Competitive Effects of Constraints on Quality: Evidence from the U.S. Airline Industry*

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Abstract

Regulations often impose quality restrictions on firms, which in turn can influence prices and welfare in a theoretically ambiguous manner. To study such quality restrictions, we investigate the Wright Amendment by analyzing its full repeal in 2014 as a natural experiment in order. The Wright Amendment constrained airlines to offer only connected flights on many routes out of Dallas Love Field Airport. Given Southwest was the only airline serving those routes using Dallas Love Field, we interpret the Wright Amendment as imposing quality restrictions on Southwest. Using a difference-in-differences methodology, we find that prices of all airlines' tickets in the affected routes were higher when Southwest's quality was constrained. In order to decompose this price effect of quality restrictions, we then build a structural model, in which firms choose prices and product quality, measured by the level of nonstop service. We find that Southwest's markup in the affected markets was higher when it was constrained by the Wright Amendment because its demand was less price elastic. For Southwest's competitors, the increase in prices was largely a result of higher marginal cost, as their markups did not increase.

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I Introduction

How would regulatory constraints on one firm's product quality affect the firm's competitive behavior? On the one hand, its production decisions would be sub-optimal under the regulation. But the firm would also be forced to differentiate from its competitors in the affected markets. The constraints' net effect on the firm is therefore not clear. Our goal in this paper is to learn the effect of such a regulation on firms' strategic decisions and therefore their incentives to lobby for or against a regulatory change. We also are interested in the effect of this kind of regulation on consumer welfare. Nevertheless, there are few instances in which the regulatory changes can be used to study the question.

In this paper, we analyze such a rare case. We study the effects of the full repeal of the Wright Amendment on the US airline industry in 2014. We investigate how the quality constraint on Southwest Airlines that resulted from the Wright Amendment affected the market outcomes. The 1979 Wright Amendment to the 1958 Federal Aviation Act restricted airline service out of the Dallas Love Field airport in order to stimulate the growth of the relatively new Dallas/Fort Worth airport. Specifically, the only nonstop flights that airlines could offer to passengers departing from Dallas Love Field would be to destinations in eight states: Texas, Louisiana, Arkansas, Oklahoma, New Mexico, Alabama, Kansas, and Mississippi. If a passenger wanted to travel beyond "the Wright zone" (i.e., beyond any of those eight states) from Dallas Love Field, the restriction would have obliged her to stop at another airport in the Wright zone before continuing beyond it. The Wright Amendment predominantly affected Southwest Airlines, the only large airline serving the Dallas area from Dallas Love Field. Consequently, the product quality of Southwest was constrained by the Wright Amendment. The Wright Amendment was fully repealed in October 2014.[1] Southwest has since been pro-

[1] In 2006, the Wright Amendment was partially repealed. After the partial repeal, Southwest had additional ticketing options. Nevertheless, the restriction on nonstop services was not lifted

vided nonstop flights from Dallas Love Field to various destinations outside of the Wright zone. Thus, Southwest was restricted from providing nonstop flights in many markets between 1979 and 2014, and was free of this restriction after 2014.

We investigate how the prices and product quality of airlines were affected by the constraints imposed by the Wright Amendment, using data on airline tickets from the Origin and Destination Survey (DB1B) and Air Carrier Statistics (T-100). We compare the changes in the prices and product quality of all airlines in the markets restricted by the Wright Amendment to the changes in other similar markets. We find that the three larger airlines, namely American Airlines, Delta Airlines, and United Airlines, had higher prices when their competitor, Southwest Airlines, was restricted by the Wright Amendment in the way described above. Southwest also had a higher price when its product quality decisions were constrained by the Wright Amendment. We also find that United increased its product quality while smaller airlines other than the four largest ones decreased their product quality in response to the quality constraints on Southwest between 1979 and 2014.

In addition, in order to understand the underlying mechanisms of the competitive effects, we build a structural model in which firms are choosing price and product quality, where quality refers to nonstop service provision and is measured by the fraction of passengers taking nonstop flights. We use a semiparametric censored regression model to analyze the cost structure of the markets, and employ a pairwise difference estimator to fit the model. An airline may choose not to offer nonstop services on a given route, so its choice of the fraction of nonstop services can be a boundary solution. Our model and estimation method address this issue of boundary solutions. In addition, we do not need parametric assumptions about either the distributions of the error terms or the equilibrium selection rule. Our structural analysis shows that Southwest had a higher markup when

in the affected routes.

its product quality was constrained. Under the Wright Amendment, Southwest served the consumers who were less sensitive to product quality, and therefore conceded the more elastic segment of the market to its competitors. As a result, Southwest earned a higher markup under relatively inelastic demand when the Wright Amendment was effective. In contrast, Southwest's competitors did not increase their markups when the Wright Amendment constrained the product quality choice of Southwest. Instead, the quality constraints on Southwest were associated with changes in the marginal costs of its competitors. In addition, we also calculated the changes in consumer welfare. We explicitly model the composition of consumers in our demand model, and we calculate separately the welfare loss of business and leisure travelers. According to our calculations, the Wright Amendment did not damage business travelers but damaged leisure travelers.

The repeal of the Wright Amendment provided an exogenous shift in Southwest's choice set regarding product quality. Our paper provides unique empirical evidence about how firms interact with each other when they make quality decisions, and contributes to the empirical literature on product quality decisions. There are many papers about product quality. Papers such as Mazzeo (2002), Seim (2006), and Gentzkow and Shapiro (2010) study product quality decisions in the hotel, video retailing, and newspaper industries respectively. All of them build structural models to study how demand drives product differentiation in those industries. Matsa (2011) studies the supermarket industry with a structural model, and finds that the entry of Walmart provided incentives for its competitors to increase product quality. For product quality in the airline industry, Greenfield (2014) studies how competition affects the ontime performance of airlines, and Li et al. (2018) estimate a structural model to analyze how an airline merger would affect nonstop services. The literature to date has focused on how product quality decisions are affected by various factors, but no study has yet been conducted on how an exogenous regulatory change in product quality would affect market outcomes and firms' responses.

Our discussion about airline regulation also fits into the literature about structural models of the airline industry. We provide ex-post analysis on the effect of the Wright Amendment, using its full repeal in 2015, and we propose a method to point estimate structural parameters without parametric assumptions on the error term distribution or the equilibrium selection rule. The Wright Amendment has also been studied by Ciliberto and Tamer (2009), who investigated the counterfactual effect of the Wright Amendment using an entry game and the moment inequality method. They predicted that, among markets affected by the restrictions on flights originating from Dallas Love Field, 64 percent would receive nonstop services. In addition, they predicted that American, Delta, and Southwest would each provide nonstop services in less than 50 percent of the markets. The prediction differs from what we observed in the data. Southwest offered nonstop services only in markets where American had operated after the repeal in 2014. Ciliberto and Tamer (2009) did not address how the repeal of the Wright Amendment affected the pricing decisions of the airlines. Their model was extended in Ciliberto, Murry, and Tamer (2016) to integrate pricing decisions into the entry game to conduct a counterfactual merger analysis. Both papers used moment inequalities to avoid assumptions on equilibrium selection, but the moment inequality approach is sometimes inadequate to point identify all parameters in the model, which are used in welfare calculation. In our paper, equilibrium selection rules are not assumed, but parameters are point identified.

Our paper also relates to two other strands of the airline literature. First, Berry, Carnall, and Spiller (2006) and Berry and Jia (2010) build structural models with random coefficient logit models to estimate marginal costs and markups in the airline industry. Both papers employ demand models of the airline industry in the spirit of Berry, Levinsohn, and Pakes (1995). Neither paper models the airlines' choices on provision of nonstop flights. We model airline demand a similar way. Second, Li et al. (2018) structurally model the airline industry, and conduct a merger analysis with the estimated model. They assume an airline's choice on nonstop flight is discrete so an airline provides either all nonstop flights or all connected flights in a given market. They model the effect of this choice on consumers as an upgrade in product quality. To estimate their model, Li et al. (2018) make parametric assumptions on the error terms in airlines' costs and use the maximum simulated likelihood method. This approach requires an additional assumption on the equilibrium selection rule. Our paper also treats the decision on providing nonstop service as a product quality decision; this follows the view of Li et al. (2018) on nonstop services. However, we model the product quality decision as a bounded continuous variable to relax the assumptions on both the error terms and the equilibrium selection rule.

Our analysis is an application of the pairwise difference estimator, an estimator for the semiparametric censored regression model. The only other industrial organization paper we are aware of that employs the pairwise difference estimator is Hong and Shum (2010), which uses the method to estimate a dynamic structural model of the milk-quota trading market in Ontario. Our paper is the first to employ the methodology to estimate oligopoly games. Oligopoly games in which firms chooses prices are standard models in empirical industrial organization. The estimation of those models usually utilizes the first order conditions of the pricing equations to form moments or likelihood functions. However, the first order condition does not hold at the boundary of the players' choice sets, and the responses of the players are truncated at the boundary. Techniques for the semiparametric estimation of censored dependent variable models are therefore applied in our analysis. Moreover, we do not observe the values of the censored variable as in the standard model in the literature, so modifications are necessary.

Our paper also relates to the econometrics literature on the estimation of a censored or truncated dependent variable model. Several methods are proposed to estimate censored models, including likelihood-based estimators in Amemiya (1973), the least absolute deviation estimator in Powell (1984), the symmetrically trimmed least square estimator in Powell (1986), and the pairwise difference estimator in Honoré and Powell (1994) and Honore and Hu (2004). Likelihood-based methods impose parametric assumptions on the error distributions that can be hard to justify, and they are in general inconsistent when the assumed parametric form of the likelihood function is incorrect (Arabmazar and Schmidt (1982)) or the error terms are heteroskedastic (Arabmazar and Schmidt (1981)). The least absolute deviation estimator requires minimizing an objective function that is not differentiable at many points, and is thus too expensive computationally for our problem. The symmetrically trimmed least square estimator is straightforward to implement in the standard censored model, but is hard to adapt to our case due to the endogeneity of firms' decisions. We therefore estimate our model using the pairwise difference estimator and form moment conditions in ways that are similar to Honore and Hu (2004).

We introduce our data set in Section II. We conduct a reduced-form analysis in Section III to analyze how firms responded to the quality constraints on Southwest before the repeal of the Wright Amendment in 2014. We introduce our model in Section IV, and present our estimation method in Section V. The results of demand estimation are presented in Section VI, and those of the cost estimations are in Section VII. Section VIII presents our conclusion.

II Data and Market Definition

We use data from four publicly available data sources. First, we use the Airline Origin and Destination Survey (DB1B) to recover prices and some product characteristic information. DB1B is a quarterly 10 percent sample of all tickets sold by all reporting carriers; it includes information about the origin, destination, route, fare class, distances traveled, nonstop distance, and fare paid. The route information about the ticket contains not only the number of stops, but also the specific airports for the stops. We focus on economy class tickets and discard (1) tickets whose price is less than $10 or above the 95th percentile of all tickets sold, (2) tickets involving multiple carriers, and (3) tickets whose prices are marked as noncredible in the data validation process. The DB1B has one shortcoming: it records stops in an itinerary according to its flight numbers. Sometimes an airline uses a single flight number for a flight with multiple nonstop segments (hereafter direct flight with stops), and the DB1B alone cannot distinguish those flights from nonstop flights. We correct for this shortcoming through our use of the second data source.

Second, we use the T-100 Domestic Segment data set for capacity information. The T-100 data set provides details on the nonstop flights between two particular airports. It includes monthly reports on the carrier, origin, destination, departures performed/scheduled, total number of seats available, total number of passengers on the plane, aircraft hours, load factors, and total freight/mail transported with the flights. T-100 is a complete report of all nonstop segments. We merged the monthly T-100 data into the quarterly DB1B data to verify whether an airline provides nonstop service in a market. This information partially remedies the shortcoming of DB1B. We assume an itinerary recorded in DB1B to be nonstop if (1) the itinerary is a direct flight according to DB1B and (2) T-100 verifies that the corresponding airline provides nonstop flights in the route of the itinerary. The fraction of nonstop passengers are calculated based on this approximation.[2]

Third, we perform a reduced-form analysis and estimate a structural model that includes the heterogeneity of consumers using he Business Travel Index data from Borenstein (2010). The index is based on the American Transportation

[2]The approximation is imperfect because an airline may provide both nonstop flights and direct flights with stops. An alternative data source would be required for a more accurate calculation of the fraction of nonstop passengers.

