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Air services on thin routes: Regional versus low-cost airlines

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ABSTRACT

An examination of the impact in the US and EU markets of two major innovations in the provision of air services on thin routes – regional jet technology and the low-cost business model – reveals significant differences. In the US, regional airlines monopolize a high proportion of thin routes, whereas low-cost carriers are dominant on these routes in Europe. Our results have different implications for business and leisure travelers, given that regional services provide a higher frequency of flights (at the expense of higher fares), while low-cost services offer lower fares (at the expense of lower flight frequencies).

1. Introduction

The liberalization of air transportation services has been deemed a successful experience both in the United States and Europe, because it has increased airline competition. As a result, travelers today enjoy lower fares, higher flight frequencies, and more alternatives on many routes, especially on those with high traffic density. The implications for travelers of this accrued competition have attracted a great deal of attention. However, as the empirical literature on airline competition has tended to focus on dense markets,[2] it is still unclear whether thin-route travelers have also benefited from market liberalization.[3]

The presence of density economies characterizes the airline industry (Caves et al., 1984; Brueckner and Spiller, 1994; Berry et al., 2006), which means that competition on thin routes is unlikely as cost minimization will typically result in just one airline offering a service. Several papers have confirmed that traffic density is one of the main determinants of airline entry decisions (Johnson, 1985; Joskow et al., 1994; Dresner et al., 2002a; Schipper et al., 2003; Oliveira, 2008). The lack of competition is especially relevant on thin routes where alternative transportation modes (i.e., bus, train or car) cannot offer an efficient service. Bilotkach et al. (2010) show that intermodal competition is only relevant in Europe on routes that are shorter than 400 mi.

The goal of this paper is to analyze the provision of air services on thin routes in the United States (US) and the European Union (EU). To conduct this analysis, emphasis should be placed on two recent major innovations which may have affected substantially air services on thin routes: regional jet technology and the low-cost business model. The development of regional jets represents a major technological innovation as these aircraft can provide higher-frequency services on longer routes than is possible with turboprops; and the emergence of a low-cost business model represents a significant managerial innovation, making it possible to offer seats at lower fares (with lower flight frequency) for any distance range.

A review of the literature fails to clarify whether regional and low-cost connections are used by airlines on thin routes. A small number of papers have analyzed the use of regional aircraft (either turboprops or regional jets) in the airline industry. Brueckner and Pai (2009) find that regional jets are mostly used by airlines to feed hub airports. In a similar vein, Dresner et al. (2002b) find that regional jets are mainly used on new hub-to-spoke routes (i.e., routes that are longer than those served by turboprops), and appear to increase demand on

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[2] In contrast to thin routes, dense routes have a sufficiently large volume of traffic such that carriers can benefit from *economies of traffic density*, i.e., economies from operating larger aircraft at higher load factors.
[3] Since Borenstein's (1989) seminal work, many studies have examined the influence of competition on airline fares. To the best of our knowledge, only Starkie and Starrs (1984) for Australia, Bitzan and Chi (2006) for the United States, and Fageda (forthcoming) for Spain, analyze the factors that determine fares on thin routes.

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dense routes where they replace turboprops. As for the provision of air services by low-cost carriers,[4] Bogulaski et al. (2004) find that Southwest tends to provide services on dense routes. In an analysis of the market between the United Kingdom and continental Europe, Gil-Moltó and Piga (2008) show that entry (and exit) of airlines such as British Airways, Easyjet, and Ryanair is more likely to occur on dense routes.

By means of a simple theoretical model, we show that airlines tend to offer lower fares and frequencies on thinner markets. However, airlines can also charge higher fares as they increase flight frequency. Thus we observe that, for a given demand, regional airlines can offer higher frequencies at higher fares, while low-cost airlines may try to take advantage of the economies of traffic density by using large aircraft with higher load factors.

In addition, we draw on data for a large number of point-to-point routes in the US and the EU to identify the influence of route characteristics (i.e., distance, traffic density, competition, and proxies for the proportion of leisure travelers) on the likelihood of services on thin routes being provided by either regional airlines or low-cost carriers. The US and the EU airline markets have different characteristics because the US market is more mature, having undergone a marked consolidation with a small number of airlines offering services, whereas the EU market is more fragmented and unstable with many airlines offering services in different countries. Furthermore, the mean route distance is notably higher in the US than it is in the EU.

We find that the advantages of regional jets on medium-haul routes are fully exploited in the US, while the use of regional jets is markedly lower in the EU. Low-cost airlines operate similarly to network airlines in the US in terms of route choices because both types of airline prefer high-density routes, whereas European low-cost airlines dominate routes with a lower number of seats. As a consequence, we find evidence of very different models for the provision of air services on thin routes in the US and European markets, respectively. While in the US thin routes are mainly served by regional carriers, in Europe they are mainly operated by low-cost airlines.

Clearly, these results have different implications for business and leisure passengers. On the one hand, regional services are especially convenient for business passengers as they allow airlines to offer a higher frequency and, moreover, flights are typically provided at airports located close to city centers. On the other hand, low-cost services with mainline jets are more convenient for leisure passengers as fares are lower, although this is typically at the expense of a lower flight frequency and, in some cases, flights are provided at airports located some distance from the city center.

The rest of this paper is organized as follows. Our theoretical model is introduced in Section 2 and our main empirical findings are presented in Section 3. Section 4 offers our conclusions. Proofs of the theoretical model are provided in Appendix A and some additional empirical material is available in Appendix B.

2. The theoretical model

Airlines use different aircraft and business models depending on the characteristics of each city-pair market (and market size is an important element). We consider a monopoly model based on the analysis conducted by Bilotkach et al. (2010) to study airline services in thin markets. The main novelty of our analysis lies in the extension of this model to consider market size, so that we can conduct a comparative-static analysis to examine the effect of thin markets. Another modeling difference is the introduction of load factor as an element that affects the number of passengers per flight (together with aircraft size), following the approach in Fageda and Flores-Fillol (forthcoming). These novelties allow us to analyze the different behavior of regional carriers and low-cost carriers in the provision of air services in thin markets.

Our model is based on indirect utilities of heterogeneous travelers choosing between scheduled services and not traveling at all (i.e., opting to stay at home). We consider a monopoly air carrier as the provider of scheduled services, a choice that is realistic on many thin routes where alternative transportation modes are not available.[5]

In the model, utility for a consumer *traveling by air* is given by *Consumption* − *Schedule delay disutility* + *Value of available time*. *Consumption* is $y-p_{air}$ where y is the common level of income and p_{air} is the airline's fare.

Letting H denote the time circumference of the circle, consumer utility then depends on *expected schedule delay* (defined as the difference between the preferred and actual departure times) which equals $H/4f$, where f is the number of (evenly spaced) flights operated by the airline. The *Schedule delay disutility* is equal to a disutility parameter $\delta>0$ times the expected schedule delay expression from above, thus equaling $\delta H/4f=\gamma/f$, where $\gamma\equiv\delta H/4$. We assume that all passengers value frequency equally and thus the parameter γ is common for all of them. Passenger heterogeneity emerges here through travelers' value of time, as is explained below.

Finally, the available time at the destination is computed as the difference between the passenger's total trip time (T) and the actual traveling time which depends on the distance between the origin and the destination (d) and the plane's speed (V), thus equaling $T-d/V$. We assume a large enough T so that $T>d/V$. Thus, taking into account the traveler's specific value of time α, the *Value of available time* at the destination equals $\alpha(T-d/V)$, where α is assumed to be uniformly distributed over the range [0, 1]. Consequently, consumer population size equals 1. However, thin markets are characterized by a lower potential demand. Therefore, to model thin markets we assume that only consumers with $\alpha\in(\mu,1-\kappa)$ can undertake air travel, where $0<\mu<\frac{1}{2}$ and $0<\kappa<\frac{1}{2}$. The parameters μ and κ measure the density of the market. Larger values of μ denote less dense markets (i.e., thinner markets) with fewer low-value consumers, whereas larger values of κ denote less dense markets (i.e., thinner markets) with fewer high-value consumers. When $\mu=\kappa=0$, we have the densest possible market with a unitarian demand; and as $\mu\to\frac{1}{2}$ and $\kappa\to\frac{1}{2}$, we move towards the thinnest possible market with 0 density.

Hence, utility from air travel is

$$u_{air}=y-p_{air}-\gamma/f+\alpha[T-d/V]. \tag{1}$$

Consumers can also choose not to travel and stay at home, obtaining a utility of $u_o=y$. Disregarding the trivial cases (either where nobody travels or where everyone flies), a consumer will undertake air travel when $u_{air}>u_o$, and this inequality holds with

$$\overline{\alpha}=\frac{p_{air}+\gamma/f}{T-d/V}. \tag{2}$$

Thus, consumers with a sufficiently high value of time will undertake air travel and consumers with a sufficiently low value of time will stay at home, as represented in Fig. 1.

[4] The literature focuses on the effect on prices, finding that entry of a low-cost carrier on a particular route tends to reduce fares. See, for instance, Gaggero and Piga (2010), Fageda and Fernández-Villadangos (2009), Goolsbee and Syverson (2008), Morrison (2001), and Dresner et al. (1996).

