	198.98	183.97	119.30	131.51
Total	0.00	441.30	400.69	178.91	238.14
Change in Airlines' Profits by airport (million $/quarter)					
By airports					
SFO	0.00	-48.04	0.61	9.58	7.48
SJC	0.00	-24.76	0.00	16.78	20.20
OAK	0.00	30.11	10.16	21.42	26.67
By type of airline					
Full cost carriers	0.00	-49.08	-2.20	21.52	22.75
Low cost carriers	0.00	6.39	12.97	26.26	31.60
Total	0.00	-42.69	10.77	47.78	54.35
Consumer surplus change (million $/quarter)[c]					
Business travelers	0.00	-2.96	-2.14	0.47	0.01
Leisure travelers	0.00	-1.46	-1.16	0.25	-0.01
General aviation travelers	0.00	-5.59	-5.84	-6.52	-6.44
Total	0.00	-10.01	-9.14	-5.80	-6.44
Change in social welfare (million $/quarter)[c]	0.00	388.60	402.32	220.89	285.85

[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.

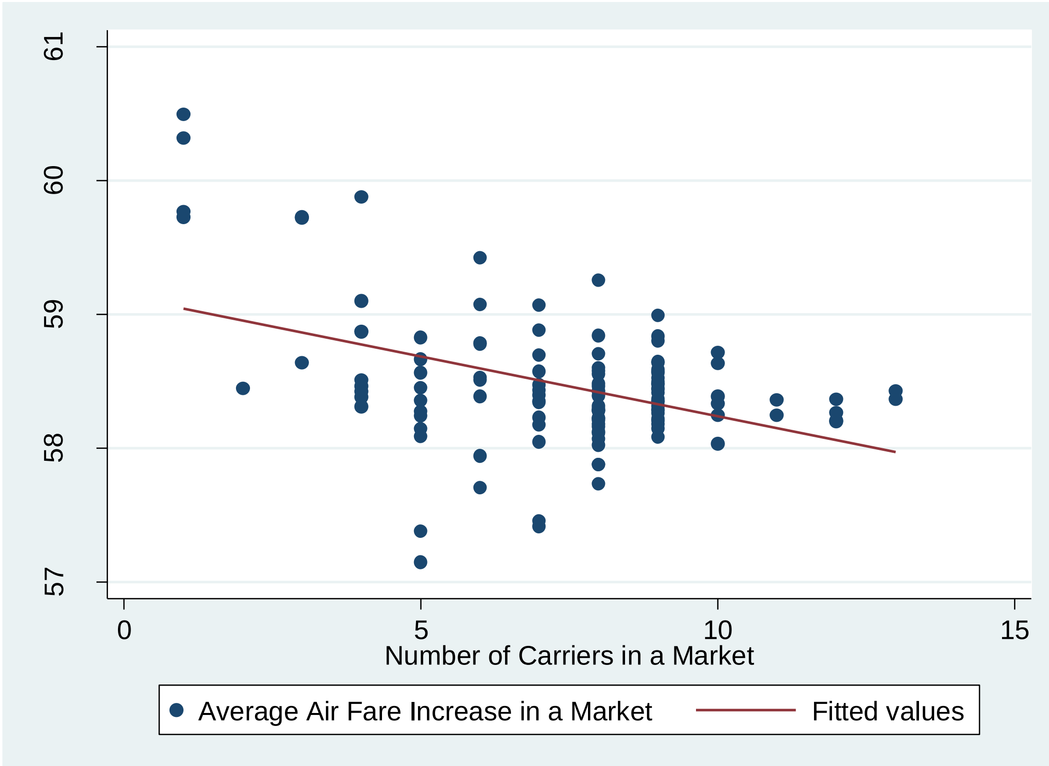
[b] The airport charge at SFO for general aviation in the base case is the current minimal charge when a general aviation aircraft lands at the airport. A general aviation aircraft is not charged when it takes off from SFO. In the privatization scenarios, the current charge is replaced by a charge that 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. When $\varpi \le 0.17$, 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 $\varpi = 0.17$

Figure 1. Delay functions of the three SF airports



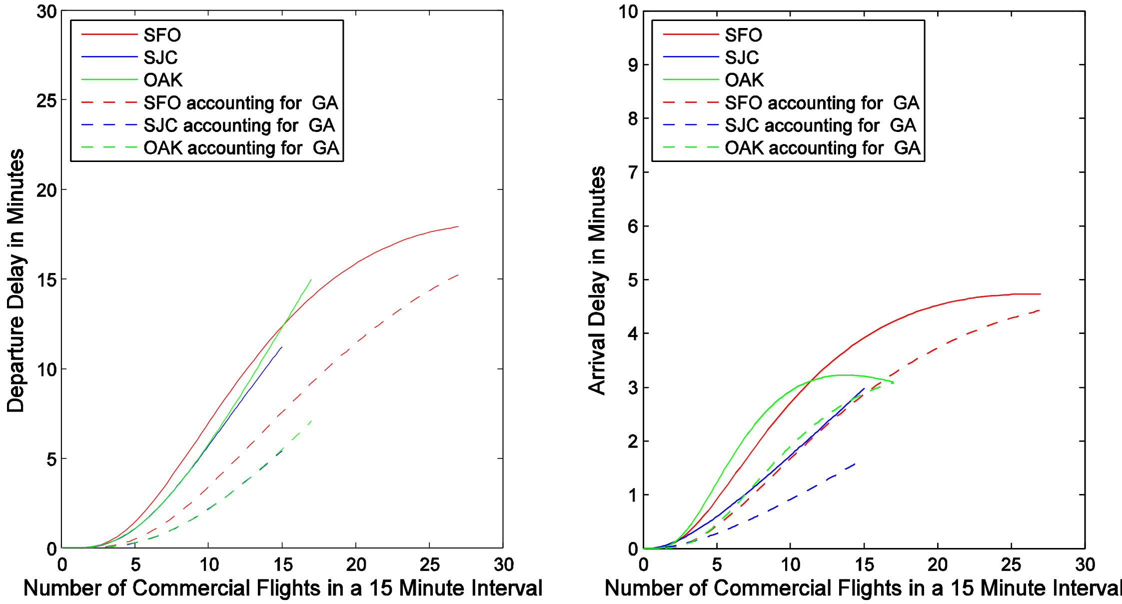
Note: Figure 1 plots the estimated delay functions presented in table 3. For each airport, we plot the departure and arrival delay functions within the range of the observed number of commercial flights in a 15 minute interval in the 3rd quarter of 2007. The maximum flights in this interval were 26 at SFO, 15 at SJC, and 17 at OAK.

Figure 2. 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 $y = \underset{(0.16)}{59.13} - \underset{(0.02)}{0.09}\,x$, where y is the average price increase (in dollars) and x is the number of carriers.

Figure 3. Delay functions of the three SF airports including GA



Note: Figure 3 plots the previously estimated delay functions presented in table 3 and the delay functions in table 12 that account for GA operations.