RAND Journal of Economics
Vol. 53, No. 1, Spring 2022
pp. 166–199

Repositioning and market power after airline mergers

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We estimate a model of route-level competition between airlines who choose whether to offer non-stop or connecting service before setting prices. Airlines have full information about all quality, marginal cost, and fixed cost unobservables throughout the game, so that service choices will be selected on these residuals. We conduct merger simulations that allow for repositioning and account for the selection implied by the model and the data. Accounting for selection materially affects the predicted likelihood of repositioning and the predicted magnitude of post-merger price changes, and it allows us to match what has been observed after consummated mergers.

1. Introduction

■ Market power created by a horizontal merger may be limited if the merger induces either new entry or existing rivals to reposition to compete more directly with the merging firms. Since 1992, the *Horizontal Merger Guidelines* have specified that the agencies should try to test

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We thank two referees, Co-Editor Katja Seim, numerous discussants, and seminar and conference participants for very useful comments. Early stages of the research were supported by NSF Grant SES-1260876 (Roberts and Sweeting). Earlier versions of this article were circulated as “Airline Mergers and the Potential Entry Defense” and “Endogenous and Selective Service Choices After Airline Mergers.” All authors contributed equally and are ordered alphabetically. The paper was accepted before Sweeting became a Co-Editor of this journal. The usual disclaimer applies.

whether entry or repositioning will be "timely" and "likely," in the sense of being profitable for rivals, and therefore likely to happen, and "sufficient," in the sense of preventing prices from rising (Shapiro, 2010, p. 65).[1] Although economists accept these criteria, they are rarely assessed in the rigorous and quantitative way that estimated or calibrated merger simulations are used to predict price changes with a fixed set of products.[2] This article presents a quantitative framework for assessing the likelihood and the sufficiency of repositioning in differentiated product markets. Our empirical analysis models service choices and pricing in route markets after airline mergers, motivated by how several airline mergers in the 1980s were approved based on ease-of-entry/repositioning arguments (Keyes, 1987), and by the suggestions of Fisher (1987) and Schmalensee (1987) that airline mergers provide a setting where repositioning could offset anticompetitive effects.

We use a two-stage model where carriers first choose their discrete service types (nonstop or connecting) and then choose prices. As motivation, suppose that nonstop service typically has significantly higher quality than connecting service, with similar marginal costs, but a higher fixed cost. A route has two carriers providing nonstop service and two other carriers, with smaller shares, that provide connecting service via other airports. The nonstop carriers propose to merge, and an analyst has to evaluate whether the merger will raise prices. The answer may (and, in our results, it often does) depend on whether the merger will create an incentive for a connecting carrier to initiate nonstop service (i.e., reposition), and, if it does, on whether the nonstop quality of the repositioning carrier will be comparable to those of the merging parties.

We make two assumptions that distinguish our analysis from the literature. First, we assume that all elements of qualities and costs, including those unobserved by the analyst, are known to all carriers when they make service choices. We describe this assumption as "full information," and it contrasts with a "limited information" assumption (e.g., Draganska, Mazzeo, and Seim, 2009, Fan and Yang, 2020) where only the distributions of quality and marginal cost unobservables are known when firms make discrete entry or positioning choices. The second assumption is that the unobservables of the nonmerging carriers after a merger will be the same as those generating the pre-merger data (we consider alternative synergy assumptions for the merged firm). This is the standard assumption made by merger simulations that treat products as fixed (Nevo, 2000), but the literature that has endogenized product choices using a limited information framework assumes that firms receive new draws after a merger.

The full information assumption implies that carriers' service choices will be selected based on the unobservables. For example, carriers that choose nonstop service will tend to have higher nonstop quality unobservables. Selection requires us to estimate the demand, marginal cost, and fixed cost equations simultaneously. We use the importance sampling method proposed by Ackerberg (2009) to keep the computational burden manageable.[3] The two assumptions also imply that we need to calculate conditional distributions of the unobservables that are consistent with observed service choices to perform counterfactuals. Our main methodological contribution comes from providing a routine that implements this type of conditioning, which we show materially affects our counterfactual predictions.[4]

Our counterfactuals consider three mergers that were completed after the period of data that we use to estimate our model (Q2 2006) and one merger, between United and US Airways,

[1] This formulation was partly a reaction to several court decisions that allowed mergers based on ease-of-entry arguments without evaluating whether entry would offset anticompetitive effects (Baker, 1996).

[2] For example, Coate (2008) describes the FTC's conclusions about the likelihood of entry in its internal memoranda as lacking a "solid foundation" in the evidence and Kirkwood and Zerbe (2009) classify only one of 35 post-1992 court opinions as reviewing the criteria in the *Guidelines* systematically.

[3] Ackerberg's Example 2 explains how the method could be applied to this type of game. Importance sampling has been used to estimate a range of different types of models, but we believe that we are the first to apply the method in the context of a discrete choice-and-price competition game with multiple unobservables.

[4] Conditioning captures the essence of a frequent agency argument that courts should be skeptical that rivals will enter or reposition after a merger when they have chosen not to do so previously (Baker, 1996, p. 364).

that was proposed but blocked in 2001. We focus on routes where the merging carriers were both nonstop as these are the markets where merger simulations with fixed products predict the largest price increases. We find that when we condition on pre-merger service choices, our predictions are consistent with what happened after completed mergers: specifically, with conditioning, we predict that rivals launch nonstop service on 18% of nonstop duopoly routes (i.e., routes where the merging firms were the only nonstop carriers), which is close to the 25% rate observed for such routes within 2 years of a completed merger. In contrast, we predict three times as many nonstop launches when we do not condition on pre-merger choices (i.e., we assume that carriers draw new unobservables post-merger). Conditioning also leads to mergers appearing to be more profitable.

Before discussing the related airline literature, we highlight several restrictive features of our approach. First, our model is static rather than dynamic. This is consistent with the short-run focus of most merger analysis (Carlton, 2004), but it means that, unlike the dynamic analyses of Aguirregabiria and Ho (2012) (AH) and Benkard, Bodoh-Creed, and Lazarev (2020) (BBCL), we cannot examine the *Guidelines*'s "timely" criterion or account for how the evolution of airlines' networks (e.g., the addition or elimination of hubs) or other characteristics may change service incentives.[5] Second, although our two assumptions are directionally supported by evidence that carrier unobservables are highly correlated over time (Section 6), they are clearly polar assumptions. Future work that generalizes our model to allow for some elements of the unobservables to be private information or to be revealed only once positioning choice are made, as well as cross-route correlations, would be valuable. Third, most of our counterfactuals focus on possible repositioning by nonmerging carriers that provided connecting service prior to the merger, ignoring the possibility of new entry. This is consistent with how most carriers that initiate nonstop service previously provided connecting service (Section 6), but it is primarily motivated by a need to lower the computational burden of our counterfactuals (Li et al., 2015 estimate a model that allows for an entry margin). Fourth, we only model carriers' choice of service types and a single price for traffic originating at each endpoint, ignoring choices of capacity, schedules, and the allocation of seats to different price bins. A more complete model would include these choices, which would introduce additional unobservables.[6] Finally, our baseline assumption will be that carriers make service choices sequentially, which guarantees a unique equilibrium, whereas much of the literature allows for multiple equilibria, and occasionally mixed strategy equilibria, in discrete choice simultaneous move games. We will explain why this assumption does not materially affect our results.

Two related literatures use airline data. Many merger retrospectives have evaluated the price effects of carrier mergers in airport-pair or city-pair markets, both in the 1980s (summarized in Ashenfelter, Hosken, and Weinberg, 2014) and more recently (Hüschelrath and Müller, 2014, Hüschelrath and Müller, 2015, Israel et al., 2013 and Carlton et al., 2017). Most studies have estimated price increases, but some results are sensitive to the chosen control group and time window.[7] There are no retrospective analyses of post-merger repositioning by rival firms or how this affects price changes in any industry.[8] We will discuss our own estimates of what happened to prices and repositioning after recent airline mergers, and we find that they are quite similar to the predictions of our model. This result contrasts with Peters (2006) who found that merger simulations with fixed products could not explain price changes after several mergers in the 1980s.

[5] Section 7 of our working paper, Li et al. (2021), contains additional discussion of this comparison.

[6] Park (2020) uses a model that includes capacity choices at one airport to address the effectiveness of slot divestitures.

[7] For example, Borenstein (1990), Werden, Joskow, and Johnson (1991), Morrison (1996), and Peters (2006) find different signs for short-run or long-run price effects after the 1986 TWA/Ozark and Northwest/Republic mergers.

[8] Hüschelrath and Müller (2015) provide an analysis of entry in airline routes but without connecting entry to pre-merger market structures.

The second literature has estimated route-level entry or service choice models using airline data (Reiss and Spiller, 1989 (RS), Berry, 1992, Ciliberto and Tamer, 2009, AH, BBCL, and Ciliberto, Murry, and Tamer, 2020 (CMT)). CMT and RS assume full information and estimate models with both service choice (RS) or market entry (CMT), and price competition. RS recognized "that entry introduces a selection bias in equations explaining fares or quantities" (p. S201) and they simplified their analysis by imposing symmetry and allowing for only one nonstop carrier, restrictions that we relax. Aside from modeling service choices, which leads to additional unobservables, there are several differences between our analysis and CMT's. CMT focus on identification and estimation of a simultaneous entry choice game where there can be multiple equilibria, and they use a computationally intensive approach to estimate where a potentially discontinuous objective function is minimized using a supercomputer. Our baseline assumption of sequential service choice eliminates multiplicity and we use importance sampling so that we can estimate the model with a lower computational burden. More importantly, we consider counterfactuals where we predict how a merger might change route-level outcomes using the outcomes observed in the data as a starting point, accounting for what these observed outcomes imply about our model's unobservables. In contrast, CMT perform counterfactuals using simulated data where all the unobservables are, by construction, known to the researcher. Our approach is therefore much closer to the type of analysis that agencies have to perform when considering proposed mergers.

Sections 2–4 detail our model, data, and estimation procedure respectively. Section 5 presents the parameter estimates, model fit, and implied selection. Sections 6–8 present the method and the results of our counterfactuals. Section 9 concludes. All of the material referenced as being in Appendices is contained in the online supplementary Appendices. These provide additional details of the data, estimation approach, and analysis of alternative assumptions.

2. Model

■ We model carrier service choices at the nondirectional route level, where a route is denoted by m and connects two airports (A and B). This is restrictive as both cities and airports have been used to define geographic markets for antitrust purposes (Naumovich, 2018). The carriers playing the game in route m are denoted $j = 1, \dots, J_m$. We will assume that, conditional on the observable variables that we include in our model, the unobservables are independent across routes. This is also restrictive as it is possible that there are correlations across routes such as Denver–Philadelphia and Denver–Chicago O'Hare that we will not account for, and we are ignoring how a change in prices or service on one route may affect passenger flows on other routes.[9]

□ **Overview.** Figure 1 shows the timing of the game. The assumption that discrete service choices are made before prices are chosen is standard. Two assumptions are less standard. First, we assume that service choices are made sequentially. We will discuss this assumption in detail below. Second, we assume that carriers observe all demand and cost variables, for all carriers, before choosing their service types. This is our "full information" assumption. It is stronger than a "complete information" assumption, which simply requires that firms have the same information.[10]

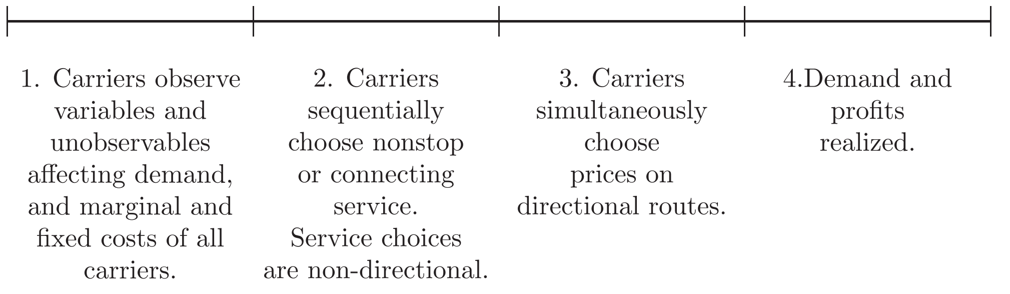
For each route, we model demand and price competition in two markets ($A \rightarrow B$, $B \rightarrow A$), one for passengers originating at each endpoint. We assume passengers make round-trips (a passenger making a one-way trip in the data will count as a half passenger). We use directional

[9] For example, there are over 6000 directional domestic routes which Delta served via a change of planes Atlanta hub.

[10] For example, Eizenberg (2014) and Wollmann (2018) assume that firms choose product portfolios knowing only the distributions from which demand and marginal cost unobservables will be drawn. This is consistent with complete information, but not full information.

FIGURE 1

TIMING OF THE GAME



markets because a carrier's presence at the originating airport has a strong correlation with its market share.[11,12]

□ **Service types.** We assume that the carriers playing the game make a binary choice between providing nonstop service and providing connecting service via one of its hub airports. We define a carrier as providing nonstop service in our Q2 2006 data if a carrier has at least 65 nonstop flights on the route in each direction, and at least 50% of its passengers in the DB1 database are identified as not changing planes. Our main specification assumes that nonstop carriers only offer nonstop service, rather than nonstop and connecting options, thereby reducing the number of prices per carrier from four to two. This is a simplification, but when a carrier has nonstop service, on average 94% of its passengers are nonstop (i.e., they do not make connections), and the average percentage is 97% in the nonstop duopoly markets on which we focus. We will show that our estimates are very similar when we assume that nonstop carriers also offer connecting service.

