Strategic uncertainty and market size: An illustration on the Wright amendment*

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April 5, 2022

Abstract

This paper exploits the repeal of the Wright amendment as a natural experiment in order to contribute to the ongoing discussion on how the enlargement of the relevant market affects the ability of firms to coordinate on a Nash equilibrium. Using data on the U.S. air transportation industry, we present a Difference-in-Difference procedure which sheds light on the significant loss of accuracy in airlines' predictions in markets originating in Dallas after the Love Field airport started operating long distance services in 2014. This suggests that competition authorities should be careful when they refer to the Nash equilibrium following market expansion reforms.

JEL classification numbers: C51, D21, L13, L40, L93.

Keywords: Market definition, Nash equilibrium, airline industry, transportation.

*The authors are grateful to two referees, as well as seminar participants at the Journées de Microéconomie Appliquée (Annecy, 2021), AFSE (Lille, 2021), and the 4th Meeting on Transport Economics and Infrastructure (Barcelona, 2022), for insightful comments. We acknowledge financial support from the Agence Nationale pour la Recherche, ANR-12-BSH1-0009-01 and EUR grant ANR-17-EURE-0001.

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1 Introduction

Competition authorities usually devote a lot of efforts to delineate some relevant market before progressing to evaluate competitive effects. This characterization is a crucial step in the analysis of merger cases, and also at the moment of determining the degree of dominance of a particular firm or group of firms, as often it drives results of antitrust cases (Kaplow, 2010; Baker, 2007). Indeed plaintiffs typically claim narrower markets and defendants broader markets, as illustrated by cases such as Federal Trade Commission (FTC) versus Staples in 1997, FTC versus Whole Foods Mkt. Inc. in 2008, United States versus Oracle in 2004, or Ziegler SA versus European Commission in 2013.

The relevant market identifies the set of products that impose constraints on each other's pricing or other dimensions of competition such as quality, service, or innovation (Davis and Garcés, 2009). The economic literature has shed light on various methodologies for identifying this set of products. Examining price differences and correlations is perhaps the most common empirical method used, the intuition being that the prices of goods that are substitutes should be connected. The researcher may as well be interested in directly estimating the degree of substitution between a good and its potential substitutes, which requires detailed consumer-level data on the set of possible choices that consumers face and the actual choice that they made. A third approach is the so-called hypothetical monopolist (SSNIP) test. Market definition can then be thought of as the set of products for which, if they were produced by a monopolist, the constraints arising from weaker substitutes outside the market would be insufficient to restrict the monopolist's incentives to increase all prices simultaneously. The SSNIP test nowadays is the standard by which researchers or courts define antitrust markets (Gaynor et al., 2013; Haucap et al., 2021), even if it is often criticized for assuming that all prices outside the candidate set remain fixed, thus neglecting strategic pricing behavior of competitors.

Belova, Gagnepain, and Gauthier (2021) (BGG hereafter) proposes an alternative approach to identify the relevant market. They rely on the presumption that coordination on a Nash equilibrium may be more difficult to achieve in the presence of a large relevant market. Firms then have to predict the outcomes of complex interactions between a higher number of competitors, each one with a richer variety of available strategies. BGG build an index based on rationalizability criteria for the likelihood that an equilibrium obtains (Guesnerie, 1992). The theory predicts a successful coordination on the Nash equilibrium if the value taken by this index is below a threshold. BGG show that the threshold gets lower as the unobserved part of the relevant market expands, hence making the occurrence of the equilibrium less plausible.

Based on BGG we use in this article data on the U.S. air transportation industry to analyze how a change in the size of the relevant market affects the ability of firms to coordinate on a Nash equilibrium. In the airline industry, there are many circumstances where it is difficult to identify the relevant market associated with a particular origin and destination city pair. One may think of multimarket contacts through common endpoints or transportation services as a composite good that consist of differentiated items, e.g., economy versus business class services, or non-stop direct versus indirect flights. Alternative products that entail other modes of transportation such as car or railway can also make identification more difficult. Neglecting part of the potential goods or services in the relevant market leads to underestimate the overall transportation capacity that the airlines have to predict. The econometrician working on a subsample of products could wrongly conclude in favor of a Nash outcome while the actual behavior in fact departs from this equilibrium in the unobserved relevant market.

To test for this prediction, we use the Wright amendment as a natural experiment. The Wright amendment was a US federal law introduced in 1979 that governed traffic at Dallas Love Field (DAL) to protect Dallas Fort Worth Airport (DFW) from competition (Ciliberto and Tamer, 2009). The amendment prohibited carriers from operating services between DAL and destinations beyond Texas and its neighboring states. The law was partially repealed in 2006 and then fully repealed in 2014. The abrogation of airline service restrictions from DAL in a Southwest stronghold area implies greater competitive pressure on DFW, where American Airlines operates direct non-stop long-haul flights. The abrogation of service restrictions affects the expansion of the size of the relevant market of services including the Dallas/Fort Worth area as an origin or destination point, depending on whether the point of destination of origin belongs to the so-called five-state region or not. After the abrogation of the Wright amendment, the same relevant market would typically include all airline services from both DAL and DFW. Whether or not such an increase of the size of the relevant market affects the ability of competing airlines to predict other carriers decisions accurately can be tested empirically.

Our main contribution in this article consists in proposing an original Difference-in-

Difference estimation procedure with data from the Bureau of Transportation Statistics over the 2003-2016 period in order to predict the impact of the repeal of the Wright amendment on a series of economic outcomes that proxy firms' ability to reach a Nash equilibrium.[1] To do so, we construct two groups of routes that serve as our treatment and our control, i.e., we separate routes that are affected by the amendment (those that entail longer flying distances) from those that are not, and we consider two periods of interest that correspond to the stage during which the amendment is active and the one after its full repeal. We find that the expansion of the Dallas airline city market following the full repeal of the Wright amendment caused a high increase in the gap between actual and Nash volumes of transported passengers, which suggests that airlines found it more difficult to make good predictions once the size of the relevant market increased.

