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Are low cost carriers airfares still lower? A comparison with full service carriers in Europe☆,☆☆

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ABSTRACT

The main objective of this work is to contribute to the existing literature on the effects of competition from Low-Cost Carriers on airfares in the European non-stop market. To the best of our knowledge, this is the first paper describing the impact of the operations of LCCs on ticket prices in Europe using data from real transactions (i.e., passengers ticket data including prices) covering all routes and not only a small sample. Data is taken from Official Aviation Guide (OAG) and consist of monthly price observations charged by all carriers marketing and operating flights in Western and Eastern Europe between January 2016 and December 2019. We find evidence that fares are about 11% lower if at least one LCC is operating in the route in comparison to markets where only FSCs are present. By taking the average fare in our data set for a non-stop flight, this reduction amounts to about $11 US savings. Moreover, we notice that FSCs increase their fares if the LCCs market share is lower than 19%; beyond this threshold they also reduce prices in order to match the strong competition and robust market presence of LCCs. These results confirm that liberalization has long-run effects, as LCCs are still cheaper after about 30 years since the beginning of liberalization and after their robust market consolidation.

1. Introduction

Over the past decades, the European aviation industry has undergone major changes that have profoundly transformed the today's travel industry. The Single European Act (1986) paved the way for removing all commercial restrictions for European airlines operating within the EU.[1] The process of deregulation began in 1987 with the approval of the first liberalization package and was completed in 1997 with the adoption of the third package. Since then, every European airline can operate national routes in all countries of the European Union, under a regulation regime of complete cabotage.

One of the most notable consequences of the European market liberalization has been the rise of Low-Cost Carriers (LCCs) that strongly impacted the *status quo*. LCCs generated additional demand by opening new routes (Calzada and Fageda, 2019; Martini et al., 2013) and subtracted market shares from incumbent carriers when they compete on the same itineraries. Therefore, key implications of the liberalization process include the increase in the number of routes flown, in the number, and in the type of competitors, the natural selection of the most efficient operators, and a generalized impact on prices, with LCCs providing low fares in most routes.

However, over 25 years since the beginning of liberalization in Europe, some of its early positive effects may have changed. For instance, LCCs consolidated their market shares and gained a strong market power in European routes (according to ICAO (ICAO, 2015)[2] they represent over 40% of the supply side of the market), and have modified strategy and business model (i.e., hybridization) to compete with Full-Service Carriers (FSCs). Furthermore (Klophaus et al., 2012) show that they are not necessarily still aiming at charging the cheapest fares. The rise of LCCs also prompted a reaction by European FSCs to retain market shares, that has included a reduction in airfares to meet the strong LCCs price competition, but also a product differentiation strategy based on re-protection in case of cancellation, more cabin space, frequent flyer programs, etc.

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[1] For a long period before deregulation in each EU country state-owned airlines–also called flag carriers–were dominating European skies and all routes were regulated by state-based bilateral agreements. There was no possibility of entry by airlines not included in the bilateral agreement.

[2] ICAO, 2015. https://www.icao.int/sustainability/pages/low-cost-carriers.aspx.

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It is therefore interesting to understand whether, at least up to year 2019, i.e., the period before the COVID-19 pandemic[3], in European routes there is still a price differential in favor of LCCs, even in presence of their high market power and of a business model slightly different from that of the beginning of liberalization; moreover, a crucial aspect of the comparison between legacy carriers and LCCs in Europe is to analyze how much the price level of FSCs is influenced by the presence of LCCs on the same route. Does product differentiation allow legacy carriers to maintain high price levels (as at the beginning of liberalization)? Or is there a backlash with a tendency towards price competition to counter possible market share erosion? Is there a threshold level of market share of LCCs that triggers a price reaction from legacy carriers? This is the goal of this paper, through the design of an econometric model for panel data relating to direct flights on European routes.

To the best of our knowledge, this is the first paper that investigates the pricing behavior of LCCs and FSCs in all the commercial European routes, since we can exploit price information coming from aviation data providers (i.e., OAG Traffic Analyser). Indeed, existing findings on LCCs price effects are mostly based on the US market (Brueckner and Whalen, 2000; Windle and Dresner, 1995), since the US Department of Transportation (DOT) provides data on 10% of airline tickets from U.S. reporting carriers in the freely available DB1B database. Few studies are available for Asia, and even less for Europe, even if LCCs have had one of the most important impact on aviation markets. The available contributions on price competition in Europe (e.g., Alderighi et al. (2015); Avogadro et al. (2021); Bilotkach et al. (2015); Malighetti et al. (2009)) cannot be generalized since data are based on web scraping a single airline's airfares, i.e., they do not allow a comparison among competitors, especially LCCs and FSCs, and usually consider a small subset of routes that does not allow to fully take into account the variation in the characteristics of routes, such as airline competition, socio-economic variables of the route end-points, etc. Their main findings are related to the different patterns of dynamic pricing followed by LCCs and FSCs, and to the occurrence of FSCs charging lower fares than LCCs in some routes.[4] Regarding dynamic pricing, the limited empirical evidence shows that LCCs tend to offer more discounts in advanced booking in the more competitive routes (Alderighi et al., 2015; Avogadro et al., 2021; Malighetti et al., 2009; Salanti et al., 2012) present some results pointing out that there are non-occasional cases where LCCs are more expensive than FSCs, either because they exploit the higher willingness to pay of business travelers or because they enjoy monopoly power on a fraction of passengers (i.e., those consumers that believe that LCCs are more convenient by definition). However, it is not available a comprehensive study (i.e., considering all direct flights in Europe and not only a small sample) comparing fares in presence of LCCs using real transaction data regarding passenger bookings and prices. This paper is a first attempt to fill these gaps.

To identify the pricing behavior of LCCs and FSCs, we develop a reduced form panel data model covering the period 2016-2019 and all the routes in both Eastern and Western Europe. Our results indicate that the presence of LCCs on a route, after more than two decades since the beginning of liberalization and in presence of higher LCCs market power, is still associated with lower fares. Furthermore, we find that the magnitude of this effect increases with the relative importance of LCCs on the route. Third, by focusing on legacy carriers' behavior when facing LCCs competition on a route, we find that the best reply pricing strategy is not linear, but it is influenced by the magnitude of the LCCs market share. Specifically, if LCCs market share on the route remains below 19%, FSCs marginally rise their fares and exploit in this way product differentiation; otherwise, they show the opposite behavior, and start decreasing airfares. Hence, FSCs seem to react competitively to the presence of LCCs only if the low-fare airlines market share in a given route is sufficiently high. Conversely, when the LCCs market share is relatively modest, the airfares of legacy carriers tend to increase, something that may be explained by vertical product differentiation. The intuition is that FSCs increase the price differential with LCCs fares when they do not represent a big threat. In these market situations FSCs fully exploit the better quality of their services. However, if LCC competition becomes sufficiently strong, FSCs try to match the prices of the LCCs.

These results have some interesting policy implications: first, LCCs still have a price competitive effect in European aviation markets, since their presence on direct flights is associated with approximately 11% lower fares than without LCCs operating on the route. This is a positive effect for consumers, and for airline competition in Europe. Policy makers have a confirmation that liberalization has long-run price effects, and therefore is a very important regulation strategy to be implemented in air transportation. Second, granting a level playing field in any possible European route is crucial to maintain these positive effects, e.g., by reducing legacy carriers' dominance in some big airports, because only if LCCs can fully adopt their typical strategy and gain a sufficiently high market share, FSCs are induced to react competitively, reacting to the LCCs substantial market presence by charging lower prices. However, LCCs pricing strategy must also be monitored since we find that their prices are higher when they have strong market power.

The paper is organized as follows. In Section 2, we provide a brief literature review, in Section 3 we discuss the estimation methods and our data, while in Section 4 we show the econometric results that we discuss in Section 5, that concludes our paper.