□ **Demand.** Demand is determined by a nested logit model, with all carriers in a single nest. For consumer k originating at endpoint A of route m, the indirect utility for a return trip on carrier j is

$$u_{kjm}^{A\to B} = \beta_{jm}^{A\to B} + \alpha_m p_{jm}^{A\to B} + \nu_m + \tau_m \zeta_{km}^{A\to B} + (1-\tau_m)\varepsilon_{kjm}^{A\to B} \tag{1}$$

where $p_{jm}^{A\to B}$ is the price charged by carrier j for a return trip from A to B. The first term represents carrier quality associated with j's service type (CON for connecting and NS for nonstop), $\beta_{jm}^{A\to B} = \beta_{jm}^{CON,A\to B} + \beta_{jm}^{NS} \times \mathcal{I}(j \text{ is nonstop})$ with $\beta_{jm}^{CON,A\to B} \sim N(X_{jm}^{CON}\beta_{CON}, \sigma_{CON}^2)$ and $\beta_{jm}^{NS} \sim TRN(X_{jm}^{NS}\beta_{NS}, \sigma_{NS}^2, 0, \infty)$, so that quality can depend on observed carrier-origin and route characteristics, and on a random component that is unobserved to the researcher. As qualities are directional, each carrier has four β_{jm} draws ($\beta_{jm}^{NS,A\to B}$, $\beta_{jm}^{NS,B\to A}$, $\beta_{jm}^{CON,A\to B}$, and $\beta_{jm}^{CON,B\to A}$). The random element of the carrier-specific quality draws (i.e., the parts not explained by the observables) will reflect differences in passenger tastes (e.g., local loyalty developed from choosing the carrier historically), and also differences in carriers' schedules and aircraft fleets. A complete model would endogenize schedules and plane choices, but this would require additional equations and unobservables.

[11] We measure presence as the number of nonstop routes that a carrier serves from an airport, divided by the number of nonstop routes served by any carrier.

[12] For example, in a route fixed effects regression, a one standard deviation increase in the difference in a carrier's presence across the endpoints increases the difference in the carrier's directional market shares by 20% of the average directional share. Although this correlation cannot be interpreted causally, it is consistent with travelers preferring to travel primarily on a single carrier.

TRN denotes a truncated normal distribution and the lower truncation of β_{jm}^{NS} at zero implies that the nonstop service is always preferred to connecting service on the same carrier. This is consistent with the existing literature finding that both leisure and business travelers have strong preferences for nonstop service (Berry and Jia, 2010 and Ciliberto and Williams, 2014) as well as the fact that in our data nonstop carriers have higher market shares and average prices than connecting carriers, but we could relax this assumption. Note that estimation will require some more restrictive support conditions on draws (see Section 4 and Appendix B.2).

The price and nesting parameters are assumed to be the same for all consumers on a given route, but we allow them to vary across routes, with $\alpha_m \sim TRN(X^\alpha \beta_\alpha, \sigma_\alpha^2, -\infty, 0)$, where X^α will include a measure of the importance of business travel on the route, and $\tau_m \sim N(\beta_\tau, \sigma_\tau^2)$. $\nu_m \sim N(0, \sigma_{RE}^2)$ is a route-specific random effect in demand, that is, a demand shock that is common across carriers and is also common across the directions on the route.[13] $\varepsilon_{kjm}^{A\to B}$ is a standard logit error for consumer k and carrier j.

Although we allow the price and nesting coefficients to vary across routes, demand has a nested logit, rather than a random coefficient structure, within each market. The nested logit model implies strong restrictions on cross-price elasticities, but it is convenient when many pricing games have to be solved to estimate the model and perform counterfactuals.[14]

□ **Marginal costs.** Each carrier has a constant marginal cost draw for each type of service, $c_{jm} \sim TRN(X_{jm}^{MC}\beta_{MC}, \sigma_{MC}^2, 0, \infty)$, where $X_{jm}^{MC}\beta_{MC}$ allows costs to depend on the type of carrier, the type of service, and the distance traveled. As passengers make round-trips, the marginal cost is nondirectional, so each carrier has two marginal cost draws (c_{jm}^{NS} and c_{jm}^{CON}). The unobserved variation in marginal costs may reflect, for example, variation in a carrier's fuel efficiency on different routes (which will depend on plane type) and its cost of handling bags.

□ **Fixed costs of nonstop service and the value of connecting traffic on routes to hubs.** We assume that carriers have to pay a fixed cost, F_{jm}, to offer nonstop service in both directions on route m. This could include the opportunity cost of assigning gates and planes to a route, as well as airport gate rental and landing fees, which may vary in unobserved ways across routes and carriers. There is no fixed cost to providing connecting service. We assume that $F_{jm} \sim TRN(X_{jm}^F\beta_F, \sigma_F^2, 0, \infty)$ where X_{jm}^F includes a dummy for a slot-constrained airport where opportunity costs may be higher.

In the data, it is common for more than 60% of passengers on routes to or from a carrier's hub to be making connections. A model is only likely to be able to predict a hub carrier's service choices if it accounts for the size of these connecting passenger flows in some way. We take a relatively simple approach of assuming that a carrier's fixed costs can be offset by a linear function of three variables, which we will call "network variables": dummy variables for domestic and international hubs, and a third variable that is (the log of) a prediction of the total number of connecting passengers that a carrier will serve when it provides nonstop service on a route that involves a domestic hub (for nonhub routes, the variable is zero).[15] Appendix A.2 describes the model used to construct the prediction, which captures the geographic convenience of different connections on different routes, and it is estimated using data from 1 year prior to our estimation sample to reduce endogeneity concerns. Appendix C provides descriptive regressions showing

[13] In contrast, the idiosyncratic variation in $\beta_{jm}^{A\to B}$ and $\beta_{jm}^{B\to A}$ is independent across directions.

[14] A natural extension would be to explicitly model differences in demand from business and leisure travelers as in Berry and Jia (2010) and Ciliberto and Williams (2014).

[15] We use the log because the standard deviation of the variable in levels is very large. We require that the net fixed cost is nonnegative as this reduces the range of the importance draws that we need to take. We show that this does not prevent us from accurately matching service choices at major hubs.

that, together with market size, the variables included in our fixed cost specification can predict service choices quite accurately.[16]

One might be concerned that a failure to model connecting traffic in more detail will make our counterfactuals less informative. However, our counterfactuals are focused on whether, when two nonstop carriers merge, their connecting rivals will introduce nonstop service. Although the pre-merger nonstop carriers are often serving their hubs, this is never true for the connecting rivals on the routes that we consider, and, as a result, their network variables are all zero. On the other hand, the merging carriers will be assumed to maintain nonstop service, which is what we observe in the data, so that changes in any of their fixed cost variables have no effect on our predictions.

□ **Price competition.** Given service choices, carriers play static, simultaneous Bertrand Nash pricing games for passengers originating at each endpoint. Our assumptions of nested logit demand, constant marginal costs, and single product firms imply that there will be unique equilibrium prices and directional variable profits, $\pi_{jm}^{A\rightarrow B}(s)$, given service choices, cost and quality draws (Mizuno, 2003). j's market-level variable profits are $\pi_{jm}(s) = \pi_{jm}^{A\rightarrow B}(s) + \pi_{jm}^{B\rightarrow A}(s)$, as service choices are assumed to be the same in both directions.

Our assumption that carriers only choose a single price in each direction abstracts away from how carriers sell tickets at many different prices because of price discrimination and revenue management incentives. There are no oligopoly revenue management models that it would be feasible to incorporate within the current model.[17]

□ **Service choices.** In the first stage, carriers choose whether to commit to the fixed cost required for nonstop service, or to provide connecting service. Their realized profits in the full game are therefore $\pi_{jm}(s) - F_{jm} \times \mathcal{I}(j \text{ is nonstop in } m)$ where F_{jm} is a fixed cost draw associated with providing nonstop service. Our baseline specification assumes that carriers make their service choices sequentially in order of their average presence (see footnote for the definition) at the endpoints. This assumption guarantees a unique predicted outcome for the whole game. We will show that our estimates are robust to making the weaker assumption that firms either move sequentially, but in an unknown order, or that they use pure strategies in a simultaneous move service choice game.

□ **Solving the game.** Conditional on service choices, Nash equilibrium prices, shares, and profits can be found by solving the system of pricing first-order conditions. One approach to finding equilibrium service choices would be to compute equilibrium profits for all combinations of service choices, and then to apply backward induction to the branches of the extensive-form game tree. However, we can reduce computation by testing whether a carrier would make positive profits from nonstop service if all later movers were not in the game at all. If it would not, we know that the carrier will never choose nonstop service and we can delete branches where it would.[18] See Appendix B.1 for more discussion.

□ **Full information, selection, and market structure.** Our full information assumption implies that service choices will be correlated with demand and marginal cost unobservables of all

[16] Ideally one would allow the profitability of a connecting passenger to vary across routes. However, when we simulate data from our estimated model, legacy carriers' implied margins on connecting passengers do not vary too much across markets (median \$94, with 50% of the predictions between \$83 and \$108).

[17] Lazarev (2013) and Williams (2020) estimate revenue management models for monopoly markets. Carriers may use the same list prices in both directions, but average realized prices may differ due to differences in demand. We will treat this outcome as reflecting different prices being set in each direction.

[18] For example, suppose that the first moving carrier's variable profits as a nonstop monopolist with no other carriers active at all would be lower than its nonstop fixed cost. This implies that it can never find nonstop service to be profitable, so one half of the tree of the extensive-form game can be eliminated.

TABLE 1 Summary Statistics for the Estimation Sample

	Numb. of Obs.	Mean	Std. Dev.	10^{th} pctile	90^{th} pctile
Market variables					
Market size (directional)	4,056	24,327	34,827	2,794	62,454
Num. of carriers	2,028	3.98	1.74	2	6
Num. of nonstop	2,028	0.67	0.83	0	2
Total passengers (directional)	4,056	6,971	10,830	625	17,545
Nonstop distance (miles, round-trip)	2,028	2,444	1,234	986	4,384
Business index	2,028	0.41	0.09	0.30	0.52
Market-carrier variables					
Nonstop indicator	8,065	0.17	0.37	0	1
Price (directional, round-trip $s)	16,130	436	111	304	581
Share (directional)	16,130	0.071	0.085	0.007	0.208
Airport presence (endpoint specific)	16,130	0.208	0.240	0.038	0.529
Indicator for low cost carrier	8,065	0.22	0.41	0	1
$\geq$ 1 Endpoint is a domestic hub	8,065	0.13	0.33	0	1
$\geq$ 1 Endpoint is an international hub	8,065	0.10	0.30	0	1
Connecting distance (miles, round-trip)	7,270	3,161	1,370	1,486	4,996
Predicted connecting traffic (at domestic hubs)	1,036	8,664	7,940	2,347	52,726

firms, leading to a nonlinear form of selection. Correlations between the unobservables could introduce additional nonlinearities. Our baseline assumption is that, with the exception of the common route-level demand effect, unobservables are independent, although, as we note in footnote , observed covariates lead to quite strong correlations between a carrier's nonstop service quality and its costs of nonstop service. Our robustness checks allow for correlations in the unobservables and we will find the estimated correlations to be small and statistically insignificant.

Appendix A of our working paper (Li et al., 2021) uses an example to investigate the implications of limited and full information for market structure. Full information can significantly lower the probability that more than one carrier will be nonstop because when a carrier expects to have a nonstop rival, it will expect that rival to be a stronger competitor, reducing its own profits from nonstop service, when the rival knows its own demand and marginal cost unobservables. On the other hand, carriers may regret their service choices in a limited information model, once unobservables are revealed.[19] If unobservables are persistent and sunk costs are small, this feature makes it doubtful that market structures predicted by a limited information model, pre- or post-merger, will actually persist in the data. This provides an additional reason for wanting to focus on a full information model to predict the effects of mergers, even in the short or medium run.

3. Data and summary statistics

■ We estimate our model using a cross-section of publicly available DB1 (a 10% sample of domestic itineraries) and T100 (records of flights between airports) data for the second quarter of 2006. We use relatively old data so that we can make predictions about subsequent mergers and avoid later years when carriers have been alleged to price cooperatively (Ciliberto and Williams, 2014). Appendix A provides additional detail and discussion. Tables 1 and 2 provide summary statistics.

Markets and carriers. We use data for 2028 airport-pair markets linking the 79 busiest US airports in the lower 48 states. Excluded routes include short routes and routes where nonstop

[19] As pointed out by a referee, regret may arise in a full information model if service choices are made simultaneously and firms used mixed strategies. Our example assumes that service choices are made sequentially.