Survey in 1995, which surveyed 80,000 households for 113,842 person-trips on domestic commercial airlines to investigate passengers' reasons for traveling. The index calculates the fraction of travelers who travelled for business purposes from and to each metropolitan area. The variation in the data helped us calculate the share of business travelers in each market and thus helped us model heterogeneity in the elasticity of different markets in our structural analysis.

Fourth, we used the population data in the 2010 US Population Census. We merged these data with other data to calculate market sizes as well as market shares.

We will define the market we will be analyzing in terms of one-way trips from one metropolitan area to another. Those trips could be paid for with either a one-way ticket or with a round-trip ticket. In the latter case, even though the traveler has purchased a single ticket, we will be considering the first part of the trip (from the origin city A to the destination city B) as belonging to one market (the A-to-B market) and the second (return) part of the trip as belonging to a different market (the B-to-A market). For example, we consider a flight from the JFK Airport in New York to Boston to be in the same market as another flight from LaGuardia Airport to Boston, because they both serve the market from New York City to Boston. A flight from Boston to LaGuardia is in a different market however, because the direction of the flight is from Boston to New York City instead of the reverse.

Our market definition, which is known as a "directional city pair", is similar to that in Aguirregabiria and Ho (2012). One alternative definition that is popular in the literature is known as the "directional airport pair", as in Berry and Jia (2010). According to our definition, airlines that serve different airports in the same city compete with each other in a market; this contrasts with the market definition of the directional airport pair, under which they may not compete with each other in a given market. Because we wanted to capture the competition in the whole Dallas area in order to study the effect of the Wright Amendment, we chose to define a market using the directional *city* pair, and not the directional *airport* pair. For example, American Airlines serves consumers who travel from Dallas to Boston using the Dallas/Fort Worth International Airport (DFW) airport, and Southwest Airlines serves the consumers with the same destination but who the Dallas Love Field Airport (DAL). According to our definition, American is competing with Southwest in the same market; in contrast, in the alternative definition, it is not competing with Southwest.

The Wright Amendment was fully repealed in October 2014, so we use the data from the third quarter of 2014 and the third quarter of 2015 to conduct our analysis. We focus on the lower 48 states only. We use the same quarter of each year to avoid potential seasonal effects. According to our model definition, our market is a directional city pair using the City Market ID provided by the DB1B database. We consider metropolitan area where population is more than 1.2 million according to the 2010 Census. The markets selected cover more than 80 percent of the passengers. Further, we focus on markets which appeared in both 2014 and 2015.

The major airlines over the period of time we analyzed were: American Airlines(AA), Alaska Airlines(AS), JetBlue (B6), Delta Airlines (DL), Frontier Airlines (F9), AirTran Airways (FL), Allegiant Airlines (G4), Spirit Airlines (NK), United Airlines (UA), US Airways (US), Virgin America Airlines (VX), and Southwest Airlines (WN). During the periods we sampled, two mergers—that between AirTran and Southwest, and that between American and US Airways— had been approved by the US federal antitrust authorities, and were already in effect. The airlines involved in both mergers were integrating. Therefore, we treated tickets sold by both AirTran and Southwest as if they had been sold by Southwest, and

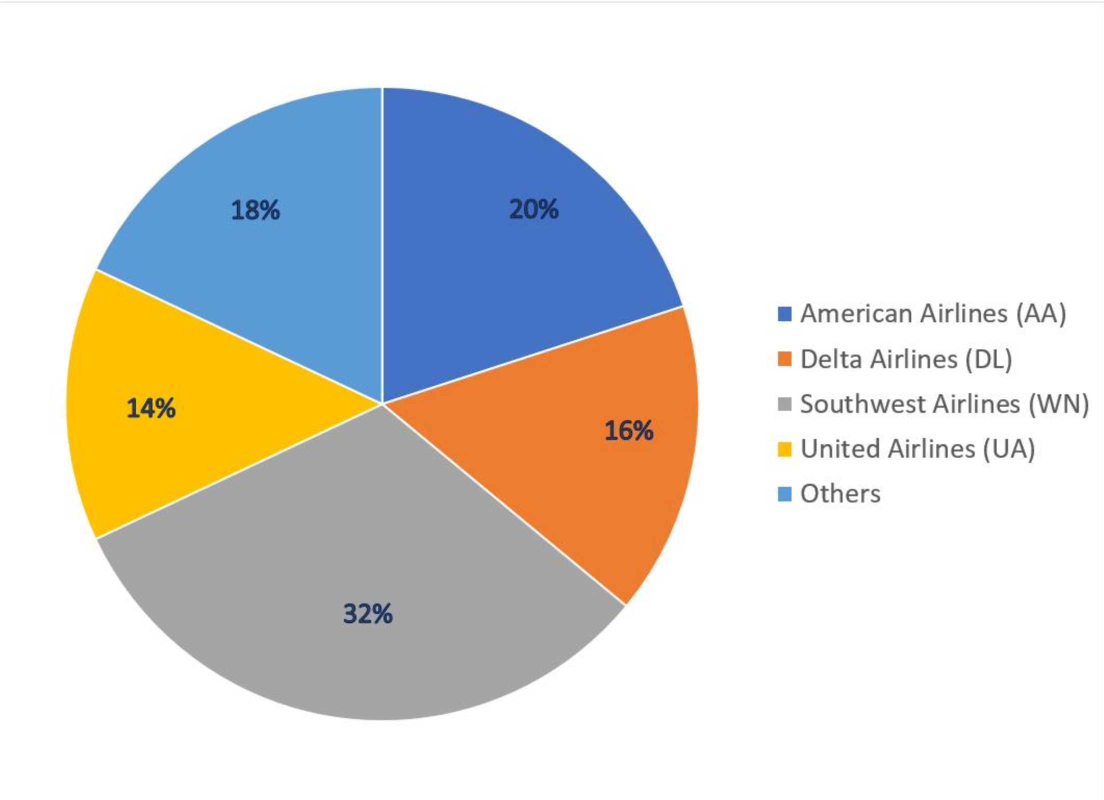


Figure 1: Market Shares of the US Airline Industry by Revenue in 2015

those by both American and US Airways as if they had been sold by American. After we take the mergers into account, the market shares of the airlines in the US domestic markets are shown in Figure 1.[3] The four biggest airlines, taken together, earned 80 percent of the market share by revenue. The balance of 20 percent of the market share was divided among the six smaller airlines.

Table 1: Changes between 2014 and 2015 in the Airlines in the Sample

Airline	Price	Passengers	Revenue	Nonstop Passengers	Seats
AA	-13%	21%	6%	18%	3%
DL	-8%	13%	4%	12%	8%
UA	-8%	11%	2%	10%	5%
WN	-9%	21%	11%	21%	6%
Others	-11%	23%	9%	24%	18%

Table 1 shows the changes in the US airline industry, per airline, from 2014Q3

[3] Market share by revenue in 2014 was very similar to that in 2015, so only the information from 2015 is presented in Figure 1.

to 2015Q3. Three patterns can be observed from the table. First, the entire industry expanded during the period sampled. All airlines increased the number of passengers transported, as well as their total revenue. Second, the expansion in the number of nonstop passengers closely matches the expansion in the number of passengers. Third, the expansion of the US airline industry was driven by cost reduction, because the overall prices of the airline industry dropped about 10 percent for each airline in the period sampled while the total number of passengers increased.

There were two sources of cost reduction during the sample period. Oil prices plummeted about 50 percent from 2014Q3 to 2015Q3, and the drop in oil price lowered the cost to the industry. In addition, the ongoing mergers of American Airlines with US Airways and Southwest Airlines with AirTran Airways improved the cost structure for those airlines. Although the capacity provided by both American (AA) and Southwest (WN), measured by number of seats offered, increased from 2014 to 2015, the increase was smaller than that of the total number of passengers by at least 15 percent. The large gap between the increase in the number of passengers and that in the capacity suggests that American and Southwest became more efficient and used less capacity to transport a given number of passengers in 2015 compared to 2014. As a result, the data suggests that the mergers improved the efficiency of both American and Southwest.

We define all air transportation of passengers provided by a particular airline in a market as its product. In other words, we assume each airline in a market offers only one product in that market. Each observation of our data set is a product-time combination. A product in our model is indexed by jm, where j is the airline and m is the market. The time of the observation is indexed by t. As a result, each observation has an index of jmt. In other words, each observation is an airline-market-time triplet. Airlines are considered operating in a market if 65 tickets or more in the market are from this airline. The threshold of 65 tickets is equivalent to 650 passengers served because of the 10 percent sampling, and is also equivalent to an average of 50 passengers per week during the quarter. With the selection rule, we focused on airlines that offer regular passenger services in the market. Based on the above data selection rule, our sample contains 1,495 markets and 8,593 product-time combinations.

We summarize into one observation the information of all airline tickets provided by airline j in market m at time t. For each observation jmt, we consider the average prices of all tickets of airline j in market m at time t, and we denote this as p_{jmt}. In addition, we consider both nonstop flights and connected flights as the same product, according to our definition of product. To summarize the routing information for different tickets, we use the fraction of nonstop services that airline j chooses to offer in market m, as shown here:

$$r_{jmt} = \frac{\text{quantity of nonstop passengers by airline } j \text{ in market } i \text{ at time } t}{\text{quantity of all passengers by airline } j \text{ in market } i \text{ at time } t}.$$

In our analysis, we abstract away from the distinctions among different connected flights for simplicity, and we use r_{jmt} as the measurement of product quality in our analysis. Provision of nonstop services, among many other product characteristics, is the product quality changed by the repeal of the Wright Amendment. The ratio r_{jmt} not only captures the extensive margin of the decisions on providing nonstop services, but also reflects the adjustment at the intensive margin through revenue management.

The average p_{jmt} in 2014 was \$227.181, and that in 2015 was \$207.44. United was the most expensive airline in our sample with an average ticket price of \$261.92, and Southwest is the cheapest among the four biggest airlines with an average price of \$206.03. Smaller airlines were cheaper than the four biggest airlines with an average price of \$156.56. The distribution of fractions of nonstop passengers has a support between 0 and 1. On the one hand, half of the observations show r_{jmt} to be 0, and 11.3 percent of the observations have r_{jmt} to be 1. On the other hand, about 40 percent of the observations in our sample have a fraction of nonstop passengers that is in the interior of the support despite the polarized distribution. Construction and summary statistics of other variables can be found in appendix A.

III Reduced-Form Analysis of the Effects of Constraints on Quality

The constraints on product quality of a firm in a market have two potential effects on the decisions of the firm. First, consumers will enjoy the firm's product less because of the constrained quality, so the firm will have a smaller market share. Second, the constraints will change the pricing decisions of the firm, but the direction of this change is indeterminate. On the one hand, the firm charges less for lower product quality. On the other hand, the marginal cost of the product will change, because the constraints change the product quality. The direction of the change in the marginal cost is uncertain in general. Consequently, the firm's pricing decision, which depends on the total effect of changes in the cost and the markup, may change in either direction. The average market price therefore may also change in either direction.

In addition, the constraints on a firm's product quality affect the product quality decisions of its competitors by affecting their benefit from improving their own product quality. A competitor invests in product quality for two reasons. First, the competitor attracts additional customers. Second, the competitor earns a higher markup through the quality investment. The constraint on the first firm's product quality increases the margin of the first benefit (more customers) for the competitors. By investing in product quality, the competitor attracts additional consumers who are not satisfied with the constrained product quality of the first firm. However, the effect of the constraints on the margin of the second benefit (higher markup) is unclear, because the change in the firm's price caused by the constraints is unclear. As a result, product quality decision taken by the competitor in response to the constraints is theoretically indeterminate.

In short, theoretical analysis alone does not suffice to predict how constraints on one firm's product quality affect either the outcomes for the market as a whole, or the behavior of each firm in that market. For that reason, we conducted the reduced-form analysis of those effects, which is the focus of this section, in order to contribute an empirical description.

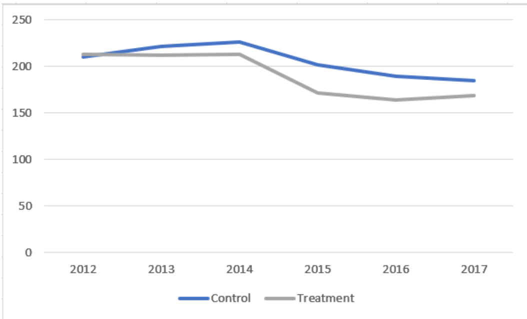
III.a Overview of the Estimation Strategy

To estimate the market's and the firm's responses to constraints on the product quality of a firm, we use the repeal of the Wright Amendment in 2014Q4 as a natural experiment to implement a difference-in-difference research design. In 2014Q3, the Wright Amendment forbade airlines to provide nonstop flights from the Dallas Love Field Airport (DAL) to destinations outside of the Wright zone. In 2015Q3, no market was affected by the Wright Amendment any more. Southwest, the only major airline serving the Dallas metropolitan area from DAL, was the only airline affected by the Wright Amendment until its repeal in October 2014. As a result, we focus on the markets in which Southwest was operating in 2014Q3, and we investigate how the Wright Amendment affected the market's performances and the strategies of Southwest's rivals.