[5] Bilotkach et al. (2010) study the effect of the competition between air travel and personal transportation, which occurs when route distance is sufficiently low. Flores-Fillol (2009) considers an outside option that can be interpreted as an alternative transportation mode, and analyzes the effect of having either fully-served markets or partially-served markets depending on the cost of the outside option. Finally, it could be argued that some (domestic) markets exhibit contestability characteristics, so that airlines behave competitively. Studying airline services on thin routes by means of a more sophisticated model of airline schedule competition in competitive markets would be an interesting contribution to the literature.

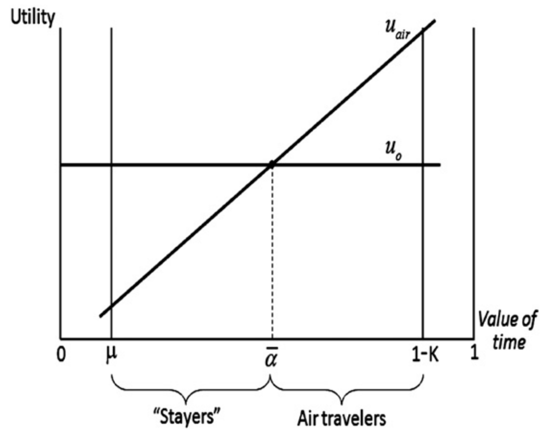

Fig. 1. Utilities.

We observe that an increase in μ reduces the number of "stayers" while an increase in κ reduces the number of air travelers. Therefore, thinner markets have a lower demand for air travel as long as there are fewer high-value consumers. In the analysis that follows, we will consider this kind of thin markets where the demand for air travel is lower.

From Eq. (2), demand for air travel is given by

$$q_{air} = \int_{\overline{\alpha}}^{1-\kappa} d\alpha = 1-\kappa-\overline{\alpha} = 1-\kappa-\frac{p_{air}+\gamma/f}{T-d/V}, \tag{3}$$

where we observe that thinner markets have a lower demand.

To characterize the equilibrium in fares and frequencies, we need to specify the carrier's cost structure. As in Fageda and Flores-Fillol (forthcoming), the number of flight departures is given by $f=q_{air}/n$, where n is the *number of passengers per flight*. Both aircraft size and load factor determine the number of passengers per flight, which is given by $n=ls$, where s stands for aircraft size (i.e., the number of seats) and $l\in[0,1]$ for load factor. It is assumed that n is an airline choice variable whose value is determined residually once q_{air} and f are known. For a given demand level, increasing either the load factor or aircraft size implies a lower flight frequency.[6]

A *flight's operating cost* is given by $\theta(d)+\tau n$, where the parameter τ is the marginal cost per seat of serving the passenger on the ground and in the air, and the function $\theta(d)$ stands for the cost of frequency (or cost per departure). $\theta(d)$ captures the aircraft fixed cost, which includes landing and navigation fees, renting gates, airport maintenance and other airport-related costs.[7] We assume that $\theta(d)$ is continuously differentiable with respect to $d>0$ and that $\theta'(d)>0$ because fuel consumption increases with distance. Further, to generate determinate results, $\theta(d)$ is assumed to be linear, i.e., $\theta(d)=\theta d$ with a positive marginal cost per departure $\theta>0$.[8]

Note that the cost per passenger, which can be written $\theta d/n+\tau$, visibly decreases with n capturing the presence of economies of traffic density (i.e., economies from serving a larger number of passengers on a certain route), the existence of which is beyond dispute in the airline industry. In other words, having a larger traffic density on a certain route reduces the impact on the cost associated with higher frequency.

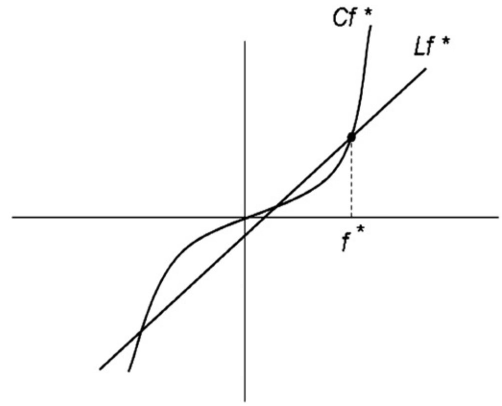

Fig. 2. The f solution.

Therefore, the *airline's total cost* is $C=f[\theta d+\tau n]$ and, using $n=q_{air}/f$, we obtain $C=\theta df+\tau q_{air}$. The airline's profit is $\pi_{air}=p_{air}q_{air}-C$, which can be rewritten as

$$\pi_{air} = (p_{air}-\tau)q_{air}-\theta df, \tag{4}$$

indicating that average variable costs are independent of the number of flights.

After plugging Eq. (3) into Eq. (4) and maximizing, we can compute the first-order conditions $\partial\pi_{air}/\partial p_{air}=0$ and $\partial\pi_{air}/\partial f=0$. From these conditions, it is easy to obtain the following expressions

$$p_{air} = \frac{(1-\kappa)(T-d/V)-\gamma/f+\tau}{2}, \tag{5}$$

$$f = \left(\frac{(p_{air}-\tau)\gamma}{\theta d(T-d/V)}\right)^{1/2}. \tag{6}$$

On the one hand, Eq. (5) shows that fares rise with market density, passengers' total time, variable costs and the aircraft's speed, and fall with schedule delay and distance. Note that flying becomes less attractive over longer distances and that the airline seeks to compensate this negative effect by lowering fares. On the other hand, Eq. (6) indicates that frequency increases with passengers' disutility of delay, carrier's margin $(p_{air}-\tau)$ and the aircraft's speed, whereas it decreases with the cost of frequency and passengers' total time. The effect of distance on f is also negative for $d<TV/2$, which is always the case for sufficiently large values of T. As in Bilotkach et al. (2010), the second-order conditions $\partial^2\pi_{air}/\partial p_{air}^2, \partial^2\pi_{air}/\partial f^2<0$ are satisfied by inspection and the remaining positivity condition on the Hessian determinant is $p_{air}-\tau > \frac{\gamma}{4f}$. Finally, we also need to assume a sufficiently small θ to ensure positive profits.[9]

By combining Eqs. (5) and (6), we obtain the following equilibrium condition

$$\underbrace{\frac{2\theta d(TV-d)}{\gamma}f^3}_{Cf*} = \underbrace{[(1-\kappa)(TV-d)-\tau V]f-\gamma V}_{Lf*}. \tag{7}$$

The equilibrium frequency is shown graphically in Fig. 2, as in Bilotkach et al. (2010), where we observe that the f solution occurs at an intersection between a cubic expression (Cf^*) and a linear expression (Lf^*) whose vertical intercept is negative. The slope of Lf^* must be positive for the solution to be positive and thus we assume that τ is small enough for this to be the case. We observe that there

[6] Although an airline may decide to decrease load factor to increase frequency, some previous papers consider load factor not to be a choice variable and assume a 100% load factor (see Brueckner, 2004; Brueckner and Flores-Fillol, 2007; Brueckner and Pai, 2009; Flores-Fillol, 2009, 2010; and Bilotkach et al., 2010).

[7] Although the cost of fuel is not a cost per departure, it may also be included in this category since it increases with distance.

[8] Since fuel consumption is higher during landing and take off operations, $\theta''(d)<0$ might be a natural assumption. Assuming a concave function of the type $\theta(d)=\theta d^r$ with $r\in(0,1)$ would have no qualitative effect on our results.

[9] Note that $q_{air}>0$ since we disregard the trivial case where nobody travels (i.e., we assume $\overline{\alpha}<1-\kappa$); $p_{air}>\tau>0$ is assumed to observe a positive Hessian determinant; and $f>0$ holds since $T>d/V$ is assumed.

are two possible positive solutions, but only the second one satisfies the second-order condition.[10]

Looking at Eq. (7) together with Fig. 2, we can carry out a comparative-static analysis for all the parameters in the model. Although some effects do not seem trivial from inspection of Eq. (7), the proposition below ascertains the overall effect by analyzing the sign of the total differential of the equilibrium frequency with respect to each parameter (see Appendix A for details).

Proposition 1. *The equilibrium flight frequency decreases as markets become thinner (i.e., as κ increases). It also falls with the cost per departure (θ), the marginal cost per seat (τ), and route distance (d). However, the frequency rises with the disutility of delay (γ), passengers' total time (T), and the plane's speed (V).*

Thinner markets (i.e., markets with larger values of κ) are characterized by a lower demand for air travel and, as a consequence, airlines schedule fewer flights. When either the cost per departure (θ) or the marginal cost per seat (τ) increases, frequency falls since air travel becomes less competitive. Flight frequency also decreases with distance (d), which is a natural outcome when there is no competition from alternative transportation modes, confirming the results in Bilotkach et al. (2010), Wei and Hansen (2007), and Pai (2010). We observe a positive effect of γ on f^* since carriers increase frequency as passengers' disutility of delay increases. When passengers' total time (T) rises, more passengers are willing to undertake air travel since the utility of flying increases and, as a consequence, the equilibrium frequency increases. Finally, when the plane's speed increases (V), we observe the same effect as with T, i.e., the valuation of air travel increases and thus the equilibrium frequency rises.

To ascertain the effect on fares, Eq. (5) shows that some parameters have a *direct effect* on fares, and that there is also an *indirect effect* through flight frequency. The indirect effect comes from the positive relationship between fares and frequencies, since a higher service quality typically implies a higher fare. The corollary below summarizes these effects.