TABLE 2 Distribution of Market Structures in the Estimation Sample

Number of Nonstop Competitors	Number of Sample Markets	Percentage of Sample Passengers (%)	Average Number of Connecting Carriers
0	1,075	15.0	3.98
1	614	33.6	2.91
2	277	35.5	2.07
3	60	15.2	1.25
4	2	0.10	0

service is limited by regulation. We model six named legacy[20] carriers, American Airlines, Continental Airlines, Delta Air Lines, Northwest Airlines, United Airlines and US Airways, and one named low-cost carrier (LCC), Southwest. We aggregate other ticketing carriers into composite "Other Legacy" (e.g., Alaska Airlines) and "Other LCC" (e.g., JetBlue and Frontier) carriers. We attribute tickets and flights to mainline ticketing carriers when they are operated by regional affiliates.

Service types, market shares, and prices. We define the competitors on a route as carriers ticketing at least 20 DB1 passengers and with at least a 1% share of traffic. On average, there are four competitors, with as many as nine on long routes, such as Orlando–Seattle, with many plausible connections. We define a carrier as nonstop when it has 64 nonstop flights in each direction and 50% of passengers do not make connections, although the exact thresholds have little effect on the classification. The remaining competitors are classified as connecting. Most routes have no nonstop carriers, but routes with at least two nonstop carriers account for a majority of passenger trips. This type of route will be the focus of our counterfactuals. Most routes with multiple nonstop carriers connect large cities or hub airports, but nonhub pairs such as Boston–Raleigh and Columbus–Tampa also have nonstop duopolies.[21]

We measure a carrier's price as the average round-trip price in DB1. A carrier's market share is calculated as the total number of passengers that it carries in DB1, regardless of service type, divided by a measure of market size. We calculate market size as the prediction from a gravity model, which accounts for historical total endpoint enplanements using endpoint fixed effects and route distance (see Appendix A.1). This reduces unexplained heterogeneity in market shares across routes, accounts for correlations in aggregate demand across routes at the same airport, and explains service choices better than alternative measures, such as average endpoint city populations.

Exogenous variables. Carrier presence is calculated using T100 data. Nonstop distance is measured as the great circle distance between two airports, and the distance for connecting service is measured as the distance via the carrier's closest connecting hub airport.[22] Appendix A.2 details which airports are domestic or international hubs and the construction of the connecting traffic variable. The business index variable, which approximates the proportion of business travelers on a route, is based on data provided by Severin Borenstein (2010).

[20] Legacy carriers are carriers founded prior to deregulation in 1978, and they typically operate through hub-and-spoke networks. Our classification of carriers as LCCs follows Berry and Jia (2010).

[21] If we had defined markets using city pairs, rather than airport pairs, there would be 192 nonstop duopolies (out of 1533 city-pair markets), with 90 city-pair markets having three or more nonstop carriers.

[22] For the composite Other Legacy and Other Low Cost carriers it is not straightforward to assign connecting routes. Therefore we use the nonstop distance for these carriers, but include additional dummies in the connecting marginal cost specification to provide more flexibility.

TABLE 3 Moments Used in Estimation

Exogenous Variables (Z)	Market Level (y_m) Endogenous Outcomes 7 per Market	Market-Carrier Level (y_{jm}) Endogenous Outcomes 5 per Carrier	Row Total
Market-level variables (Z_m) (7 per market)	49	315	364
Carrier-specific variables (Z_{jm}) (up to 5 per carrier)	280	200	480
"Other Carrier"-specific variables (Z_{-jm}) (5 per "other carrier")	315	225	540
Column total	644	740	1,384

Note: Z_m = {constant, market size, market (nonstop) distance, business index, number of low-cost carriers, tourist dummy, slot-constrained dummy.}
Z_{jm} = {presence at each endpoint airport, our measure of the carrier's connecting traffic if the route is served nonstop, connecting distance, international hub dummy} for named legacy carriers and for Southwest (except the international hub dummy). For the Other Legacy and Other LCC Carrier we use {presence at each endpoint airport, connecting distance} as we do not model their connecting traffic. Carrier-specific variables are interacted with all market-level outcomes and carrier-specific outcomes for the same carrier.
Z_{-jm} = {the average presence of other carriers at each endpoint airport, connecting passengers, connecting distance, and international hub dummy} for each other carrier (zero if that carrier is not present at all in the market).
y_m = {market-level nonstop price (both directions), connecting price (both directions), sum of squared market shares (both directions), and the square of number of nonstop carriers}.
y_{jm} = {nonstop dummy, price (both directions), and market shares (both directions)} for each carrier.

4. Estimation

■ We estimate the model parameters, $\Gamma = (\beta, \sigma)$, using a simulated method-of-moments estimator. In this section we outline the algorithm, the moments, identification, and possible alternative implementations. Appendix B provides additional details, including evidence on the performance of the algorithm and its underlying assumptions.

□ **Objective function and moments.** The objective function is defined as

$$h(\Gamma)'Wh(\Gamma)$$

where W is a weighting matrix, and $h(\Gamma)$ is a vector of moments where each element has the form $\frac{1}{M}\sum_{m=1}^{m=M}(y_m^{data} - E_m\widehat{(y|\Gamma, X_m)})Z_m$. y_m^{data} are observed outcomes and Z_m are a set of observed exogenous variables that serve as instruments. $E_m\widehat{(y|\Gamma, X_m)}$ are the predicted outcomes of the model for market m given the parameters Γ and observed variables X_m. We describe the moments that we use before describing how we compute $E_m\widehat{(y|\Gamma, X_m)}$.

Standard demand estimation with fixed product characteristics (e.g., Berry, 1994) uses moments that are based on the assumed orthogonality of a structural unobservable and instruments. However, the selection implied by the full information assumption implies that the structural errors for the service type that is chosen will not have mean zero and will be correlated with all of the exogenous variables in the model. Instead, we create moments using the fact that, for the true parameters, the expected value of the observed outcomes should match the expectation of predicted outcomes from the model.[23] The number of moments of different types is summarized in Table 3. The outcomes include both market-carrier outcomes (e.g., Delta's price, its share and an indicator for whether it enters nonstop) and market/route outcomes (such as the sum of squared market shares, and the squared number of nonstop carriers). In principle, any function of the observed variables that are assumed to be exogenous can be used as instruments. The ones that we

[23] Moments where outcomes are matched are usually used to estimate endogenous entry models (e.g., Berry, 1992), but here we are also applying them to prices and market shares.

use can be broken into three groups: market-level variables (e.g., market size and the business index), market-carrier characteristics (e.g., endpoint presence, and distance of connecting service), and the characteristics of rival carriers (e.g., Delta's presence when we are looking at an outcome for a carrier other than Delta). One robustness check will use a subset of the instruments.

□ **Computation of the moments using importance sampling.** A nested fixed point algorithm would recompute $E_m(y|\Gamma, X_m)$, by resolving simulated games for each market, each time a parameter is changed. We instead approximate $E_m(y|\Gamma, X_m)$ using importance sampling following Ackerberg (2009).

The idea is straightforward. Denoting a particular realization of all of the draws as θ_m,

$$E_m(y|\Gamma, X_m) = \int y(\theta_m, X_m) f(\theta_m|X_m, \Gamma) d\theta_m$$

where $y(\theta_m, X_m)$ is the unique equilibrium outcome given our baseline assumptions. This integral cannot be calculated analytically, but we can exploit the fact that

$$\int y(\theta_m, X_m) f(\theta_m|X_m, \Gamma) d\theta_m = \int y(\theta_m, X_m) \frac{f(\theta_m|X_m, \Gamma)}{g(\theta_m|X_m)} g(\theta_m|X_m) d\theta_m$$

where $g(\theta_m|X_m)$ is an "importance density" chosen by the researcher.[24]

This leads to a two-step estimation procedure. In the first step we take many draws, indexed by s, from densities $g(\theta_{ms}|X_m)$ and solve for the equilibrium outcome, $y(\theta_{ms}, X_m)$, for each of these draws. In the second step we estimate the parameters, approximating $E_m(y)$ using

$$E_m\widehat{(y|\Gamma, X_m)} = \frac{1}{S} \sum_{s=1}^{S} y(\theta_{ms}, X_m) \frac{f(\theta_{ms}|X_m, \Gamma)}{g(\theta_{ms}|X_m)}$$

where we only need to recalculate $f(\theta_{ms}|X_m, \Gamma)$ when the parameters change. The objective function is smooth because the $f(\theta_{ms}|X_m, \Gamma)$ densities are smooth in the parameters. We minimize the objective function using the `fminunc` function in MATLAB.

Appendix B details our selection of the parameters of the g density functions that we use in estimation and also our specification of the supports of the random variables (quality draws, costs, nesting and price parameters). As suggested by Ackerberg, the choice of g comes from initially estimating the model using gs that place weight on a broad set of draws.[25]

We form the W matrix by using the results from initially estimating the model using an identity weighting matrix. However, rather than using the inverse of the full covariance matrix, our final estimation uses a diagonal weighting matrix, with equal total weight on the groups of moments associated with price, share, and service choice outcomes and, within each group, the weight on each moment is proportional to the reciprocal of the variance of that moment from previous estimates. We choose this approach because, with many moments relative to the number of observations (16,130 carrier-market directions), the estimated covariances are likely to be inaccurate, and, in practice, some estimates are less stable if we use the full covariance matrix.

□ **Computational burden.** For the final round of estimation, solving 2000 games for 2028 routes takes less than 2 days on a medium-sized cluster, and the point estimates of the parameters are calculated in 1 day on a laptop without any parallelization.[26] In contrast, a nested fixed point approach, although it should be econometrically more efficient for a given number of draws,

[24] The "change of variables" discussed by Ackerberg is implicit in our presentation of the model. For example, if we had expressed a fixed cost as $F_{jm} = X_{jm}\beta_F + u^F_{jm}$, then a change of variables would be required to explain why the approach takes draws of F_{jm} rather than u^F_{jm}.

[25] Unlike the choice of starting values, the chosen g will always matter for the exact values of the estimated parameters. However, we have found that alternative gs, or using additional rounds of estimation, leads to very similar results.

[26] The calculation of standard errors using a bootstrap requires repeating the estimation step 100 times, so this is performed on a cluster.

would require parallelization to repeatedly solve games for different parameters, and it would also likely require more function evaluations to minimize a discontinuous objective function.[27]

It has been suggested to us that importance sampling could be used in different ways to make estimation more efficient. This is possible, but at least two suggested alternatives cannot be used. For example, Roberts and Sweeting (2013) use importance sampling to calculate a simulated likelihood but this exploits the fact that in their incomplete information auction game, any possible outcome has positive likelihood for any set of unobservable draws for auction characteristics, whereas, in our setting, many outcomes may have a zero simulated likelihood even with many simulations. The Geweke–Hajivassiliou–Keane (GHK) estimator (Keane, 1994) provides an efficient method for estimating models with multiple normally distributed errors using sequential conditioning. However, in our setting, the dependence of a firm's variable profits on the draws of every carrier in the market would make sequential conditioning infeasible.

□ **Identification.** As explained above, standard identification arguments for demand and marginal cost parameters will fail as selection implies that carrier demand and marginal cost residuals for chosen service types will neither have mean zero, nor be uncorrelated with exogenous demand and marginal cost variables. Identification therefore requires accounting for the exact form of selection implied by the full model. However, in our setting, the observed exogenous variables, including market size and the network variables affecting fixed costs, are able to predict the service choices of a large proportion of carrier-route observations almost perfectly (see Appendix C). This implies that, for these observations, there should be almost no selection on demand and marginal cost unobservables (i.e., the expected value of the unobservables should be close to zero, and they should be almost uncorrelated with the exogenous variables), in which case standard identification arguments should approximately apply.

CMT estimate the demand and marginal cost parameters by adjusting the standard demand and marginal cost moments to account for selection, with all of the observed exogenous variables (i.e., observed fixed cost shifters for a firm and its rivals, as well as demand and marginal cost shifters) as valid instruments.[28] We take a different approach, using moments conditions that directly match observed and predicted carrier and market price, share and service choice outcomes, but we can also use the observed exogenous variables as valid instruments. Given consistent estimates of the demand and marginal cost parameters, identification of the fixed cost parameters follows from how carrier service choices vary with the changes in the distribution of variable profits, as market size, a carrier's own exogenous characteristics and the exogenous characteristics of rivals vary. Our carrier service choice moments are similar to those used in the literature on discrete choice games (Berry, 1992).

5. Parameter estimates

■ The first columns of Tables 4 and 5 present our baseline estimates. The coefficients are consistent with expected patterns. All else equal, consumers have a strong preference for nonstop service, legacy carriers, and carriers with greater originating airport presence. Demand is less elastic on routes with more business travelers.[29] The average own price demand elasticity is -4.25, and the elasticity of demand for air travel (i.e., when all prices rise by the same proportion) is -1.3, close to the literature average reported by Gillen, Morrison, and Stewart (2003). For the average nonstop carrier, consumers' preference for nonstop service is $118.

[27] CMT lower their computational burden by allowing a maximum of only six players per market, rather than our nine, and assuming that demand and pricing are nondirectional.

[28] CMT allow for multiple equilibria so that, for some market structures, the moments take the form of inequalities, although there are moment equalities for outcomes where no firms or all firm enter. Given that we assume sequential entry, similar moments for our model would all be moment equalities.

[29] The expected price coefficient (α) for Dayton–Dallas–Fort Worth, which has the highest business index, is -0.34 compared to the cross-market average of -0.57.