The rest of our article is organized as follows. We present BGG's main insights on the computation of the stability index and the identification of a relevant market in Section 2. Section 3 presents the Wright amendment. Section 4 discusses the data. Section 5 present the empirical model and the estimation results. Finally section 6 concludes.

2 Stability index and relevant market

In a Nash equilibrium firms are assumed to be able to predict correctly the behavior of others. Desgranges and Gauthier (2016) relax this requirement and examine whether firms can convince themselves to play Nash if they only know that the other firms play close to the equilibrium. Using a rationalizability-based device, they show that firms should succeed to coordinate on a Nash equilibrium of a Cournot game if and only if

$$\text{STAB} \equiv \sum_f \frac{R'_f(Q^*_{-f})}{R'_f(Q^*_{-f}) - 1} < \bar{S}, \tag{1}$$

where $R_f(Q^*_{-f})$ is the production of firm f best-response to the aggregate production Q^*_{-f} of firms other than f, evaluated at the equilibrium.

If the econometrician observes the whole relevant market, the value of the threshold $\bar{S}$ in Condition (1) is 1. Hence Condition (1) can be viewed as a test that predicts a

[1]BGG focuses on the Wright amendement as well but provides only anecdotal evidence of the effect of the repeal of the amendment on a limited number of routes.

low spread between the actual observed production and the theoretical Nash equilibrium production if the stability index STAB is below 1. The spread should be magnified if instead STAB stands above 1. BGG adapt this test to the particular case of the airline industry. They estimate a structural model for this industry using quarterly data from the U.S. Bureau of Transportation Statistics over the 2003-2016 period. The model yields the volume of transported passengers in the equilibrium for every U.S. domestic route $\times$ airlines $\times$ quarter, as well as the slope of the best-response functions, and so the value of the index for every route $\times$ quarter in their sample. BGG find that the index is below 1 in approximately 90% of the markets in their dataset, and they show that a 10% increase of the index is associated with a 7% increase in the difference between observed and Nash quantities. This finding also serves as an indirect test for the assumption that the strategic interaction between airlines fits Cournot behavior: as airlines are predicted to reach an equilibrium in 90% of the cases, we can infer that the Cournot assumption works reasonably well. Several authors, such as Brander and Zhang (1990), Brueckner (2002) or Basso (2008), have considered Cournot competition in the airline industry as well since, as suggested by Kreps and Scheinkman (1983), the equilibrium outcome of price competition may coincide with Cournot predictions if firms first choose production capacity (choosing and occupying slots in airports is an important strategic task for airlines) before competing in prices.

If the econometrician only observes a part of the relevant market, and so computes the index STAB missing the other part, the threshold $\bar{S}$ has to be adjusted downward below 1. One main innovation in BGG is to develop an empirical method to estimate this threshold. They argue that a lower value of $\bar{S}$ comes with a higher share of missing products not identified in the set of potential substitutes on a given route. As the threshold goes down, it becomes more likely that the observed strategies differ from Nash. The corresponding gap thus can be used as a tool to assess empirically the scope of the relevant market in a given industry.

3 The Wright amendment

The Wright amendment investigated in Ciliberto and Tamer (2009) serves as a natural experiment which can be exploited in order to provide additional feedback about the validity of the methodology proposed in BGG. The aim of the Wright amendment was to restrict airline services out of the Dallas Love airport (DAL) in order to stimulate the activity of the Dallas/Fort Worth airport (DFW).

To put things into perspective, it is important to note that both airports are strategic hubs for two of the largest carriers in the U.S., American Airlines and Southwest. On the one hand, American Airlines is headquartered in Fort Worth and has its largest hub in DFW. In 2015, American Airlines had about 84% of the market share at DFW, making it the largest carrier at the airport. On the other hand, Southwest headquarter is located on the grounds of DAL and enjoys a significant dominant position as well: in 2020, DAL has a single terminal with 20 gates; Southwest has leases to all but two of the gates (Alaska Airlines leases the remaining two and Delta uses a Southwest gate for their flights).

In 1980, the Wright amendment gets effective and states that airline services in DAL could be provided only to airports within Texas and its neighboring U.S. states, namely Louisiana, Arkansas, Oklahoma, New Mexico, Alabama, Kansas, and Mississippi (see for instance Allen, 1989). From DAL airlines could neither offer connecting flights, through service on another airline, nor through ticketing beyond the Wright region. In October 2006 a partial repeal allows flights using the same aircraft with some stop between Love Field and destinations outside the Wright zone. The full repeal gets effective in 2014.

The abrogation of service restrictions affects the expansion of the relevant market of services including the Dallas/Fort Worth area as an origin or destination point, depending on whether the endpoint belongs to Texas and its neighboring states region or not. Consider the case of the Dallas-Washington market for instance: under the Wright amendment, all non-stop flights had to go through DFW because no services were allowed from/to DAL; all of the airline services of the relevant market Dallas-Washington would therefore be products operated from/to DFW. After the abrogation of the Wright amendment, the same relevant market would typically include all airline services from both DAL and DFW. If the econometrician has only data on airline services from/to DFW (which is the exercise we implement here), she does not suffer from any missing information as long as the Wright amendment is effective (in which case the stability index threshold should be close to 1); after the abrogation of the Wright amendment however, a significant share of information would be missing, and this should be reflected in a greater divergence between actual and Nash numbers of transported passengers and in Equation (1) a fall in the stability threshold $\bar{S}$ in airlines routes involving Dallas.