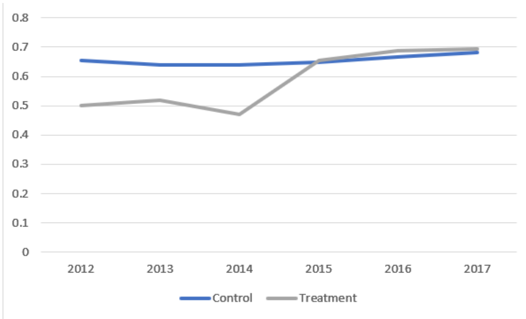
In our market level analysis, a market is in the treatment group if (1) the market in which the product provided was restricted by the Wright Amendment in 2014Q3, and (2) Southwest was operating in that market in 2014Q3. Note that the Wright Amendment constrained product quality effectively only in the markets in which Southwest operated, and Southwest was not operating in all of the markets restricted by the Wright Amendment. We define "operating in a market" here as transporting more than 65 passengers in the DB1B quarterly record, or more than 650 passengers accounting for the 10 percent sampling of DB1B. Under this definition, an airline is operating in a market if it transfers more than 50 passengers weekly. This definition is to ensure that the airlines we analyze in a market have regular operations in it. In 2014Q3,American provided nonstop services in all treated markets. Therefore, we define a market as being in the control group if (1) American provided nonstop services there in 2014Q3, (2) Southwest operated in that market in 2014Q3, and (3) the origin or destination of the market is not Dallas. The choice of control group assumes that the simultaneous provision of services by American and Southwest is an indicator of similar market characteristics. Among the 72 markets that were restricted by the Wright Amendment, Southwest operated in 59 markets in 2014Q3, and provided nonstop services in 52 of the markets after the repeal of the Wright Amendment.[4] In addition, there are 238 markets in the control group.

Figure 2 compares the trends in conducts of the firms in the treatment markets with those in the control markets. The figure shows that the treatment group and the control group had generally parallel trends in the fraction of nonstop passengers, the total number of passengers, and the total number of seats around the time of the repeal of the Wright Amendment. However, the trend in the average prices of the control and treatment groups showed a pattern that was less parallel than the other three trends. This suggests that our control group is valid in general for several market outcomes, although our choice of the control group is not perfect for price. The price in the treatment group is flatter than that in the control group, so we may have underestimated the effect of the Wright

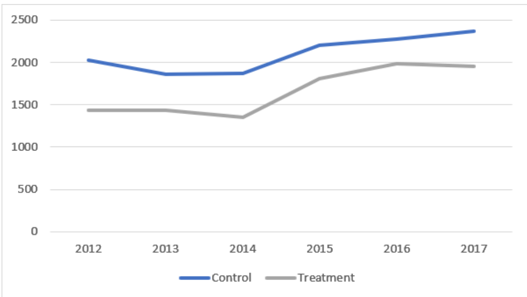
[4]After the repeal, Southwest did not provide nonstop services in markets in which it had not operated 2014 .



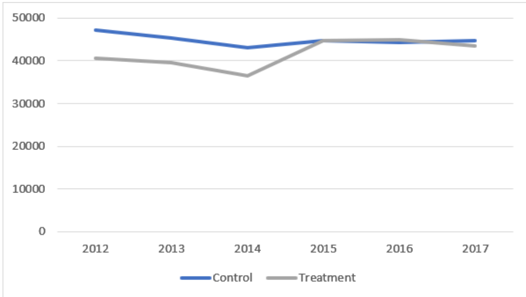
(a) Price



(b) Nonstop Services



(c) No. of Passengers



(d) No. of Seats

Figure 2: Trends in the treatment vs. the control markets

Amendment on prices.

The interdependence of markets in the airline industry imposes a unique challenge in using the difference-in-differences research design, namely, the quality constraints on markets in the Dallas area may spill over to the control group from two channels. First, airlines allocate seats or capacity across different markets. To provide additional nonstop services in the treatment markets, an airline needs to pull capacities out of other markets and to reallocate them to the treatment markets. Second, the opportunity cost of a ticket in a control market may depend on the prices of tickets in the treatment markets, so the Wright Amendment may have had an effect on control markets. For example, an airline will sell a connected ticket from Atlanta to Seattle via Dallas if it is more profitable than selling two nonstop tickets separately— one from Atlanta to Dallas and one Dallas to Seattle. Alternatively, if the airline can sell the nonstop tickets for a higher price, the price of the connected flight will be higher. Consequently, our difference-in-differences analysis will underestimate the causal effect of the Wright Amendment on prices and overestimate its effect on capacity and nonstop services. Nevertheless, the reduced-form analysis provides descriptive evidence on how firms actually responded to the quality constraints.

III.b Effects of Constraints on the Markets

To investigate the effect of the quality constraints on market performances, we run the following regression:

$$Y_{mt} = \beta \cdot Wright_{mt} + \gamma X_{mt} + \mu_m + \sigma_t + \epsilon_{mt}, \tag{1}$$

where (1) Y_{mt} is the outcome of interest, (2) β is the estimated effect of the quality constraints, (3) $Wright_{mt}$ is a dummy variable equal to 1 if the market m was restricted by the Wright Amendment at time t, (4) X and γ are control variables and their respective coefficients, (5) μ_m is the treatment group fixed effect, (6) σ_t is the time fixed effect, and (7) ϵ_{mt} is the unobserved error term. The control variables include the Borenstein (2010) business index at the origin and the destination, the distance between the origin and the destination, and the distance squared between the origin and the destination. The regressions were run using the market-level aggregated data.

Table 2 displays the results of the regressions. The response variables are market average price (Price), fraction of nonstop services (Nonstop), log total number of passengers (Log Pass.), log total number of seats (Log Seat), and log total revenue (Log Rev.) in regressions 1-5, respectively. In particularly, the log total number of seats available in a market measures the capacity in the market. Although capacity and number of consumers are similar concepts in many industries, the number of seats is very different from the number of passengers in the airline industry, because airlines may use a seat in one route to serve a connected-flight passenger in other markets. This is why we highlight the distinction between

Table 2: Effects of Quality Reduction on Markets

	Dependent variable:				
	Price	Nonstop	Log Pass.	Log Seat	Log Rev.
	(1)	(2)	(3)	(4)	(5)
Wright	28.150***	−0.122***	−0.122**	−0.171***	0.026
	(1.764)	(0.004)	(0.057)	(0.046)	(0.062)
FE: Treated	Yes	Yes	Yes	Yes	Yes
FE: 2015	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Observations	594	594	594	594	594
R^2	0.579	0.265	0.079	0.124	0.078
Adjusted R^2	0.574	0.256	0.068	0.113	0.067

Note: *p<0.1; **p<0.05; ***p<0.01

the number of passengers and the number of seats in our analysis. We calculate the three-way clustered standard errors by origin, destination, and year using the methodology proposed by Cameron, Gelbach, and Miller (2011).[5]

The regression results suggest that the supply of airline services, particularly the nonstop ones, contracted as a result of the restriction imposed by the Wright Amendment. The statistical significance in the increase in price, as well as in the decrease in the fraction of nonstop services, in the log number of passengers, and in the capacity provide evidence for this contraction of supply. The price was $28.15 higher (or 15 percent of the average price of $ 188.26) while the total number of passenger is lower by 12.2%. This is consistent with our estimate that the total revenue in the affected markets did not change by much under the quality constraints.

[5] All the cluster calculations in this paper are implemented in R with the "sandwich" package with the fix option.

III.c Responses of the Firms

The regression analysis we conducted to analyze the competitive responses of the firms is:

$$Y_{jmt} = \sum_{j} \beta_j \cdot \mathbb{I}[Airline_j] \cdot Wright_{jmt} + \gamma X_{jmt} + \mu_{jm} + \alpha_j + \sigma_t + \epsilon_{jmt}, \qquad (2)$$

where (1) Y_{jmt} is the variable of interest, (2) β_j is firm j's response to the constraints on Southwest's quality, (3) $\mathbb{I}[Airline_j]$ is an indicator function that equals 1 for airline j, (4) $Wright_{jmt}$ is a dummy variable equal to 1 if the market m was restricted by the Wright Amendment at time t, (5)X and γ are control variables and their respective coefficients, (6) μ_{jm} is the treated group fixed effect for airline j, (7) α_i is the airline fixed effect, (8) σ_t is the time fixed effect, and (9) ϵ_{jmt} is the unobserved error term. In the model, different airlines may respond heterogeneously to the constraints on Southwest's quality from the Wright Amendment. They also have different fixed effects in the treated markets. Although the data covers 10 airlines, airlines other than AA, DL, UA, and WN are considered as having had the same response and the same fixed effect. The control variables are the same as in the market-level analysis.

Table 3 displays the results of the regressions. The response variables are the average price (Price), fraction of nonstop services (Nonstop), log total number of passengers(Log Pass.), log total number of seats which measures the capacity provided by airline j (Log Cap.), and log total revenue (Log Rev.), in regressions 1-5, respectively. We calculate the four-way clustered standard errors by origin, destination, airline, and year using the same methodology as in the market-level analysis.

Our empirical results show that when Southwest was constrained by the Wright Amendment, its price were \$23.23 higher in the treatment markets. The empirical results have two potential causes. On the one hand, constraints on nonstop ser-

Table 3: Competitive Responses to Quality Change

	Dependent variable:				
	Price	Nonstop	Log Pass.	Log Cap.	Log Rev.
	(1)	(2)	(3)	(4)	(5)
AA's Response	31.738***	0.006	0.089	0.267	0.213***
	(5.264)	(0.020)	(0.070)	(0.193)	(0.053)
DL's Response	17.668***	0.009	0.298***	0.295**	0.371***
	(5.208)	(0.013)	(0.058)	(0.123)	(0.065)
UA's Response	51.110***	0.075***	0.182*	1.087***	0.410***
	(8.605)	(0.026)	(0.108)	(0.380)	(0.123)
WN's Response	23.229***	−0.717***	−0.690***	−8.174***	−0.547***
	(4.479)	(0.020)	(0.058)	(0.208)	(0.041)
Others' Response	5.888	−0.076***	−0.014	−0.536**	0.162
	(7.533)	(0.018)	(0.073)	(0.232)	(0.164)
FE: Airlines	Yes	Yes	Yes	Yes	Yes
FE: 2015	Yes	Yes	Yes	Yes	Yes
FE: Airlines-Treated	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Observations	2,469	2,469	2,469	2,469	2,469
R^2	0.665	0.425	0.227	0.401	0.213
Adjusted R^2	0.663	0.420	0.221	0.397	0.207
Note:					*p<0.1; **p<0.05; ***p<0.01

vices could lead to a higher marginal cost for Southwest. Restricted to connected flights only, Southwest had to detour and stop at airports within the Wright zone, and thus the Wright Amendment obliged it to fly extra miles compared to its competitors in the same market. On the other hand, the Wright Amendment could alter the market segment that Southwest was facing by constraining Southwest's nonstop services. In this circumstance, Southwest would charge a higher markup and thus a higher price. Our structural analysis will identify which of the two factors caused Southwest to have a higher price under the restriction of the Wright Amendment. Southwest's competitors increased their prices in response to constraints on Southwest's product quality, and the price increases of American, Delta, and United are statistically significant. Those responses are consistent with the fact that Southwest had a higher price under the constraints of its product quality.

Capacities of two competing firms are usually strategic substitutes. In other words, a firm will increase its capacity if its rival reduces its capacity. The provision of nonstop services is closely tied to decisions about capacity allocation in the airline industry. Serving one nonstop passenger requires at least the capacity of one seat in that market, while serving one connected-flight passenger does not require the same kind of capacity. For this reason, our belief a priori was that fractions of nonstop passengers should be strategic substitutes. However, even though Delta offered additional capacity when Southwest was constrained, it did not offer additional nonstop services. The empirical result regarding Delta shows that the decision on nonstop services is related to but not identical to the capacity decision, and thus nonstop services are not necessarily strategic substitutes.