TABLE 4 Parameter Estimates: Demand

Route-Level Parameters				(1) Independent Unobservables	(2) Correlation Specific. 1	(3) Correlation Specific. 2	(4) Nonstop and Connecting
Demand RE	S.D.	σ_{RE}	Constant	0.311	0.538	0.469	0.369
[−2, 2]				(0.138)	(0.151)	(0.122)	(0.135)
Nesting	Mean	β_τ	Constant	0.645	0.634	0.640	0.617
parameter				(0.012)	(0.013)	(0.015)	(0.013)
[0.5,0.9]	S.D.	σ_τ	Constant	0.042	0.005	0.050	0.020
				(0.010)	(0.010)	(0.008)	(0.009)
Price	Mean	β_α	Constant	−0.567	−0.542	−0.612	−0.602
Coefficient				(0.040)	(0.045)	(0.031)	(0.041)
(price in $100 units)			Business	0.349	0.189	0.435	0.382
[−0.75, −0.15]			index	(0.110)	(0.118)	(0.088)	(0.113)
	S.D.	σ_α	Constant	0.015	0.043	0.013	0.035
				(0.010)	(0.011)	(0.013)	(0.010)
Carrier-Level Parameters							
Carrier	Mean	β_{CON}	Legacy	0.376	0.322	0.465	0.291
connecting			Constant	(0.054)	(0.064)	(0.047)	(0.054))
quality			LCC	0.237	0.336	0.150	0.223
[−2, 10]			Constant	(0.094)	(0.086)	(0.094)	(0.113)
			presence	0.845	0.674	0.524	0.835
			at Origin	(0.130)	(0.125)	(0.127)	(0.196)
	S.D.	σ_{CON}	Constant	0.195	0.208	0.201	0.255
				(0.025)	(0.027)	(0.028)	(0.026)
Incremental	Mean	β_{NS}	Constant	0.258	0.192	0.560	0.519
Quality of				(0.235)	(0.214)	(0.221)	(0.181)
Nonstop			Distance	−0.025	−0.057	−0.009	−0.061
Service				(0.034)	(0.037)	(0.036)	(0.044)
[0,5]			Business	0.247	0.841	−0.396	0.288
			index	(0.494)	(0.455)	(0.479)	(0.372)
	S.D.	σ_{NS}	Constant	0.278	0.241	0.213	0.257
				(0.038)	(0.042)	(0.034)	(0.045)

Note: standard errors, in parentheses, are based on 100 bootstrap replications where 2028 markets are sampled with replacement, and we draw a new set of 1000 simulation draws (taken from a pool of 2000 draws) for each selected market. Distance is measured in thousands of miles. See Table 5 for estimates of the cost and covariance parameters. The supports of the random variable parameters are indicated in square brackets underneathe the name of the parameter. For example, the nesting parameter can lie between 0.5 and 0.9.

The estimated average level of marginal costs reflects the elasticity of demand, our assumption of Nash pricing and our use of average prices as our price measure.[30] LCCs are estimated to have lower marginal costs, and costs increase with distance. To illustrate, consider the 3000 mile round-trip Miami–Minneapolis route. For the named legacy carriers, the expected nonstop marginal cost is $345, compared to an average of $367 for (longer distance) connecting service. Marginal costs for Southwest (and Other LCC) are lower and, for this route, Southwest's expected nonstop and connecting (via Chicago Midway) costs are almost identical ($303 and $298, respectively). On a nonhub route, the average nonstop fixed cost is $924,000, but, on domestic hub routes, the average fixed cost, once we offset the value of the network variables, is $399,000.

□ **The role of unobservables.** Accounting for selection on unobservables will be a key feature of our counterfactual analysis. It is therefore natural to look at the relative importance of observable covariates and unobservables in different parts of our model. To assess this, we simu-

[30] As noted by a referee, airlines will often sell some seats at very low fares (e.g., $99 returns) suggesting that the true marginal cost of an additional passenger is lower, and that higher average fares reflect the ability of carriers to extract consumer surplus using revenue management techniques.

TABLE 5 Parameter Estimates: Marginal Costs, Fixed Costs, Network Effects and Covariances

				(1) Independent Unobservables	(2) Correlation Specific. 1	(3) Correlation Specific. 2	(4) Nonstop and Connecting
Carrier marginal costs ($100 units) [0,6]	Mean	β_{MC}	Legacy Constant	1.802 (0.168)	1.350 (0.146)	1.847 (0.190)	1.389 (0.229)
			LCC Constant	1.383 (0.194)	0.961 (0.169)	1.344 (0.207)	1.100 (0.247)
			Conn. X Legacy	0.100 (0.229)	0.443 (0.211)	0.040 (0.251)	0.629 (0.295)
			Conn. X LCC	−0.165 (0.291)	0.288 (0.255)	0.140 (0.273)	0.388 (0.322)
			Conn. X Other Leg.	−0.270 (0.680)	−0.213 (0.166)	−0.228 (0.160)	0.051 (0.188)
			Conn. X Other LCC	0.124 (0.156)	0.046 (0.152)	−0.173 (0.167)	0.171 (0.168)
			Nonstop Distance	0.579 (0.117)	0.823 (0.101)	0.510 (0.128)	0.865 (0.155)
			Nonstop Distance^2	−0.010 (0.018)	−0.044 (0.016)	−0.001 (0.019)	−0.059 (0.023)
			Connecting Distance	0.681 (0.083)	0.661 (0.096)	0.675 (0.091)	0.524 (0.083)
			Connecting Distance^2	−0.028 (0.012)	−0.018 (0.013)	−0.026 (0.013)	0.000 (0.012)
	S.D.	σ_{MC}	Constant	0.164 (0.021)	0.191 (0.016)	0.143 (0.018)	0.148 (0.020)
Carrier fixed costs ($1m. units) [0,5]	Mean	β_F	Legacy Constant	0.887 (0.061)	0.897 (0.056)	0.855	1.104 (0.075)
			LCC Constant	0.957 (0.109)	1.008 (0.118)	0.857 (0.100)	0.922 (0.124)
			Slot Const. Airport	0.568 (0.094)	0.424 (0.099)	0.514 (0.085)	0.411 (0.105)
	S.D.	σ_F	Constant	0.215 (0.035)	0.275 (0.029)	0.220 (0.030)	0.195 (0.033)
Carrier network variables (offset fixed costs)			Dom. Hub Dummy	−0.058 (0.127)	−0.302 (0.157)	−0.205 (0.193)	0.000 (0.212)
			Log $\widehat{\text{(Conn. Traff.)}}$	−0.871 (0.227)	−1.000 (0.207)	−0.602 (0.257)	−0.972 (0.287)
			Intl. Hub	−0.118 (0.120)	−0.144 (0.090)	−0.107 (0.093)	−0.261 (0.137)
Covariances	Incremental nonstop quality & fixed cost			—	0.012 (0.010)	0.018 (0.010)	—
	Connecting quality & connecting marginal cost			—	—	0.006 (0.007)	—

Note: See notes below Table 4. The Log(Predicted Connecting Traffic) variable is zero for routes that do not involve a domestic hub, and for hub routes it is re-scaled with mean 0.52 and standard deviation 0.34.

late each market 20 times using the baseline coefficients, and compute how much of the variation (across carrier-market simulations) in a particular type of draw is accounted for by variation in the observed Xs. For example, the standard deviation of F_{jm} is \$301, 912, and the standard deviation of $X^F_{jm}\widehat{\beta_F}$ is \$259, 481, so that unobserved heterogeneity provides only 14% of the variation. Similarly, unobserved heterogeneity accounts for only 3% of the variation in marginal costs and 15% of the variation in the price sensitivity of demand. However, it accounts for 26% and 34% of variation in connecting and nonstop carrier quality, respectively, and our estimates also indicate that the variance in the unobserved route-level demand effect is quite large. These results suggest that accounting for selection on demand unobservables may be particularly important.

TABLE 6 Model Fit: Predictions of Service Decisions at Raleigh–Durham

	Number of Routes	Mean Presence at Route Endpoints	% Routes Nonstop	
			Data	Simulation
American	44	0.29	22.7	22.8 (1.6)
Continental	30	0.14	10.0	10.0 (1.0)
Delta	57	0.24	8.7	14.8 (1.9)
Northwest	22	0.18	9.1	11.0 (1.2)
United	25	0.12	4	14.4 (1.9)
US Airways	54	0.12	5.6	9.4 (2.7)
Southwest	48	0.30	12.5	14.5 (4.3)
Other Low Cost	25	0.08	4	13.4 (4.9)

Note: Predictions from the model calculated based on 20 simulation draws from each market from the relevant estimated distributions.

□ **Model fit.** We use the 20 sets of draws to assess how well our model predicts observed service choices (discussed here) and variation in prices and market shares across service types (Appendix B.5). We correctly predict a carrier's service choice for 87.5% of draws (with standard error 1.1%), and for 82.6% (2.2%) of observations where a majority of our simulations predict a carrier will be nonstop, the carrier is nonstop in the data. We accurately predict carrier choices at hubs (Appendix B.2, e.g., Delta serves 96.5% of routes at Atlanta nonstop compared to a prediction of 92.5% (2.3%)) and nonhub airports. Table 6 illustrates the nonhub fit for routes with Raleigh–Durham (RDU) as an endpoint. The proportion of nonstop routes is served accurately for each carrier. The prediction is least accurate for United, as our simulations predict that United should serve Denver and San Francisco nonstop. United has launched nonstop service on both routes since 2006.

□ **Robustness checks.** We now discuss what happens when we relax some of the assumptions imposed on our baseline estimates.

Correlations between the unobservables. Our baseline specification imposes that demand and cost unobservables are independent.[31] Columns 2 and 3 of Tables 4 and 5 present our estimates when we allow for correlations between the unobserved incremental quality of nonstop service and the fixed cost of providing nonstop service, and between connecting quality and connecting marginal costs. The estimated covariances are small, and only one of them is statistically significant at the 10% level. When we have tried to allow for unrestricted correlations, the objective function has often had multiple local minima, but we have not found clear improvements in fit.[32,33]

Nonstop service includes connecting service. Our baseline model assumes that a carrier that offers nonstop service only provides nonstop service. However, carriers often offer both nonstop and connecting service. Column 4 of Tables 4 and 5 presents our estimates when we assume nonstop carriers provide connecting service and set four prices on each route.[34] The majority of the coefficients are close to their baseline values.

[31] However, the coefficients on observed covariates lead to strong correlations between demand and costs. For example, based on the 20 sets of draws used to examine model fit, the correlation between a carrier's nonstop quality and its fixed costs of nonstop service is -0.56.

[32] For the reported estimates, a grid search on the covariance parameters confirms that values close to zero minimize the objective function.

[33] CMT estimate a more flexible covariance structure and find that some covariances are large. This may reflect how unobservables in their model have to account for large share and price differences between nonstop and connecting carriers, whereas we explicitly model these differences.

[34] The difference in this model is that, when solving our simulated games, we solve for four prices and quantities (two types of service in each direction) for carriers that choose to be nonstop. These are then matched, as carrier-direction-nonstop service type averages, to the moments from the data that are calculated in the same way.

Reduction in the number of moments. Our baseline estimation uses 1384 moments, which is large relative to the sample size, creating the possibility of bias. Appendix B.6 presents estimates, an analysis of fit and some example counterfactual results using only the 740 carrier-specific moments. All of the results are similar to the baseline.

Relaxing the known, sequential order assumption. Our baseline estimates assume that service choice decisions are made in a known sequential order, which guarantees a unique equilibrium and point identification.[35] In contrast, Ciliberto and Tamer (2009), Eizenberg (2014), and Wollmann (2018) estimate using inequalities assuming that moves are simultaneous and that any pure strategy equilibrium can be played. Ciliberto and Tamer (2009) report that there are multiple equilibria in over 95% of simulations of their airline entry game. If this was true in our setting then one might be very concerned that our sequential move assumption could produce very misleading estimates.

There are two reasons to believe that this is not the case. Leaving aside the possibility that a carrier is exactly indifferent between two service types, given what other carriers choose, the model can only support more than one equilibrium outcome if at least two carriers do not have strictly dominant strategies. Without estimating a specific model, one indicator that, in fact, most carriers are likely to have dominant strategies is that probit regressions using market and a carrier's own characteristics are able to predict carriers' observed choices with very high probability. As discussed in Appendix C, two or more carriers have predicted nonstop probabilities between 0.1 and 0.9 in only 15% of markets. In contrast, if we use the same covariates to predict whether carriers that serve the endpoints provide either connecting or nonstop service, similar to Ciliberto and Tamer's outcome of interest, the corresponding figure is 96%. This suggests that the sequential assumption is very likely to be less restrictive when examining service choice. This is supported by more formal analysis. When we simulate data from our estimated baseline model, we find that multiple equilibrium outcomes can be supported (either by pure strategies in a simultaneous move game, or a sequential game with any order of moves) for only 1.6% of simulated games. Appendix B.7 also reports the parameters that minimize the objective function when we extend our estimation methodology to use moment inequalities to allow for simultaneous moves or unknown orders. These parameters are very similar to the baseline estimates, and the percentage of games that support more than one equilibrium outcome is almost identical.