Corollary 1. *The equilibrium fare decreases as markets become thinner (i.e., as κ increases). It also falls with the cost per departure (θ) and route distance (d). However, fares rise with passengers' total time (T) and the plane's speed (V). The effects of the marginal cost per seat (τ) and the disutility of delay (γ) are ambiguous.*

The direct effect of κ, d, T, and V on p^*_{air} reinforces the indirect effect through flight frequency, and yields the natural result that higher frequencies result in higher fares. In the case of θ, there is no direct effect because it does not appear in Eq. (5), and thus it only affects fares through flight frequency. Finally, in the cases of τ and γ there is a conflict between the direct and the indirect effects. An increase in τ has a positive direct effect and a negative indirect effect on fares. A priori, if the airline becomes more inefficient, it has to increase fares. However, this increase in costs may also imply a fall in flight frequency since air travel becomes less competitive, which yields lower fares. A rise in γ has a negative direct effect and a positive indirect effect on fares. The reason is that, if passengers become more sensitive to schedule delay, the airline will have to lower fares unless it chooses to compensate for this increased sensitivity to schedule delay by offering a better service quality. The aforementioned comparative-static analysis for fares and frequencies is recapitulated in Table 1 below.

The comparative-static analysis reported above suggests that fares and frequencies are lower in thinner markets. Nevertheless, there are substantial differences across thin markets. An explanation for this can be found by considering the type of aircraft and business model adopted by airlines in each market. In particular, fares and frequencies are typically higher on routes served by regional aircraft (for a given number of total seats), whereas they are typically lower on routes operated by low-cost carriers.

Regional jet technology (which has made the use of regional aircraft on relatively long routes widespread) and the low-cost business model constitute two recent innovations in the airline industry that have been implemented by carriers to discriminate better between business and leisure passengers. Business passengers are characterized by their high disutility of delay, whereas leisure travelers are more fare sensitive, i.e., $\gamma_B > \gamma_L$, where subscript B stands for business travelers and subscript L denotes leisure passengers. As a consequence, a higher proportion of business travelers on a certain route should create incentives for airlines to increase flight frequency.

Since airport-related costs are lower for smaller aircraft, regional jet aircraft incur lower costs per departure than mainline jets used by low-cost carriers, i.e., $\theta_{RJ} < \theta_{LC}$, where subscript RJ stands for regional jet services and subscript LC denotes low-cost services. However, costs per passenger are clearly higher for regional jet services than they are for low cost services, i.e., $\tau_{RJ} > \tau_{LC}$.

In addition, for a given demand level, increasing either the load factor or aircraft size implies a lower flight frequency since $f = q_{air}/n$ and $n = ls$. By increasing frequency (which implies either a smaller aircraft size or a lower load factor), airlines provide a 'higher-quality' product and reduce passengers' schedule delay, but they incur an extra cost of departure. However, by decreasing frequency (which implies either a larger aircraft size or a higher load factor), they reduce the cost per passenger because of the presence of economies of traffic density. This trade-off is solved very differently depending on the service provided by the airline. On the one hand, regional carriers may prefer to use small aircraft (either turboprops or regional jets) and even lower load factors to be able to offer a higher frequency of service, and having a low cost per departure (θ_{RJ}) helps in adopting such a strategy. On the other hand, low-cost carriers try to achieve low airfares by making use of mainline jets with a high load factor at the expense of offering a lower flight frequency.

Taking into account the above analysis, we can better understand the provision of air services in thin markets. At first glance, we observe that thinner routes yield lower frequencies. In addition, the higher cost per passenger of regional jet aircraft could make regional services inappropriate on these routes. However, when the proportion of business travelers is high, flight frequency becomes an important market attribute and regional services may be better. Regional aircraft are smaller, have a lower cost per departure, and can offer higher flight frequency at higher fares (even at the expense of a lower load factor). By contrast, when the proportion of leisure travelers is high, passengers are fare-sensitive and prefer lower fares (at the expense of poorer frequencies). In this case, low-cost airlines may try to take advantage of the economies of traffic density by using large aircraft with higher load factors.

The empirical analysis that follows, provides a more thorough analysis of the use of regional and low-cost services on thin routes, and identifies interesting differences between the US and European markets.

Table 1
Comparative-static effects.

Parameter	f^* (frequency)	P^*_{air} (fare)
κ (inverse market density)	−	−
θ (cost per departure)	−	−
τ (marginal cost per seat)	−	?
d (route distance)	−	−
γ (disutility of delay)	+	?
T (passengers' total time)	+	+
V (plane's speed)	+	+

Note: A larger κ denotes thinner markets.

[10] Observe that for the second intersection to be relevant, the slope of Cf^* must exceed the slope of Lf^*, i.e., $\frac{6\theta d(TV-d)}{\gamma} f^2 > (1-\kappa)(TV-d) - \tau V$. Using Eqs. (5) and (6), this expression reduces to $p_{air} - \tau > \frac{\gamma}{4f}$, which is exactly the condition required by the positivity of the Hessian determinant.

3. The empirical model

In this section, we conduct an empirical analysis to examine which type of airline service is being offered on thin routes in the US and the EU. First, we explain the criteria used in selecting the route sample and describe the variables used in the empirical analysis. Then, we examine the data and estimate the equations to identify how different route features (distance, demand, competition, and the proportion of business and leisure travelers) influence the type of airline service that dominates thin routes.

3.1. Data

The empirical analysis uses route-level data from the US and the EU for 2009. We draw on data for all routes served in continental US where both airports (origin and destination) are located in Metropolitan Statistical Areas (MSAs). We exclude airports located in Micropolitan Statistical Areas as direct comparison with their European counterparts is not as straightforward. In the EU, we have data for all routes served by direct flights from the ten largest countries in terms of their air traffic volume to all European destinations (EU-27 + Switzerland and Norway). The ten countries are the United Kingdom, Spain, Germany, France, Italy, the Netherlands, Portugal, Sweden, Greece, and Ireland. For the remaining European countries, a very high proportion of traffic takes off and lands at their largest airport.

Since our focus here is point-to-point thin routes,[11] we use a subset of the routes for which we have data, so that the eventual sample used in our empirical analysis is restricted to routes that do not have a network airline hub as an endpoint.[12] Proceeding in this way, we exclude the routes in the US and EU markets with a high proportion of connecting traffic from our empirical analysis. Our final sample comprises 2803 US routes and 2788 European routes.[13]

Thus, we can take advantage of a large cross-section in our empirical analysis. A limitation of our data is that they refer to just one year. While extending our sample to create a panel would be preferable, we still think that our analysis is valuable. Note that airlines' aircraft fleet can only change in the long run and there is a strong inertia in airlines' choice of frequencies.

Network airlines are understood to be those carriers that belonged to an international alliance (i.e., Oneworld, Star Alliance, and SkyTeam) in 2009. Today, the amount of connecting traffic that can be channeled by an airline not involved in an international alliance is necessarily modest. Therefore, our approach distinguishes between airlines that exploit connecting traffic as an essential part of their business (i.e., network airlines) and airlines that focus their business on point-to-point routes (mainly low-cost airlines). By adopting this criterion, we are able to avoid the complex task of having to drawing up a list of low-cost carriers without comprehensive data regarding airline costs.

Most *non-network airlines* can be considered l*ow-cost carriers* (both in the US and in the EU). Low-cost carriers, which are either independent or subsidiaries of network airlines, have been able to exploit cost advantages on point-to-point routes by implementing a model based on a high utilization of aircraft and crews, lower labor costs, lower airport charges and a simpler management model (e.g., just one type of plane, a single-fare class, no free on-board frills, etc.).

Regional services, which are the ones where regional aircraft (either turboprops or regional jets) are used, are provided by network airlines either directly or by means of a subsidiary or partner airline. However, on routes where regional aircraft are dominant, as the dataset allocates these flights to a network carrier, we are unable to determine whether the services are provided by a regional carrier that is a subsidiary of the network airline, or by an independent regional carrier that has signed a contract with the network airline.[14]

Airline supply data (frequencies, type of aircraft and total number of seats) for each route both in the US and the EU have been obtained from RDC aviation (capstats statistics). As for aircraft type, the most frequently used turboprops in our sample are the following: ATR 42/72, British Aerospace ATP, De Havilland DHC-8, Embraer 120, Fairchild Dornier 328, Fokker 50, and Saab 340/2000; while the most frequently used regional jets are: Avro RJ 70/85/100, BAe 146, Canadian Regional Jet, Embraer RJ 135/140/145/270/175/190/195, and Fokker 70/100. Finally, the most frequently used mainline jets in our sample are the following: Airbus 318/319/320/321, Boeing 717/737/757, and MD 80/90.