In addition, our empirical results suggest that different firms responded to the constraints on Southwest's product quality differently in terms of their own product quality decisions. When Southwest served a lower fraction of nonstop passengers because of the Wright Amendment, United provided more nonstop services in the treated market while other airlines provided fewer nonstop services. Moreover, neither American nor Delta changed their decisions on their product quality. As previously mentioned, by improving its product quality, an airline gains additional market share and can charge a higher markup. Constraints on Southwest's product quality would motivated its competitors to make their own quality improvement in order to reach additional customers, so the market-share channel alone suggests that a competitor would have had more nonstop services. Therefore, a competitor that did not provide additional nonstop service had either a smaller markup effect of its quality improvement due to the constraint or a higher cost for improving quality. This suggests that the idiosyncrasies in cost structures among different airlines should be thoroughly examined in our structural estimation.

Comparing columns (3) and (4) in Table 3, we found that the change in the total number of seats was greater than the change in the total number of passengers for United, Southwest, and other airlines. Two factors may have contributed to the gap. First, an increase in the fraction of nonstop passengers contributed to the gap, because an airline needs additional capacity in a market to provide more nonstop services. This explanation is supported by the changes in product quality observed in the data. The second factor is that airlines may use the increased capacity for connected flights in other markets. The added capacity is excessive for a single market, and it therefore may serve connected flights in other markets. In this case, the increase in capacity would produce spillover to other markets. The pattern we observe is likely to be a joint result of both channels.

Last but not least, we see that all of Southwest's competitors had higher revenue when the product quality of Southwest was constrained, although the change in revenue of other airlines is not statistically significant. The quality constraint on Southwest therefore gave its competitors a larger consumer base.

IV Structural Model

IV.a Overview

In this section, we present our structural model of the markets in the airline industry. The structural model will help us better understand the economic reasoning behind the competitive responses of the firms to constraints on their competitor's product quality.

For the demand side of the market, we use a modeling strategy similar to that in Berry and Jia (2010), which is a "discrete-type" version of the random-coefficient logit model in Berry, Levinsohn, and Pakes (1995). In our model, travelers are explicitly divided into two groups, business and leisure. The model design allows us to explicitly model the differences between the business travelers and the leisure travelers. Business travelers are those who travel for business purposes and are not necessarily traveling in business class. Leisure consumers are those who travel for other purposes. The two groups of travelers may have different responses to prices and product quality, and may have been affected differently by the Wright Amendment.

For the supply side of the market, an airline is assumed to choose the average price and the fraction of nonstop passengers of its product in each market. We decided to model each firm's behavior in this way for four reasons. First, our modeling strategy succinctly covers the two important aspects of airline decisions: pricing and provision of nonstop capacity. The average price reflects the pricing decision, and the fraction of nonstop passengers measures how much nonstop capacity are provided to each consumer. Second, both decision variables have interpretations when they enter a consumer's decision problem. The fraction of nonstop services entering a consumer's payoff can be interpreted as the probability of buying a nonstop ticket that satisfies her traveling needs. A passenger does not necessarily have a choice between nonstop and connected services for a fixed traveling date, even though airlines may offer nonstop services on another day. The lack of choices is partially captured by the fraction of nonstop passengers. From the model based on our design, firms can learn how much they can raise their price if they increase the consumer's chance to buy a nonstop ticket. One alternative decision variable to use is the capacity offered in a market. Although the total capacity also measures the provision of nonstop flights as well, it does not enter the consumer's decision problem. Third, firms do not make discrete choices, so the model can be point identified without any parametric assumption on the error terms of the costs. Last but not least, the modeling choice is consistent with our reduced-form analysis. Consequently, the structural model will help us to extend our reduced-form analysis.

An alternative approach to modeling a market is considering the nonstop flights and connected flights as separate products. In this modeling approach, firms decide implicitly on how many nonstop services to provide by adjusting the relative price between the two products. However, this alternative approach has a drawback. Additional assumptions would be required to use the alternative approach. Under the setup, firms make discrete decisions on providing nonstop service. As a result, additional assumptions on the distributions of the error terms of the costs and the equilibrium selection rules would be necessary to guarantee point identification.

We assume the market structure is exogenous. In our model, an airline makes its decision only on service quality (by adjusting the fraction of nonstop passengers), but not on whether it enters a market. An airline is considered to be in the market if it operates either connected or nonstop flights. Airlines may serve a market with connected flights if they serve both the origin and the destination. The decision to enter a new market is therefore similar to the decision to enter a new city. Such a decision is different from adding nonstop services to a route on which the airline has already been operating. The decision to enter a new city does not depend on the idiosyncrasy of an individual market. Rather, it depends on the overall network structure of the airline, a subject which is beyond the scope of this paper. As a result, we do not model the city-level entry decisions.

IV.b Demand

The utility for individual i from choosing airline j's service in market m at time t is as follows:

$$u_{ijmt} = \beta_{0i} + X'_{jmt}\beta + \alpha_i^p p_{jmt} + \alpha_i^r r_{jmt} + \xi_{jmt} + \nu_{it} + (1-\lambda)\epsilon_{ijmt}, \tag{3}$$

and the utility from the outside option is $u_{i0mt} = \epsilon_{i0mt}$. The outside option follows the Type-I Extreme value distribution and represents either not traveling or traveling with methods other than air travel. X_{jmt} are variables for exogenous product characteristics, including the constant term, the distance between the origin and the destination, the square of the distance, the market presence of airline j at the origin, whether the destination is a tourism destination, time fixed effect, and airline fixed effect.[6] Detailed information about the aforementioned control variables can be found in appendix A. ξ_{jmt} is the unobserved market-airline-time payoff for the product. $\nu_{it} + (1-\lambda)\epsilon_{ijmt}$ is the individual specific unobserved payoff following the Type-I Extreme distribution as specified in Cardell (1997), where λ is the nesting parameter.

We assume there are two types of customers, business travelers and leisure travelers, in every market. We assume consumers of the same type have the same taste coefficients, and we allow those with different types to have different constants and different responses to price and to the product quality (measured by the fraction of nonstop passengers). Other controls, including the time fixed effect and the airline fixed effects are assumed to be the same across the two types of consumers. In particular, we assume some of the individual i's coefficients, namely, β_{0i}, α_i^p,and α_i^r, vary across types, while others, β, are the same across different types of consumers. In addition, our model assumes that both types of consumers face the same average price and fraction of nonstop services. This assumption rules out price and quality discrimination behaviors by the airlines. Although practice is common in the airline industry, it is beyond the scope of this paper.

The share of business consumers varies across different markets, Borenstein (2010) surveyed the share of business travelers at different airports. He measured the share of business travelers from and to every city. We assume the share of

[6] American, Delta, United, and Southwest are the only airlines with the airline fixed effect in our model. Fixed effects on all airlines would increase the dimension of our model, which works against both the speed and precision of our estimation. The fixed effects of other airlines are therefore omitted. We did not add airport fixed effects to our model to avoid the increase in the dimension of the model as well. Fourteen airports are located in the metropolitan areas with multiple airports. Adding the airport fixed effect would almost double the dimension of the parameter space for demand estimation.

business consumers in market m at time t is:

$$\iota_m = BusinessOrigin_m^{\rho} * BusinessDest_m^{1-\rho}, \tag{4}$$

where $BusinessOrigin$ is the share of business travelers from the origin city in the survey, $BusinessDest$ is the share of business travelers to the destination city in the survey, and the share of business travelers in the market is the geometric average weighted by ρ.

Specifically, the probability of consumer i to choose airline j in market m at time t is therefore:

$$\frac{exp((\beta_{0i} + X'_{jmt}\beta + \alpha_i^p p_{jmt} + \alpha_i^r r_{jmt} + \xi_{jmt})/(1-\lambda))}{D_{imt}}, \tag{5}$$

where the denominator is:

$$D_{imt} = \sum_{k=1}^{J} exp((\beta_{0i} + X'_{kmt}\beta + \alpha_i^p p_{kmt} + \alpha_i^r r_{kmt} + \xi_{kmt})/(1-\lambda)).$$

Therefore the market share of product j given the vectors of (1) prices, (2) fractions of nonstop flights, (3) product characteristics, and (4) unobserved payoffs, is:

$$s_j = \sum_{i \in b,l} \iota_{im} \cdot exp((\beta_{0i} + X'_{jmt}\beta + \alpha_i^p p_{jmt} + \alpha_i^r r_{jmt} + \xi_{jmt})/(1-\lambda)) \cdot \frac{D_{imt}^{-\lambda}}{1 + D_{imt}^{1-\lambda}}, \tag{6}$$

where the subscript i denotes the type of the consumers (business or leisure); in addition, $\iota_{im} = \iota_m$ if i is a business traveler and $\iota_{im} = 1 - \iota_m$ if i is a leisure traveler.

The random-coefficient logit model calculates the market shares of each firm given the controls and the firms' decisions. To calculate the market shares, we need to divide the number of passengers by the total market size. We use one fiftieth of the geometric mean of the population in origin and the destination as the market size.

IV.c Supply

On the supply side, airline j chooses $p_{jmt} \geq 0$ and $r_{jmt} \in [0,1]$ to maximize its profit in market m at time t:

$$\pi_{jmt} = \max_{p_{jmt}, r_{jmt} \in [0,1]} [p_{jmt} - MC_{jmt}] \mathcal{M}_m \cdot s_j(\mathbf{p}_{mt}, \mathbf{r}_{mt}, \mathbf{X}_{mt}, \xi_{mt}) - UC_{jmt}, \tag{7}$$

where MC is the constant marginal cost for the airline, $\mathcal{M}_m$ is the market size, s_j is the market share of airline j, and UC is the quality upgrade cost of direct flight. $\mathbf{p}_{mt}$ and $\mathbf{r}_{mt}$ are vectors which include the decisions of firm j and its competitors in market m at time t.

The marginal cost function of airline j in market m at time t is:

$$MC_{jmt} = \kappa r_{jmt} + \varphi W_{jmt} + \eta_{jmt}, \tag{8}$$

where (1) r_{jmt} is airline j's choice of the fraction of nonstop passengers at time t in market m and κ is its coefficient, (2) W_{jmt} are the controls of the marginal cost and φ are their corresponding coefficients, and (3) η_{jmt} is the marginal cost component that is unobserved by the econometrician. The controls include distance between the origin and the destination, distance squared, numbers of cities connected to the origin and the destination cities via airline j's nonstop service, numbers of cities connected to the origin and the destination via any air transportation, whether the origin or the destination city has a hub of airline j, the time fixed effect, and the airline fixed effects of American, Delta, United and Southwest. W_{jmt} also includes the constant term. Detailed information about the aforementioned control variables can be found in appendix A.

"Quality upgrade cost" refers to the cost that a firm has to pay to upgrade connected services to nonstop services. The quality upgrade cost varies with the choice of the fraction of nonstop passengers and does not vary with the number of tickets sold. The upgrade cost is assumed to be quadratic in r_{jmt} in order to model the diminishing return on quality investment. Otherwise, airlines would not choose any fraction of nonstop passengers other than 0 and 1. The quality upgrade cost function of airline j in market m at time t is:

$$UC_{jmt} = r_{jmt}(\tau r_{jmt} + \gamma Y_{jmt} + \omega_{jmt}), \tag{9}$$

where (1) r_{jmt} is airline j's choice of fraction of nonstop passengers at time t in market m and κ is its coefficient, (2) Y_{jmt} are the controls of the upgrade cost and γ are their corresponding coefficients, and (3) ω_{jmt} is the upgrade cost component that is unobserved by the econometrician. The controls include distance between the origin and the destination, distance squared, numbers of cities connected to the origin and the destination cities via airline j's nonstop service, whether the origin or the destination city has a hub of airline j, whether the origin or the destination city is slot-constrained, the time fixed effect, and the airline fixed effects of American, Delta, United and Southwest. Unlike W_{jmt}, Y_{jmt} does not include the constant term due to the limitation of the estimation method.[7] Correspondingly, ω_{jmt} may have a mean that is different from zero. A quality upgrade may spill over to other markets. To upgrade quality on a route, an airline assigns capacity of nonstop flights to the route. The capacity might be used to produce connected flights on other routes, and thus the quality upgrade may benefit other routes. The upgrade cost might be negative when the quality upgrade produces more spillover than its economic cost.