6. Merger counterfactuals

■ We now present our analysis of counterfactuals, which we spread across three sections for ease of referencing. This section describes the mergers that we consider, and describes the assumptions and predictions of standard merger simulations where service choices are held fixed. We find that the mergers we consider tend to have the most potential to raise prices in markets where both merging parties are nonstop. Section 7 implements merger simulations endogenizing the service choices of the nonmerging firms, focusing on markets where both nonmerging firms are nonstop. Section 8 uses the model to examine how far two alternative remedies can constrain post-merger market power. We use the baseline demand and cost estimates throughout these sections (see Appendix B.6 for an example that shows the results are very similar using an alternative set of parameter estimates).

□ **The set of mergers and routes considered.** We examine the three legacy mergers (Delta/Northwest (2008), United/Continental (2010), American/US Airways (2013)) completed after 2006 and a United/US Airways merger that was proposed in 2000, but abandoned when

[35] On the other hand, the parameters can be point identified even if some equilibria are not unique, because an outcome such as "no firms are nonstop" will always be unique. In our data the most common outcome is that no firms are nonstop.

the Department of Justice opposed it.[36] We do not consider the consummated merger between Southwest and Airtran, because Airtran is part of our composite "Other LCC."

The United/Continental and American/US Airways mergers were allowed to proceed on the condition that the parties divested slots and other facilities at major airports to LCCs. In the United/US Airways merger, the parties proposed a remedy where a third carrier, American, would commit to provide nonstop service for 10 years on several routes where the merging parties were nonstop duopolists. The Department of Justice did not accept the remedy on the grounds it was insufficient to restore pre-merger competition.[37] Section 8 will discuss both types of remedy.[38]

□ **Merger counterfactuals with fixed products.** We first present results from a set of standard merger counterfactuals (e.g., Nevo, 2000) that do not allow for repositioning. We make the following assumptions when we resolve for equilibrium prices.

Assumption 1 (Merger Counterfactuals with Fixed Products). We assume

1. The products owned by the merging parties are eliminated and replaced by a single product of the merged carrier ("Newco"). We consider two alternative assumptions about Newco's demand and costs:
   (a) ("baseline assumption") Newco has the quality and marginal cost of the merging party with the higher average endpoint presence before the merger when both parties have the same service type, and otherwise it has the quality and marginal cost of the nonstop party.
   (b) ("best case assumption") Newco has the higher quality and the lower marginal cost of the merging parties.
2. the nesting and price parameters are equal to their expected values for each market given observed market characteristics and the baseline parameter estimates.
3. the products of the nonmerging carriers remain the same, with the same service type and the same demand and marginal cost draws as in the data.

The second assumption reduces the computational burden, although we have verified that the results are almost identical if we relax it, consistent with the small estimated standard deviations of the price coefficient and the nesting parameter. The best case assumption parallels the assumption of Li and Zhang (2015) concerning valuations and hauling costs in the context of timber auctions, and it tends to increase the profitability of the merger relative to the baseline assumption. We can implement the merger simulation by inverting the demand of each carrier (for its offered service type) and its marginal cost from the observed price and market share data in each market, given the demand system parameters and the Nash pricing assumption.[39]

Comparison of merger price effects across different market structures. The first panel of Table 7 reports pre-merger and post-merger prices for four different groups of markets under the baseline assumption about the merging parties. The reported pre-merger price is the average of the share-weighted average prices for the merging carriers across directions, and the post-merger price is the average for Newco across directions. To save space, we do not report standard errors for the post-merger prices, although, as can be seen when we report them for nonstop duopoly routes in

[36] BBCL consider the United/US Airways, Delta/Northwest, and United/Continental mergers, and CMT consider the American/US Airways merger.

[37] A November 2001 speech by R. Hewitt Pate, Deputy Assistant Attorney General, explaining that the proposed remedy was insufficient can be found at https://www.justice.gov/atr/department-justice-10(accessed June 29, 2017).

[38] Park (2020) uses a model that allows for the allocation of slots across routes to provide a detailed analysis of the effectiveness of the American/US Airways divestiture.

[39] For this exercise it is not necessarily to separate out the components of quality that come from the market demand and carrier-specific unobservables. There is, however, one nonstandard feature of the problem, that arises from our assumption that marginal costs are nondirectional. We proceed by calculating the directional marginal costs implied by the prices and market shares of each carrier, and then taking the average.

TABLE 7 Predicted Effects of Mergers with Service Choices Held Fixed

	Delta/Northwest		United/Continental		American/US Airways		United/US Airways		Average	
	Data	Post	Data	Post	Data	Post	Data	Post	Data	Post
1. Alternative market structures and merger eliminates lower presence carrier										
Merging parties nonstop	$566.39	$593.20	$503.75	$556.17	$459.13	$521.15	$479.32	$549.49	$481.40	$541.25
duopolists	2 routes		4 routes		11 routes		7 routes		24 routes	
Merging parties nonstop	$351.26	$382.04	$438.08	$464.98	$363.11	$404.84	$350.02	$378.15	$368.70	$402.08
with nonstop rivals	2 routes		4 routes		10 routes		10 routes		26 routes	
One party nonstop,	$472.99	$524.67	$502.60	$513.29	$447.95	$478.95	$443.30	$462.53	$458.02	$486.40
other connecting	91 routes		59 routes		158 routes		163 routes		471 routes	
Both parties connecting	$433.26	$444.63	$487.04	$486.86	$464.20	$457.77	$484.25	$479.62	$466.00	$465.97
	479 routes		334 routes		471 routes		521 routes		1,805 routes	
2. Merging parties nonstop duopolists and merger eliminates lower presence carrier										
Number of routes	2 routes		4 routes		11 routes		7 routes		24 routes	
Merging carrier prices	$566.39	$593.20 (1.17)	$503.75	$556.17 (1.57)	$459.13	$521.15 (1.79)	$479.32	$549.49 (1.44)	$481.40	$541.25 (1.55)
Combined market share	19.2%	14.3% (0.1)	29.0%	21.7% (0.0)	26.9%	18.8% (0.1)	20.8%	12.9% (0.0)	24.8%	17.2% (0.0)
Combined variable profit ($k)	1, 292 (47)	1, 235 (43)	6, 112 (208)	6, 225 (208)	4, 336 (201)	4, 006 (187)	4, 023 (124)	3, 907 (104)	4, 287 (164)	4, 116 (151)
Combined fixed costs ($k)	689 (108)	194 (55)	1, 143 (144)	536 (66)	1, 564 (90)	621 (47)	1, 248 (100)	503 (61)	1, 321 (96)	537 (51)
Average rival prices	$471.63	$474.96 (0.10)	$455.71	$457.29 (0.03)	$400.49	$404.18 (0.14)	$392.42	$394.93 (0.15)	$412.47	$415.46 (0.08)
Change in cons. surp. per traveler	−$51.36 (1.64)		−$62.81 (2.21)		−$64.06 (2.89)		−$80.03 (2.19)		−$67.04 (2.47)	
3. Merging parties nonstop duopolists and merged firm receives highest qualities and lowest costs of the merging parties										
Merging carrier prices	$566.39	$598.77 (1.14)	$503.75	$558.63 (1.58)	$459.13	$513.34 (2.18)	$479.32	$537.60 (1.57)	$481.40	$535.09 (1.75)
Combined market share	18.9%	15.1% (0.0)	29.1%	21.9% (0.0)	26.9%	19.9% (0.01)	20.8%	14.3% (0.0)	24.8%	18.2% (0.0)
Combined variable profit ($k)	1, 287 (47)	1, 343 (414)	6, 112 (208)	6, 359 (209)	4, 336 (201)	4, 418 (162)	4, 023 (124)	4, 566 (103)	4, 287 (164)	4, 528 (141)
Combined fixed costs ($k)	689 (108)	162 (39)	1143 (144)	375 (57)	1, 564 (90)	565 (39)	1, 248 (100)	446 (64)	1, 321 (96)	465 (47)
Rival carrier prices	$471.63	$473.74 (0.06)	$455.71	$457.14 (0.03)	$400.49	$403.46 (0.14)	$392.42	$393.90 (0.04)	$412.47	$414.76 (0.08)
Change in Cons. Surp. per traveler	−$44.88 (1.72)		−$60.83 (2.18)		−$56.94 (3.21)		−$68.25 (2.19)		−$59.74 (2.63)	

Note: For routes where the merging carriers are nonstop duopolists, standard errors for measures not directly observed in the data are reported in parentheses, and the share, fixed cost, and profit numbers are for the merging carriers combined. Prices averaged across directions, and pre-merger prices are averages across carriers. For other pre-merger market structures, the table shows the number of affected routes, and merging carrier prices with no standard errors. All calculations assume that the price and nesting parameters have their expected values for each market. Each merger is considered separately, not cumulatively.

other parts of the table, they are small. Looking at the cross-merger average prices in the final column, the price increases are largest when the merging parties are both nonstop and they are the only nonstop carriers (nonstop duopolies) (12.4%), and, next, when they are both nonstop and there is at least one nonstop rival (9.1%). Price increases are smaller when one (6.1%) or both (no change) of the merging carriers are connecting.[40] Given these results, we will focus the rest of our analysis on the 50 routes where both the merging carriers are nonstop prior to the merger, and particularly the 24 routes where they are nonstop duopolists.[41]

Some have suggested that our focus on routes where the merging firms are already nonstop means that we are missing the possibility that the merger might expand the set of routes where the merging parties offer nonstop service.[42] It is true that a full welfare evaluation of the merger would need to examine all routes, but our focus on nonstop overlaps is consistent with antitrust practice that focuses on markets where there are anticompetitive concerns without a requirement to credit "out of market" benefits (Rybnicek and Wright, 2014). Second, in practice, the completed mergers were not followed by significant expansions of nonstop service, at least in the short run, although it is not, of course, clear what would have happened without a merger. For example, three quarters before their merger, United and Continental served a total of 258 of our sample routes nonstop, and the merged carrier served 259 routes nonstop seven quarters after the merger.[43]

Detailed analysis for nonstop duopoly markets. The second and third panels of Table 7 report more detailed results for the 24 nonstop duopoly markets, under the baseline (second panel) and best case (third panel) assumptions. We report standard errors, and all of the predictions are precise. On two routes (one for Delta/Northwest and one for United/US Airways) there are no connecting rivals, so the mergers create monopoly.

In the baseline case, all of the considered mergers are predicted to raise the merging carriers' average prices by between 5% and 15%, and the parties' market shares are predicted to fall by between 25% and 30%, reflecting both the price increases and the elimination of a product. The next rows allow us to examine the profitability of the merger. Although the decision to merge is taken at the network level, not the route level, the predicted profitability of a merger can be used to understand whether the assumptions are plausible. Although the elimination of a product and the lack of synergies means that variable profits tend to fall, total profits tend to increase because a fixed cost of nonstop service is eliminated. Connecting rivals are predicted to raise their prices, although the increases are small. Consumer surplus, measured in dollars per pre-merger traveler, tends to fall quite significantly.[44]

The directional changes in the predictions when we make the best case assumption are intuitive, with the merging parties losing fewer passengers, and their profits increasing. However, the magnitudes of the changes are quite small, because the higher presence carrier, which survives under the baseline assumption, will usually be the carrier with the highest quality, and our estimates imply that nonstop legacy carriers have very similar marginal costs, so choosing one rather than the other makes little difference. For example, we predict that the merged firm's prices increase by 11.2%, rather than 12.4% under the baseline assumption.

[40] When two connecting carriers merge, consumer surplus still falls because of the disappearance of a choice, but the drop is much smaller than for nonstop duopolies (average \$5 per pre-merger traveler, compared to \$67 for nonstop duopolists).

[41] Appendix A.3 provides a comparison of these 24 routes with routes where there were two other nonstop legacy carriers. We find that the nonstop duopolists tend to have smaller shares on the 24 routes, suggesting that there may have been less scope for the merged firm to exercise market power on the routes that we examine.

[42] These expansions are a prediction of the analyzes in BBCL and CMT, although neither present evidence that these expansions actually took place after consummated transactions.

[43] The equivalent numbers for the Delta/Northwest merger are 336 and 296, but with a declining trend before the merger, and for American/US Airways they are 291 and 302, with a slight upward trend before the merger.

[44] We measure consumer surplus per pre-merger traveler because the markets considered vary quite dramatically in size, and our definition of market size is imperfect.

7. Mergers counterfactuals with repositioning by rivals

■ We now analyze counterfactuals where we allow rivals to change their service choices after the merger. Our discussion of our assumptions and method will assume that we are considering markets where the merging carriers are nonstop duopolists, but we will also consider markets where there are additional nonstop rivals.

Assumption 2 (Merger Counterfactuals with Repositioning). We assume

1. the nonstop products owned by the merging parties are eliminated and replaced by a single nonstop product of the merged carrier ("Newco"). We consider two alternative assumptions:
   (a) ("baseline assumption") Newco has the quality and marginal cost of the merging party with the higher average endpoint presence before the merger .
   (b) ("best case assumption") Newco has the higher quality and the lower marginal cost of the merging parties.
2. the nesting and price parameters are equal to their expected values for each market given observed market characteristics and the baseline parameter estimates.
3. the nonmerging carriers have the same quality and cost draws for both types of service as they do before the merger, which should, therefore, be consistent with their pre-merger service choices. They choose their service type in the same sequential order as before the merger, knowing that Newco will be nonstop. We assume that no additional carriers, that do not provide some type of service in the data, can enter.