2. Literature review

The liberalization of the airline industry and its consequences have been extensively investigated in the literature since the beginning of the deregulation process in the 1980s. As technology advanced and the global airline industry evolved (i.e., the advent of Computer Reservation Systems (CRSs)), more detailed databases have been made available, and empirical studies began to thrive (Bennett and Craun, 1993; Whinston and Collins, 1992). Since 1998 the U.S. Department of Transport (DOT) collected information about fares, traffic, and departures between the United States and the rest of the world giving a valuable instrument to US American researchers that could start to exploit the nowadays well-known T-100 and DB1B databases. Soon after the 1978 US deregulation, the pioneering LCC, *Southwest Airlines*, developed an aviation model that reduced costs and increased efficiencies, relying on a standardized and homogeneous fleet, simple point-to-point (P2P) connections, fast turnaround times at gates, high aircraft utilization, and the use of secondary airports. Operations emphasized short-medium haul routes, where the low-cost model could readily be implemented. Other LCCs in North America, Europe, Asia, and elsewhere followed suit. As the LCCs grew and saturated their markets, they searched for new operating strategies to gain market share. From offering complementary networks to the ones served by FSCs, some LCCs increasingly moved in frontal competition with FSCs on pre-existing airport pairs (Dobruszkes, 2013), sometimes moving operations from secondary airports to more costly, primary airports to attract business travelers (Dobruszkes et al., 2017; Jimenez and Suau-Sanchez, 2020); other LCCs diversified their fleets or established hubs to connect passengers and feed thinner routes. In general, LCCs entry decisions have become less sensitive to airline competition in the same market (Fu et al., 2015; Zou and Yu, 2020). In recent years, some LCCs began operating long-haul routes in addition to (or instead of) short-medium haul connections (i.e., *Norwegian*, (Dresner et al., 2021)), or began offering connecting flights (i.e., *Ryanair*, (Morlotti et al., 2020)). Some others expanded their sales

[3] As in the rest of the world, the COVID-19 pandemic has had a dramatic effect on the air transport sector in Europe, resulting in a drastic reduction in traffic in 2020 (Andreana et al., 2021) and a slow recovery in 2021-2022. For this reason, a robust analysis of the effect of LCCs on prices in Europe must be limited to the last pre-pandemic year, therefore 2019.

[4] Dynamic pricing, also known as yield management, is a pricing strategy implemented by airlines that adjusts ticket fares based on the number of days remaining before departure (Alderighi et al., 2015).

network and started to rely on external channels (i.e., Global Distribution Systems (GDSs)) to reach more potential customers through travel agencies. Finally, some LCCs introduced ancillary services (e.g., reserved seats, free check-in, flexible and refundable tickets, airport transfers, accommodation options), and entered cooperative agreements or changed their network structures, moving from P2P networks towards mixed architectures (Birolini et al., 2022). This whole trend has narrowed down the differences between the two business models. In fact, it is well recognized in the literature that a clear distinction of business models (i.e., LCC *vs* FSC) does no longer exist, and would probably be inaccurate (Fageda et al., 2015; Wensveen and Leick, 2009).

Numerous other scientific contributions that investigated the so-called airline hybridization phenomenon by which the two previously well distinct categories have approached each other over time (Klophaus et al., 2012; Klophaus and Fichert, 2019; Lohmann and Koo, 2013; Mason and Morrison, 2008; Morandi et al., 2015). Clear evidence from this stream of literature is that LCCs have managed to adapt better and more easily to market conditions and demands. At the beginning, they focused on tourist routes, while after the 9/11 terrorist attack in the US they shifted to richer destinations and then, again, on leisure routes, as the market needed (Alderighi and Gaggero, 2022). There is no doubt that the emergence and expansion of LCCs strongly impacted the evolution of the airline industry, and allowed for the huge growth that characterized it in the last decades. Many researchers have focused on the impact of LCCs emergence on air travel demand, tourism stimulation, and development through regional externalities or connections to remote regions (Antunes et al., 2020; Chung and Whang, 2011; Vergori and Arima, 2022; Williams and Baláž, 2009).

This paper, however, delves into the literature that analyses the impact of LCCs on airfares. This topic can be divided into three main groups of contributions: (1) papers related to the US markets, (2) contributions related to Eastern-Asia and Australia, and (3) previous findings on Europe. For the US markets, earlier studies indicate that LCCs have operating costs 20-30% below network carriers (Wilken et al., 2016; Windle and Dresner, 2017; 1995), while Kwoka et al. (2016) finds that fares are 20% or more below competitors. Morrison (2001) also shows that *Southwest Airlines* generated savings for the US passengers equal to about 20% of the total industry 1998 domestic scheduled passenger revenue. Hofer et al. (2008) investigates the price premiums in the US markets (defined as the price markup due to market dominance and concentration at the airport and route level) and find that LCCs do not charge price premiums, and that FSCs price premiums tend to be lower when there is competition by low cost carriers.

For Eastern-Asia and Australian routes, the liberalization process started later than in the US and Europe (Zhang et al., 2008), but some positive effects of LCCs on pricing have already been identified. Homsombat et al. (2014) find that in Australian routes the number of LCCs operating a connection generates a reduction of about 18% in airfares.[5] In China, Fu et al. (2015) present evidence that the LCC *Spring Airlines* gives rise to a 5% reduction in the airfares of the most important Chinese FSCs in domestic routes. Wang et al. (2018) make a comparison of the LCCs impact on airfares in China and India, and find that they reduce prices by about 14% in India but identified no effect in China after controlling for possible endogeneity effects. In Southeast Asia Chang and Lee (2008) investigate the impact of LCCs on airfares and find a significant reduction (equal to $0.17 US per km flown) in their airfares if compared to those charged by FSCs. In Northeast Asia Ma et al. (2021) identify that LCCs reduce the airfares by about 3%.

The third group pertains to Europe and is closest to our contribution. To the best of our knowledge, the existing contributions regarding airfares and LCCs in Europe are mainly based on data coming from web scraping and mostly focus on the analysis of the low-cost business model and the study of dynamic pricing schemes, i.e., the price levels charged in different days before the departure. Examples are Alderighi and Gaggero (2022); Alderighi et al. (2015); Bilotkach et al. (2015); Malighetti et al. (2009); Salanti et al. (2012). Alderighi et al. (2015) present a well structured paper that analyses only *Ryanair* data taken from its website for a short period of time, i.e., not actual bookings data, and find that yield management of this LCC regarding dynamic pricing implies a higher price premium for each extra seat sold, which is higher in less competitive routes. Malighetti et al. (2009) examine *Ryanair*'s pricing strategy using web scraped one-year data regarding all its European flights and find that there is a positive correlation between the average route fare and its length, frequency, and share of fully booked flights. Salanti et al. (2012) analyze web scraped data taken from *easyJet* website to find that leisure tickets bought several days before departure are not always cheaper than business tickets purchased few days before the departing day. Bilotkach et al. (2015) use web scraped *Ryanair* and *easyJet* data to show that tourists are not always responsive to price changes in the time interval before the departure. Alderighi and Gaggero (2022) study the route entry decision of LCCs in Italy and show that they have changed the market type over the years, moving from operations concentrated only in tourist destinations, to connecting also business cities. Two papers attempt to compare LCCs and FSCs fares in Europe: Alderighi et al. (2011) study web scraped fare data from some legacy carries and LCCs on the London-Amsterdam route, to study their dynamic pricing behaviour and incidentally find that *easyJet* and *Ryanair* charge lower prices. Avogadro et al. (2021) analyze web scraped data on some European fares and find that not always LCCs charge lower fares than FSCs. Clearly, no studies are available that compare LCCs and FSCs airfares using the full sample of European flights, and with bookings data rather than just a single airline or a small sample of routes. This paper is the first attempt to fill this gap.

3. Model and data

In the first part of this section, we present the econometric model adopted to study the impact of LCCs on prices in the intra-European non-stop market, the related econometric challenges that we face, and how our models address these challenges. The second part describes the data and the variables used in the econometric analysis, together with some descriptive statistics.