4 Data

Our primary data combines the Airline Origin and Destination Survey (DB1B) and financial data made freely available by the U.S. Bureau of Transportation Statistics. Financial data only provide information on aircraft costs at the segment level, so that the structural model in BGG is estimated on direct non-stop flights. Table 1 below reports summary statistics on such flights in routes involving Dallas Fort Worth and airports located inside or outside the Wright zone. We restrict our attention to routes where transportation services are active before and after the repeal of the Wright amendment. We also require that they transport at least $1,200$ passengers over one year. As expected, flights unrestricted by the Wright amendment (linking Dallas to other destinations within Texas as well as its neighboring states) display a shorter distance, and they link Dallas to cities smaller than the densely populated cities reached from Dallas using long-haul flights. The average number of passengers transported by an airlines is similar in the two groups: in the last column the higher average number of passengers in restricted routes (outside the Wright zone) thus reflects a higher number of competitors active outside the Wright zone.

Table 1: Summary statistics

	distance (km)	Endpoint city market population (millions)		Average number of passengers by	
		Highest	Lowest	route × quarter × airlines	route × quarter
Routes inside the Wright Zone	330	5.18	1.10	162.97	345.78
Routes outside the Wright zone	970	5.44	3.14	135.27	366.20

Table 2 and 3 below list all the routes served by Southwest and American Airlines respectively. We observe that Southwest serves no destination outside the Wright zone, which were allowed from Fort Worth on the whole sample period, using direct non-stop flights before the full repeal of 2014. Kansas City is an exception due to a special exemption of Missouri negotiated in 2005. Southwest starts to provide long distance non-stop flight services between Fort Worth and cities outside the Wright zone only after the full repeal of the amendment in 2014.

Instead American Airlines uses its hub airport of Fort Worth to offer a broad range of services, both on short distance routes not restricted by the Wright amendment where it competes against Southwest, and on long distance restricted routes free of Southwest competitive pressures. The cities in bold are those where both Southwest and American Airlines are active during at least one quarter within the considered sub-period: it is clear that, inside the Wright zone, American competes against Southwest in most routes during the three sub-periods. Outside the Wright zone however, both airlines are competitors on longer distance non-stop flights only after the repeal of the amendment. We might expect then that the repeal of the amendment had no significant impact on the strategic interaction between American and Southwest on routes located in the Wright Zone, while it might have affected predictions on services supplied outside the Wright zone.

5 Empirical model and results

To measure how the actual quantity q_{stf} of passengers transported by airline f departs from the Nash quantity q^*_{stf} in route s during quarter t, we refer to the normalized Nash spread

$$\Delta_{stf} = \frac{(q_{stf} - q^*_{stf})^2}{q^*_{stf}}.$$

The Nash volume q^*_{stf} obtains from the estimation of a structural model of the U.S. airline industry based on a linear demand and quadratic cost specification. The market demand is $P_{st} = \delta^0_{st} - \delta_{st} Q_{st}$ where Q_{st} is the aggregate demand of passenger transportation services in route s during quarter t and P_{st} represents the corresponding airline fare. The cost function of airlines f during quarter t is $q^2_{fst}/2\sigma_{fst}$ when transporting q_{sft} passengers in route s during quarter t. The aggregate equilibrium production is then

$$Q^*_{st} = \frac{\displaystyle\sum_f \frac{\delta^0_{st}\sigma_{fst}}{1+\delta_{st}\sigma_{fst}}}{1 + \displaystyle\sum_f \frac{\delta_{st}\,\sigma_{fst}}{1+\delta_{st}\sigma_{fst}}}. \qquad (2)$$

while the Nash equilibrium production of firm f is

$$q^*_{fst} = \frac{\sigma_{fst}}{1+\sigma_{fst}\delta_{st}}(\delta^0_{st} - \delta_{st} Q^*_{st}). \qquad (3)$$

Table 2: SouthWest (WN) operations at Dallas/Fort Worth

Status of the Wright amendment	Routes inside the Wright zone	Routes outside the Wright zone
active	Little Rock, AR	**Kansas City, MO**
2003-1:2006-2	Lubbock, TX	
	Midland/Odessa, TX	
	San Antonio, TX	
	New Orleans, LA	
	Oklahoma City, OK	
	Tulsa, OK	
	Amarillo, TX	
	Austin, TX	
	El Paso, TX	
	Albuquerque, NM	
	Houston, TX	
partial repeal	**Little Rock**, AR	**Kansas City, MO**
2006-3:2014-2	Lubbock, TX	
	Midland/Odessa, TX	
	San Antonio, TX	
	New Orleans, LA	
	Oklahoma City, OK	
	Tulsa, OK	
	Amarillo, TX	
	Austin, TX	
	El Paso, TX	
	Albuquerque, NM	
	Houston, TX	
full repeal	**Lubbock**, TX	**Kansas City, MO**
2014-3:2016-4	**San Antonio**, TX	**Milwaukee, WI**
	New Orleans, LA	**Philadelphia, PA**
	Oklahoma City, OK	**Salt Lake City, UT**
	Tulsa, OK	**Denver, CO**
	Austin, TX	**Atlanta, GA**
	El Paso, TX	**Phoenix, AZ**
	Albuquerque, NM	**Seattle, WA**
		Washington, DC
		Chicago, IL
		Charlotte, NC
		Orlando, FL
		Las Vegas, NV
		San Francisco, CA

Note: Routes where both WN and AA are present are marked in bold.