In the case of the US, data for population and gross domestic product per capita of route endpoints refer to the MSA and the information has been obtained from the US census. In the case of the EU, these data refer to the NUTS 3 regions (the statistical unit used by Eurostat) and have been provided by Cambridge Econometrics (European Regional Database publication). Data on route miles distance are taken from the Official Airline Guide (OAG) and the webflyer website.[15]

Our analysis also seeks to identify those routes with the highest proportions of tourist travelers. In the EU, all airports on the following islands are considered tourist destinations: the Balearic and Canary Islands (Spain), Sardinia and Sicily (Italy), Corsica (France), and many Greek islands, together with the airports of Alicante (ALC), Faro (FAO), Malaga (AGP), Nice (NCE) and Saint Tropez (LTT). In the US, it is less clear which airports are located in what might be deemed exclusively tourist destinations. According to data from the US Department of Commerce (2010), among the top 20 tourist destinations, only Orlando, Las Vegas, and Gran Canyon have a high tourism intensity (i.e., their rate of international visitors per capita is higher than one). In fact, Brueckner and Pai (2009) only consider Las Vegas, Orlando, and two ski resorts as tourist destinations. In this empirical analysis, we consider as tourist destinations the airports of Las Vegas (LAS), Orlando (MCO), Grand Canyon (FLG), Spokane (GEG), Vail (EGE), and certain coastal cities in Florida and California, which are the two most popular states for tourism in the US. Some ski resort airports (such as Aspen) are not included in our sample because they are located in Micropolitan Statistical Areas.

Additionally, we constructed an airport access variable that measures the distance between the airport and the city center using Google Maps. In most cases, the identity of the relevant city was self-evident. However, for airports between cities, we calculated the distance from the airport to the closest city with more than 100,000 inhabitants. The airport access variable may influence the proportion of business travelers on a route, as they are highly sensitive to trip

[11] We exclude data for airlines that offer a flight frequency of less than 52 services per year on a particular route: operations with less than one flight per week should not be considered as scheduled.

[12] Hub airports in the US are the following: Atlanta (ATL), Charlotte (CLT), Chicago (ORD), Cincinnati (CVG), Cleveland (CLE), Dallas (DFW), Denver (DEN), Detroit (DTW), Washington Dulles (IAD), Houston (IAH), Memphis (MEM), Miami (MIA), Minneapolis (MSP), Los Angeles (LAX), New York (JFK and EWR), Philadelphia (PHL), Phoenix (PHX), San Francisco (SFO), and Salt Lake City (SLC). Hub airports in the EU are the following: Amsterdam (AMS), Budapest (BUD), Copenhagen (CPH), Frankfurt (FRA), Helsinki (HEL), London (LHR), Lisbon (LIS), Madrid (MAD), Munich (MUC), Paris (CDG and ORY), Prague (PRG), Rome (FCO), Stockholm (ARN), Vienna (VIE), Warsaw (WAW), and Zurich (ZRH).

[13] Note that we do not treat airline services in different directions on a given route as separate observations as this would overlook the fact that airline supply must be identical, or nearly identical, in both directions of the route. Thus, we consider the link with the origin in the largest airport. For example, on the route Saint Louis–Akron–Saint Louis, we consider the link Saint Louis–Akron but not the link Akron–Saint Louis.

[14] Decisions of this type lie beyond the scope of this paper. Forbes and Lederman (2009) examine the conditions under which major airlines in the US provide regional air services either using vertically integrated carriers or via contracts with independent regional carriers. They find that major airlines are likely to rely on trusted regional subsidiaries on those routes where schedule disruptions are costly and likely to occur.

[15] See http://webflyer.com.

Table 2
Some data about the endpoints.

	US ($N=2803$)	EU ($N=2788$)
Number of annual seats	54,413 (0.54)	60,242 (0.71)
Distance (miles)	943.10 (1.61)	724.54 (1.45)
Airport distance to the city center	22.21 (1.83)	45.44 (1.42)
Proportion of tourist routes	18.51%	33.53%
Flight frequency (annual)	478.35 (0.56)	462.53 (0.72)
Mean aircraft size	105.56 (2.62)	143.87 (2.70)

time and, so, airports at some distance from the city center will be less attractive for them.

Table 2 shows some of the features of the routes in our sample. The mean number of seats offered by airlines in the US is lower than the one offered by their EU counterparts, while the variability over this mean is also lower. The total number of seats offered by an airline on a route can be considered as a proxy for demand because the variability in the load factor is typically low.[16]

Routes in the US are, on average, longer than those in the EU. In fact, 83% of routes in the US sample exceed 400 mi, while this percentage stands at just 66% in the EU. Airports are more distant from the city center in the EU and the proportion of routes with a tourist destination as an endpoint (according to the criterion mentioned above) is also higher. While 33% of routes in the EU sample have a tourist destination as an endpoint, this percentage falls to 18% in the US sample. Finally, the mean aircraft size is higher and flight frequency is lower on European routes.

Next, we examine the type of aircraft that is used most frequently by the dominant airlines of each of the routes included in our sample. Then we analyze whether network carriers or low-cost carriers dominate the routes in our sample.

3.2. Regional services

Fig. 3 shows the proportion of routes that are served by the different types of aircraft (i.e., turboprops, regional jets and mainline jets) both in the US and the EU. We focus our attention on routes shorter than 1500 mi as neither turboprops nor regional jets can be used on routes beyond this threshold distance. In fact, the distance range of turboprops is less than 1000 mi.

Fig. 3 indicates that regional jets are used notably more in the US than they are in the EU: regional jets dominate about 45% of routes in the US and account for just 11% of routes in the EU. Although turboprops are still important in the EU, where they are dominant on 18% of routes, their presence is much more modest in the US where they dominate just on 6% of routes.

Figs. 4 and 5 show the use of the three types of aircraft for different distance ranges on American and European routes, respectively. On very short-haul routes (shorter than 400 mi), turboprops are the most frequent type of aircraft used in the EU and they are also frequently used in the US. Importantly, regional jets are the most frequently used type of aircraft in the US on routes shorter than 800 mi and they are also used regularly on routes within the 800 to 1200-mile distance range. Mainline jets are clearly dominant in the EU on routes longer than 400 mi, while in the US they are dominant on routes that exceed 800 mi.

The fact that in the EU turboprops are still used more frequently than regional jets could be a possible explanation for the considerably lower presence of regional aircraft on routes longer than 400 mi (compared to the situation in the US). An important advantage of

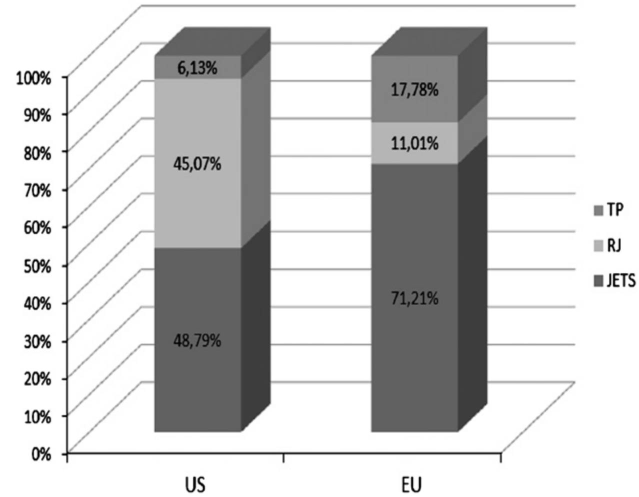

Fig. 3. Regional services on routes shorter than 1500 mi.
Note 1: TP are turboprops, RJ are regional jets, and JETS are mainline jets.
Note 2: Number of US routes = 2364; Number of EU routes = 2554.

regional jets in relation to turboprops is that they enable airlines to provide services on thin routes that are too long for surface transportation modes. Indeed, the provision of air services on thin routes may be particularly relevant on routes longer than 400 mi where intermodal competition is soft or even non-existent.

Note that the highest number of routes in our sample falls within the 400 to 800-mile distance range (especially in the US). Intermodal competition may be fiercer on shorter routes, and network airlines may prefer to provide indirect services (via their hub airports) on longer routes.

Along with this exploratory analysis of data, we implement a multivariate analysis to identify the influence of several route characteristics (i.e., distance, competition, traffic density, and proportion of leisure travelers) on the likelihood that regional airlines (either with regional jets or with turboprops) provide services on thin routes. To this end, we estimate the following equation for any route k

$$Type\_aircraft_k = \alpha + \beta_1 log(Dist_k) + \beta_2 Seats_k + \beta_3 D_k^{tourism} + \beta_4 Dist\_center_k + \beta_5 D_k^{monop} + \varepsilon_k. \quad (8)$$

Note that different types of aircraft may be used on the same route. Hence, we need to compute the market share of all aircraft of the same category used on any given route (i.e., turboprops, regional jets, and mainline jets) in terms of the total number of seats. A discrete variable for the type of aircraft used is constructed as the dependent variable ($Type\_aircraft_k$). This variable takes a value of zero for routes where regional jets have the largest market share (which will be the reference case), a value of one for routes where turboprops have the largest market share, and a value of two for routes where mainline jets have the largest market share. Usually the market share of the dominant category of aircraft is well over 50%.

We consider the following exogenous explanatory variables of the type of aircraft used by the airlines.

1. $Dist_k$: Number of miles flown to link the endpoints of the route. The cost superiority of mainline jets in relation to regional jets increases with distance, while on very short-haul routes turboprops are less costly than regional jets. Thus, as route distance increases, we can expect regional jets to be used less intensely than mainline jets. Furthermore, the longer range capability of regional jets with respect to that of turboprops yields a clear prediction as regards the expected effect of the distance variable: turboprops should be

[16] However, the total number of seats is not a good proxy for demand on routes where there is a high proportion of connecting traffic.