Our goals are to investigate whether LCCs are still charging lower airfares than FSCs after they achieved market consolidation and dominance in many European routes, and to analyze the FSCs pricing behavior as function of the relative importance of LCCs in the non-stop routes, we introduce two econometric panel data models.

The first econometric model investigates the impact of LCCs on airfares at the city pair level, considering all airlines competing in a specific European non-stop flight. In this case the dependent variable is the average airfare at the market (city pair) level, including, if they are present, both FSCs and LCCs. The second econometric model analyzes the different prices charged by FSCs as a function of the intensity of LCCs competition on a route. LCCs intensity is measured as their market share in a specific city pair. In this case the dependent variable is the average airfare charged only by FSCs.

In both scenarios we estimate a panel data econometric model with fixed effects to control for the unobserved heterogeneity.[6] We also control for time trend by including time dummy variables. Finally, standard errors are clustered at the city pair level which is the cross identifier of our panel, and together with the time dimension defines each unique item of our data set.

[5] Deregulation in Australia started in the 90s, and it is well described in Forsyth (2003).

[6] A Hausman test has also been run and confirms that a random effect specification was not a consistent alternative.

3.1. The econometric models

The baseline econometric specification for studying if LCCs still charge lower fares than FCSs in Europe is as follows:

$$log(FARE)_{jt} = \boldsymbol{X_1} \cdot \boldsymbol{\beta_1'} + \alpha_1 \cdot LCC_{jt} + \alpha_2 \cdot TOTCOMP_{jt} + \psi_j + \tau_t + v_{jt} \quad (1)$$

In Eq. (1), the dependent variable is the logarithm of the weighted average monthly $FARE_{jt}$ in the European city pair j in period t, i.e., a month. In each city pair the fare charged by an airline is weighted by its passengers. Fares are function of a matrix $\boldsymbol{X_1}$ of exogenous explanatory control variables covering some aviation and socio-economic characteristics of each city pair. These are given by the number of airports at the endpoints of the city pair ($NUMAPT$), the flown distance ($DIST$), the product of the population in the two endpoint cities (POP), and the product of the per capita income at the city endpoits (GDP). LCC is a variable capturing LCCs competition in the specific city pair, that will take different specifications: first, it is given by a dummy indicating the presence of LCCs, and it is equal to 1 if the seats offered by LCCs are more than 5% of the total available seats in a specific city pair. We denote this variable as $LCCPRESENCE$. Second, we take into account the relative importance of LCCs in the city pair by computing their overall city pair market share given by their seats over the total. This variable is denoted as $LCCINTENSITY$. Fares are also function of a variable capturing the degree of competition ($TOTCOMP$), given by the number of airlines operating in the city pair.

Fares are directional (i.e., flying from city A to city B and from city B to A are counted as separate markets) calculated in US dollars and do not include fees paid for allocating seats, baggages, or priority boarding. Nor do they include payments for onboard food and drinks, taxes, airport fees, and surcharges. To limit the inclusion of unrealistic data, we apply price and frequency cutoffs: although other choices have been tested, we constrain fares to be higher than $5 and lower than $1,000 and we exclude flights reporting a frequency lower than 16 times a month (similarly to Brueckner and Singer (2019) where the frequency cutoff threshold is set to 48 departures per quarter).

Since competition in aviation takes place at the city pair level, we aggregated all the airports serving a specific local area, and this is given by the variable $NUMAPT$. However, while in the U.S. airports are aggregated according to the Metropolitan Statistical Area (MSA), in Europe it is common to aggregate all airports within 90 minutes travel time distance or 100 kilometers (Scotti et al., 2012). In this paper we follow the OAG city pair aggregation. The latter is based on the airline's declaration regarding the city of origin and destination. For example, Milan-Bergamo (BGY), Milan-Linate (LIN) and Milan-Malpensa (MXP) are all aggregated to Milan city. On top of this, a 90-minute travel distance from the city center is also adopted as a criterion. For this reason, Parma (PMF) airport is also belonging to Milan. Similarly, London city has six airports: City (LCY), Gatwick (LGW), Heathrow (LHR), Luton (LTN), Southend (SEN) and Stansted (STN), while Paris city has Beauvais-Tille (BVA), Chalons-Vatry (XCR), Charles de Gaulle (CGD), and Orly (ORY).

$\boldsymbol{\beta_1'}$ is a column vector of coefficients for the exogenous explanatory variables, α_1 identifies the impact of LCCs on airfares, α_2 is the coefficient for the effect of competition, ψ_j identifies the city pair fixed effects which capture time-invariant unobserved factors that may affect airfares in a market, while τ_t represents time dummy variables and identifies a time trend common to all city pairs. Finally, v_{jt} is the error term which is assumed to be normally distributed with zero mean and constant variance σ_v^2.

3.2. Econometric challenges

Developing such a model presents some econometric challenges like the potential endogeneity of LCC and $TOTCOMP$. First, although most of the LCCs operating in our sample are experienced and consolidated players, active in the majority of the European network, the selection of the routes they operate it is highly likely not the result of random sampling; therefore, we need to correct for possible selection bias regarding the variables $LCCPRESENCE$ and $LCCINTENSITY$. Second, the direction of the causal link between ticket prices and competition is not *a priori* clear, and previous studies have shown the importance to explicitly address this possible reverse causality bias (Bilotkach and Hüschelrath, 2013; 2019; Dresner et al., 2021).[7] We deal with both problems using a control function approach (CFA) (Heckman and Robb Jr (1985); Wooldridge (2010, 2015)).

As in Dresner et al. (2021), to estimate the parameters in Eq. (1) and to control for endogeneity, the CFA is used to generate two control functions: one for the endogeneity of LCCs, and the other for the similar problem affecting the city pair degree of competition, i.e., $TOTCOMP$.[8] The generation of the two control function variables is done *via* a two-step procedure based on the inclusion of instrumental variables in a first-step equations, i.e., an equation having LCCs as dependent variable and another equation having $TOTCOMP$ as dependent variable.[9] The first-step estimated equation to treat LCCs endogeneity is as follows:

$$LCC_{jt} = \boldsymbol{X_1} \cdot \boldsymbol{\beta_2'} + \delta_1 \cdot HUB_{jt} + u_{jt} \quad (2)$$

As required in CFA the set of exogenous explanatory variables in Eq. (2) must include at least one variable that is left out from the main outcome equation (1), i.e., all those included in $\boldsymbol{X_1}$ plus an instrumental variable. Our instrument is the variable HUB, i.e., a dummy variable equal to 1 if the city pair j has at least a hub airport in one of the endpoints. We classify an airport as hub if it belongs to the last decile of the airport distribution according to the number of departing destinations, excluding the destinations operated by LCCs only. This means that an airport is classified as hub if it has a number of European non-stop destinations higher than those at the 90^{th} percentile of airport distribution. Given that our observations are at the city pair level, and since in a city there might be more than one airport, the variable HUB is equal to 1 even if at one of the endpoints there is only a hub airport. The intuition for using this variable as instrument is that in presence of a hub airport is less likely that LCCs are present. Therefore, we anticipate an adverse effect of this variable on LCCs. Since HUB is a variable based on a distribution of destinations, it may vary over time. The error term u is assumed to have 0 mean and unit variance.

In order to be a good instrument for $LCCPRESENCE$ or $LLCINTENSITY$, HUB must satisfy two requirements: (1) it must be correlated with $LCCPRESENCE$ or $LCCINTENSITY$; and (2) it must not be correlated with error v in equation (1). Regarding the first condition, in a hub airport the incumbent carrier(s) tends to occupy the majority of available slots, making very difficult the entrance of new airlines. Hence, HUB should be an important determinant of $LCCPRESENCE$ and $LCCINTENSITY$ (with negative impact), satisfying the first condition.

Regarding the second condition, it is necessary to consider whether an increase in unobserved determinants of $FARE$ might affect HUB. Since fares are mainly influenced by market size, tourist flows, fuel price, degree of competition, etc., with the variables in $\boldsymbol{X_1}$ we control for most of these factors, while the possible remaining ones are captured by the fixed effects and the time effects variables, making the second condition also fulfilled.