Airlines are assumed to play a Nash equilibrium in each period at every market,

[7]Estimating the constant term requires an auxiliary estimation procedure after the main routine which is not necessary for the purpose of this paper. See Honoré and Powell (1994) for more details.

and multiple equilibria are possible. For example, a market whose demand supports any equilibrium in which only one of the two firms operates nonstop flights has two equilibria outcomes in which either firm provides nonstop flights. The specific equilibrium selection rule is not assumed in the model and is not required for the estimation process. The simplifying assumption is by no mean innocuous, which has two distinct implications that raise cautions. First, the airlines do not have dynamic concerns when they make decisions. Although this implication matches with the fact that both allocation of fleets and pricing decisions are not hard to adjust by airlines within a year, some literature such as Peteraf and Reed (1994), Goolsbee and Syverson (2008), and Gedge, Roberts, and Sweeting (2014) empirically identified dynamic motivations in the airline industry such as entry deterrence by limit pricing. Second, the airlines do not engage in multimarket contact and compete in each market independently. The second implication is not consistent with findings in Evans and Kessides (1994), Aguirregabiria and Ho (2010), Aguirregabiria and Ho (2012), and Ciliberto and Williams (2014). The simplifying assumption is therefore a "necessary evil" to enable us to take an agnostic stance on equilibrium selection.

V Structural Estimation Method

The structural model is estimated in three steps. First, the demand model is estimated using an algorithm similar to that in Berry and Jia (2010). Second, the marginal cost parameters are estimated using the standard two-stage least squares. Third, the upgrade costs are estimated with a pairwise difference estimator inspired by Honoré and Powell (1994) and Honore and Hu (2004).

V.a Demand

Given enough proper instruments, the identification argument of our demand model follows the arguments in Berry, Levinsohn, and Pakes (1995) and Berry and Jia (2010). The average product characteristics of all rivals are used as instruments in the estimation process. Specifically, the set of instruments includes (1) whether any other low cost carrier is competing in the market, (2) the average mileage flown of rivals in the market[8], (3) the average market presence of rivals at the origin and the destination, and (4) the pairwise interactions of those rivals' characteristics. All of the rivals' product characteristics affect the pricing and nonstop service provision via competition in the market, but are not correlated with the consumer's unobserved payoff of a product.

To estimate the demand, we first invert the market share equation as in Equation 6 to obtain $\xi(\mathbf{p}, \mathbf{r}, \mathbf{X}, \mathbf{s}|\alpha, \beta)$. Given the parameters and the data, s_j is an invertible function of ξ_{mt} by the argument in the classic work by Berry, Levinsohn, and Pakes (1995), and the inversion of s can be calculated with the fixed-point algorithm used in Berry and Jia (2010); we therefore have:

$$\xi_{jmt}^{M} = \xi_{jmt}^{M-1} + (1-\lambda)[\ln s_{jmt}^{*} - \ln s_{jmt}(\mathbf{p}_{mt}, \mathbf{r}_{mt}, \mathbf{X}_{mt}, \xi_{mt})], \tag{10}$$

where s_{jmt}^{*} is the realized market share in the data, s_{jmt} denotes the market share function in Equation 6, and M denotes the M^{th} iteration of the calculation.[9]

Then the function ξ is embedded into a Generalized Method of Moment (GMM) estimator, where the moment conditions are:

$$\mathbb{E}[\xi_{jmt}(\mathbf{p}, \mathbf{r}, \mathbf{X}, \mathbf{s}|\alpha, \beta) \cdot Z_{jmt}^{D}] = 0, \tag{11}$$

[8]The average mileage flown by an airline is determined by both its nonstop service provision and its networks structure.

[9]The algorithm is implemented with the SQUAREM package in R, and we iterate until the tolerance $||\xi^{M} - \xi^{M-1}||_{\infty} = \max_{jmt}\{\xi_{jmt}^{M} - \xi_{jmt}^{M-1}\} < 10^{-12}$.

where Z^D denotes the combined set of instruments and exogenous variables. The GMM estimator is implemented with the two-stage feasible GMM algorithm.

V.b Marginal Cost

In equilibrium, airlines choose prices optimally in response to the prices set by others. The prices observed in the data therefore satisfy the first order condition for the profit maximization problem in Equation 12:

$$\frac{\partial \pi_{jmt}}{\partial p_{jmt}} = 0, \tag{12}$$

and the first order condition can be algebraically transform to:

$$p_{jmt} + \frac{s_{jmt}}{\partial s_j(\mathbf{p}_{mt}, \mathbf{r}_{mt}, \mathbf{X}_{mt}, \xi_{mt})/\partial p_{jmt}} = MC_{jmt} = \kappa r_{jmt} + \varphi W_{jmt} + \eta_{jmt}. \tag{13}$$

The left-hand side of Equation 13 has no unknown parameter after the demand parameters are estimated. In particular, the prices and market shares are observed in the data, and the partial derivative $\partial s_{jmt}/\partial p_{jmt}$ is calculated as follows:

$$\iota_m \cdot \alpha_b^p \cdot s_{bjmt} \cdot (\frac{1}{1-\lambda} - s_{bjmt}) + (1-\iota_m) \cdot \alpha_l^p \cdot s_{ljmt} \cdot (\frac{1}{1-\lambda} - s_{ljmt}), \tag{14}$$

where (1) ι_m is given by Equation 4, (2) α_b^p and α_l^p are responses to price for business and leisure travelers respectively, and (3) s_{bjmt} and s_{ljmt} are the choice probabilities for business and leisure travelers, respectively, to choose airline j in market m at time t. The expression is the average of the corresponding partial derivatives of both business and leisure travelers.

The right-hand side of Equation 13 contains one endogenous variable, namely, r_{jmt}, and several exogenous variables in W_{jmt}. The parameters in the marginal cost model are therefore identified, as long as appropriate instruments are used to resolve the endogeneity of r. The estimated value of ξ_{jmt} is used as the instrument, because it affects r_{jmt} by shifting the demand for airline j. In addition, ξ_{jmt} is assumed to be conditionally uncorrelated with η_{jmt}, so the instrument is valid.

V.c Upgrade Cost

The first order conditions of profit-maximizing decisions with respect to product quality r_{jmt} are used to estimate the upgrade cost. The first order condition with respect to r_{jmt} is more complicated than that with respect to p because r_{jmt} is constrained to be within the interval $[0, 1]$. We make the following two assumptions to simplify the analysis:

1. The point $r_{jmt} = 1$ is interior. The inequality $r_{jmt} < 1$ holds as long as there exists one connected flight ticket sold by firm j in market m at time t. The actual value of the quality parameter r_{jmt} may not be equal to 1 even if the observed r_{jmt} is, because DB1B is a 10 percent sample of the data. As a result, we make the assumption in order to avoid the complication of two-way censorship in the response variable.

2. The profit π_{jmt} is concave in r_{jmt}. We make this assumption to satisfy the second order sufficient condition globally.

With these two assumptions, firms in equilibria will choose r_{jmt} to satisfy:

$$\begin{aligned} \frac{\partial \pi_{jmt}}{\partial r_{jmt}} &= \mathcal{M}_m \cdot s_j(\mathbf{p}, \mathbf{r}, \mathbf{X}_{mt}, \xi) \left[\frac{\partial s_j(\mathbf{p}, \mathbf{r}, \mathbf{X}_{mt}, \xi)/\partial r_{jmt}}{-\partial s_j(\mathbf{p}, \mathbf{r}, \mathbf{X}_{mt}, \xi)/\partial p_{jmt}} - \kappa \right] - 2\tau r_{jmt} - \gamma Y_{jmt} - \omega_{jmt} \\ & \begin{cases} \leq 0 & \text{if } r_{jmt} = 0 \\ = 0 & \text{if } r_{jmt} > 0 \end{cases} \end{aligned} \tag{15}$$

A natural way to proceed is to impose parametric assumptions on ω_{jmt}, and then estimate the model using the maximum likelihood estimation (MLE) method. Complications arise with MLE since, for some realizations of the ω's, there exist multiple equilibria in the corresponding markets. When there are multiple equilibria, one can either bound the likelihood function and form a model inequality model (see, for example, Ciliberto and Tamer (2009)), or specify a parametric form for the equilibrium selection rule and then maximize the likelihood function jointly over the upgrade-cost parameters and the equilibrium selection parameters (e.g., Bajari, Hong, and Ryan (2010)). However, we apply a GMM-based method to estimate the model for three reasons. First, while MLE performs well when the parametric model is correctly specified, it is generally inconsistent under model-misspecification. Second, these two MLE-based methods are computationally very intensive. And finally, it is difficult to study counterfactuals of interest to us with these two MLE based methods for these reasons: the moment inequality model does not give point estimate, and the model with parametric assumptions on the equilibrium selection rule may be misspecified.

To proceed with the estimation and to derive the moment conditions, note that the FOC can be rewritten as:

$$B_{jmt} \quad = \quad \max\{C_{jmt} - \gamma Y_{jmt} - \omega_{jmt}, 0\}, \tag{16}$$

where B_{jmt} is computed using

$$B_{jmt} = (C_{jmt} - D_{jmt}) + 2\tau r_{jmt}, \tag{17}$$

and C_{jmt} and D_{jmt} are defined in appendix C. Note that C_{jmt} and D_{jmt} can be computed for all markets, and $B_{jmt} = 0$ whenever $r_{jmt} = 0$.

Our model looks very similar to the standard censored model, but with the following two important distinctions:

1. The latent variable of this model contains C_{jmt}, which changes across observations; in contrasts, in the standard censored model, C_{jmt} is equal to a

constant that needs to be estimated.

2. The dependent variable B_{jmt} of this model is not directly observed, but it is calculated based on data and an unknown parameter τ.

We proceed by applying one of the existing method used in the literature on limited dependent variable models, with modifications that are necessary to deal with our case. In particular, we adopt the pairwise difference estimator developed in Honoré and Powell (1994). This estimation strategy is the most suitable one in our situation because we do not want to impose parametric assumptions on ω_{jmt}, and because other methods are hard to modify to suit our situation.

The identification argument is similar to that in Honoré and Powell (1994); the most notable difference is how τ is identified. The censoring of B_{jmt} happens when airlines choose the boundary point at which $r_{jmt} = 0$. As a result, r does not enter B_{jmt} when B_{jmt} is censored. Thus, τ can be identified only through the range of data for which the boundary point $r = 0$ is not chosen. However, proper instruments are necessary to identify τ because of the endogeneity of r_{jmt}.

To estimate the model, we take pairwise differences between every pair of observations that are not in the same market. Error terms in the censored dependent variable are selected by the boundary condition of the firm's decision problem, and thus they do not necessarily have a zero mean. As a result, they cannot form the usual moment condition with instruments or exogenous variables. However, the difference between any two i.i.d. random variables is symmetrically distributed and has a mean of zero; it can therefore be used to form moment conditions with instruments or exogenous variables.

Formally, let i, k denote two different indices of jmt; we then define

$$e_{ik}(t, g) = \max\{[(C_i - D_i) + 2tr_i] - (C_i - gY_i), -(C_k - gY_k)\}. \tag{18}$$

Then, at the true parameter values (τ, γ), we have

$$\begin{aligned} e_{ik}(\tau,\gamma) &= \max\{B_i - (C_i - \gamma Y_i), -(C_k - \gamma Y_k)\} && (19) \\ &= \max\{\max\{C_i - \gamma Y_i - \omega_i, 0\} - (C_i - \gamma Y_i)\}, -(C_k - \gamma Y_k)\} \\ &= \max\{-\omega_i, -(C_i - \gamma Y_i), -(C_k - \gamma Y_k)\}. && (20) \end{aligned}$$

We assume that (1) ω_i is i.i.d across i conditional on (Y_i, Y_k, C_i, C_k) if the two error terms are not in the same market, and (2) ω_i is independent from (Y_i, Y_k, C_i, C_k) in any pairwise difference. Then, $e_{ik}(\tau,\gamma)$ and $e_{ki}(\tau,\gamma)$ are identically distributed at the true parameter values, which yields moment conditions in the following form:

$$\mathbf{E}\{\Xi(e_{ik}(\tau,\gamma) - e_{ki}(\tau,\gamma)) \cdot (Y_i - Y_j)\} = 0, \qquad (21)$$

for any odd function $\Xi(\cdot)$. We choose $\Xi(x) = x$ in our estimation. Moreover,

$$\mathbf{E}[\Xi(e_{ik}(\tau,\gamma) - e_{ki}(\tau,\gamma)) \cdot (Z_i - Z_j)] = 0, \qquad (22)$$

for any instrument Z such that conditional on $(Y_i, Y_k, C_i, C_k, Z_i, Z_k)$, $e_{ik}(\tau,\gamma)$ and $e_{ki}(\tau,\gamma)$ are identically distributed. For the standard truncation model, Honoré and Powell (1994) proved that the moment conditions are uniquely satisfied at the true value for the pairwise difference moment. Our setup is similar to theirs that the endogenous variable does not enter the truncation point. We therefore have assumed that, in our model, the moment conditions are uniquely satisfied.