Table 3: American airlines (AA) operations at Dallas/Fort Worth

Status of the Wright amendment	Routes inside the Wright zone	Routes outside the Wright zone
active	**San Antonio, TX**	Louisville, KY
2003-1:2006-2	**New Orleans, LA**	**Kansas City, MO**
	Oklahoma City, OK	Philadelphia, PA
	Tulsa, OK	Salt Lake City, UT
	Austin, TX	Denver, CO
	El Paso, TX	Atlanta, GA
	Albuquerque, NM	Phoenix, AZ
	Houston, TX	Seattle, WA
		Chicago, IL
		Charlotte, NC
		Detroit, MI
		Orlando, FL
		Las Vegas, NV
		San Francisco, CA
partial repeal	**Little Rock, AR**	Louisville, KY
2006-3:2014-2	**San Antonio, TX**	**Kansas City, MO**
	New Orleans, LA	Philadelphia, PA
	Oklahoma City, OK	Salt Lake City, UT
	Tulsa, OK	Denver, CO
	Austin, TX	Atlanta, GA
	El Paso, TX	Phoenix, AZ
	Albuquerque, NM	Seattle, WA
	Houston, TX	Washington, DC
		Chicago, IL
		Charlotte, NC
		Detroit, MI
		Orlando, FL
		Las Vegas, NV
		San Francisco, CA
full repeal	**Lubbock, TX**	**Kansas City, MO**
2014-3:2016-4	**San Antonio, TX**	**Milwaukee, WI**
	New Orleans, LA	**Philadelphia, PA**
	Oklahoma City, OK	**Salt Lake City, UT**
	Tulsa, OK	**Denver, CO**
	Austin, TX	**Atlanta, GA**
	El Paso, TX	**Phoenix, AZ**
	Albuquerque, NM	**Seattle, WA**
		Washington, DC
		Chicago, IL
		Charlotte, NC
		Orlando, FL
		Las Vegas, NV
		San Francisco, CA

Note: Routes where both WN and AA are present are marked in bold.

BGG estimate the parameters δ^0_{st}, δ_{st} and σ_{fst} in demand and supply functions and obtain equilibrium quantities from (3).[2] Figure 1 depicts how the average Nash spread

$$\Delta_t = \frac{1}{n}\sum_{fs}\Delta_{fst}$$

evolves over time for routes s restricted by the Wright amendment (in red) and for routes s unrestricted (in black). Here n stands for the numbers of quarter $\times$ airlines observations in the group of routes under scrutiny, either restricted or not. The two vertical dotted lines indicate the moment of partial and full repeal.

The gap between the actual and Nash volumes of transported passengers was possibly magnifying before 2006 in both groups of routes. Recall that Southwest launched public relations campains against the Wright amendment from 2004. The partial repeal of the Wright amendment in 2006 seems to have stopped this trend, and eventually yielded a gap closer to 0 in both groups. The gap stabilizes at this low level until one approaches the full repeal in 2014. It then starts increasing in routes that were previously restricted by the amendment (in red), while it instead falls in the remaining routes, those unrestricted by the amendment (in black).

Figure 2 depicts how the difference $\Delta^{\text{outside}}_t - \Delta^{\text{inside}}_t$ between the Nash spreads in (restricted) routes outside the Wright zone and (unrestricted) routes inside the Wright zone evolves over time. The difference is therefore positive when the gap between the actual and Nash quantities is greater in restricted routes. Before the full repeal, the difference remains close to 0, except between the start of public relations campaign by Southwest in 2004 and the implementation of the partial repeal in 2006. Indeed Figure 1 has shown that, at the moment of the partial repeal implementation, the Nash spread goes back to 0 more slowly in restricted routes. After the full repeal in 2014, as the relevant market from Dallas expands with new services offered from Love Field and Southwest starts scheduling flights from Fort Worth, the difference between the Nash spread in previously restricted routes increases compared to the spread in non restricted routes (linking Dallas to city markets within Texas and its neighboring states).

This pattern suggests to use (unrestricted) routes inside the Wright zone as a control group for our empirical test of the effect of an expansion of the relevant market. We con-

[2] The estimation is performed by maximum likelihood and relies on several proxies related to routes and airlines characteristics to identify supply and demand parameters.