From the fitted values obtained by regressing Eq. (2) we generate the residuals $\hat{u}_{jt}$ that represent the control function variable to capture the unobserved effects of LCCs that would be otherwise included in the

[7] Brueckner and Singer (2019) do not address this issue as they believe the correction has little effect on the final estimates.

[8] Dresner et al. (2021) actually tackle a more complicated approach as one endogenous variable is also a determinant of the other one.

[9] As in Dresner et al. (2021), to avoid inflated t-statistics we bootstrap the entire procedure resampling city pairs by time blocks.

error term of the main fare equation. We apply the same procedure for *TOTCOMP*. In this case we estimate the following first-step equation:

$$TOTCOMP_{jt} = \boldsymbol{X_1} \cdot \boldsymbol{\beta_3'} + \epsilon_1 \cdot AVGCOMP_{jt} + e_{jt} \tag{3}$$

The instrument is the variable $AVGCOMP$, defined as the average number of competitors on the city pair j in the six months before month (period) t. Although changes are possible even within seasons, the structure of the market do not typically vary too much over time as airlines select routes and frequencies 818 months in advance (Birolini et al., 2021). Hence, $AVGCOMP$ should be correlated with the number of competitors at the current time t. $AVGCOMP$ has also to be uncorrelated with the error term v in Eq. (1). Again, the number of airlines competing in a route is function of some variables included in $\boldsymbol{X}_1$, and of some unobserved factors that we control with fixed effects and time effects.[10] As before, we obtain the fitted value for the variable $TOTCOMP$ and then compute $\hat{e}_{it}$, the control function variable that will be included in the main fare equation. The error term e is assumed to have 0 mean and constant variance σ_e^2.

Hence, the extended econometric model regarding the fare equation can be written as:

$$\begin{aligned} log(FARE)_{jt} = {} & \boldsymbol{X_1} \cdot \boldsymbol{\beta_1'} + \alpha_1 \cdot LCC_{jt} + \alpha_2 \cdot TOTCOMP_{jt} \\ & + \alpha_3 \cdot \hat{u}_{jt} + \alpha_4 \cdot \hat{e}_{jt} + \psi_j + \tau_t + v_{jt} \end{aligned} \tag{4}$$

where $\hat{u}_{jt}$ and $\hat{e}_{jt}$ are the two control functions that we generate from Eq. (2–3). A test for the endogeneity in Eq. (4) is given by the t-ratio of the estimated coefficient of $\hat{u}_{jt}$ (and $\hat{e}_{jt}$). The null hypothesis is that there is no endogeneity. Therefore, if the coefficient is statistically significant, we can reject the null hypothesis and obtain valid estimates with the CFA. On the contrary, estimates without $\hat{u}_{jt}$ (and/or $\hat{e}_{jt}$) are valid.

When we consider the relative importance of the LCCs competition by introducing the variable $LCCINTENSITY$ we take into account for a possible non-linear relationship between fares and this variable. Hence, we include a quadratic variable for $LCCINTENSITY$ in the fare equation, that takes the following specification:

$$\begin{aligned} log(FARE)_{jt} = {} & \boldsymbol{X_1} \cdot \boldsymbol{\beta_3'} + \gamma_1 \cdot LCCINTENSITY_{jt} \\ & + \gamma_2 \cdot LCCINTENSITY\_SQ_{jt} \\ & + \gamma_3 \cdot TOTCOMP_{jt} + \gamma_4 \cdot \hat{u}_{jt} + \gamma_5 \cdot \hat{e}_{jt} + \psi_j + \tau_t + v_{jt} \end{aligned} \tag{5}$$

3.3. FSCs price reaction to LCCs

The second part of our empirical investigation focuses on the FSCs pricing behavior as function of the relative importance of LCCs in a city pair. To do this, only those city pairs with at least one LCC (and one FSC) have been analyzed, and without LCCs fares contributing to the computation of average monthly fares in each route. In this second specification, the new dependent variable represents the average of the FSCs fares only, i.e., the variable denoted as $FSCFARE$.

Again, we control for the possible endogeneity of $TOTCOMP$ and $LCCINTENSITY$ using two first-step equations with the same instruments than before. We then compute from these first-step equations the predicted errors, that we denote as $\hat{\eta}$ for the $LCCINTENSITY$, and $\hat{\zeta}$ for $TOTCOMP$. These are the control function variables and so the second-step estimated equation is as follows:

$$\begin{aligned} log(FSCFARE)_{jt} = {} & \boldsymbol{X_1} \cdot \boldsymbol{\beta_3'} + \lambda_1 \cdot LCCINTENSITY_{jt} \\ & + \lambda_2 \cdot LCCINTENSITY\_SQ_{jt} \\ & + \lambda_3 \cdot TOTCOMP_{jt} + \lambda_4 \cdot \hat{\eta}_{jt} + \lambda_5 \cdot \hat{\zeta}_{jt} + \psi_j + \tau_t + w_{jt} \end{aligned} \tag{6}$$

$\boldsymbol{X}_1$ is the same matrix of control variables described before, while ψ_j are city pair fixed effect and τ_t dummy variables capturing the time trend, as in the previous econometric model.

[10] Instrumental variables working on this principle in studies of this kind were proposed in (Bilotkach and Hüschelrath, 2013; 2019; Evans et al., 1993; Whalen, 2007), among others.

3.4. Data

Data on fares in the European aviation market come from the Official Airline Guide (OAG) database, supplemented by other official and website sources. Our data set is a panel that considers the period 2016-2019 and 5,851 city pairs, and is built as follows. We consider all intra-European direct flights marketed between January 2016 and December 2019 on a monthly base. Data on all flights are aggregated up to the city pair level by grouping airports in the same metropolitan area following multi-airport designations in the Official Aviation Guide (OAG). Our sample counts 189,073 observations where each item is identified by the unique city pair-month combination over the 48 months time interval.

Fares are obtained from the OAG Traffic Analyser, that provides prices charged by airlines on scheduled flights worldwide. OAG Traffic Analyser data consists primarily of Marketing Information Data Transfer–MIDT data obtained through Travelport Global Distribution System (GDS), and then adjusted with additional data from other GDSs, to get a complete data set of airfare monthly transactions. Since one of our main purposes is to determine the impact of LCCs on airfares

Table 1
European countries in the dataset, share of total and LCCs discount economy seats

Country Name	Seats (%)	LCCs' Seats (%)	Share of LCCs' Seats (%)
United Kingdom	16.74	9.96	59.47
Spain	13.25	7.86	59.33
Germany	11.19	3.95	35.32
Italy	10.10	5.65	55.95
France	8.56	3.27	38.22
Turkey	4.23	0.73	17.34
Norway	3.47	1.56	44.83
Netherlands	3.24	1.40	43.13
Switzerland	3.08	1.04	33.72
Portugal	2.94	1.32	44.73
Sweden	2.64	0.92	34.92
Ireland	2.36	1.23	52.16
Poland	1.95	1.13	58.04
Denmark	1.91	0.75	39.03
Austria	1.85	0.39	21.27
Greece	1.80	0.79	43.84
Belgium	1.61	0.73	45.27
Finland	1.26	0.21	16.74
Romania	1.11	0.71	63.80
Czech Republic	0.80	0.27	34.16
Ukraine	0.78	0.09	11.05
Hungary	0.67	0.46	69.57
Croatia	0.56	0.23	40.95
Bulgaria	0.41	0.21	50.84
Malta	0.39	0.18	46.82
Serbia	0.36	0.08	22.22
Cyprus	0.35	0.20	56.49
Latvia	0.32	0.09	29.26
Lithuania	0.29	0.19	65.73
Iceland	0.29	0.08	27.81
Luxembourg	0.20	0.04	19.60
Azerbaijan	0.19	0.00	0.78
Georgia	0.14	0.03	19.20
Belarus	0.13	0.00	0.39
Estonia	0.13	0.03	18.80
Albania	0.12	0.01	7.15
Slovakia	0.11	0.09	80.75
Slovenia	0.10	0.02	21.43
Macedonia	0.10	0.07	69.76
Montenegro	0.10	0.02	15.97
Moldova	0.09	0.02	22.45
Bosnia and Herzegovina	0.07	0.03	49.53
Armenia	0.02	0.00	0.21

and since LCCs sell predominantly discount economy tickets, we only include discount economy data.[11]