These assumptions follow the assumptions made in the fixed product case as closely as possible, except for allowing connecting rivals to reposition. One might ask why assuming that qualities and costs remain the same is a reasonable assumption for either type of merger simulation. An empirical justification is that, when we apply our estimated demand model to panel data on prices and market shares, the implied carrier demand and marginal cost unobservables are highly persistent, although we recognize that our assumption of perfect persistence is even stronger. Persistence is also consistent with our assumption that carriers will know the values of the unobservables.

We measure persistence by examining the correlation between unobservables using a regression where the implied demand or marginal cost unobservable in the second quarter of 2006 (our estimation period) is regressed on a constant and the carrier's unobservable in the second quarter of 2005. The unobservables are backed out using the expected values of the price and nesting coefficients in the demand system and the pricing first-order conditions, under the assumption that the same demand system is appropriate in both years. The serial correlation coefficient for demand unobservables for carriers that are nonstop in both quarters is 0.638 (standard error 0.016) for a specification without market fixed effects, and 1.013 (0.030) when we include market fixed effects to control for differences in the level of demand across markets. For connecting carriers, the average coefficients are lower (0.410 and 0.690, respectively). We also observe persistence for marginal cost unobservables. For nonstop carriers, the serial coefficients are 0.889 (standard error 0.014) and 0.802 (0.028) without and with market fixed effects, and 0.798 (0.008) and 0.419 (0.015) for connecting carriers.[45] Carriers' service choices are also highly persistent, consistent with persistence of demand, marginal cost, and fixed cost unobservables.[46] Of course,

[45] Smaller estimates for connecting carriers may reflect how the small DB1 samples make small market shares, and implied qualities and costs, quite volatile. If we use residuals from earlier years as instruments, to try to correct for measurement error, the coefficient estimates for both demand and marginal costs are between 0.9 and 1.25 for connecting carriers.

[46] We have identified all cases where the named carriers added nonstop service, other than through mergers, after Q1 2001 but before 2006, and then followed their service choices over subsequent quarters. On average, these carriers maintained nonstop service for 27 consecutive quarters.

persistence in service choices could also be explained by the addition of nonstop service requiring a large sunk cost, even if fixed costs and variable profits are not persistent. However, the existence of large sunk costs is inconsistent with the fact that carriers serve many smaller routes nonstop on a seasonal basis and the fact that they have responded to short-run demand spikes in 2020 by offering nonstop service temporarily on some routes.[47]

A possible objection is that unobservables should reflect aspects of quality that are chosen by carriers, and that, therefore, even if they persist for most observations, they would change in response to a change in market structure caused by a merger. We have therefore also repeated the analysis using the subset of markets where another carrier entered, exited, or changed its service type between 2005 and 2006. Our estimates of serial correlation, controlling for market fixed effects, change very little.[48] Therefore, while it is obviously possible for carriers to invest over time in improving their market-specific quality, treating the demand and marginal cost unobservables of the non-merging carriers as fixed appears a reasonable assumption for predicting the effects of a merger over a 1 to 2 year period.

We view the assumption that no other carriers can enter the route as more restrictive, and we will consider one analysis where we allow for an additional competitor. However, we view the assumption as being reasonable, given the computational costs of the alternative (see footnote 50), because, over the period from the first quarter of 2005 to the first quarter of 2008, 86.2% of carriers that began nonstop service on a route offered connecting service in the previous quarter, and, after mergers affecting nonstop carriers, three quarters of rivals that began nonstop service were previously connecting carriers.

Method: The simulation of conditional distributions. To calculate equilibrium post-merger service choices, we need to infer the qualities and costs that rival carriers would have if they changed their service choices (i.e., qualities and costs that are not observed in the data). We do this by forming "conditional distributions" of qualities, including the route-level demand effect, and costs which are consistent with both the estimates and pre-merger service choices.[49] The natural interpretation of the conditional distributions is that they are posteriors, with the estimated distributions treated as priors, with the conditioning being on the service choices, prices, and market shares observed in the data.

We form the conditional distributions using the following steps. We first specify a discrete set of possible values for the route-level demand effect. For each value, we calculate the qualities and marginal costs implied by observed prices and market shares for the chosen service types. We then take draws of the remaining random components of the model (carrier qualities and marginal costs for the nonchosen service types, and the fixed costs of nonstop service) from their estimated distributions and, for each set of draws, we keep (accept) those draws which would support the observed service choices as an equilibrium outcome. We weight the accepted draws using the estimated densities of the route-level demand effect and the implied carrier qualities and costs for chosen service types, to form the conditional joint distribution of the route-level demand effect, carrier qualities, marginal costs and fixed costs for all of the carriers in the market.[50]

We illustrate the effect of conditioning in Figure 2 for the Philadelphia (PHL)–San Francisco (SFO) route, one of the nonstop duopoly routes affected by the United/US Airways merger. The solid line in the left panel shows the estimated density of the route-level demand effect, and

[47] Wall Street Journal article, October 6, 2020, "How Are Legacy Airlines Surviving Covid-19? By Borrowing from the Low-Cost Playbook.'

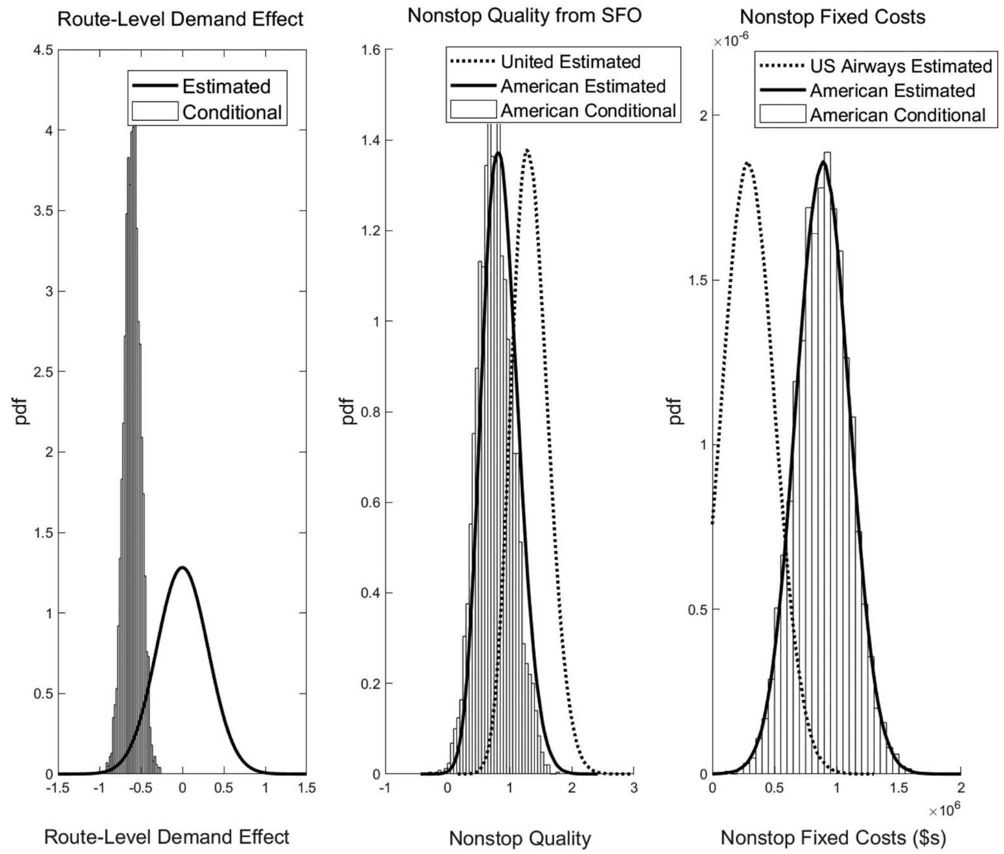
[48] For example, with fixed effect controls, the demand and marginal cost serial correlation coefficients for nonstop carriers are 0.899 (s.e. 0.047) and 0.826 (s.e. 0.049), respectively.

[49] We note that one could also choose to condition, for example, on the profitability of the merger, and to also form a conditional distribution for the merger synergy.

[50] The acceptance rate drops when more unobserved variables are added to the model or we add additional players. For example, if we considered a model where carriers choose between {do not enter, enter connecting, enter nonstop}, as in Li et al. (2015), we would have to calculate the conditional distribution of four qualities, two marginal costs, and two fixed costs for each carrier that does not enter.

FIGURE 2

SELECTION OF MARGINAL CONDITIONAL DISTRIBUTIONS FOR PHILADELPHIA-SAN FRANCISCO



Note: Left panel: solid line: estimated, histogram: conditional. Middle panel: dotted line: United estimated, solid line: American estimated, histogram: American conditional. Right panel: dotted line: US Airways estimated, solid line: American estimated, histogram: American conditional

the histogram shows the simulated marginal conditional density (50,000 simulation draws). The conditional distribution has a lower mean, reflecting the fact that the number of observed passengers, across all carriers, is relatively low (combined market share is 28.3%, averaged across directions) given market size and the observed covariates. As a comparison, the mean of the conditional distribution of the demand effect for Las Vegas–Miami, where combined market shares equal 42.5%, is 0.5.

Nonstop quality is the sum of a carrier's connecting quality and the incremental quality of nonstop service. The lines in the middle panel show the density of nonstop quality for passengers originating at SFO for United and American based on the estimates (i.e., not conditioning on what is observed). United's expected quality is higher, because of its high presence at SFO. The histogram shows the conditional density for American's nonstop quality. This distribution is similar, but with a slightly lower mean, than the distribution implied by the estimates. The intuition is that given observed shares and prices and the likely value of the random effect, we need to shift our expectation of American's nonstop quality down, by a small amount, to explain why it chooses connecting service. The posteriors for carrier quality would be identical to those implied by the estimates in a limited information model. The third panel shows the densities for the fixed cost of nonstop service for American and US Airways. US Airways has a lower expected

TABLE 8 Predicted Effects of United/US Airways Merger in Four Nonstop Duopoly Markets Allowing Repositioning by Rivals

Counterfactual	Pre-Merger United/US Airways Price	Exp. Number of Rivals Launching Nonstop Service American	Others	Post-Merger Merged Carrier Price	Change in Consumer Surplus
Baseline Merger Assumption					
1. Service types fixed	$531.97	—	—	$576.18	-$48.07
				(0.77)	(1.69)
Allow rival service changes					
Connecting rivals nonstop quality and costs drawn from:					
2. Conditional distns.	$531.97	0.035	0.063	$573.37	-$42.96
		(0.024)	(0.055)	(2.36)	(4.88)
3. Estimated distns.	$531.97	0.190	0.325	$559.56	-$16.22
		(0.062)	(0.106)	(5.08)	(11.22)
4. Average of merging parties	$531.97	0.678	1.915	$531.79	+$62.36
		(0.062)	(0.106)	(1.97)	(8.43)
Best Case Merger Assumption					
5. Service types fixed	$531.97	—	—	$562.82	-$37.76
				(0.94)	(1.77)
Allow rival service changes					
Connecting rivals nonstop quality and costs drawn from:					
6. Conditional distns.	$531.97	0.020	0.043	$560.73	-$33.80
		(0.015)	(0.042)	(1.96)	(4.00)

Note: Predictions with endogenous service choices are averages from 1000 draws from the appropriate distributions. Pre-merger prices are averages across the merging parties. Implementation of rows 3 and 4 explained in the text. Standard errors reported in parentheses.

effective fixed cost because of its domestic and international hubs at PHL. The estimated and conditional distributions for American's fixed costs look essentially identical.

We note that the step of forming conditional distributions of qualities and costs that are consistent with observed outcomes in the data, is an important difference between our counterfactual analysis and the one provided by CMT. CMT estimate a full information entry and price competition model, and then simulate market outcomes, and perform counterfactuals by implementing an American/US Airways merger using the simulated data, where all of the demand and cost draws are known to the researcher, including for carriers that do not enter. Their counterfactuals tell us what happens in simulated markets, not actual markets. Instead, we take the approach that an agency has to take when analyzing a proposed merger, where they need to predict what will happen in one or more actual markets, with known competitors and observed market shares, if a merger takes place. Our approach is also the only way to make sure that our predictions are consistent with those from a standard fixed product merger simulation, which predicts changes from observed (not simulated) prices and market shares.

Results.

Predicted effects of a United/US Airways merger. We start by presenting our results for the United/US Airways merger on four routes where the merging carriers were nonstop duopolists and American was a connecting competitor, so that we can connect our discussion to our calculation of conditional distributions for the Philadelphia–San Francisco route, and our discussion of the proposed service remedy where these are the affected routes.

The upper panel in Table 8 presents results under our baseline merger assumption. We expect the merged firm's prices to increase by 8.3% on these routes if service types are held fixed with a significant predicted decline in consumer surplus. Such predictions would usually lead an antitrust agency to challenge a merger unless offsetting synergies or repositioning are likely.