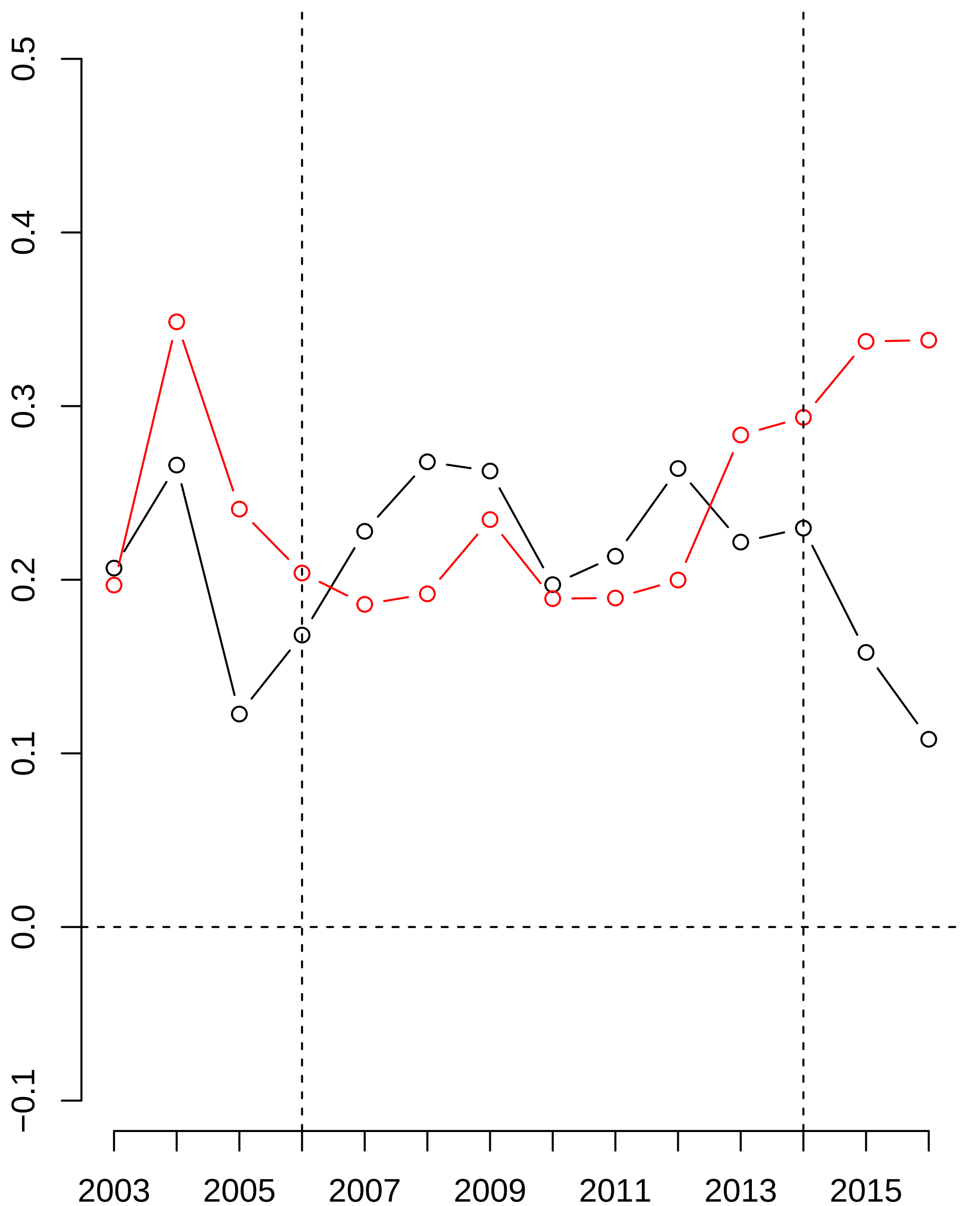

Figure 1: Nash departures in restricted and unrestricted routes

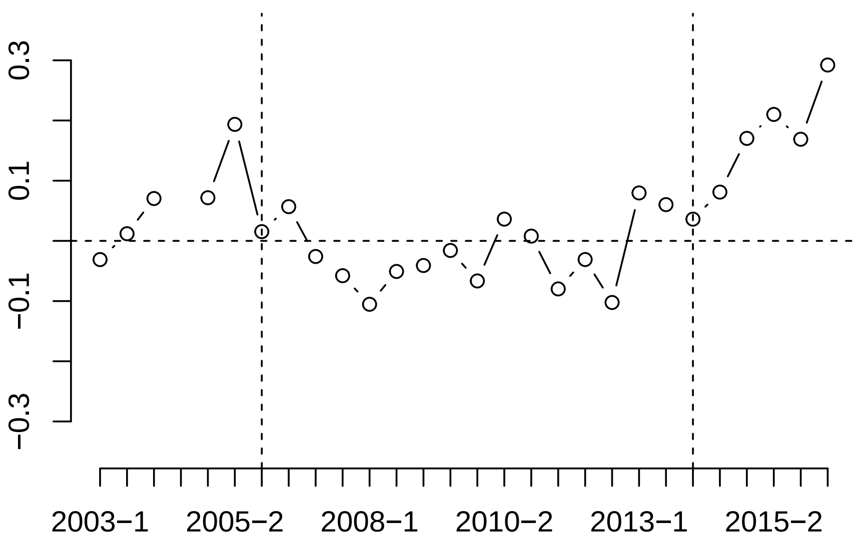

Figure 2: Relative Nash spread

struct a Difference-in-Difference (DiD) estimation procedure as follows: all routes from/to DFW to/from any airport located *outside* the Texas neighboring states are in our treatment group, while the control group comprises all routes from/to DFW to/from any airport located *inside* Texas and its neighboring states. Moreover, we define two periods: *before* runs from 2003:1 to 2014:2 and corresponds to the period during which the Wright amendment is active in our data; *after* runs from 2014:3 to 2016:4 and corresponds to the period after the full repeal of the Wright amendment. This methodology fits our research question very well for two reasons: In order to accurately assess the impact of a change in the size of the relevant market on airlines ability to reach a Nash equilibrium, we need to have two differences present in the estimation. First, we need to have a difference over time, namely, the differences in the Nash spreads between the first and last period. Second, we ought to account for cross-sectional differences between routes located in the Texas and neighboring states area, and those going beyond the neighboring states zone.

We estimate the equation

$$\Psi = \beta_0 + \beta_1 \text{ AFTER} + \beta_2 \text{ OUT} + \beta_3 \text{ AFTER} \times \text{OUT} + \delta X + \varepsilon, \tag{4}$$

where Ψ is the outcome to be explained. AFTER is a dummy variable that takes value 1 if the observation happens over the period 2014:3 to 2016:4, OUTSIDE is a dummy variable that takes value one if the observed route links DFW to an airport located outside Texas and neighboring states, X is a vector of additional explanatory variables, and ε is an error term. This setup allows us to specify four categories, namely INSIDE-BEFORE, INSIDE-AFTER, OUTSIDE-BEFORE, OUTSIDE-AFTER, whose aggregated effects on the explained variable are measured by β_0, $\beta_0+\beta_1$, $\beta_0+\beta_2$, and $\beta_0+\beta_1+\beta_2+\beta_3$ respectively. Our main coefficient of interest is β_3 as it measures the average increase in the explained outcome Ψ in routes outside the Wright zone over the increase in the routes inside the Wright zone.