Our data set covers available seats from all airlines providing direct flights in the European markets. These data are taken from OAG Schedule Analyzer. The list of all the European countries included in the analysis can be found in Table 1. UK is the country with the highest share of available seats (taking into account departing airports), equal to about 17%. Spain, Germany, Italy, and France follow ranging from about 13 to 9%. The third column shows the share of available seats that is offered by LCCs in each country. Again, UK is the country with the highest share of available seats offered by LCCs (10%), followed by Spain (8%), Italy (5.7%), Germany (4%), and France (3.3%). The last column is a measure of LCCs importance in the country, and reflects the percentage of seats offered by them over the total available seats of the country. United Kingdom, Spain, and Italy have about 56%-60% LCCs' seats share, while in Germany and France LCCs' seat share is close to 35%-40%.

As mentioned before, this data set differentiates our contribution from the existing literature as it includes data from all airlines serving the market and all non-stop intra-European routes. The list of airlines and the corresponding market shares computed on the basis of available discount economy seats is reported in Table 2. European LCCs have the highest market shares if we consider intra-Europe direct flights. The main five LCCs, i.e., *Ryanair, easyJet, Vueling, Norwegian*, and *Wizz Air*, account for about 40% of total available discount economy seats, with *Ryanair* and *easyJet* holding the top positions in the ranking. *Lufthansa* has approximately 6% of discount economy seats, followed by *British Airways* with 5.3%, and *Air France* with 4.5%. Clearly, market shares would be different if we consider connecting and long-haul flights and all ticket categories (i.e., business, economy, etc.) where FSCs dominate the markets.[12]

An important factor of our paper is to define which airlines are classified as LCCs. We follow the classification made by OAG schedule analyzer. The airlines considered low-cost in our data set are shown in Table 3.

3.5. Variables

Table 4 presents descriptive statistics for the variables included in the econometric models.

Table 4 presents some descriptive statistics regarding the variables included in our econometric models. The average price for the economy class ($FARE$) is about \$100 with a pretty high standard deviation and a range going from \$5 to \$834. The number of competitors on a specific route ($TOTCOMP$) goes from 1 to 10 with a mean value of 1.88 indicating a moderately competitive environment. In about half of the observations at least one LCC is operating, as $LCCPRESENCE$ takes value 1 in 54% of the cases. The average LCCs share ($LCCINTENSITY$) is 34%, but with a high standard deviation.[13] The average number of competitors ($AVGCOMP$) in equal to 1.88, with a lower maximum compared to $TOTCOMP$ and equal to about 9. A quarter of the records is related city pairs that involve at least one hub airport (HUB) on the route. On average a city pair j has direct flights connecting about 2.3 airports

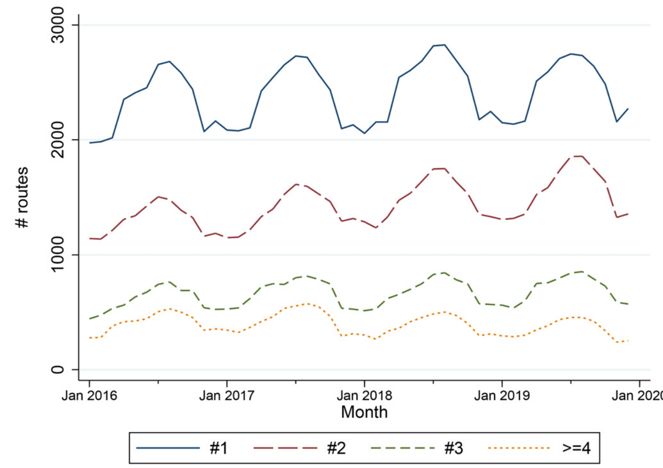

Fig. 1. European routes by # of airlines and month

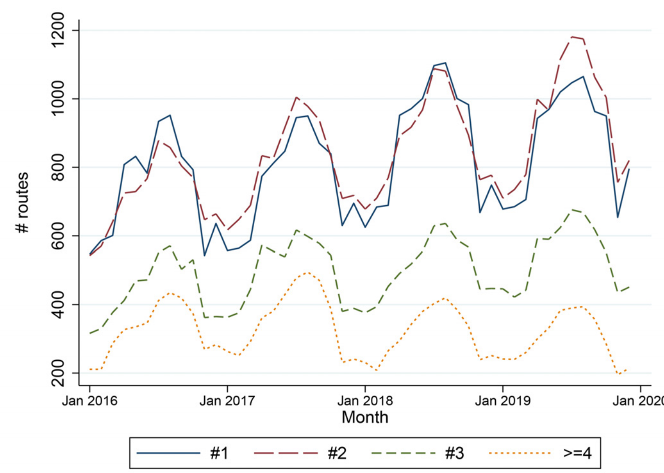

Fig. 2. European LCCs routes by # of airlines and month

($NUMAPT$), with a maximum of 9 airports in the case of Milan-London. The average distance ($DIST$) of the route represented in our sample is 1,023 kilometers, with the shortest route connecting two Greek islands (21 km), and the longest linking Helsinki (FI) and Tenerife (ES) (4,738 km). The average product of the two endpoints population (POP) is about 13 trillion while the average product of per capita income (GDP) is almost \$2 billion.

To better understand the nature of our data set we provide some descriptive evidence on the distribution of market structures in the European markets (i.e., we observe how many city pairs are served by a single airlines, i.e., a monopoly, by two airlines, etc.), and on the corresponding yields per different market structures. As shown in Fig. 1, European routes exhibit high monthly variability in market structure. The majority of routes are monopolies, with about 2,000 monopoly markets during the winter period and more than 2,700 during the peak demand period in the summer. The remaining routes are more than 1,000 duopolies (increasing to almost 2,000 in summer) and about 500 routes with 3 or more operating carriers, with the peak of about 800 during the summer.

Figure 2 displays the market structure of routes where instead only LCCs operate. In this case there is about the same number of monopolies and duopolies. In winter about 600 routes are monopolies of LCCs, and in the same number of routes there are only two LCCs competing. In summer these numbers increase to more than 1,000 routes, with a peak of 1,200 routes that are monopolies and about 1,100 routes with only two LCCs in the summer of year 2019. Between 300 (in winter) and

[11] OAG Traffic Analyzer provides two variables for economy fares: *Full Y* fare that has very few restrictions regarding reimbursements in case of cancellation, possibility to change the flight etc., and *Discount economy*, with much more restrictions. The *Full Y* fare is not adopted by LCCs and therefore is not reported. Very few data are related to *Full Y* fares charged by FSCs in European direct flight. For instance in January 2022 *Air France* had 6,135 bookings in discount economy, and only 109 in *Full Y*, while *Ita Airways* had 3,132 bookings in discount economy and only 12 in *Full Y*. Overall, in our data set about 94% of FSCs bookings are in discount economy class. Hence, both for direct comparison (i.e., discount economy tickets in FSCs and LCCS) and for relevance of the bookings we concentrate the analysis only on discount economy data.

[12] The ranking presented in Table 2 would also change if we consider the shares of the subsidiaries as an integral part of the holding company.

[13] In the FSC restricted sample, the mean value of $LCCINTENSITY$ is 0.11 and the maximum is 0.99.