TABLE 9 Predictions for the Philadelphia–San Francisco Market Allowing Repositioning by Rivals Following a United/US Airways Merger

Carrier (Pre-Merger Service Type, Price and Share)	No Service Changes 3267/5000 Draws		American Nonstop 570/5000 Draws		Delta Nonstop 483/5000 Draws	
	Price	Share	Price	Share	Price	Share
US Airways/Newco	$691.53	15.4%	$661.67	14.1%	$661.46	14.0%
(NS, $649.74, 13.0%)	(1.17)	(0.0)	(0.66)	(0.1)	(1.64)	(0.1)
United	—	—	—	—	—	—
(NS, $613.54, 12.1%)						
American	$478.98	1.2%	$554.64	8.1%	$477.30	0.8%
(CON, $476.52, 0.5%)	(0.05)	(0.0)	(9.70)	(0.4)	(0.07)	(0.0)
Delta	$666.89	0.6%	$666.08	0.4%	$550.98	7.9%
(CON, $665.77, 0.3%)	(0.03)	(0.0)	(0.04)	(0.0)	(8.74)	(0.5)
Northwest	$307.35	3.5%	$302.51	2.4%	$302.47	2.4%
(CON, $300.60, 1.9%)	(0.18)	(0.0)	(0.23)	(0.1)	(0.23)	(0.1)
Other LCC	$377.27	1.1%	$375.82	0.7%	$375.80	0.7%
(CON, $375.27, 0.6%)	(0.06)	(0.0)	(0.07)	(0.0)	(0.07)	(0.0)

Note: Predictions are averages from 5000 draws from the conditional distributions. Standard errors in parentheses based on the same bootstrap estimates used for the parameter estimates. The merger assumed to eliminate United (lower presence carrier). NS denotes nonstop and CON denotes connecting pre-merger.

The second row reports our predictions when we allow rivals' service types to change after the merger, using 1000 draws from the conditional distributions for each market. The expected number of rivals initiating nonstop service, a measure of the likelihood of repositioning, is small, leading to the result that, in expectation, the merged carrier's price increases by $41 (7.8%). We also find that the merger is, on average, profitable for the merging firm despite the repositioning that takes place, with its profits increasing by an average of $279k (standard error $78k) per route. We will return to rows 3 and 4 below.

The lower panel (rows 5 and 6) report the results under the best case assumption. As Newco now tends to have slightly lower marginal costs, the predicted price increase is smaller, but there is also less repositioning by rivals. The merger now appears to be much more profitable, raising profits by an average of $1.1m (standard error $85k) per route.

To understand the predictions for the baseline assumption, Table 9 provides more detail for the PHL–SFO route. On this route, United, the lower average presence carrier that is assumed to be eliminated by the merger, has a particularly large share, so that the merger potentially creates a significant opportunity for a connecting carrier that launches nonstop service. The results in the table use 5000 draws so we can measure the probability of different outcomes accurately.

For two thirds of the draws, no connecting rival launches nonstop service, and the merged carrier's price increases by 9.5% (from the pre-merger average) and its market share falls by 38%. The nonmerging carriers, with small connecting shares pre-merger, increase their prices slightly and double their combined market share. Reflecting the loss of a large carrier, consumer surplus falls by an average of $72.91 per pre-merger traveler.

The remaining columns show what happens when one of American or Delta launch nonstop service, which are the most common outcomes involving repositioning (for 0.9% of draws more than one rival launches nonstop service). The increased competition reduces (but does not eliminate) the equilibrium price increase for US Airways, and the new nonstop carrier usually has a market share that is significantly smaller than United's prior to the merger, causing consumer surplus to fall by around $30 per pre-merger traveler in both cases. Repositioning by rivals, when it happens, does tend to make the merger unprofitable for this route: for example, the merged firm's profits fall by $920k when American becomes nonstop.[51]

This route provides an example where there can be multiple equilibrium outcomes in the counterfactuals depending on timing assumptions about service choices. For example, there are 27 (out of 5000) draws where either American launching nonstop service or Delta launching nonstop service (but not both) are equilibrium outcomes. However, the different outcomes typically have very similar welfare implications. For example, the average within-draw-across-outcome standard deviation in the predicted US Airways price is $3.

Predicted effects using alternative assumptions about rival qualities. Rows 3 and 4 of the upper panel of Table 8 show what happens if we make assumptions about rivals' qualities and costs that may not be consistent with their pre-merger service choices. We make the baseline assumptions about the merger.[52]

Row 3 uses new draws from the estimated (i.e., not conditional) cost and incremental nonstop quality distributions for the nonstop qualities and costs of the connecting carriers. We therefore account for differences in the observed characteristics of the connecting carriers, but do not account for the additional information in pre-merger service choices. Row 4 assumes that if any connecting rival becomes nonstop then it would have the average quality and marginal costs of the merging nonstop carriers and draw its fixed cost from a distribution that has a mean equal to the average of the means for the merging carriers. This approach ignores observable differences between carriers.[53] In both cases, we continue to draw the route-level demand effect from its conditional distribution and we use the qualities and marginal costs for observed service types that are implied by observed prices and market shares, so that we can isolate the effects that arise from making alternative assumptions about how competitive connecting rivals will be if they launch nonstop service.[54]

Compared to our preferred results using the conditional distributions, the estimated distributions imply it is more likely that rivals will launch nonstop service (the expected number of nonstop launches is 0.52, rather than 0.1), leading to a smaller expected price increase, and a smaller, statistically insignificant, decrease in consumer surplus of $16.22 per pre-merger traveler (standard error $11.22). These results also imply that the merger is likely to be unprofitable: average profits fall by $105k (standard error $150k), compared to the $279k (standard error $78k) increase using the conditional distributions.

Assuming that connecting carriers can offer nonstop service on similar terms to the merging parties leads to a prediction that, on average, 2.6 of them would launch nonstop service[55] and that, because consumers prefer nonstop service, consumer surplus is predicted to increase after the merger. However, if we use the same assumption to solve for equilibrium outcomes *before the merger*, we often predict that several connecting carriers should have chosen to offer nonstop service (e.g., American's probability of launching nonstop service would be 0.6 pre-merger), which is inconsistent with the observed data. This illustrates the importance of considering whether assumptions about the post-merger competitiveness of repositioning firms, or new entrants, are consistent with their pre-merger choices.

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[51] Using the best case assumption, there is no repositioning for 78% of draws (rather than 65%), US Airways' price increases by an average of 4.3% (rather than 6.4%) when there is no repositioning and the merger is only marginally unprofitable when repositioning occurs.

[52] The results are similar if we make the best case assumption about the merger: for example, the expected number of carriers launching nonstop service are 0.46 (row 3) and 2.4 (row 4), rather than 0.52 and 2.6.

[53] One might view this approach as reflecting the District Court's approach in *United States v. Waste Management, Inc*. (743 F.2d 976, 978, 983–984, 2nd Cir. 1984) where it held that it was sufficient to consider only whether potential entrants would face higher entry barriers than the merging parties.

[54] A rationale for using the conditional distribution of the route-level demand effect is that we include this component of the model to address the fact that our market size measure may be imperfect. The parties and the agencies would likely be able to construct a better measure in a merger investigation.

[55] If we assumed that connecting carriers would be similar to the eliminated carrier, rather than the average of the merging carriers, we would expect 1.5 of them to launch nonstop service.

TABLE 10 Predicted Price and Service Changes for Subsequent Completed Mergers on Routes where Merging Parties Are Nonstop Duopolists (Baseline Assumption)

	Delta/Northwest		United/Continental		American/US Airways		Average for Completed Mergers	
	Price	Exp. Numb. New Nonstop	Price	Exp. Numb. New Nonstop	Price	Exp. Numb. New Nonstop	Price	Exp. Numb. New Nonstop
Pre-merger	$566.39	—	$503.75	—	$459.13	—	$482.25	—
Post-merger								
Service types Fixed	$593.20	—	$556.17	—	$521.15	—	$537.86	—
Allow Rival Service Changes								
Connecting rivals nonstop quality and costs drawn from:								
Conditional distributions	$590.34	0.07	$547.65	0.14	$511.33	0.21	$529.17	0.18
Estimated distributions	$584.20	0.19	$534.08	0.35	$488.45	0.73	$510.45	0.57
Average of merging parties	$573.83	0.93	$454.36	2.62	$460.25	2.10	$472.23	2.08
Number of routes	2		4		11		17	

Predicted effects of completed legacy mergers on nonstop duopoly routes. The upper panel of Table 10 summarizes our baseline merger assumption predictions for repositioning and post-merger prices for the 17 nonstop duopoly routes affected by the consummated mergers, under our different assumptions about the nonstop quality and costs of connecting carriers.

The qualitative patterns are very similar to Table 8, although magnitudes vary across mergers reflecting differences in conditions across routes. When we use our preferred conditional distributions, we expect 0.18 rivals to launch nonstop service on each affected route, and the merged carriers' prices are predicted to increase by an average of just under 10%, which is only 2 percentage points smaller than if service types are held fixed. Using the estimated distributions we predict more than three times as much repositioning by rivals and smaller, although still economically significant, price increases.[56] If we assume that connecting carriers could provide nonstop service with similar quality and costs to the merging parties, we predict that, on average, the mergers would have no anticompetitive effects.

Comparing predictions to what happened after legacy mergers on nonstop duopoly routes. It is natural to compare these predicted changes to what we observe actually happening after these mergers, albeit with the caveat that market conditions may have changed between 2006, the year of our analysis, and the year that the mergers were consummated.

Appendix A.4 uses panel data to estimate what happened to rivals' service choices, and the prices and shares of the merging carriers after the three completed legacy mergers, comparing routes where the parties were nonstop duopolists prior to the merger, with routes where only one of the merging carriers had a significant market share.[57] We summarize the findings here. On the nonstop duopoly routes, the merged carrier always maintained nonstop service. Within 2 years of the merger closing (the Department of Transportation explicitly used 2 years when considering repositioning (Keyes, 1987), a rival launched nonstop service on no routes, out of five, for Delta/Northwest, one route, out of five, for United/Continental and three routes, out of six, for American/US Airways.[58] There were two additional nonstop launches in the third year following these mergers. The Appendix also presents analyses of changes in the prices and market shares of the merging firms on routes where the merging firms were nonstop duopolists for 3 years before the merger, using a comparison set of routes where one of the parties was nonstop

[56] Under the best case merger assumption, we predict two-and-a-half times as much repositioning using the estimated distributions, so that the comparisons we make below to repositioning in the data still hold.

[57] Estimated changes may be affected by the choice of control group or time window, as illustrated by the contrasting price effects found by Hüschelrath and Müller (2015) and Carlton et al. (2017) after recent mergers. Ultimately any control group is likely to be imperfect when analyzing a network industry.

[58] There is no overlap in the routes across these mergers.

and the other was either absent or a connecting carrier with a small share. On routes where no rivals initiated nonstop service, we find that the merged carrier increased its prices by an average of 10%, with its number of local passengers (i.e., those only flying the route itself) falling by almost 30%. On routes where rival nonstop service was launched, the merged carriers' prices did not rise, although they did lose market share, presumably reflecting the new competition. These patterns suggest that rivals tend not to launch nonstop service because they would not be competitive, rather than because the merged carrier enjoys large synergies.

These patterns are broadly consistent with the predictions of our model when we use draws from the conditional distributions of qualities and costs for the rival carriers. In particular, our analysis predicts that, on average, 0.18 rival carriers will initiate nonstop service, compared with 0.25 in the data, and that prices will increase by around 12% when there is no repositioning, compared with 11% in the data. It is also the case that we observe the most nonstop launches after the American/US Airways merger, consistent with our prediction. Our predictions of changes in merging carrier market shares when there is no repositioning are also close to the data. Although the numbers of mergers and routes are too small to claim that the close match proves that our approach is correct, we view the match as at least encouraging. It stands in contrast to the conclusion of Peters (2006) that fixed product merger simulations poorly predict outcome changes after airline mergers.

Predictions for markets with additional nonstop rivals pre-merger. Merger simulations with fixed products also indicate that prices would rise significantly on routes where the merging parties are nonstop but have at least one nonstop rival (there is one route with two nonstop rivals). Table 11 presents our predictions for these routes. When we simulate counterfactuals allowing for repositioning, we assume that the merged firm will be nonstop and make the same assumptions about connecting rivals that we made for nonstop duopoly routes. However, we also now endogenize the service choice of the nonstop rival(s). The nonstop quality and marginal costs of this type of carrier are observed, but we need to make assumptions about the quality and marginal costs of its connecting service, and its fixed costs of providing nonstop service.

When we use conditional distributions, we predict that the nonstop rival(s) will always continue to provide nonstop service and that connecting carriers will rarely introduce nonstop service. As a result, predicted price changes are almost identical to those where service types are assumed fixed. This is consistent with our earlier results. However, differences to our earlier results emerge for the other assumptions, because it becomes likely that the nonstop rival, which is usually quite an effective nonstop competitor, may cease nonstop service and this type of repositioning can lead to price increases. For example, a nonstop rival ceases nonstop service for around one-third of simulations in the results reported in the final ("Average of Merging Parties") row of the table. As a result, we now predict significant price increases under all three approaches, and the largest predicted prices increases and the greatest probability of post-merger nonstop monopoly are when we use the estimated distributions. Therefore, although the intuition that the conditional distributions will tend to predict the largest price increases when nonstop duopolists merge is fairly clear, there are additional nuances for other market structures that are relevant for merger analysis.

8. Performance of alternative remedies

■ Remedies are often negotiated when only a small part of a transaction is likely to have anticompetitive effects. The agencies have a well-known preference for structural remedies, such as divestitures, but, in some circumstances, they also accept behavioral remedies or remedies that involve some ongoing relationship between the merging firm and third parties.[59] We use our

[59] See September 2020 Department of Justice "Merger Remedies Manual" (https://www.justice.gov/atr/page/file/1312416/download, accessed November 11, 2020).