The main estimation results are shown in Columns (1) to (6) of Table 4. The explained variable Ψ is the Nash spread Δ_{sft} defined by route $\times$ firm $\times$ quarter. They all show that the repeal of the Wright amendment has implied a huge rise in the Nash spread. The average spread in routes with an endpoint located outside the Wright zone is 0.23 over the whole period before the full repeal of the amendment. Therefore, the 0.15 increase reported

Table 4: Nash spread and market size

	Nash spread Δ_{sft}					
	(1)	(2)	(3)	(4)	(5)	(6)
AFTER	-0.056^{*}	-0.070^{**}	-0.058^{*}	-0.059^{*}	-0.076^{**}	-0.078^{***}
	(0.031)	(0.031)	(0.031)	(0.031)	(0.030)	(0.026)
OUTSIDE	0.001	-0.045^{**}	0.010	-0.082^{***}	-0.108^{***}	-0.150^{***}
	(0.019)	(0.021)	(0.019)	(0.025)	(0.026)	(0.024)
POPULATION (millions)		0.042^{***}			0.043^{***}	0.035^{***}
		(0.009)			(0.009)	(0.007)
TEMPERATURE			0.004^{**}		0.006^{***}	0.004^{**}
			(0.002)		(0.002)	(0.002)
DISTANCE (1,000 km)				0.125^{***}	0.117^{***}	0.117^{***}
				(0.026)	(0.026)	(0.024)
Alaska Airlines Inc.						-0.188^{***}
						(0.057)
America West Airlines Inc.						-0.145^{*}
						(0.076)
American Airlines Inc.						0.213^{***}
						(0.034)
Delta Air Lines Inc.						0.048
						(0.044)
Envoy Air						-0.122^{*}
						(0.063)
ExpressJet Airlines Inc.						0.241^{***}
						(0.092)
Frontier Airlines Inc.						-0.070
						(0.055)
Mesa Airlines Inc.						-0.056
						(0.164)
Republic Airlines						0.288^{**}
						(0.119)
SkyWest Airlines Inc.						0.034
						(0.058)
Southwest Airlines Co.						-0.147^{***}
						(0.037)
Spirit Air Lines						0.025
						(0.039)
United Air Lines Inc.						0.047
						(0.043)
US Airways Inc.						-0.104^{***}
						(0.039)
Virgin America						-0.038
						(0.063)
AFTER x OUTSIDE	0.155^{***}	0.145^{***}	0.159^{***}	0.165^{***}	0.159^{***}	0.202^{***}
	(0.036)	(0.036)	(0.036)	(0.036)	(0.036)	(0.031)
Constant	0.231^{***}	0.102^{***}	-0.045	0.190^{***}	-0.355^{**}	-0.226
	(0.016)	(0.030)	(0.135)	(0.018)	(0.142)	(0.144)
Observations	1,478	1,478	1,478	1,478	1,478	1,478
R^2	0.026	0.042	0.029	0.041	0.061	0.349

Notes: ***Significant at the 1 percent level; ** 5 percent; * 10 percent.

in Columns (1) to (5) following the Dallas market expansion approximately represents 60 per cent of the Nash spread prevailing in the presence of flight restrictions. Column (1) reports the results of the most parsimonious specification including neither fixed effects nor additional explanatory variables in X. Columns (2) to (5) account for route characteristics in X: the average population in the endpoint city markets, the average temperature and the route distance. The Nash spread is higher in routes linking Dallas to densely populated cities, in hot weather conditions, and on long-haul flights, presumably outside the Wright zone. The increase in the Nash spread is magnified when one introduces airlines fixed effects, using AirTran Airways as reference. Northwest and America West appear as the least Nash spread airlines, while regional carriers ExpressJet and SkyWest and the low cost Spirit Air Lines displays the greatest gap between their actual and Nash strategies. Of course it is no longer optimal to play Nash when facing non-Nash competitors, so that the least spread carriers may not necessarily adopt the best seat strategies.

Tables 5 and 6 discuss the status of the stability index STAB and the threshold $\bar{S}$ as suitable summary statistics for the plausibility of the Nash equilibrium. In the linear demand and quadratic cost specification, the stability index (1) in route s during quarter t writes

$$\mathrm{STAB}_{st} = \sum_{f} \frac{\delta_{st}\sigma_{fst}}{1 + 3\delta_{st}\sigma_{fst}}.$$

It depends on the same parameters δ_{st} and σ_{fst} as those entering the expression of the Nash equilibrium production. The index STAB increases with $\delta_{st}\sigma_{fst}$ for every firm f, market s, and quarter t. On the one hand, an increase in δ_{st} corresponds to a higher sensitivity of the actual price to the total quantity produced. A small error made by any given airlines when assessing the production of the others then implies a larger change in the price used by the airlines to set their own production. This translates into a greater uncertainty about individual productions, which makes accurate predictions more difficult to achieve. On the other hand, an increase in σ_{fst} reduces the magnitude of the change in the marginal cost when production increases. It is then easier for airlines to adjust individual production in response to others' decisions; hence, production is more flexible, which complicates again predictions about others' production. Table 5 reports estimation results of the model in Equation (4) with the stability index as an explained variable Ψ. Since BGG estimate STAB at the route level, the (robust) standard errors are clustered by route. All the specifications show that the repeal of the Wright amendment yielded a significant increase