Table 2
Airlines included in the analysis by share of discount economy seats

Airline Code	Airline Name	Seats (%)	Cumulated (%)	Airline Code	Airline Name	Seats (%)	Cumulated (%)
FR	Ryanair	14.61	14.61	QS	SmartWings	0.19	97.87
U2	Easyjet	13.64	28.26	DE	Condor Flugdienst	0.18	98.05
LH	Lufthansa German Airlines	5.94	34.19	JP	Adria Airways	0.16	98.20
BA	British Airways	5.28	39.48	BV	Blue Panorama Airlines	0.15	98.35
AF	Air France	4.53	44.01	FB	Bulgaria Air	0.14	98.49
VY	Vueling Airlines	3.87	47.88	GR	Aurigny Air Services	0.12	98.61
TK	Turkish Airlines	3.71	51.59	S4	SATA International-Azores Airlines S.A.	0.10	98.71
DY	Norwegian Air Shuttle	3.68	55.27	W2	FlexFlight ApS	0.09	98.80
SK	SAS Scandinavian Airlines	3.58	58.85	SP	SATA Air Acores	0.09	98.89
W6	Wizz Air	2.99	61.84	ST	Germania	0.08	98.97
IB	Iberia	2.70	64.53	YM	Montenegro Airlines	0.08	99.05
AZ	Alitalia - Societa Aerea Italiana S.p.A	2.63	67.17	9U	Air Moldova	0.08	99.13
KL	KLM-Royal Dutch Airlines	2.19	69.36	WX	City Jet	0.07	99.20
LX	SWISS	2.08	71.43	W9	Wizz Air UK	0.07	99.27
EW	Eurowings	1.96	73.40	LM	Loganair	0.06	99.34
OS	Austrian Airlines AG dba Austrian	1.71	75.10	EN	Air Dolomiti S.p.A L.A.R.E	0.06	99.40
TP	TAP Portugal	1.56	76.67	BM	BMI Regional	0.06	99.45
EI	Aer Lingus	1.56	78.22	8Q	Onur Air Tasimacilik A.S.	0.06	99.51
BE	Flybe	1.38	79.61	GQ	Sky Express S.A.	0.05	99.56
AY	Finnair	1.33	80.93	EL	Ellinair S.A.	0.05	99.61
AB	Air Berlin	1.30	82.23	ZI	Aigle Azur	0.05	99.66
UX	Air Europa	1.08	83.31	T3	Eastern Airways	0.02	99.69
LS	Jet2.com	1.06	84.37	2N	Nextjet	0.02	99.71
SN	Brussels Airlines	0.96	85.33	EK	Emirates	0.02	99.73
A3	Aegean Airlines	0.86	86.19	ET	Ethiopian Airlines	0.02	99.75
HV	Transavia.com	0.83	87.02	CO	Cobalt Aero	0.02	99.77
LO	LOT - Polish Airlines	0.81	87.83	LA	Lan Airlines	0.02	99.79
4U	germanwings	0.77	88.60	A9	Georgian Airways	0.02	99.80
PC	Pegasus Airlines	0.74	89.34	VK	LEVEL operated by Anisec Luftfahrt	0.02	99.82
PS	Ukraine International Airlines	0.67	90.01	SX	Sky Work Airlines	0.02	99.83
V7	Volotea	0.54	90.55	CE	Chalair	0.01	99.85
A5	HOP!	0.53	91.08	CY	Cyprus Airways	0.01	99.86
NT	Binter Canarias	0.49	91.57	M9	Motor Sich PJSC	0.01	99.88
0B	Blue Air	0.45	92.02	WW	WOW Air	0.01	99.89
TO	Transavia.com France	0.44	92.47	T7	Twin Jet	0.01	99.90
ZB	Monarch Airlines	0.44	92.90	XQ	SunExpress	0.01	99.91
WF	Wideroe's Flyveselskap	0.42	93.32	F7	Darwin Airline	0.01	99.92
BT	Air Baltic Corporation	0.41	93.73	PE	Peoples Vienna Line	0.01	99.93
OK	Czech Airlines	0.35	94.07	Z6	Dnieproavia Joint Stock Aviation Co	0.01	99.94
IG	Meridiana fly S.p.A.	0.34	94.42	UH	Aircompany Atlasjet Ukraine LLC	0.01	99.95
RO	Tarom	0.33	94.75	5F	Fly One	0.01	99.96
FI	Icelandair	0.33	95.08	YE	Yanair	0.01	99.97
TF	Braathens Regional Aviation	0.32	95.40	CA	Air China	0.01	99.97
JU	Air Serbia	0.31	95.70	7W	Wind Rose Aviation	0.01	99.98
XK	Air Corsica	0.30	96.01	QR	Qatar Airways	0.01	99.99
KK	AtlasGlobal	0.29	96.30	GM	Germania Flug AG	0.00	99.99
OU	Croatia Airlines	0.28	96.58	VG	VLM Airlines N.V.	0.00	99.99
KM	Air Malta	0.28	96.85	2L	Helvetic Airways	0.00	99.99
HG	NIKI	0.22	97.07	HU	Hainan Airlines	0.00	99.99
J2	Azerbaijan Airlines	0.22	97.29	3U	Sichuan Airlines	0.00	99.99
B2	Belavia	0.20	97.49	SE	XL Airways France	0.00	99.99
LG	Luxair	0.19	97.68	U8	TUS Airways	0.00	100.00

600 (in summer) routes are LCCs triopolies, while between 200 and 400 routes have 4 or more LCC competitors.

Figure 3 presents descriptive evidence on the impact of the number of competitors on European non-stop airfares. The figure shows monthly fare per kilometer flown in monopolies (#1), duopolies (#2), triopolies (#3), and on routes where 4 or more airlines operate (#>=4). As predicted by economic theory average monthly fares are higher on monopoly routes (equal to about $0.2/km) than on routes with two competitors (equal to $0.12/km). In turn, the latter are higher than the average monthly fares in routes with 3 competitors (equal to $0.09/km), while the lowest fares ($0.07/km) are in routes with 4 or more competing airlines. On average fares in monopoly routes are three times higher than those observed in the more competitive routes. Interesting and well visible in Fig. 3, there is also an important seasonality effect, with the highest peaks in July and August.

Figure 4 shows descriptive evidence of the average yield offered by 6 of the the top carriers operating in the European markets. We can distinguish two groups: the LCCs (*Ryanair* (FR), *easyJet* (U2), and *Vueling* (VY)) and the major European legacy carriers (*British Airways* (BA), *Lufthansa* (LF), and *Air France* (AF)). As expected, Fig. 4 allows to infer how the former group operates with lower yields compared to the latter one. *Ryanair* has the cheapest fares per kilometer followed by *easyJet*, with both carriers characterized by remarkable summer peaks. Among the three legacy carriers, *British Airways* seems to set the lower yields, followed by *Lufthansa* and *Air France*. The three FSCs yields are about twice the LCCs ones. *Vueling* has always higher prices than *Ryanair* and *easyJet*, quite close to those of *British Airways* at the end of the observed period.

Table 5 reports a list of routes belonging to different categories according to the importance of the LCCs presence. The first column shows some examples of routes where LCCs are monopolist. Some of them are linked with tourist destinations (e.g., Amsterdam-Lanzarote, Ancona-London, Bristol-Lanzarote, Dublin-Malta), the other ones may involve both business, tourist and family network traffic (e.g., Athens-

Table 3
Airlines classified as LCCs included in the dataset

Airline Code	Airline Name
0B	Blue Air
4U	germanwings
8Q	Onur Air
CO	Cobalt Aero
DY	Norwegian Air Shuttle
EW	Eurowings
FR	Ryanair
FZ	Flydubai
HG	NIKI
HV	Transavia.com
LS	Jet2.com
PC	Pegasus Airlines
TO	Transavia.com France
U2	Easyjet
V7	Volotea
VK	LEVEL operated by Anisec Luftfahrt
VY	Vueling Airlines
W6	Wizz Air
W9	Wizz Air UK
WW	WOW Air
XQ	SunExpress