One drawback with this method is that the location of ω_{jmt} (or the intercept parameter of the latent variable) is not identified, since it is differenced out and does not enter the GMM objective function. However, after we have estimation results on all the other parts of our model, this parameter can be recovered by, for example, the auxiliary procedure proposed by Honoré and Powell (1994), which makes use of the censored least absolute deviation estimator. We skipped the recovery process in this paper because it does not provide additional insights about the industry.

We deployed the two-stage feasible GMM to estimate the moment conditions. The sample analogue of the moment condition will replace the expectation with the sample average taken over all pairs (i, k) ,where $i < k$, and the pairwise differences are skipped within the same market. The pairwise differences among products in the same market produce differences in some exogenous variables that are close to zero, and thus would not contribute to estimating the parameters. As a result, we chose to exclude the pairs that are in the same market.

The endogeneity of r_{jmt} in the model is addressed by using instrument variables. For airline j in market m at time t, the averages of its competitors' estimated ξ and r_{jmt}, weighted by number of passengers, are used as the instruments. The exclusion of the rivals' ξ is established by assuming that ξ_{jmt} is conditionally uncorrelated with ω_{imt} for any i and j in market m. In addition, ω_{jmt} affects rivals' decisions only by affecting firm j's decision about r_{jmt}, so the average of the rivals' r is excluded conditional on r_{jmt}. We use instruments that are different from the estimation of the marginal cost parameters to avoid correlations between the instruments and ω_{jmt}. If the same instrument is used in both the marginal cost and the upgrade cost estimations, the instrument will correlate with the calculated residual by affecting the estimated κ.

VI Demand Estimation Results and Consumer Surplus

Table 4: Demand Parameter Estimates with Standard GMM S.E.

Variables	Coefficient	S.E.
Leisure Travelers		
Constant	-7.7783***	0.2611
Avg. Price	-0.0121***	0.0000
Product Quality	4.7919***	0.1742
Business Travelers		
Constant	-7.6715***	0.6005
Avg. Price	-0.0063***	0.0000
Product Quality	3.3967***	0.2959
Other Product Characteristics		
Distance (1k Miles)	1.6956***	0.0272
Distance^2 (1m Miles^2)	-0.2019***	0.0027
Market Presence at Origin	-0.2526***	0.0156
Tourism Destinations	0.1250***	0.0004
Other Model Parameters		
ρ	0.0008	2.2521
λ	0.1243***	0.0000
Time Fixed Effect		
2015	-0.0552***	0.0000
Airline Fixed Effects		
American	1.8323***	0.0160
Delta	2.0751***	0.0201
United	1.1614***	0.0184
Southwest	1.9263***	0.0218
Significance Level:	*p<0.1; **p<0.05; ***p<0.01	

Table 4 presents the estimation results of the demand parameters. The estimated slopes of the price, α_p, are -0.0063 and -0.0121 for business and leisure travelers respectively.The estimated slopes of product quality (measured by the fraction of nonstop services), α_r, are 3.3967 and 4.7919 for business and leisure travelers, respectively. Business travelers are less sensitive to both price and product quality according to those estimates. This qualitative conclusion is aligned with the estimates in Berry and Jia (2010), which uses a dummy variable of connected flights to indicate the same product characteristics.[10]

Although the product quality coefficient for business travelers (3.3967) shown in Table 4 is smaller than that for leisure travelers (4.7919), our estimates suggest that business consumers are willing to pay more for nonstop flights than leisure travelers. A consumer's willingness to pay for an upgrade from connected services to nonstop services can be calculated by $-\frac{\alpha^r}{\alpha^p}$. Intuitively, a full upgrade from connected services to nonstop services increases the utility that a consumer receives from the product by α^r; the consumer can therefore give up at most $-\frac{\alpha^r}{\alpha^p}$ dollar to maintain the same level of utility. According to the formula $-\frac{\alpha^r}{\alpha^p}$, a business consumer is willing to pay \$539.16 for the quality upgrade while a leisure consumer is willing to pay only \$396.02. The calculation matches the conventional wisdom that business travelers are willing to pay more to avoid connected flights and to reduce traveling time.

The interpretation of our model highlights the difference between the utility of a consumer and her willingness to pay for a quality improvement. In our case, business consumers are not as sensitive in terms of utility to product quality as leisure consumers when they decide which product to purchase, but they are willing to pay more for quality improvements. Our estimates imply that business consumers will be less likely than the leisure consumers to switch to other airlines or to an outside option (i.e., not to fly at all) when they face a price hike or a quality drop. One reason is that business travelers typically have to complete their

[10]Estimates in Berry and Jia (2010) translated into our scale are (1) -0.0007 and -0.0078 in 1996 and (2) -0.0010 and -0.0105 in 2006 for business and leisure travelers respectively.

trips regardless of any price hike or disutility from connected flights. In contrast a price hike or quality drop could make leisure travelers, especially those who travel for tourism or entertainment purposes, switch to car, bus, or train travel, where feasible— or even cancel their trip. And in regard to switching airlines in response to a price hike or quality drop, business travelers might not do so as frequently as leisure consumers would. This is because business travelers are often locked into the choice of a particular airline because of an established relationship between their business and that airline, while leisure travelers have more freedom to switch to more affordable products.

Table 5: Effects of the Wright Amendment on Consumer Surplus by Types

Groups	Treated	OtherRes	WrightZone	Dallas	Control	All
Total CS	-39%	-17%	-3%	-36%	-21%	-24%
Business CS	-25%	-17%	3%	-22%	-19%	-21%
Leisure CS	-60%	-9%	-13%	-56%	-23%	-27%
Business Pass.	-14%	-6%	1%	-12%	-12%	-12%
Leisure Pass.	-38%	-2%	-5%	-34%	-19%	-19%

Table 5 shows the effects of the Wright Amendment on consumer surplus and the simultaneous changes in different benchmark groups. We calculated the changes in consumer surplus and the number of passengers in six different groups of markets. Each column represents a different market group. Specifically, they are markets in the treatment group in our reduced form analysis (Treated), other markets which were restricted by the Wright Amendment but not in the treatment group (OtherRes), markets in the Wright zone that were in Dallas but not restricted by the regulation (WrightZone), all markets in the Dallas area (Dallas), the control group in our reduced form analysis (Control), and all markets in our sample (All). The rows contain information about: changes in total consumer surplus of the two groups (Total CS), changes in consumer surplus of business travelers (Business CS), changes in consumer surplus of leisure travelers (Leisure

CS), changes in total number of business passengers (Business Pass.), and changes in total number of leisure passengers (Leisure Pass.). The consumer surplus for each type of passenger was calculated at the market level,[11] and we summed up the corresponding measure across all markets in the group to calculate the overall effect of the constraints on product quality.

In most of the groups, both the consumer surplus and the total number of passengers had a larger decrease for leisure travelers than for business travelers. In the treatment markets, the drop in the consumer surplus and the total number of passengers of the leisure consumers is larger than the control group, while those of the business passengers are close to the control group and the overall industry trend. This relationship holds in the whole Dallas area as well.

The empirical pattern suggests that leisure travelers were damaged more than business travelers when the Wright Amendment restricted product quality, even though business travelers were willing to pay more to maintain a high product quality. We found two reasons why leisure travelers were damaged more by the quality constraints. First, more leisure travelers than business travelers decided to take the outside, as explained previously and shown in the table. Second, leisure travelers were damaged more than business travelers whenever cheaper airlines raised their prices according to the estimated coefficients. Compared to business travelers, more leisure travelers would like to fly with cheaper airlines, so a price increase or quality reduction by a cheaper airline damages leisure consumers more. Nonstop flights were allowed from Dallas Love Field to areas within the Wright Zone before the repeal of the Wright Amendment. Southwest, which served markets beyond the Wright zone from Dallas Love Field, had to make additional stops in the Wright zone to comply with the Wright Amendment, and thus provided ad-

[11]For each type of passenger, we calculated the market consumer surplus using three steps. First, we recovered fitted indirect utility, denoted as δ_j for product j, by plugging our estimates into Equation 3. Second, we calculated the consumer's expected payoff in the market by calculating $u = \ln(\sum_j [\exp(\delta_j/(1-\lambda))]^{1-\lambda} + 1)$, where λ is the estimated nesting parameter. Third, we converted the expected payoff into a dollar value by calculating $-\frac{u}{\alpha^p}$.

ditional capacity to the Wright zone. As a result, consumers in those markets benefited from the Wright Amendment. The welfare calculation displayed in Table 5 shows that both types of travelers in the Wright zone benefited from the Wright Amendment, because their welfare decreased less compared to the control group or the industry trend. However, the welfare benefit for markets in the Wright zone did not offset the negative effect of the quality constraints in the restricted markets. Thus, the Wright Amendment had an overall negative effect on the markets in the Dallas area.

Our estimate of the weight of the Borenstein (2010) Business Index at the origin, used to calculate share of business consumers in a market and denoted as ρ, is very close to zero. This suggests that the share of business consumers in each market is mainly determined by how many travelers to the destination are for business purpose. However, this empirical finding might not be reliable, since the parameter ρ has a large standard error.

VII Supply Estimates and Sources of the Competitive Responses

Table 6 presents our estimates of the marginal cost and the upgrade cost for each airline. The effect of the fraction of nonstop passengers on the marginal cost is negative, as shown in our estimates. A higher fraction of nonstop passengers lowers the marginal cost in two ways. First, more nonstop flights lead to less mileage flown to complete a trip, so the airlines save fuel and wages. A higher fraction of nonstop passengers therefore decreases the airline's operating cost in the market. Second, a higher fraction of nonstop passengers also leads to a lower opportunity cost. A nonstop trip uses only one nonstop segment, while a connected

Table 6: Cost Parameter Estimates

Variables	Marginal Cost (unit $)	S.E.	Upgrade Cost (unit 10m $)	S.E.
Constant	98.5614***	3.9419		
Fraction of Nonstop Passengers	-39.5767***	2.6252	6.7726***	0.0133
Distance (1k Miles)	22.3357***	3.1874	4.6449***	0.0103
Distance2 (1m Miles2)	9.5295***	1.0476	-0.6738***	0.0019
Cities Connected to the Origin via Airline's Non-stop Service	0.9000***	0.0461	-0.1367***	0.0003
Cities Connected to the Destination via Airline's Non-stop Service	0.7720***	0.0459	-0.1350***	0.0003
Cities Connected to the Origin	-0.5053***	0.0227		
Cities Connected to the Destination	-0.3362***	0.0227		
Hub at Origin or Destination	22.5848***	1.3956	-5.4064***	0.0110
Slot Constrained			0.2309***	0.0018
Fixed Effects				
2015	-17.5815***	0.8543	0.4947***	0.0013
American	32.9980***	2.0761	9.8314***	0.0199
Delta	38.5456***	2.0782	10.4577***	0.0213
United	58.7786***	2.0689	6.6555***	0.0135
Southwest	-3.3140***	2.3608	11.0631***	0.0226

[1] S.E. of the marginal cost estimates are calculated with 2SLS standard error
[2] S.E. of the upgrade cost estimates are calculated with standard GMM S.E.
Note: *p<0.1; **p<0.05; ***p<0.01

trip necessarily uses at least two nonstop segments. Those nonstop segments are combined into connected flights to serve other markets. A higher fraction of nonstop passengers decreases the number of nonstop segments forgone to serve the market, so it decreases the opportunity cost.

The upgrade cost in our model is therefore an investment which improves both product quality and cost efficiency. Previous literature has either ignored the investment, as in Berry, Carnall, and Spiller (2006) and Berry and Jia (2010), or assumes the investment as a fixed cost, which does not improve the marginal cost, as in Ciliberto and Tamer (2009) and Li et al. (2018).

A surprising result in our estimates is that airlines have higher marginal costs at their hubs. This result suggests that most of the cost reduction from hubs reported in previous literature is indeed from additional nonstop flights to destinations. This result is also supported by the negative coefficient of the hub dummy in the upgrade cost estimates. Consequently, our empirical finding suggests that the main function of hubs is to lower the cost of providing nonstop flights. Three reasons might result in the positive sign for the coefficient of the hubs in the marginal cost estimation. First, a hub may reduce the cost of connected flights via that more than the cost of the nonstop flights that originate from it. This mechanism of cost reduction will result in an empirical pattern such that the flights from hubs are more costly than those are not from the hub. Second, the hub might be more congested than airports which are not hubs, so the marginal cost of serving one additional passenger is higher. Third, a ticket at a hub has a higher opportunity cost than those at an airport that is not a hub, because the airline has more options to combine a hub ticket into connected flights to serve more profitable markets.