Table 5: Stability index and market size

	Stability index $STAB_{st}$				
	(1)	(2)	(3)	(4)	(5)
AFTER	0.034	0.009	0.038	0.039	0.017
	(0.032)	(0.036)	(0.033)	(0.031)	(0.036)
OUTSIDE	0.028	−0.050	0.011	0.184*	0.106
	(0.051)	(0.047)	(0.054)	(0.095)	(0.077)
POPULATION (millions)		0.073***			0.077***
		(0.027)			(0.027)
TEMPERATURE			−0.008		−0.006
			(0.007)		(0.005)
DISTANCE (1,000 km)				−0.237**	−0.261***
				(0.094)	(0.083)
AFTER x OUTSIDE	0.201***	0.183***	0.194***	0.183***	0.157***
	(0.049)	(0.052)	(0.048)	(0.047)	(0.047)
Constant	0.571***	0.348***	1.079**	0.648***	0.785*
	(0.016)	(0.085)	(0.470)	(0.031)	(0.407)
Observations	1478	1478	1478	1478	1478
R^2	0.267	0.37	0.288	0.384	0.518

Notes: ***Significant at the 1 percent level; ** 5 percent; * 10 percent. Robust standard errors clustered by route.

in the index, in accordance with the theoretical analysis that markets with a high index are more likely to display a high departure from Nash. The index is higher in routes with densely populated cities endpoints, which is consistent with the high Nash spread found for these routes in Table 4. Note that the index tends to be lower on long-haul flights, which is not consistent with the distance effect obtained in Table 4. The distance variable effect should probably be taken with caution as our treatment in Equation (4) is already conditioned by distance, which could potentially create multicollinearity. The introduction of the distance variable however does not influence our main treatment effect which is quite consistent across the different specifications.

Table 6 shows that the threshold $\bar{S}$ diminishes as the relevant market expands from Love Field. As explained above, a lower threshold $\bar{S}$ has two main consequencies: First, it implies that a higher fraction of air services included in the relevant market of a particular route is missing in the database. Moreover, it makes stability on a particular market more unlikely as the condition expressed in (1) tightens. As the threshold is estimated at the route level in BGG, the (robust) standard errors are again clustered by route. The threshold is smaller in routes with densely populated endpoints, which goes in line with the view that a low threshold captures a large market.

Overall, the combination of the results in Tables 5 and 6 accord with our previous finding of a higher Nash spread following the repeal in Table 4: the stability index STAB increases while the threshold $\bar{S}$ decreases over the AFTER period in routes outside the Wright zone, so that in Equation (1) it becomes more likely to get eventually STAB above $\bar{S}$ in these routes.

6 Robustness checks

The evolution of the spread between the actual and Nash volumes of transported passengers closely depends on our modeling specification through the estimated equilibrium volume. If, for instance, the actual volume gets higher in routes previously subject to the Wright amendment, while the specification does not capture the equilibrium change in the enlarged market, the increase in the spread mostly reflects some model misspecification. It is therefore important to investigate further how the estimated value of the equilibrium responds to the repeal. Appealing to (2) and (3), this amounts to assessing the change in the cost

Table 6: Stability threshold and market size

	Threshold $\bar{S}_{st}$				
	(1)	(2)	(3)	(4)	(5)
AFTER	−0.009	0.011	−0.011	−0.006	0.013
	(0.028)	(0.029)	(0.030)	(0.031)	(0.032)
OUTSIDE	−0.054	0.011	−0.048	0.040	0.091
	(0.063)	(0.067)	(0.065)	(0.079)	(0.082)
POPULATION (millions)		-0.061^{*}			−0.057
		(0.034)			(0.036)
TEMPERATURE			0.003		0.0001
			(0.008)		(0.007)
DISTANCE (1,000 km)				−0.142	−0.126
				(0.099)	(0.104)
AFTER x OUTSIDE	-0.124^{**}	-0.109^{**}	-0.122^{**}	-0.135^{**}	-0.120^{**}
	(0.055)	(0.053)	(0.055)	(0.055)	(0.052)
Constant	0.793^{***}	0.979^{***}	0.608	0.839^{***}	1.003^{**}
	(0.046)	(0.110)	(0.510)	(0.064)	(0.466)
Observations	1478	1478	1478	1478	1478
R^2	0.137	0.22	0.14	0.186	0.259

Notes: ***Significant at the 1 percent level; ** 5 percent; * 10 percent. Robust standard errors clustered by route.

and demand parameters σ_{fst} and δ_{st} following the enlargement of the Dallas market.

Table 7: Supply and demand ingredients

	Cost (σ_{fst})		Demand (δ_{st})	
	(1)	(2)	(3)	(4)
AFTER	-0.016	-0.058	0.175^{***}	0.072^{**}
	(0.065)	(0.061)	(0.030)	(0.032)
OUTSIDE	-0.638^{***}	-0.292^{***}	0.490^{***}	-0.160^{***}
	(0.040)	(0.052)	(0.083)	(0.056)
POPULATION (millions)		0.130^{***}		0.268^{***}
		(0.017)		(0.045)
TEMPERATURE		0.024^{***}		0.001
		(0.004)		(0.004)
DISTANCE (1,000 km)		-0.656^{***}		0.555^{***}
		(0.052)		(0.074)
AFTER x OUTSIDE	0.044	-0.017	0.164^{*}	0.141^{**}
	(0.076)	(0.071)	(0.091)	(0.062)
Constant	1.411^{***}	-0.352	1.209^{***}	0.166
	(0.033)	(0.284)	(0.017)	(0.240)
Observations	1478	1478	1478	1478
R^2	0.189	0.299	0.332	0.671