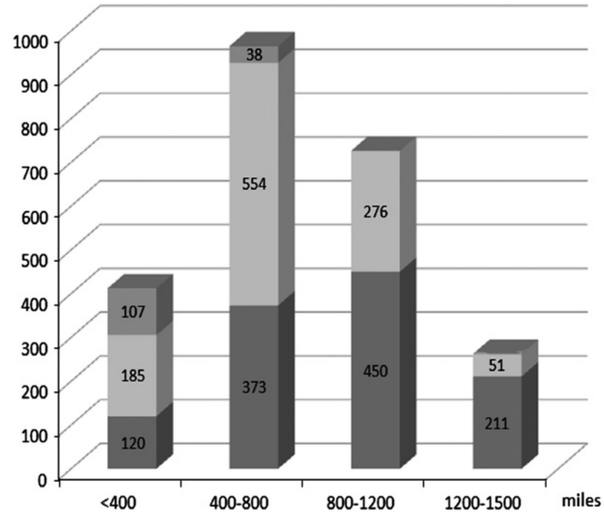

Fig. 4. Regional services by distance (US sample).
Note 1: TP are turboprops, RJ are regional jets, and JETS are mainline jets.
Note 2: Number of routes by aircraft type inside each bar.

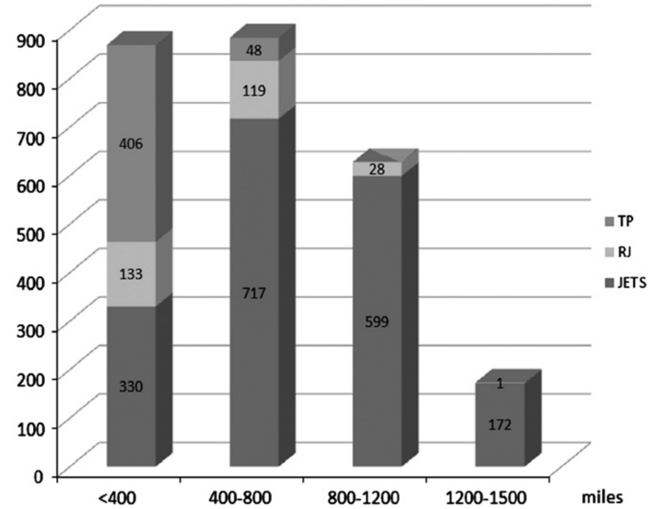

Fig. 5. Regional services by distance (EU sample).
Note 1: TP are turboprops, RJ are regional jets, and JETS are mainline jets.
Note 2: Number of routes by aircraft type inside each bar.

used less intensely on longer routes. Since we may expect a non-linear relationship between distance and flying costs, the variable of distance is expressed in logs.[17]

2. $Seats_k$: Total number of seats offered on the route. This variable may work as a proxy for demand.
   The simultaneous determination by airlines of the type of aircraft and the number of seats could imply an endogeneity bias in the estimation. Hence, we apply an instrumental variables procedure to correct for any possible bias. We use the following instruments of the seats variable:
   Pop_k: Weighted average of population in the route's origin and destination regions.
   $GDPC_k$: Weighted average of GDP per capita in the route's origin and destination regions, with weights based on population.
   Traffic density should be higher in more populated and richer endpoints. Thus, we argue that population and GDP are suitable instruments for the seats variable. Indeed, these two variables are clearly exogenous but, at the same time, they are correlated with the number of seats (these correlations are within the range 20–30% for both variables).
   Results for the $Seats_k$ variable are the main point of interest in our analysis. The question remains as to whether regional services will be used more intensely on thinner routes. We seek to determine whether regional jets are mainly used to provide services on thin point-to-point routes. Looking at the data, we can expect differences between the EU and the US markets.
3. $D_k^{tourism}$: Dummy variable that takes the value of one for those routes where at least one of the endpoints is a major tourist destination. The proportion of leisure travelers should be higher on routes that have tourist destinations as endpoints. Thus, regional services (either regional jets or turboprops) should be used more intensely on non-tourist routes with a higher proportion of business travelers because they yield a higher frequency of services (at higher fares).
4. $Dist\_center_k$: Sum of the distances between the origin and the destination city centers and their respective airports. The proportion of leisure travelers should be higher on routes where airports are further from the city center. As a consequence, regional services should be used more intensely on routes with airports located closer to the city center where the proportion of business travelers is higher.
5. D_k^{monop}: Dummy variable that takes the value of one for those routes where only one airline is offering services. The expected sign of the coefficient associated with this variable is, a priori, ambiguous. With this variable, we can examine whether route competition influences airlines' choice of aircraft type.

The estimation is made using a multinomial probit where the use of regional jets is the reference case. A higher value for the corresponding explanatory variable means that the use of regional jets is more (less) likely if the sign of the coefficient associated with this variable is negative (positive).

In Appendix B, we show the results of the estimates of Eq. (8) for the whole sample of routes (see Table A1). In this regression, we include a dummy variable for routes from the US, and our interest lies precisely in this dummy variable. The results confirm what we have seen in the exploratory analysis of the data: regional jets are used more intensely in the US because the coefficient associated with this variable is negative and statistically significant when we consider the choice of both turboprops and mainline jets with respect to regional jets. The predicted decrease in the probability of using mainline jets in relation to regional jets is about 28% when we move from the EU to the US market.

The Chow test advises in favor of separate estimations for the EU and the US. Tables 3 and 4 show the results of these separate estimations. The first two columns of both tables show the coefficients estimated and their respective standard errors. The last two columns show the predicted change required in the probability for an outcome to take place (i.e., the use of regional jets as opposed to either turboprops or mainline jets) as each independent variable changes from its minimum to maximum value (i.e., from 0 to 1 for discrete variables),

[17] Alternatively, we could have used the quadratic term of distance as additional explanatory variable. However, this approach distorts the statistical significance of the $Dist_k$ variable due to its high correlation with its quadratic term. In terms of the expected variation in probabilities of the $Dist_k$ variable and the results for the rest of variables, our analysis does not get altered regardless of the way we introduce distance in the analysis.

while all other independent variables are held constant at their mean values. The results in the first two columns report the statistical significance of the relationships considered, while the results in the last two columns report the quantitative impact of each explanatory variable. Recall that the estimation is based on routes shorter than 1500 mi.

Table 3
Estimates of the use of regional services — US sample.
Multinomial probit with endogenous regressors.

	Coefficients		Change in predicted probabilities	
	Dep. variable: RJ = 0, TP = 1	Dep. variable: RJ = 0, JETS = 2	Dep. variable: RJ = 0, TP = 1	Dep. variable: RJ = 0, JETS = 2
log ($Dist_k$)	−1.46 (0.13)***	0.88 (0.09)***	−96.39%	71.57%
$Seats_k$	5.49e−06 (2.09e06)***	5.43e−06 (1.42e−06)***	3.01%	42.37%
$D_k^{tourism}$	0.79 (0.19)***	0.79 (0.12)***	0.29%	20.46%
$Dist\_center_k$	−0.01 (0.009)***	0.02 (0.004)***	−3.84%	58.23%
D_k^{monop}	0.39 (0.27)	−0.39 (0.15)***	1.58%	−11.98%
Constant	6.93 (0.99)***	−6.36 (0.73)***	–	–
L – pseudolikelihood	−1676.19			
x^2 *(joint sig.)*	557.24***			
N	2364			

Note 1: TP are turboprops, RJ are regional jets, and JETS are mainline jets.
Note 2: Standard errors in parentheses (robust to heteroscedasticity).
Note 3: Statistical significance at 1% (***), 5% (**), and 10% (*).
Note 4: The instruments of the variable $Seats_k$ are Pop_k and $GDPC_k$.
Note 5: Routes longer than 1500 mi are excluded.

Table 4
Estimates of the use of regional services — EU sample.
Multinomial probit with endogenous regressors.

	Coefficients		Change in predicted probabilities	
	Dep. variable: RJ = 0, TP = 1	Dep. variable: RJ = 0, JETS = 2	Dep. variable: RJ = 0, TP = 1	Dep. variable: RJ = 0, JETS = 2
log ($Dist_k$)	−1.53 (0.11)***	0.92 (0.09)***	−99.95%	96.61%
$Seats_k$	−9.31e−06 (3.28e−06)***	−6.72e−06 (2.25e−06)***	−7.58%	−16.98%
$D_k^{tourism}$	0.07 (0.13)	0.31 (0.12)***	3.27%	9.98%
$Dist\_center_k$	0.006 (0.003)**	0.020 (0.002)***	11.75%	37.61%
D_k^{monop}	−0.79 (0.26)***	−0.81 (0.19)***	−1.45%	−8.87%
Constant	10.05 (0.85)***	−4.21 (0.69)***	–	–
L – pseudolikelihood	−1403.00			
x^2 *(joint sig.)*	615.37***			
N	2554			

Note 1: TP are turboprops, RJ are regional jets, and JETS are mainline jets.
Note 2: Standard errors in parentheses (robust to heteroscedasticity).
Note 3: Statistical significance at 1% (***), 5% (**), and 10% (*).
Note 4: The instruments of the variable $Seats_k$ are Pop_k and $GDPC_k$.
Note 5: Routes longer than 1500 mi are excluded.

Table 5
Estimates of the use of regional services — US sample.
Additional dependent variable.