Following structural estimation, we conducted the same regression analysis as in Section III.c on the markup, marginal cost, and upgrade cost (the unit is ten million dollars) to analyze how the quality reduction caused by the Wright

Table 7: Competitive Effect of Quality Change

	Dependent variable:			
	Price	Markup	MC	UC
	(1)	(2)	(3)	(4)
AA's Response	31.738^{***}	1.873^{*}	29.865^{***}	-0.205
	(5.264)	(0.989)	(5.382)	(0.196)
DL's Response	17.668^{***}	1.114^{*}	16.554^{***}	0.091
	(5.208)	(0.576)	(5.379)	(0.189)
UA's Response	51.110^{***}	2.192^{***}	48.918^{***}	-0.175^{*}
	(8.605)	(0.730)	(7.925)	(0.090)
WN's Response	23.229^{***}	16.875^{***}	6.354	3.355^{***}
	(4.479)	(0.597)	(4.673)	(0.182)
Others' Response	5.888	1.354^{*}	4.535	0.672^{***}
	(7.533)	(0.807)	(7.623)	(0.117)
FE: Airlines	Yes	Yes	Yes	Yes
FE: 2015	Yes	Yes	Yes	Yes
FE: Airlines-Treated	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Observations	2,469	2,469	2,469	2,469
R^2	0.665	0.664	0.638	0.335
Adjusted R^2	0.663	0.662	0.635	0.330
Note:			$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$	

Amendment affected the firms' strategies. The results are shown in Table 7. The four response variables displayed in the Table 7 are price, markup, marginal cost (MC), and product quality upgrade cost (UC). Price in this table is the same as in the previous reduced-form analysis, and we display the result here for convenience. Markup and marginal cost are calculated based on the first order condition of the firm's problem with respect to price as in Equation 13 to decompose the price. The markup is calculated by:

$$-\frac{s_{jmt}}{\partial s_j(\mathbf{p}_{mt}, \mathbf{r}_{mt}, \mathbf{X}_{mt}, \xi_{mt})/\partial p_{jmt}},$$

and the marginal cost for each product is its price minus the calculated markup. The upgrade cost is based on the first order condition of the firm's problem with respect to the fraction of nonstop passengers as in Equation 15, and is calculated by the following equation:

$$r_{jmt}(\tau r_{jmt}+\gamma Y_{jmt}+\omega_{jmt}) = r_{jmt}\{\mathcal{M}_m \cdot s_j(\mathbf{p}, \mathbf{r}, \mathbf{X}_{mt}, \xi)\left[\frac{\partial s_j(\mathbf{p}, \mathbf{r}, \mathbf{X}_{mt}, \xi)/\partial r_{jmt}}{-\partial s_j(\mathbf{p}, \mathbf{r}, \mathbf{X}_{mt}, \xi)/\partial p_{jmt}} - \kappa\right] - \tau r_{jmt},\}$$

where τ and κ are estimated coefficients.

According to our empirical results, the constraints on product quality had two effects on Southwest. On the one hand, the constraints limited Southwest's supply in the Dallas area, so it faced a higher upgrade cost. On the other hand, the constraints on Southwest's product quality boosted Southwest's markup in the treated markets. The higher markup is a result of a shift in the composition of Southwest's customers. According to our model, 79.1 percent of Southwest customers were business travelers before the repeal of the Wright Amendment, while only 50.7 percent of them were business travelers after the repeal. In other words, the product quality constraints imposed by the Wright Amendment on Southwest forced it to serve an inelastic market segment, which consists mostly business travelers. Because the product quality constraints drove away elastic consumers, namely, leisure travelers, Southwest faced a less elastic demand and earned a higher markup.

In addition, the statistical insignificance of the increase in Southwest's marginal cost can be explained by the possibility that Southwest may adjust its capacity allocation across the network. Southwest had incentive to increase the supply in the constrained markets for the higher markup, and this would drive down its marginal cost. Thus, the network adjustment might have compensated the adverse effect of the product quality constraints on the marginal cost.

In contrast, the constraints on Southwest's quality did not increase the markup of its competitors. Rather, Southwest's competitors increased their prices because they faced increased marginal cost. The increased marginal cost could not be explained by the change in the fraction of nonstop passengers either. An airline may invest in product quality and lower its marginal cost, so the quality investment should result in a lower rather than a higher marginal cost. Their surging marginal costs can be explained by their competition with Southwest in other markets. When Southwest was constrained, it assigned capacities to other markets outside of Dallas, so its prices in those markets would be lower. To remain competitive in those markets, Southwest's competitors would have assigned more efficient fleets to those markets, and deployed their less efficient fleets to the restricted markets. This suggests a large spillover effect of the Wright Amendment, as well as an underestimation of the price effect.

The upgrade costs of United decreased while those of airlines other than the largest four increased. This is consistent with an antitrust ruling on the American-US Airways merger, which awarded two gates at the Dallas Love Field Airport to Virgin America after the repeal of the Wright Amendment. When Southwest was constrained, United was using two gates owned by American Airlines in the Dallas Love Field Airport for destinations within the Wright zone. When Southwest was no longer constrained, Virgin America took over the two gates in the Dallas Love Field airport and moved their operation from the Dallas/Fort Worth Airport to the newly obtained gates. Therefore, United had a lower upgrade cost when Southwest was constrained, and airlines other than the four largest ones had lower upgrade costs when Southwest was not constrained. The gaps between the upgrade costs of other airlines and that of United coincided with the gate swap event.

VIII Conclusion

In this paper, we built a structural model and used the 1979 Wright Amendment as a natural experiment to analyze the effect of a regulatory product quality constraint. To estimate the structural model, we used an estimator based on the pairwise difference estimator proposed by Honoré and Powell (1994) and Honore and Hu (2004) from the econometrics literature on semiparametric censored regression. We found that Southwest had a higher markup when its product quality was constrained, because the constraints forced it to focus on an inelastic segment in the markets by driving away elastic consumers. We also found that an increase in the fraction of nonstop passengers would decrease the marginal cost; as a result, quality provision in the airline industry can be interpreted as an investment that lowers marginal cost.

In addition, we calculated the Wright Amendment's effect on consumer welfare. Our demand model allowed us to explicitly calculate consumer welfare by types of consumers and to find out which were affected more by the policy change. We found that business travelers did not take a welfare loss compared to the industry trend, and the total number of business travelers was not affected. However, leisure consumers suffered large welfare damage, and more leisure consumers decided not to travel with any air transportation as a result of the Wright Amendment. This is likely because that the Wright Amendment affected a cheaper carrier, which would have been used by leisure travelers extensively.

The paper suggests to two lines of future research. First, capacity decisions in the airline industry can be modeled and estimated with similar techniques. Capacity is a decision for which a firm may choose a corner solution, and our technique will help with the estimation. Second, a proper model of the spillover effect in the network can help us better understand the competitive behaviors of airlines. Although our finding suggests the existence of a spillover effect, additional research is required to pinpoint the exact underlying mechanism.

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Appendices

Appendix A Summary Statistics of Data

The summary statistics of market characteristics is in Table 8. Each observation is a market-time combination. There were significant changes in the U.S. passenger airline markets between 2014 and 2015. The average number of passengers in each market increased from 53027 to 63210[12], or by 19.2%. Other market level characteristics varied slightly between 2014 and 2015.[13] The fluctuations of number of passengers in the metropolitan areas with multiple airports caused this variation, because those characteristics are calculated by the average of all airports in the metropolitan area weighted by number of passengers.

The construction of variables about market information that requires an explain:

- Tourist Destinations: a dummy variable which is 1 if the destination is Las Vegas or anywhere in Florida.
- Slot Constrained: The three slot constrained airports during the sample period are DCA, JFK, and LGA. As a result, the New York city metropolitan area and the Washington D.C. metropolitan area are flagged as slot constrained in our data.
- Cities Connect to the Origin/Destination: Number of cities connected to origin/destination via nonstop flights by any airlines

The summary statistics of product characteristics is in Table 9. Each observation is a product (airline-market-time combination). During the sampled period,

[12]The numbers are calculated by multiplying the number of DB1B passengers from the summary statistics table by 10 because the DB1B is a 10% sample.

[13]To construct the variable cities connected to the origin, we consider a city is connected to the origin if there exists any airline services (not necessarily non-stop) between the city and the origin. The same applies to cities connected to the destination.

the average price of a product fell from \$ 227.18 to \$ 207.44, or by 9.5%. The ratio of the non-stop flights did not vary by much during the sample period, and were 0.46 and 0.47 in 2014 and 2015 respectively. Other variables were largely stable during the sample period.

- Hub at Origin or Destination: a dummy variable which is 1 at the hub of the airline

- Market Presence at Origin: market presence of an airline j at an airport is defined as the total number of destinations served by airline j from the airport divided by the total number of destinations customer can reach from that airport. The market presence is used to capture the customer loyalty for airline j at the given airport.

- Cities Connect to the Origin/Destination via Airline's Nonstop Service: Number of cities connected to origin/destination via nonstop flights by this airline.

Table 8: Summary Statistics of Market Characteristics

	2014		2015	
	Mean	SD	Mean	SD
Number of Passengers (in DB1B)	5302.718	8085.561	6320.980	9097.098
Total Market Share of Air Transportation	0.063	0.077	0.075	0.086
Number of Firms	3.561	1.571	3.764	1.550
Distance (1k Miles)	1.319	0.663	1.307	0.658
Distance^2 (1m Miles^2)	2.179	1.949	2.143	1.929
Tourist Destinations	0.169	0.375	0.171	0.376
Slot Constrained	0.102	0.303	0.106	0.308
Cities Connected to the Origin	77.589	21.090	78.622	19.694
Cities Connected to the Destination	77.515	21.097	78.683	19.713

Table 9: Summary Statistics of Product Characteristics

	2014		2015	
	Mean	SD	Mean	SD
Avg. Price	227.181	64.487	207.440	65.719
Ratio of Non-stop Flights	0.459	0.471	0.471	0.464
Market Share	0.016	0.026	0.018	0.027
Hub at Origin or Destination	0.444	0.497	0.434	0.496
Market Presence at Origin	0.519	0.255	0.527	0.259
Cities Connected to the Origin via Airline's Non-stop Service	15.526	15.988	16.290	16.080
Cities Connected to the Destination via Airline's Non-stop Service	15.545	16.114	16.240	15.999
American	0.210	0.408	0.205	0.404
Delta	0.227	0.419	0.226	0.419
United	0.090	0.287	0.096	0.295
Southwest	0.304	0.460	0.296	0.456
Other Airlines	0.168	0.374	0.177	0.382

Appendix B Detailed Regression Tables of Wright Amendment's Effects

Table 10: Detailed Results of Effects of Quality Reduction on Markets

	Dependent variable:				
	Price	Ratio	Log Pass.	Log Cap.	Log Rev.
	(1)	(2)	(3)	(4)	(5)
Wright	28.150***	−0.122***	−0.122**	−0.171***	0.026
	(1.764)	(0.004)	(0.057)	(0.046)	(0.062)
Distance (1k miles)	16.813	−0.137***	−0.735	−1.108***	−0.544
	(22.245)	(0.044)	(0.469)	(0.387)	(0.411)
Distance2 (1m miles2)	17.282**	−0.005	0.208	0.187	0.249*
	(7.672)	(0.018)	(0.168)	(0.143)	(0.149)
Business Index in Origin	146.659***	−0.255**	−2.997***	−2.125***	−2.303***
	(29.321)	(0.126)	(0.828)	(0.690)	(0.751)
Business Index in Dest.	80.656***	−0.074	−0.772	−0.575	−0.361
	(19.323)	(0.082)	(0.579)	(0.518)	(0.522)
Fixed Effect: Treated Group	−28.355***	0.076***	0.284*	0.312**	0.142
	(5.668)	(0.024)	(0.165)	(0.129)	(0.145)
Fixed Effect: 2015	−23.579***	−0.019***	0.181***	0.018	0.071
	(1.066)	(0.003)	(0.043)	(0.033)	(0.046)
Constant	81.519***	1.136***	10.476***	13.790***	15.104***
	(21.953)	(0.073)	(0.522)	(0.481)	(0.479)
Observations	594	594	594	594	594
R^2	0.579	0.265	0.079	0.124	0.078
Adjusted R^2	0.574	0.256	0.068	0.113	0.067
Note:					*p<0.1; **p<0.05; ***p<0.01