Notes: ***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

Table 7 reports the results of the regression (4) with cost and demand parameters used as explained variables. On the one hand, columns (1) and (2) indicate that the technology used by the airlines over the two-year time window of the AFTER period does not change in the treated routes (that were subject to restricted flights before the repeal in 2014). On the other hand, columns (3) and (4) show a significant change in the demand function as δ_{st} increases in the treated routes. That is, the repeal of flight restrictions from Love Field makes the fare more sensitive to the volume of passengers. As shown in BGG, the slope of the best-response function of firm f

$$R'_f(Q^*_{-f}) = -\frac{\delta_{st}\sigma_{fst}}{2\delta_{st}\sigma_{fst} + 1} \tag{5}$$

is negative and decreases with δ. Thus, airlines are more sensitive to the decisions of the others in the Wright routes, which makes it more difficult for each firm to make accurate predictions. We conclude that changes in the theoretical Nash quantities after the repeal of the Wright amendment are mostly driven by passengers demand. The change in STAB following the repeal is therefore fully driven by the demand side: STAB increases since the actual airlines fare becomes more sensitive to the total number of transported passengers on the treated routes compared to those of the control group. The theoretical prediction is an increase in the Nash spread. The change in δ influences directly the Nash equilibrium quantities that enter as references in the Nash spread. However, we expect no spurious correlation between STAB and the Nash spread as the latter also depends on the actual productions.

We now discuss several variants of our main framework. First, note that, in the list of routes given in Table 2, Kansas City is operated by Southwest though the amendment is in force. Several flights connecting Love Field and Missouri airports were actually exempted from the Wright restrictions before 2006. In columns (1) and (2) of Table 8, we reproduce the outcome of an additional DiD estimation with the flights between Fort Worth and Kansas City moved to the control group. The increase in the Nash spread is shown to be slightly higher compared to our specification presented in Table 3 but the general results are left unchanged.

Second, assume that AFTER takes value 1 earlier on during both sub-periods of partial and full repeal, i.e., from 2006 instead of 2014 as in Table 4. Figure 2 suggested a low divergence between the actual and Nash quantities of passengers during the partial repeal

Table 8: Variants on stability threshold and market size

	Nash spread Δ_{sft}					
	Kansas City in INSIDE		Partial repeal in AFTER		American Airlines without Southwest	
	(1)	(2)	(3)	(4)	(5)	(6)
AFTER	-0.061^{**}	-0.081^{***}	0.011	-0.006	-0.033	-0.037
	(0.028)	(0.028)	(0.059)	(0.058)	(0.074)	(0.069)
OUTSIDE	0.011	-0.115^{***}	0.111	0.002	-0.002	-0.245^{***}
	(0.018)	(0.028)	(0.070)	(0.071)	(0.068)	(0.069)
POPULATION (millions)		0.044^{***}		0.053^{***}		-0.023
		(0.009)		(0.008)		(0.015)
TEMPERATURE		0.008^{***}		0.006^{***}		0.016^{***}
		(0.002)		(0.002)		(0.004)
DISTANCE (1,000 km)		0.126^{***}		0.103^{***}		0.359^{***}
		(0.029)		(0.026)		(0.044)
AFTER x OUTSIDE	0.177^{***}	0.179^{***}	-0.070	-0.075	0.113	0.165^{**}
	(0.034)	(0.034)	(0.072)	(0.070)	(0.078)	(0.073)
Constant	0.224^{***}	-0.448^{***}	0.206^{***}	-0.349^{**}	0.199^{***}	-0.942^{***}
	(0.014)	(0.144)	(0.057)	(0.154)	(0.067)	(0.234)
Observations	1,478	1,478	1,478	1,478	494	494
R^2	0.037	0.065	0.006	0.047	0.023	0.159

Notes: ***Significant at the 1 percent level; ** 5 percent; * 10 percent.

sub-period. Columns (3) and (4) show that the total increase in the Nash spread measured over both partial and full repeal sub-periods is not statistically different from 0. This suggests that the partial repeal allowing direct flights with stops did not significantly impact the relevant market of non-stop flights. The actual expansion of the relevant market starts in 2014, when long distance non-stop flights are allowed from Love Field.

Finally, we suspect that the increase after 2014 of the Nash spread on routes located outside the Wright zone is the sum of two distinct effects. First, starting from 2014, competition increases on many markets originating in DFW as both Southwest and American airlines are present, which might affect predictions of all competing firms and change the Nash spread. Second, the relevant market is expanded as long distance flights are operated from both DAL and DFW, which makes convergence to a Nash equilibrium more difficult. In an attempt to separate both effects, we neutralize the higher competition outcome in DFW. To do so, we reproduce the DiD estimation using a subsample where American Airlines only (not Southwest) is present. Hence, the expansion of the relevant market should be the only relevant effect in this case. The results presented in columns (5) and (6) show a stronger impact of the unobserved market expansion at Love Field on the Nash spread. This suggests that the second effect (induced by the simultaneous presence of Southwest and American Airlines) is negative, as the total effect measured by β_3 in Table 4 is lower. This suggests that American Airlines and Southwest are probably able to understand each other's strategy much better than those of the other competing airlines.

7 Conclusion

This article exploits the brutal change in the supply of air transportation services caused by the repeal of the Wright amendment in 2014 to examine how the gap between the observed quantities of transported passengers and the hypothetical Nash quantities has changed after 2014. We find that the larger relevant market magnified departures from Nash.

The previous literature interested in assessing firms' conduct has put a great effort on trying to evaluate the effect of firms' entry on the economic outcome of a particular industry. The usual result is that prices go down after entry, which benefits consumers (see Amir and Lambson (2000) for instance). This result assumes that the market equilibrium is obtained before and after entry. Here, we suggest instead that more competition can complicate the ability of firms to make predictions about their competitors' strategies when the number of products or services supplied in a specific market increases. The repeal of the Wright amendment magnifies competitive pressure on airlines services provided from DFW, and this may compromise the occurrence of an equilibrium, which complicates welfare analysis. Obviously, this effect should not be limited to the airline industry: in any industry where the usual indicators of high competitive pressure are present, i.e., where several firms with similar market shares or new technologies are observed, the traditional equilibrium welfare analysis has to be worked out carefully.

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