	Two-stage least squares Dep. variable: aircraft size	Generalized linear model with fractional response variables Dep. variable: share of regional aircraft
log ($Dist_k$)	28.95 (1.43)***	−0.81 (0.06)***
$Seats_k$	0.00012 (0.000023)***	−3.73e−06 (9.00e−07)***
$D_k^{tourism}$	11.46 (1.91)***	−0.47 (0.07)***
$Dist\_center_k$	0.36 (0.05)***	−0.017 (0.002)***
D_k^{monop}	−1.46 (2.22)***	0.20 (0.09)**
Constant	−103.52 (10.79)***	5.87 (0.47)***
R^2	0.30	–
F(joint sig.)	199.19***	–
L – pseudolikelihood	–	−1340.62
AIC	–	1.13
BIC	–	−15,846.31
N	2364	2364

Note 1: Regional aircraft includes turboprops and regional jets.
Note 2: Standard errors in parentheses (robust to heteroscedasticity).
Note 3: Statistical significance at 1% (***), 5% (**), and 10% (*).
Note 4: The instruments of the variable $Seats_k$ are Pop_k and $GDPC_k$.
Note 5: Routes longer than 1500 mi are excluded.

As may be expected, regional jets are used more intensely on longer routes in comparison with the use made of turboprops, whereas the former are used more frequently on shorter routes than mainline jets. This finding holds for both the US and the EU. The impact of the distance variable is especially important: the predicted increase in the probability of using mainline jets as opposed to regional jets as distance shifts from its minimum to its maximum value is about 70–90%, while the predicted decrease in the probability of using turboprops as opposed to regional jets is about 95–99%.

Regional jets are used on thinner routes in the American market. Indeed, regional jets are more likely to be used by US carriers on routes with a lower number of seats. The coefficient associated with the seats variable is positive and statistically significant when analyzing the choice of mainline jets in relation to regional jets: the predicted increase in the probability of using mainline jets as the number of seats shifts from its minimum to its maximum value is about 42%. The coefficient of the seats variable is also positive and statistically significant when analyzing the choice of turboprops in relation to regional jets but the predicted increase in probabilities is minimal.

The results for the EU market are the opposite. The coefficient associated with the seats variable is negative and statistically significant when analyzing the choice of mainline jets in relation to regional jets. The predicted decrease in the probability of using mainline jets as the number of seats shifts from its minimum to its maximum value is about 17%. The coefficient of the variable of seats is also negative and statistically significant when analyzing the choice of turboprops in relation to regional jets but again the predicted increase in probabilities is low.

Therefore, we find marked differences between the EU and the US markets in their respective uses of regional jets: while these jets are not used more intensely on thinner routes in the EU market, they clearly are in the US.

Furthermore, we find clear evidence that regional jets are used more frequently on routes with a higher proportion of business travelers in the US. Mainline jets (in relation to regional jets) are used more intensely on routes with tourist destinations and with airports that are located at a greater distance from the city center. The coefficients associated with these variables are positive and statistically significant, and the predicted increase in probabilities is high. As expected, we do not find substantial differences in terms of the predicted variation in probabilities in the analysis of the choice of turboprops in relation to regional jets. Both types of aircraft should be used more frequently on routes with a higher proportion of business travelers because of the frequency advantage they provide over mainline jets.

The results for the EU indicate that mainline jets (in comparison to regional jets) are used more often on routes where airports are located some distance from the city center. The predicted increase in probabilities is about 37%. The variable for tourist destinations is also statistically significant (in the comparison between regional and mainline jets) but the expected increase in probabilities is modest. As in the US case, we do not find substantial differences in terms of the predicted variation in probabilities in the analysis of the choice of turboprops in relation to regional jets when considering routes with a higher proportion of business travelers.

Both in the US and the EU, mainline jets are used less frequently than regional jets on monopoly routes. The expected decrease in probabilities is about 8–11%. Regarding the choice of turboprops in relation to regional jets, we do not find substantial differences when either one or several airlines are offering services. Both the sign and the statistical significance of D_k^{monop} differ in the US and the EU, but the probabilities are very low in both cases. A possible explanation of this difference is that mainline jets dominate a high proportion of both monopoly and non-monopoly routes in the EU, while regional aircraft are typically used on monopoly routes in the US.

Table 6
Estimates of the use of regional services — EU sample.
Additional dependent variables.

	Two-stage least squares Dep. variable: aircraft size	Generalized linear model with fractional response variables Dep. variable: share of regional aircraft
log ($Dist_k$)	38.87 (1.39)***	−1.24 (0.06)***
$Seats_k$	−0.000039 (0.000038)	1.45e−06 (1.52e−06)
$D_k^{tourism}$	3.58 (1.92)*	−0.13 (0.07)*
$Dist\_center_k$	0.39 (0.02)***	−0.013 (0.0014)***
D_k^{monop}	−1.49 (3.30)	0.30 (0.12)**
Constant	−116.87 (11.47)***	7.27 (0.46)***
R^2	0.35	–
F(joint sig.)	312.79***	–
L – pseudolikelihood	–	−1004.84
AIC	–	0.79
BIC	–	−18,095.4
N	2554	2554

Note 1: Regional aircraft includes turboprops and regional jets.
Note 2: Standard errors in parentheses (robust to heteroscedasticity).
Note 3: Statistical significance at 1% (***), 5% (**), and 10% (*).
Note 4: The instruments of the variable $Seats_k$ are Pop_k and $GDPC_k$.
Note 5: Routes longer than 1500 mi are excluded.

Our data show that US airlines usually prefer to employ regional jets on routes with a 400 to 800-mile distance range, which is the range with the highest number of routes in our sample. Regional jets in the US market seem to be particularly suited to providing services on the thinnest routes, as well as on routes with a relatively high proportion of business travelers. In the EU, however, it seems that airlines have yet to adopt the advantages of regional jets for the provision of services on thin and relatively long routes.

As a robustness check, we make additional estimations of Eq. (8) with different dependent variables. First, we make an additional regression where the dependent variable is aircraft size and the explanatory variables are the same as in Eq. (8). The estimation is made using the two-stage least square estimator because the seats variable may be endogenous (we use the same instruments as in the multinomial regression). Column 1 in Tables 5 and 6 show the results of this estimation. Second, we also consider as dependent variable the share of regional aircraft (i.e., regional jets and turboprops) in terms of the seats offered on the route, keeping the same explanatory variables as in Eq. (8). This estimation is made using the generalized linear model with fractional response variables, taking into account the possible endogeneity of the seats variable.[18] Column 2 in Tables 5 and 6 show the results of this estimation. In Appendix B, we show the results of the same regression but considering as dependent variable the share of regional jets and the share of turboprops, respectively (see Table A2). Since differences in the use of regional jets and turboprops are mainly related with the distance variable, we have decided to relegate these last regressions to the appendix.

These estimations confirm our previous findings. Larger aircraft are used more intensely on longer routes, on routes with more than one airline offering services, and on routes with a higher proportion of leisure travelers (both in the US and the EU). In the same vein, the share of regional aircraft is higher on shorter routes, on monopoly routes, and on routes with a higher proportion of business travelers (both in the US and the EU).

In the US, larger aircraft are used on routes with a higher number of seats, while the share of regional aircraft is lower on denser routes. In the EU, the seats variable is not statistically significant neither when considering aircraft size nor when considering the share of regional aircraft as dependent variable. However, Table A2 in Appendix B shows that, in the EU, the share of regional jets is higher on routes

[18] See Papke and Wooldridge (1996) for details on this econometric method.

Table 7
Estimates of the use of low-cost services — US sample.

	Probit with endogenous regressors Dep. variable: network airline = 0, non-network airline = 1		Generalized linear model with fractional response variables
	Coefficients	Change in predicted probabilities	Dep. variable: share of non-network airlines
log ($Dist_k$)	0.40 (0.052)***	63.85%	0.42 (0.04)***
$Seats_k$	4.47e − 06 (1.23e − 06)***	44.30%	4.38e − 06 (7.80e − 07)***
$D_k^{tourism}$	0.54 (0.07)***	33.70%	0.39 (0.06)***
$Dist\_center_k$	0.01 (0.002)***	45.82%	0.011 (0.0021)***
D_k^{monop}	− 0.13 (0.09)	− 3.83%	0.11 (0.07)
Constant	− 3.25 (0.41)***	–	− 3.60 (0.34)***
L – pseudolikelihood	− 37,494.50		− 1690.21
X^2 (*joint sig.*)	231.15***		–
AIC	–		1.21
BIC	–		− 19,185.76
N	2803		2803

Note 1: Regional aircraft includes turboprops and regional jets.
Note 2: Standard errors in parentheses (robust to heteroscedasticity).
Note 3: Statistical significance at 1% (***), 5% (**), and 10% (*).
Note 4: The instruments of the variable $Seats_k$ are Pop_k and $GDPC_k$.

with a higher number of seats while the seats variable is not statistically significant when the dependent variable is the share of turboprops. Looking at the US sample, the share of regional jets is higher when the number of seats on the route is lower.

3.3. Low-cost services

Here we focus our attention on examining the type of airline (be it network or low-cost) that provides services on thin routes. From the previous analysis, in the US it is clear that regional airlines (either subsidiaries of network airlines or independent carriers) dominate a vast number of routes that do not exceed 800 mi, whereas in the EU mainline jets (used by network or low-cost airlines) are dominant on routes longer than 400 mi. Recall that we consider network airlines to be those that form part of an international alliance (i.e., Oneworld, Star Alliance, and SkyTeam).