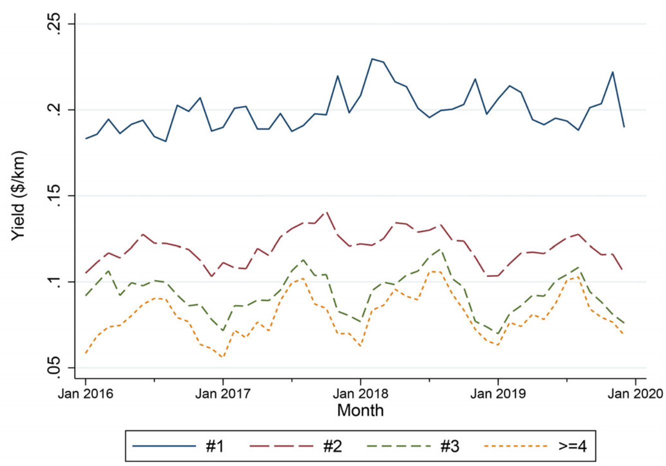

Fig. 3. European routes average monthly price per kilometer, by competitive level

Eindhoven, Berlin-Porto, Brussels-Bratislava, Geneva-Toulouse). The middle column displays a sample of routes where LCCs and FSCs have the same market share. There two tourist destinations (Bremen-Palma de Mallorca, Paris-Faro), while the other connections are related to all traffic types. Last, the third column presents a sample of routes with no

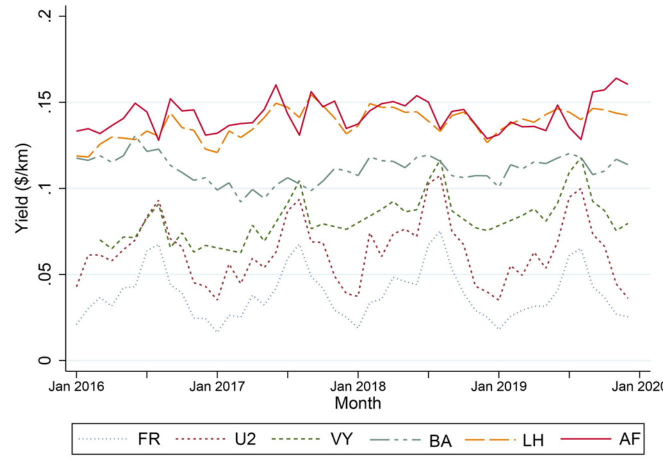

Fig. 4. European routes' average monthly price per kilometer, of the top 6 airlines (by discount economy seats)

LCCs. It is evident that these routes don't focus on tourist destinations, with flights linking country capitals, business centers, etc.

Figures 1–4 and Tables 1, 2, and 5 provide insights into the main treats of the European competitive landscape. However, to shed some light upon the descriptive clues just provided, a proper econometric model must be estimated to account for other factors that may be influencing fares. Results are reported in the next section.

4. Results

In this section, we present the empirical results of our econometric models to estimate the impact of LCCs on non-stop intra-European markets. In Table 6 we show the results of our first econometric specification that investigates whether LCCs in Europe are still cheaper than FSCs. Columns (2) and (4) display the coefficients of the OLS regression model, while columns (3) and (5) present the estimates obtained with the extended control function approach. The first two columns only capture the presence of LCCs with dummy variables, while columns (4) and (5) consider the relative importance of LCCs in the city pair.

In column (3) the OLS estimate of the LCCs presence is negative and statistically significant, equal to -0.18. The variable representing the degree of competition has also a negative and significant estimated coefficient, equal to -0.04. Column (3) presents the CFA results correcting for possible endogeneity. The estimated coefficient of $LCCPRESENCE$ is negative and significant, with lower magnitude compared to that of the OLS estimation: -0.11. $TOTCOMP$ has also negative and significant estimated coefficient, in this case a bit higher than that of the OLS esti-

Table 4
Summary statistics and description of the variables included in the econometric panel data models

Variable	Mean	Std. Dev.	Min	Max	Description
FARE ($US)	100.11	55.01	5	834	Average fare in discount economy class[a]
TOTCOMP (#)	1.88	1.09	1	10	Number of operating carriers
LCCPRESENCE	0.54		0	1	Low-Cost carriers presence
LCCINTENSITY (%)	0.34	0.40	0	1	Low-Cost carriers intensity
AVGCOMP (#)	1.88	1.11	1	8.5	Number of operating carriers the previous semester
HUB	0.25		0	1	At least one endpoint city has a hub airport
NUMAPT (#)	2.30	0.74	2	9	Number of airports in the city pair
DIST (km)	1,023	671.76	21	4,738	Weighted average route distance
POP (billion)	13,100	16,100	33.60	185,000	Product of the two endpoints population
GDP (mil. $)	1,980	2,660	1,660	2,830	Product of the two endpoints income per capita[b]

[a] No taxes, airport fees and fuel surcharges but they do include agency commissions
[b] POP and GDP are computed at the NUTS2 level

Table 5
Ten sample routes by LCCs' Seat Share

100% LCCs' Seat Share	50% LCCs' Seat Share	0% LCCs' Seat Share
AMS-ACE (Amsterdam-Lanzarote)	ATH-NTE (Athens-Nantes)	AMS-BLQ (Amsterdam-Bologna)
AOI-LON (Ancona-London)	BCN-ZAG (Barcelona-Zagreb)	ANR-LON (Antwerp-London)
ATH-EIN (Athens-Eindhoven)	BOD-BRU (Bordeaux-Brussels)	BER-PRG (Berlin-Prague)
BCN-BRI (Barcelona-Bari)	BRE-PMI (Bremen-Palma de Mallorca)	DUS-RIX (Duesseldorf-Riga)
BER-OPO (Berlin-Porto)	BRS-PAR (Bristol-Paris)	FRA-BIO (Frankfurt-Bilbao)
BRS-ACE (Bristol-Lanzarote)	HAM-BUH (Hamburg-Bucharest)	HEL-WAW (Helsinki-Warsaw)
BRU-BTS (Brussels-Bratislava)	MIL-VNO (Milan-Vilnius)	LIS-ALC (Lisbon-Alicante)
BUD-EDI (Budapest-Edinburgh)	NAP-BCN (Naples-Barcelona)	LUX-MUC (Luxembourg-Munich)
DUB-MLA (Dublin-Malta)	PAR-FAO (Paris-Faro)	MAD-SDR (Madrid-Santander)
GVA-TLS (Geneva-Toulouse)	VCE-PRG (Venice-Prague)	MIL-ZRH (Milan-Zurich)

Table 6
Fare estimates from different specifications - full sample

	Dep. Variable *log(FARE)*			
	(2) OLS	(3) CFA	(4) OLS	(5) CFA
LCCPRESENCE	-0.178***	-0.112***		
	(-13.32)	(-5.84)		
LCCINTENSITY			-0.889***	-0.849***
			(-13.82)	(-10.89)
LCCINTENSITY_SQ			0.522***	0.494***
			(10.38)	(8.05)
$\hat{u}$		-0.089**		-0.481***
		(-3.14)		(-4.99)
TOTCOMP	-0.037***	-0.118***	-0.049***	-0.136***
	(-7.96)	(-14.42)	(-10.82)	(-16.24)
$\hat{e}$		0.139***		0.147***
		(14.46)		(14.89)
F-statistic (*HUB*)		122.55		90.62
F-statistic (*AVGCOMP*)		795.36		773.23
Observations	189,073	189,073	189,073	189,073
Adjusted *R*-squared	0.70	0.71	0.70	0.71
Route and Time FEs	✓	✓	✓	✓

Robust *t*-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 7
FSCs only fare estimates from different specifications

	Dep. Variable *log(FSCFARE)*		
	(2) OLS	(3) 2-CFA	(4) 1-CFA
LCCINTENSITY	0.062	0.266*	0.102*
	(1.37)	(1.73)	(2.14)
LCCINTENSITY_SQ	-0.246***	-0.264***	-0.272***
	(-4.64)	(-4.47)	(-4.31)
$\hat{\eta}$		-0.168	
		(-1.15)	
TOTCOMP	-0.035***	-0.093***	-0.084***
	(-9.49)	(-11.84)	(-10.46)
$\hat{\zeta}$		0.086***	0.079***
		(9.32)	(8.33)
F-statistic (*HUB*)		141.43	
F-statistic (*AVGCOMP*)		719.88	719.88
Observations	134,698	134,698	134,698
Adjusted *R*-squared	0.72	0.72	0.72
Route and Time FEs	✓	✓	✓

Robust *t*-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

mation. Thus, by correcting for endogeneity we do not obtain changes in the sign and significance of the coefficients, but only in their magnitude.