Table 11: Detailed Results of Competitive Response to Quality Change

	Dependent variable:				
	Price	Ratio	Log Pass.	Log Cap.	Log Rev.
	(1)	(2)	(3)	(4)	(5)
AA's Response	31.738***	0.006	0.089	0.267	0.213***
	(5.264)	(0.020)	(0.070)	(0.193)	(0.053)
DL's Response	17.668***	0.009	0.298***	0.295**	0.371***
	(5.208)	(0.013)	(0.058)	(0.123)	(0.065)
UA's Response	51.110***	0.075***	0.182*	1.087***	0.410***
	(8.605)	(0.026)	(0.108)	(0.380)	(0.123)
WN's Response	23.229***	−0.717***	−0.690***	−8.174***	−0.547***
	(4.479)	(0.020)	(0.058)	(0.208)	(0.041)
Others' Response	5.888	−0.076***	−0.014	−0.536**	0.162
	(7.533)	(0.018)	(0.073)	(0.232)	(0.164)
Distance (1k miles)	24.950	−0.213*	−0.776*	−2.020	−0.485
	(19.731)	(0.113)	(0.406)	(1.397)	(0.363)
Distance2 (1m miles2)	14.320**	0.007	0.183	0.102	0.203
	(7.090)	(0.049)	(0.153)	(0.592)	(0.139)
Business Index in Origin	100.157***	−0.145	−1.680***	−2.961	−1.191**
	(16.528)	(0.153)	(0.527)	(1.830)	(0.529)
Business Index in Destination	66.667***	0.064	−0.116	0.625	0.245
	(11.786)	(0.062)	(0.381)	(0.753)	(0.371)
FE: Treated Market-AA	−11.911**	0.053*	0.532***	0.174	0.505***
	(5.147)	(0.028)	(0.112)	(0.223)	(0.093)
FE: Treated Market-DL	−16.926***	−0.204***	−0.936***	−2.517***	−0.995***
	(4.550)	(0.027)	(0.130)	(0.311)	(0.123)
FE: Treated Market-UA	−37.691***	−0.087**	−1.155***	−1.667***	−1.315***
	(7.585)	(0.043)	(0.169)	(0.463)	(0.160)
FE: Treated Market-Other	−42.579***	0.068	0.152	0.571	−0.232
	(5.662)	(0.053)	(0.195)	(0.543)	(0.180)
FE: Treated Market-WN	−22.983***	0.096***	0.199	1.548***	0.063
	(4.226)	(0.036)	(0.135)	(0.372)	(0.113)
FE: DL	−13.577***	−0.549***	−1.353***	−7.110***	−1.407***
	(2.851)	(0.043)	(0.100)	(0.192)	(0.095)
FE: Other	−76.972***	0.002	−0.366***	−2.071***	−0.828***
	(14.369)	(0.062)	(0.140)	(0.532)	(0.236)
FE: UA	2.704	−0.131***	−0.566***	−2.395***	−0.573***
	(2.735)	(0.047)	(0.058)	(0.330)	(0.055)
FE: WN	−40.591***	−0.293***	−0.393***	−3.789***	−0.564***
	(1.882)	(0.020)	(0.078)	(0.282)	(0.086)
FE: 2015	−23.427***	−0.001	0.220***	0.251***	0.100**
	(3.419)	(0.015)	(0.040)	(0.085)	(0.040)
Constant	116.784***	1.156***	8.631***	14.073***	13.345***
	(16.966)	(0.074)	(0.298)	(0.846)	(0.321)
Observations	2,469	2,469	2,469	2,469	2,469
R^2	0.665	0.425	0.227	0.401	0.213
Adjusted R^2	0.663	0.420	0.221	0.397	0.207
Note:					*p<0.1; **p<0.05; ***p<0.01

Table 12: Detailed Results of Competitive Response of Quality Change

	Dependent variable:			
	Price	Markup	MC	UC
	(1)	(2)	(3)	(4)
AA's Response	31.738***	1.873*	29.865***	−0.205
	(5.264)	(0.989)	(5.382)	(0.196)
DL's Response	17.668***	1.114*	16.554***	0.091
	(5.208)	(0.576)	(5.379)	(0.189)
UA's Response	51.110***	2.192***	48.918***	−0.175*
	(8.605)	(0.730)	(7.925)	(0.090)
WN's Response	23.229***	16.875***	6.354	3.355***
	(4.479)	(0.597)	(4.673)	(0.182)
Others' Response	5.888	1.354*	4.535	0.672***
	(7.533)	(0.807)	(7.623)	(0.117)
Distance (1k miles)	24.950	−0.305	25.256	0.267
	(19.731)	(3.619)	(18.542)	(0.889)
Distance2 (1m miles2)	14.320**	2.391*	11.928*	0.268
	(7.090)	(1.331)	(6.819)	(0.331)
Business Index in Origin	100.157***	3.924**	96.233***	−1.136***
	(16.528)	(1.751)	(15.332)	(0.325)
Business Index in Destination	66.667***	58.492***	8.175	−0.432**
	(11.786)	(2.261)	(10.011)	(0.186)
FE: Treated Market-AA	−11.911**	0.385	−12.296**	0.158
	(5.147)	(0.814)	(5.117)	(0.260)
FE: Treated Market-DL	−16.926***	2.736***	−19.661***	1.025***
	(4.550)	(0.992)	(4.190)	(0.208)
FE: Treated Market-UA	−37.691***	−1.777	−35.914***	−0.446*
	(7.585)	(1.184)	(6.907)	(0.253)
FE: Treated Market-Other	−42.579***	−4.366***	−38.213***	−0.650*
	(5.662)	(1.204)	(4.860)	(0.347)
FE: Treated Market-WN	−22.983***	−4.420***	−18.563***	−0.544**
	(4.226)	(1.013)	(4.000)	(0.227)
FE: DL	−13.577***	10.265***	−23.842***	2.553***
	(2.851)	(1.085)	(3.452)	(0.402)
FE: Other	−76.972***	−6.158***	−70.814***	−0.702
	(14.369)	(1.271)	(13.960)	(0.503)
FE: UA	2.704	3.456***	−0.752	0.500
	(2.735)	(1.198)	(2.164)	(0.330)
FE: WN	−40.591***	3.822***	−44.413***	1.836***
	(1.882)	(0.412)	(2.258)	(0.087)
FE: 2015	−23.427***	−1.364**	−22.063***	0.196
	(3.419)	(0.539)	(3.235)	(0.178)
Constant	116.784***	67.278***	49.505***	−4.509***
	(16.966)	(2.430)	(14.660)	(0.364)
Observations	2,469	2,469	2,469	2,469
R^2	0.665	0.664	0.638	0.335
Adjusted R^2	0.663	0.662	0.635	0.330
Note:				*p<0.1; **p<0.05; ***p<0.01

Appendix C Estimating the Upgrade Cost

In this appendix, we show how our model for the upgrade cost is derived. First, the underlying decision process of the airlines is detailed as the following:

1. Firm sets $r_{jmt} = 0$, and solve for the value of the price $\acute{p}_{jmt}$ that satisfies Equation 13 at $r_{jmt} = 0$.

2. Firm calculates the value of $\frac{\partial \pi_{jmt}}{\partial r_{jmt}}$ evaluated at $r_{jmt} = 0, p_{jmt} = \acute{p}_{jmt}$:

$$\begin{aligned} A_{jmt} &\equiv \frac{\partial \pi_{jmt}}{\partial r_{jmt}}|_{r_{jmt}=0, p_{jmt}=\acute{p}_{jmt}} \\ &= \mathcal{M}_m \cdot s_j(\mathbf{p}, \mathbf{r}, \mathbf{X}_{mt}, \xi) \left[\frac{\partial s_j(\mathbf{p}, \mathbf{r}, \mathbf{X}_{mt}, \xi)/\partial r_{jmt}}{-\partial s_j(\mathbf{p}, \mathbf{r}, \mathbf{X}_{mt}, \xi)/\partial p_{jmt}} - \kappa \right] - \gamma Y_{jmt} - \omega_{jmt} \end{aligned} \tag{23}$$

3. If $A_{jmt} \leq 0$, firm sets $r_{jmt} = 0$ and $p_{jmt} = \acute{p}_{jmt}$.

4. If $A_{jmt} > 0$, firm chooses $r_{jmt} > 0$ and $p_{jmt} > 0$ such that (5) and (8) are satisfied.

For notation simplicity, let C_{jmt} and D_{jmt} denote the value of

$$\mathcal{M}_m \cdot s_j(\mathbf{p}, \mathbf{r}, \mathbf{X}_{mt}, \xi) \left[\frac{\partial s_j(\mathbf{p}, \mathbf{r}, \mathbf{X}_{mt}, \xi)/\partial r_{jmt}}{-\partial s_j(\mathbf{p}, \mathbf{r}, \mathbf{X}_{mt}, \xi)/\partial p_{jmt}} - \kappa \right]$$

evaluated at $r_{jmt} = 0, p_{jmt} = \acute{p}_{jmt}$ and $r_{jmt} = r_{jmt}, p_{jmt} = p_{jmt}$ (the r and p values observed in data), respectively. More specifically,

$$C_{jmt} = \mathcal{M}_m \cdot s_j(\mathbf{p}, \mathbf{r}, \mathbf{X}_{mt}, \xi) \left[\frac{\partial s_j(\mathbf{p}, \mathbf{r}, \mathbf{X}_{mt}, \xi)/\partial r_{jmt}}{-\partial s_j(\mathbf{p}, \mathbf{r}, \mathbf{X}_{mt}, \xi)/\partial p_{jmt}} - \kappa \right] |_{r_{jmt}=0, p_{jmt}=\acute{p}_{jmt}} \tag{24}$$

$$D_{jmt} = \mathcal{M}_m \cdot s_j(\mathbf{p}, \mathbf{r}, \mathbf{X}_{mt}, \xi) \left[\frac{\partial s_j(\mathbf{p}, \mathbf{r}, \mathbf{X}_{mt}, \xi)/\partial r_{jmt}}{-\partial s_j(\mathbf{p}, \mathbf{r}, \mathbf{X}_{mt}, \xi)/\partial p_{jmt}} - \kappa \right] |_{r_{jmt}=r_{jmt}, p_{jmt}=p_{jmt}} \tag{25}$$

and

$$A_{jmt} = C_{jmt} - \gamma Y_{jmt} - \omega_{jmt} \tag{26}$$

The unobserved part of the upgrade cost ω_{jmt} does not directly enters C_{jmt}.[14] Both C_{jmt}, D_{jmt} are well-defined for all markets, and $C_{jmt} = D_{jmt}$ when $r_{jmt} = 0$.

Let us consider the information about ω_{jmt} from the above decision process:

- If $r_{jmt} = 0$, we know that $A_{jmt} \leq 0$, and

$$\omega_{jmt} \geq C_{jmt} - \gamma Y_{jmt}, \tag{27}$$

  i.e. in this case we do not have any equations for ω_{jmt}.

- If $r_{jmt} > 0$, we know that $A_{jmt} > 0$, we observe:

$$D_{jmt} - 2\tau r_{jmt} - \gamma Y_{jmt} - \omega_{jmt} = 0 \tag{28}$$

In this case, we have an equation to calculate ω_{jmt} based on the data and guessed parameters. Thus, the decision at the boundary where $r_{jmt} = 0$ effectively censors the error term ω_{jmt}. In addition, neither C_{jmt} nor Y_{jmt} depends on ω_{jmt}, so the censoring point $(C_{jmt} - \gamma Y_{jmt})$ does not depend on ω_{jmt}.

To write our model in a form that's more similar to the standard censoring model, define

$$B_{jmt} \quad = \quad \max\{A_{jmt}, 0\} \tag{29}$$

[14]It is possible that other firms' choices of r and p depends on ω_{jmt}, and C_{jmt} is correlated with ω_{jmt} through this dependence. However, this complication is beyond the scope of this paper.

With some algebra,

$$
\begin{aligned}
B_{jmt} &= \max\{C_{jmt} - \gamma Y_{jmt} - \omega_{jmt}, 0\} \\
&= \begin{cases} 0 & \text{if } r_{jmt} = 0 \\ A_{jmt} = C_{jmt} - D_{jmt} + 2\tau r_{jmt} & \text{if } r_{jmt} > 0 \end{cases}
\end{aligned}
\tag{30}
$$

where B_{jmt} is computed using

$$
B_{jmt} = (C_{jmt} - D_{jmt}) + 2\tau r_{jmt} \tag{31}
$$

Note that equation 31 holds for all observations. When $r_{jmt} = 0$, $C_{jmt} = D_{jmt}$, and thus $(C_{jmt} - D_{jmt}) + 2\tau r_{jmt} = 0 = B_{jmt}$.