Airlines not involved in international alliances dominate a vast number of monopoly routes in the EU. Indeed, 87% of routes in our sample are dominated by non-network airlines. Differently, network carriers in the US (using either mainline jets or regional aircraft) have an important role in the provision of air services: only 46% of routes in our sample are dominated by non-network airlines.

As in the previous analysis of the use of regional services, we undertake a multivariate analysis to identify when it is more likely for a non-network airline to be dominant in our sample of thin routes. Hence, we estimate the following equations for any route *k*

$$D^{\text{non-network}} = \alpha + \beta_1 log(Dist_k) + \beta_2 Seats_k + \beta_3 D_k^{tourism} + \beta_4 Dist\_center_k + \beta_5 D_k^{monop} + \varepsilon_k, \quad (9)$$

where the dependent variable is dichotomous and takes the value of one on routes dominated by non-network airlines (generally low-cost airlines) and the value of zero on routes dominated by network airlines.

We use the same explanatory variables as in Eq. (8), including distance, number of seats, a dummy variable for monopoly routes, and variables for the proportion of leisure travelers (i.e., tourist destinations and distance from the airport to the city center). As in Eq. (8), we implement an instrumental variables procedure where the instruments of the variable $Seats_k$ are population (Pop_k) and gross domestic product per capita ($GDPC_k$) of the route endpoints.

We can expect low-cost airlines to dominate longer thin routes because network airlines may prefer to provide an indirect service (through hub airports) in city-pair markets where the route distance is sufficiently high. This is consistent with the theoretical analysis conducted in Fageda and Flores-Fillol (forthcoming). Additionally, low-cost airlines may dominate routes with a high proportion of leisure travelers (i.e., routes from/to tourist destinations and routes with airports some distance from the city center). Less clear is whether low-cost airlines prevail in monopoly routes. In this context, we wish to examine whether low-cost airlines provide services on routes with a relatively low number of seats.

The estimation is made using the probit technique. A higher value of the corresponding explanatory variable would mean that low-cost airlines are more (less) likely to dominate the route if the sign of the coefficient associated with this variable is positive (negative).

In Appendix B, we show the results of the estimates of Eq. (9) for the whole sample of routes (see Table A3). These results confirm what we have seen in the exploratory analysis of the data: the likelihood of a low-cost carrier dominating a route is higher in the European market than in the US market. The predicted increase in the probability of using low-cost carriers as opposed to network carriers is 41% when we shift from the US to the EU market.

The Chow test advises in favor of separate estimations for the EU and the US. Tables 7 and 8 show the results of the estimation of Eq. (9) for the US and the EU samples, respectively. The first column of both tables shows the coefficients estimated and their respective standard errors. The second one provides the predicted change required in the probability for an outcome to take place (i.e., the use of a low-cost airline as opposed to that of a network airline) as each independent variable changes from its minimum to maximum value (i.e., from 0 to 1 for discrete variables), while all other independent variables are held constant at their mean values.

We find a higher presence of low-cost carriers on longer routes in the US market. The coefficient associated with the distance variable is positive and statistically significant and the change in the predicted probabilities is about 64%. However, the interpretation of these results is less clear in the EU market: although the coefficient associated with the distance variable is negative and statistically significant, the change in the predicted probabilities is small.

Our results indicate a higher presence of low-cost airlines on denser routes in the US market. Indeed, it is more likely that a low-cost airline dominates a route when the total number of seats offered is higher. The coefficient associated with the seats variable is positive and statistically significant. The predicted increase in probabilities is about 44%. Our results suggest that some low-cost carriers prefer to provide services on denser routes (as is the case of Southwest, for example).[19]

[19] This is consistent with the analysis in Bogulaski et al. (2004), which shows that Southwest prefers to operate on high-density routes.

Table 8
Estimates of the use of low-cost services — EU sample.

	Probit with endogenous regressors		Generalized linear model with fractional response variables
	Dep. variable: network airline = 0, non-network airline = 1		
	Coefficients	Change in predicted probabilities	Dep. variable: share of non-network airlines
log ($Dist_k$)	−0.07 (0.03)*	−5.19%	−0.038 (0.042)
$Seats_k$	−8.74e−06 (8.59e−07)***	−59.30%	−0.000011 (0.042)***
$D_k^{tourism}$	0.006 (0.06)	1.41%	0.027 (0.06)
$Dist\_center_k$	0.008 (0.0009)***	22.46%	0.010 (0.001)***
D_k^{monop}	−0.42 (0.08)***	−10.27%	−0.54 (0.11)***
Constant	1.78 (0.26)***	–	1.96 (0.34)***
L – pseudolikelihood	−36,287.21		−995.36
X^2 (*joint sig.*)	167.77***		–
AIC	–		0.71
BIC	–		−20,216.03
N	2788		2788

Note 1: Regional aircraft includes turboprops and regional jets.
Note 2: Standard errors in parentheses (robust to heteroscedasticity).
Note 3: Statistical significance at 1% (***), 5% (**), and 10% (*).
Note 4: The instruments of the variable $Seats_k$ are Pop_k and $GDPC_k$.

By contrast, European low-cost airlines dominate routes with a lower number of seats. The coefficient associated with the seats variable is negative and statistically significant and the predicted decrease in probabilities is about 60%. Hence, we conclude that European low-cost carriers prefer to serve thinner routes (as may be the case of Ryanair, for example).

In the US, the coefficients associated with the variables of tourism and distance to the city center are both positive and statistically significant. The predicted increase in probabilities is about 33 and 45% respectively. Therefore, low-cost airlines are more likely to dominate a route when the proportion of leisure travelers is higher.

In the EU, the presence of low-cost airlines is also higher on routes with airports further from the city center, and the expected increase in probabilities is about 22%. However, the coefficient associated with the variable of tourism is not statistically significant and the change in probabilities is minimal. Overall, our results suggest that low-cost airlines in the EU are more likely to offer services from secondary airports at some distance from large cities, but not necessarily in major tourist destinations.[20]

The dummy variable for monopoly routes is not statistically significant in the US and its associated probability is low. These results could be distorted by the fact that a high proportion of monopoly routes in the US are dominated by regional aircraft while mainline jets dominate most non-monopoly routes. In the EU, this variable is negative, statistically significant, and the expected decrease in probabilities is about 10%. Thus, the presence of low-cost airlines is lower on European monopoly routes. In contrast to the US, mainline jets dominate most of monopoly and non-monopoly routes in the EU, so that the type of aircraft more frequently used does not condition the results of the monopoly variable.

As a robustness check, we make an additional estimation of Eq. (9) with a different dependent variable: the share of non-network airlines in terms of the seats offered on the route. The explanatory variables are the same as in Eq. (9). This estimation is made using the generalized linear model with fractional response variables, taking into account the possible endogeneity of the seats variable. Column 3 in Tables 7 and 8 show the results of this estimation, which confirm our previous findings.

4. Discussion and concluding remarks

This paper has examined the provision of air services on thin routes by comparing the differences between the US and EU markets. We have focused specifically on the impact of two major innovations in the airline industry in recent decades: regional jet technology and the low-cost business model. We have found evidence of very different patterns in the two markets. Our empirical analysis indicates that low-cost airlines operate similarly to network airlines in the US, at least in terms of route choices. Both types of airline prefer to operate on high-density routes, while thin routes are served mainly by regional carriers using regional jet aircraft. In addition, the emergence of regional jet technology constitutes a key innovation that has enabled regional services to be extended to longer routes. By contrast, in the EU thin routes are mainly operated by low-cost airlines. Therefore, only in the US market are the advantages of regional jets on medium-haul routes fully exploited. The success enjoyed by Ryanair in the EU market, where it operates mostly from secondary airports, could be a determining factor in our results.

Regional services allow airlines to offer higher flight frequency, typically employing airports located close to city centers. Low-cost services using mainline jets allow airlines to charge lower fares, but this is typically at the expense of a lower flight frequency and the need to use airports located some distance from their respective city centers. Thus, the US model is more convenient for business travelers, while the EU model is more convenient for leisure travelers.

Compared to the European market, the American market is more mature and its routes are longer, which may help account for the success of regional jets in the US. By contrast, turboprops remain the dominant regional aircraft in the EU. Moreover, the influence of the public authorities on the air transportation markets in the US and the EU differs. On the one hand, the US government implemented a program known as Essential Air Services following liberalization in the late-1970s, which subsidized routes run by airlines connecting small communities with the nearest large airport (Metrass-Mendes and de Neufville, 2010). Clearly, traffic density on routes with these small communities as an endpoint is very low. This guarantee of air services refers in most instances to very short-haul routes that

[20] We consider the relevant market to be the route between two airports. A more thorough analysis would require to consider urban areas. However, this would create additional problems, not the least of which is establishing the limit of each urban area and determining the market structure in each city-pair market, given that airlines operating on different routes in the same market may compete imperfectly.

typically connect the airports of Micropolitan Statistical Areas with hub airports. Thus, very few subsidized routes are included in our US sample.

By contrast, several European governments have imposed Public Service Obligations on certain routes via the regulation of fares, frequencies, and market access (Williams and Pagliari, 2004; Calzada and Fageda, 2012). However, many of these are applied not to thin routes but rather to routes connecting airports in isolated locations (islands). Moreover, the public authorities have played an active role in the success of Ryanair by offering either discounts in airport charges or direct subsidies. This may have had an influence in the dominance enjoyed by low-cost airlines in Europe. As a result, fares on thin routes may be lower in the EU than in the US, but this places an additional burden on public resources.