TABLE 11 Predicted Price and Service Changes where Merging Parties and at Least One Rival Are Nonstop

	Delta/Northwest		United/Continental		American/US Airways		United/US Airways		Average	
	Price	Δ in # Of NS Rivals	Price	Δ in # Of NS Rivals	Price	Δ in # Of NS Rivals	Price	Δ in # Of NS Rivals	Price	Δ in # Of NS Rivals
Pre-merger	$351.26	—	$438.08	—	$363.11	—	$350.02	—	$377.51	—
Post-merger										
Service types fixed	$382.04	—	$464.98	—	$404.84	—	$378.15	—	$412.27	—
Allow Rival Service Changes										
Connecting rivals nonstop quality and costs drawn from:										
Conditional distributions	$378.90	0.16	$464.86	0.01	$404.41	0.03	$377.24	0.06	$411.07	0.06
Estimated distributions	$386.40	−0.51	$466.18	−0.03	$403.55	−0.27	$375.17	−0.11	$413.33	−0.28
Average of merging parties	$374.37	−0.35	$455.64	0.54	$398.85	−0.03	$367.68	0.48	$404.95	0.24
Number of routes	2		4		10		10		26	

Note: See notes to Table 8. All predictions make the baseline merger assumption and, when service types are endogenous, use 1000 draws from the relevant distribution. Standard errors not reported. In the case where we assume that connecting rivals would have the same nonstop quality as the merging nonstop parties, we use the observed nonstop quality and marginal costs for the nonstop rival(s), and draw its (their) connecting qualities and marginal costs, and fixed costs, from the estimated distributions.

TABLE 12 Predicted Effects of the American Service Remedy in United/US Airways Merger

Service Change Considered	Pre-Merger United/US Airways Price	Expected Number of Rivals Launching Nonstop Service: American	Expected Number of Rivals Launching Nonstop Service: Other Rivals	Post-Merger Merged Carrier Price	Change in Consumer Surplus
No Remedy					
1. Service types fixed	\$531.97	—	—	\$577.72	-\$48.07
2. Allow rival service changes (condit. distns.)	\$531.97	0.035	0.063	\$573.37	-\$42.96
American Nonstop Remedy					
3. Allow rival service changes (condit. distns.)	\$531.97	1	0.030	\$566.34	-\$31.29

Note: See notes to Table 8. The merger is assumed to eliminate the party with the lowest presence on the route. Consumer surplus changes measured per pre-merger traveler. For American, the expected number of rivals launching nonstop service is the probability that American launches nonstop service. Standard errors are not reported.

model to consider, in a stylized way, the effectiveness of two different types of remedies that have been proposed or used in airline mergers.

The service remedy proposed in the United/US Airways merger. The results presented so far suggest that when rivals launch nonstop service, the merged carrier can only increase prices by a small amount. This might be interpreted as implying that the remedy proposed in the United/US Airways merger, where American would guarantee to initiate nonstop service on routes where the parties were nonstop duopolists (see footnote), so that the number of nonstop carriers would not have changed, would have been effective. However, this logic implicitly assumes that American's nonstop service would constrain the merged carrier's prices even when it is unprofitable.[60]

The first two rows of Table 12 repeat the results from Table 8 for the four routes where United and US Airways were nonstop and American was a connecting competitor. The third row repeats the analysis under the remedy so that, whatever its draws from the conditional distribution, American is nonstop and other carriers then make their service choices taking this into account. We see that the effect of the remedy on expected post-merger prices is small. The insignificance of American as a nonstop competitor when its nonstop service is not profitable is also illustrated by how other rival carriers' service decisions are largely unaffected by the remedy.

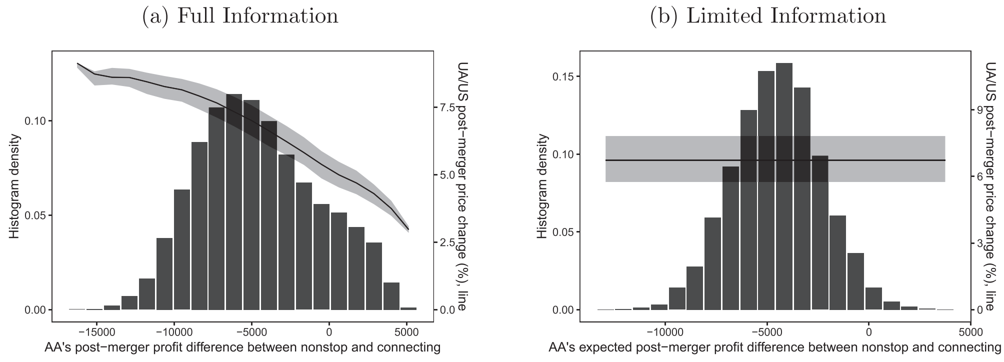
Figure 3a provides additional insight into what happens. The histogram shows the distribution of the difference between nonstop and connecting profits for American on the PHL–SFO route. For simplicity, we draw the figure assuming that American knows no other connecting carriers will launch nonstop service. The line on the figure shows the median simulated post-merger price increase for US Airways (relative to the average of United's and US Airways' pre-merger prices) when we force American to provide nonstop service given this level of profitability (the shaded area indicates the interquartile range generated by our simulations). There is a monotonic relationship between American's profitability and its effectiveness at reducing increases in the US Airways' prices, and there is only a significant constraining effect on those prices when nonstop service is at least close to being profitable for American.

To illustrate the effects of our assumption that demand and cost shocks are known when making service choices ("full information"), Figure 3b shows the same figure assuming that American has no information about its quality or marginal cost unobservables when making its service choice (for comparability, we assume American does know its fixed costs and the qualities and costs of other carriers). The variance of the (expected) profit distribution is reduced, as it now reflects only the distribution of fixed costs. As fixed costs will not affect the prices that carriers set, there is no link between the level of profit that American expects when it launches nonstop service and how much this will constrain the market power of the merging carriers.

[60] The parties did not claim that nonstop service on the affected routes would be profitable for American: instead the attraction for American was that it would receive a package of assets on the East Coast if the merger was completed.

FIGURE 3

DISTRIBUTION OF AMERICAN INCREMENTAL PROFITS (IN $00S) FROM NONSTOP SERVICE ON PHL-SFO AND THE PREDICTED INCREASE IN THE MERGED CARRIER'S PRICE IF AMERICAN LAUNCHES NONSTOP SERVICE (RELATIVE TO PRE-MERGER AVERAGE PRICES) GIVEN AMERICAN'S PROFITABILITY UNDER ALTERNATIVE ASSUMPTIONS ABOUT WHAT AMERICAN KNOWS ABOUT ITS NONSTOP QUALITY AND MARGINAL COST. THE GREY AREA MARKS THE INTERQUARTILE RANGE OF PRICE OUTCOMES.



The effect of adding an additional low-cost competitor. We consider the effects of introducing an additional low-cost competitor as an alternative remedy. The Department of Justice allowed the United/Continental and American/US Airways mergers to proceed when the parties agreed to divest slots and gates to LCCs at major airports.[61] The aim of these divestitures was to increase competition at the affected airports. Although our model does not formally include slots, we can use it to ask the question of whether the addition of a LCC as a competitor would offset the anticompetitive effects of a merger.[62] As the new carrier was not on the route prior the merger, we assume that its quality and cost draws are not selected (i.e., they are new draws from the estimated distributions), and that it takes on the observed characteristics of the average "Other LCC" carrier in the data. We then repeat our conditional distribution counterfactuals for routes where the merging parties were nonstop duopolists, assuming that the new carrier is last in the sequential order.

Table 13 compares the predictions of price and the number of new nonstop carriers (in total) when we add the new competitor to our baseline predictions for the nonstop duopoly routes. The pattern in the results varies across the mergers, reflecting differences in market structure. For example, on the two routes where the merged firms are the only competitors, adding the new carrier has a significant pro-competitive effect. However, the addition of a new rival, by reducing profitability of the remaining carriers, can actually lead to fewer carriers initiating nonstop service than in the baseline. Averaging across the 24 routes, the remedy reduces, but does not eliminate, the expected post-merger price increase (the average increase is 5% rather than 11%).

For the four United/US Airways routes where American offers connecting service, we can compare the effectiveness of the two remedies. We see that they are roughly equally effective in the sense that the expected post-merger prices are similar ($564.66 with an additional LCC competitor compared to $566.34 with the service remedy). We also investigated what would happen if the additional LCC is a stronger competitor, by increasing the assumed presence of the new carrier from 0.17 to 0.5 (which would be equivalent to the new carrier establishing

[61] The settlement in the American/US Airways case also required divestitures of slots at Washington Reagan and New York LaGuardia, and of ground facilities at seven airports. The settlement in United/Continental required divestitures at Newark.

[62] Our stylized analysis will miss the fact that the additional LCC and the merging parties will need to choose how to allocate their scarce slots across routes. Park (2020) explicitly includes this type of slot allocation decision for a single carrier at a single airport.

TABLE 13 Predicted Effects of a Remedy When an Additional Other Low-Cost Carrier is Added as a Competitor on Nonstop Duopoly Routes

		Post-Merger Predictions with Repositioning			
	Pre-Merger	Pre-Merger Rivals		Pre-Merger Rivals + Addn. LCC	
Merger	Price	Exp. New NS	Price	Exp. New NS	Price
Delta/Northwest (2 routes)	$ 566.39	0.07	$590.34	0.05	$556.69
United/Continental (4 routes)	$503.75	0.14	$547.65	0.14	$530.03
American/US Airways (11 routes)	$459.13	0.21	$511.33	0.25	$492.24
All United/US Airways (7 routes)	$479.32	0.08	$546.74	0.32	$496.18
United/US Airways with AA connecting (4 routes)	$531.97	0.10	$573.37	0.14	$564.66
Average (24 routes)	$481.40	0.15	$ 534.30	0.24	$505.03

Note: See notes to Table 8. The additional LCC carrier receives unconditional draws from the estimated distributions, has the characteristics of the average "Other LCC" carrier (e.g., presence 0.17 at both endpoints), and is assumed to make its service choice last in the sequential move order. The merger is assumed to eliminate the party with the lowest presence on the route. Standard errors are not reported.

some type of focus airport presence at both endpoints). In this case, the new carrier is more likely to add nonstop service, and the merged carrier's expected price increase is smaller, but still economically significant. For example, on the four United/US Airways routes where American was a competitor the expected post-merger price is $557.70. Therefore, we conclude that neither remedy is necessarily effective at preventing anticompetitive harm from the merger on nonstop duopoly routes, although it is plausible that a remedy that introduces more competition to an airport would be preferred because of the potential benefits that it would bring to other routes.

9. Conclusions

■ We have developed a model of endogenous service choices and price competition in airline markets, assuming that carriers have full information about demand and marginal costs when they make their service choices. In this framework, carriers will tend to choose the service type in which they are most competitive, and this naturally has implications for how likely they will be to change their service types in response to a change in their competitive environment, such as when two rivals merge. Although it will not be the right assumption for all industries or all counterfactuals, we believe the full information assumption is the natural one to use when trying to predict product repositioning by experienced market participants in an environment where demand and marginal cost unobservables are persistent, and when trying to understand whether repositioning will sustainably limit market power after a merger.

We make two contributions. First, we show how a full information model can be estimated without an excessive computational burden. This is a significant result for the academic literature, as researchers have often chosen to estimate models where firms do not have any information on the realization of demand and marginal cost shocks when entry or positioning decisions are made in order to avoid the computational burden that is perceived to be involved with estimating discrete entry/positioning choice and pricing games simultaneously.

Our second, and more important, contribution comes from performing a set of counterfactuals which try to systematically assess the likelihood and sufficiency of repositioning, consistent with the *Horizontal Merger Guidelines*. We show how to account for the selection on unobserved demand and marginal cost shocks that is implied by assuming that the observed data comes from equilibrium play prior to the merger, and we find that doing so is important. When we take selection into account we predict that rivals are much less likely to launch nonstop service when nonstop duopolists merge, and we predict larger average price increases and significant decreases in consumer surplus. We find that our predictions are consistent with what has been observed after actual airline mergers only when we account for selection. These results are important both for academic research, where we are not aware of this type of conditioning being used previously, and for the analysis of mergers at antitrust agencies, where it is common to perform merger simulations and other counterfactuals, even when parameters come from documents, expert testimony, or simple calibrations rather being econometrically estimated.

As we have tried to make clear, many of our assumptions are strong and it would be valuable to investigate how relaxing them would affect the predictions of the model and our ability to explain what happens after mergers. One direction would be to allow for additional unobservables that are private information, as well as unobservables that are known to all firms throughout the game. Another important direction would be to include dynamics that would allow unobservables to evolve over time, possibly due to endogenous investments, while relaxing the usual assumption of dynamic models that unobservables are independent across periods.

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Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Figure A.1: Proportion of DB1 Passengers Traveling with Connections, Based on the Type of Service
Table A.1: Market Size Measures and the Number of Nonstop Carriers
Table A.2: Domestic and International Hubs for Each Named Carrier
Table A.3: Estimation Coefficients for Ancillary Model of Connecting Traffic
Table A.4: Characteristics of the Nonstop Duopoly Routes