Furthermore, the different use of regional jets in the US and the EU may also be explained by the existence of slot controls in Europe. In the US, airlines typically sign contracts with airport authorities to regulate the access to the infrastructure and they do not need to own slots. Nevertheless, the access of airlines to airports in Europe is based on slot allocation rules like 'grandfather rights' (i.e., an operator who currently uses a slot can retain the slot each period) or 'use-it-or-lose-it' rules (i.e., airlines must operate slots as allocated by the coordinator at least 80% of the time during a season to retain historic rights to the slots). Hence, the use of larger aircraft with lower flight frequency may constitute a better strategy in a slot-constrained European environment.

A final caveat of our analysis is that it focuses on scheduled services. On several thin routes, especially those having tourist destinations as endpoints, low-cost connections may be complemented by charter services. This is particularly true in Europe where many low-cost airlines come from the charter market. Currently, competition authorities consider scheduled and charter services to be different markets, as it can be seen in several merger reports.[21] The reason is that airlines deal with individual passengers in the scheduled market, while they deal with tour-operator firms in the charter market.[22] Furthermore, the amount of frequencies offered in the charter market is usually much lower than in the scheduled market. In any case, the possible link between scheduled and charter services must be taken into account in the interpretation of our empirical results.

In conclusion, our analysis has shown that travelers flying on thin routes benefit from the two key innovations examined here in the air transport industry, but that significant differences are to be found in the US and EU markets. Further research should provide a fuller understanding of these differences.

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[21] See, for example, the case COMP/M-5364 — Iberia/Vueling/Clickair analyzed by the European Commission; and the case C105/07 — Air Berlin/LTU analyzed by the Spanish Competition Commission.

[22] In fact, charter airlines are often integrated with tour-operator firms.

Appendix A. Proofs

Proof of Proposition 1. From Eq. (7), let us define $\Omega \equiv Cf^* - Lf^* = 0$, that is

$$\Omega = \frac{2\theta d(TV-d)}{\gamma} f^3 - [(1-\kappa)(TV-d) - \tau V]f + \gamma V = 0. \quad \text{(A.1)}$$

The total differential of the equilibrium frequency with respect to a parameter x is $\frac{df^*}{dx} = -\frac{\partial\Omega/\partial x}{\partial\Omega/\partial f}$. Notice that $\partial\Omega/\partial f = slope(Cf^*) - slope(Lf^*)$, and thus $\partial\Omega/\partial f > 0$ because at the equilibrium frequency the slope of Cf^* exceeds the slope of Lf^*. Therefore, we just need to explore the sign of $\partial\Omega/\partial x$.

- $\partial\Omega/\partial\kappa = (TV-d) > 0$ since $T > d/V$ is assumed to hold. Then $\frac{df^*}{d\kappa} < 0$.
- $\partial\Omega/\partial\theta = \frac{2d(TV-d)}{\gamma} f^3 > 0$ since $T > d/V$ is assumed to hold. Then $\frac{df^*}{d\theta} < 0$.
- $\partial\Omega/\partial\tau = Vf > 0$. Then $\frac{df^*}{d\tau} < 0$.
- $\partial\Omega/\partial d = \frac{2\theta(TV-2d)}{\gamma} f^3 + (1-\kappa)f$ and, plugging Eq. (A.1) into the derivative, we obtain $\partial\Omega/\partial d = \frac{2\theta(TV-d)}{\gamma} f^3 + \frac{\gamma+\tau f}{(TV-d)} V$ that is positive because $T > d/V$ is assumed to hold. Then $\frac{df^*}{dd} < 0$.
- $\partial\Omega/\partial\gamma = -\frac{2\theta d(TV-d)}{\gamma^2} f^3 + V < 0$ since $T > d/V$ is assumed to hold. Then $\frac{df^*}{d\gamma} > 0$.
- $\partial\Omega/\partial T = \frac{2\theta dV}{\gamma} f^3 - (1-\kappa)Vf$, so that $\partial\Omega/\partial T < 0$ requires $f^2 < \frac{(1-\kappa)\gamma}{2\theta d}$. Then using Eq. (6) this inequality becomes $p_{air} < \frac{1}{2}(1-\kappa)(T-d/V) + \tau$, and finally using Eq. (5) we obtain $-\gamma/f < \tau$, which is always true. Therefore, $\partial\Omega/\partial T < 0$ and thus $\frac{df^*}{dT} > 0$.
- $\partial\Omega/\partial V = \frac{2\theta dT}{\gamma} f^3 - (1-\kappa)Tf + \tau f + \gamma$ and, using Eq. (A.1), this expression can be rewritten as $\partial\Omega/\partial V = -\frac{TV(\gamma+\tau f)}{TV-d} + \tau f + \gamma$, so that $\partial\Omega/\partial V < 0$ requires $-\gamma/f < \tau$, which is always true. Therefore, $\partial\Omega/\partial V < 0$ and thus $\frac{df^*}{dV} > 0$. ■

Proof of Corollary 1. Straightforward. ■

Appendix B. Estimates using the whole sample (US + EU).

Table A1
Estimates of the use of regional services — US + EU.
Multinomial probit with endogenous regressors.

	Dep. variable:	Dep. variable:
	RJ = 0, TP = 1	RJ = 0, JETS = 2
$log(Dist_k)$	−1.36 (0.089)***	1.06 (0.07)***
$Seats_k$	6.79e−06 (2.15e−06)***	8.01e−06 (1.66e−06)***
$D_k^{tourism}$	0.44 (0.11)***	0.64 (0.08)***
$Dist\_center_k$	−0.0003 (0.002)	0.01 (0.001)***
D_k^{monop}	0.29 (0.19)	−0.007 (0.14)
D_k^{US}	−1.33 (0.10)***	−1.32 (0.07)***
Constant	7.41 (0.68)***	−6.41 (0.55)***
$L-pseudolikelihood$	−3102.50	
$\chi^2(joint\ sig.)$	1687.95***	
N	4918	

Note 1: TP are turboprops, RJ are regional jets, and JETS are mainline jets.
Note 2: Standard errors in parentheses (robust to heteroscedasticity).
Note 3: Statistical significance at 1% (***), 5% (**), and 10% (*).
Note 4: The instruments of the variable $Seats_k$ are Pop_k and $GDPC_k$.
Note 5: Routes longer than 1500 mi are excluded.
Note 6: Change in the predicted probabilities for the variable D_k^{US}: −3.30% when we consider the choice of TP with respect to RJ, and −27.67% when we consider the choice of JETS with respect to RJ.

Table A2
Estimates of the use of regional services.
Generalized linear model with fractional response variables.

	Dep. variable: share of RJ		Dep. variable: share of TP	
	US sample	EU sample	US sample	EU sample
$log(Dist_k)$	−0.25 (0.06)***	−0.06 (0.04)	−1.39 (0.09)***	−1.61 (0.07)***
$Seats_k$	−4.34e−06 (9.02e−07)***	5.77e−06 (1.45e−06)***	2.21e−06 (1.49e−06)	−2.99e−06 (2.07e−06)
$D_k^{tourism}$	−0.57 (0.07)***	−0.25 (0.07)***	0.29 (0.13)**	−0.17 (0.08)***
$Dist\_center_k$	−0.01 (0.002)***	−0.012 (0.001)***	−0.018 (0.007)***	−0.007 (0.001)***
D_k^{monop}	0.10 (0.09)	0.53 (0.12)***	0.52 (0.18)***	−0.08 (0.16)
Constant	2.06 (0.44)***	−0.99 (0.36)***	6.73 (0.71)***	9.19 (0.57)***
L−pseudolikelihood	−1445.46	−803.83	−334.20	−674.70
AIC	1.22	0.63	0.28	0.53
BIC	−15,636.23	−18,553.43	−17,666.73	−18,754.55
N	2364	2554	2364	2554

Note 1: TP are turboprops and RJ are regional jets.
Note 2: Standard errors in parentheses (robust to heteroscedasticity).
Note 3: Statistical significance at 1% (***), 5% (**), and 10% (*).
Note 4: The instruments of the variable $Seats_k$ are Pop_k and $GDPC_k$.
Note 5: Routes longer than 1500 mi are excluded.

Table A3
Estimates of the use of low-cost services — US + EU.
Probit with endogenous regressors.

	Dep. variable: network airline = 0, non-network airline = 1	
	Coefficient	Change in predicted probabilities
$log(Dist_k)$	0.35 (0.03)***	43.18%
$Seats_k$	6.20e−06 (9.84e−07)***	34.71%
$D_k^{tourism}$	0.30 (0.05)***	17.18%
$Dist\_center_k$	0.005 (0.001)***	30.61%
D_k^{monop}	0.30 (0.07)***	8.71%
D_k^{US}	−1.21 (0.05)***	−40.66%
Constant	−1.97 (0.26)***	–
L−pseudolikelihood	−74,116.19	
χ^2*(joint sig.)*	1188.32***	
N	5591	

Note 1: Standard errors in parentheses (robust to heteroscedasticity).
Note 2: Statistical significance at 1% (***), 5% (**), and 10% (*).
Note 3: The instruments of the variable $Seats_k$ are Pop_k and $GDPC_k$.

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