The estimated coefficients of the control function variables $\hat{u}$ and $\hat{e}$ are both significant, and this implies that both $LCCPRESENCE$ and $TOTCOMP$ are endogenous and that we have corrected the estimates for this distortion.

The $FARE$ equation's estimates shown in Table 6 are related to a log-linear model. Thus, the effect of the presence of LCCs on airfares in Europe is given by $(e^{-0.11} - 1) \times 100$, that is about -11%. LCCs are still cheaper than FSCs in Europe after their market consolidation and hybridisation, and the FSCs long-run response to the LCCs entrance. From the magnitude of $TOTCOMP$ coefficient we get that an additional competitor in a city pair gives rise to a -11% reduction in airfares.

Coefficients for the control variables in $\boldsymbol{X_1}$, time and city pair dummies are also included in the model, but not reported due to space considerations. The *F*-statistic from the first-step estimates are reported at the bottom of the table and demonstrate that our instruments are both relevant.[14]

In columns (4)-(5) of Table 6 we have the estimated effects on fares of the relative importance of LCCs in the city pair, with a quadratics specification. The OLS estimates for both $LCCINTENSITY$ and $LCCINTENSITY\_SQ$ are both statistically significant. The first degree coefficient is negative and equal to -0.85, while the second degree one is positive and equal to $+0.49$. Hence, we have a U-shaped effect of the intensity of LCCs competition on airfares, as shown in Fig. 5.

The left panel displays the impact on $FARE$ of increasing values of $LCCINTENSITY$. Airfares in the European city pairs decrease as the LCCs market share increases up to a threshold equal to 86% market share. The right panel shows the average (across all city pairs) value of the marginal effect of LCCs market shares on airfares, which is equal to 0 at 86% LCCs market share, the minimum of the quadratic function in the left panel.

A second important goal of this contribution is the analysis of FSCs pricing behavior in presence of an increasing market share of LCCs in the city pair. The aim, through this empirical investigation, is to get some insights about FSCs strategies after the LCCs consolidation in European markets: do legacy carriers exploit the different quality of their services when they face the fierce LCCs price competition? Or do FSCs tend to match the LCCs price levels to avoid losing market shares? Is there a threshold of LCCs importance in the city pair that leads FSCs to stop exploiting their high quality service and simply matching the LCCs lower airfare? Our second econometric specification investigates these issues by considering a sub-sample of our data where only FSCs' airfares are taken into account. This implies that when we calculate the monthly average airfare in the city pair we only include the price levels charged by FSCs, Furthermore, only the city pairs where both FSCs and LCCs are operating are part of the analysis. Table 7 presents the econometric results.

As before, columns (2)-(3) report the estimated coefficients of the OLS and CFA regression models. When we do not correct for the possible endogeneity of $LCCINTENSITY$ and $TOTCOMP$, we get that the first degree estimated coefficient of $LCCINTENSITY$ is not statis-

[14] The rule of thumb for assessing the relevance of the instruments is that the first step *F*-statistic should be higher than 10 in order for the instruments not to be weak (Staiger and Stock, 1997). We have two endogenous variables and two instruments: hence overspecification of the econometric model is not possible.

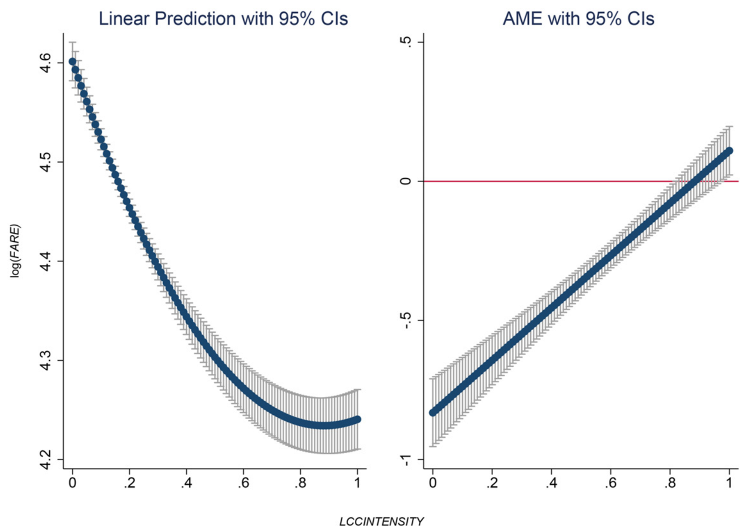

Fig. 5. Airfares in nonstop European city pairs as function of LCCs market share

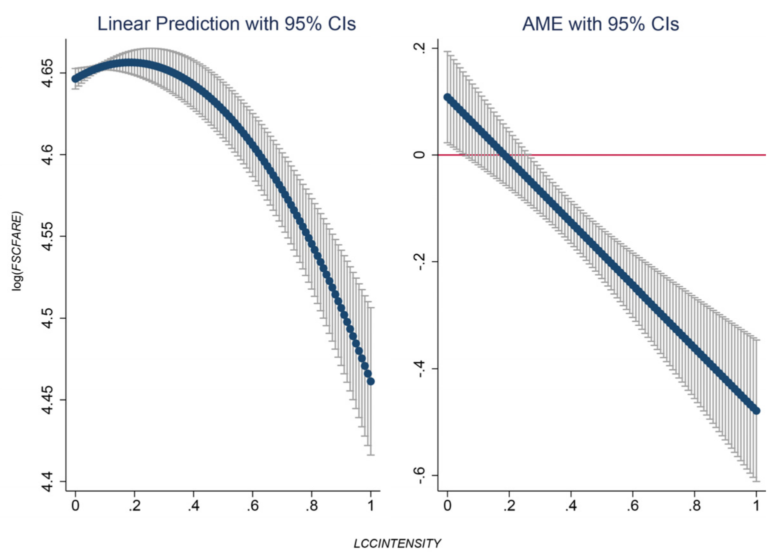

Fig. 6. FSCs airfares in nonstop European city pairs as function of LCCs market share

tically significant, while the statistical relevance is identified for the estimated coefficient of the second degree term, which is negative and equal to -0.25. The coefficient of $TOTCOMP$ is instead statistically significant and, as expected, negative, equal to -0.04. The CFA estimates in column (3) encompass both control function variables $\hat{\eta}$ and $\hat{\zeta}$, that correct for the possible endogeneity of $LCCINTENSITY$ ($\hat{\eta}$) and $TOTCOMP$ ($\hat{\zeta}$). The estimated coefficient of $\hat{\eta}$ is not statistically significant, and this implies that the correction for the endogeneity of $LCCINTENSITY$ is not necessary, while the inclusion of $\hat{\zeta}$ is relevant since it tackles the possible distortion in the estimated coefficients of $TOTCOMP$. Hence, column (4) provides the main empirical results regarding FSCs strategies in presence of different degrees of LCCs competition in the city pair.

The estimated coefficient of the first degree term of $LCCINTENSITY$ is now statistically significant and equal to $+0.10$, while the second degree term is again significant, negative and equal to -0.27. Hence, differently from the results obtained when we consider the full sample of data and the dependent variable is given by the average fare of both FSCs and LCCs, in this case the coefficient of $LCCINTENSITY$ is positive while the estimated coefficient of $LCCINTENSITY\_SQ$ is negative. This implies an inverse U-shaped relationship between the level of LCCs market share in the city pair and the price charge by FSCs, that is shown in Fig. 6.

The left panel of Fig. 6 displays the estimated prediction of FSCs price in response of an increasing LCCs market share in the city pair. In this case, the relationship is concave, and this implies that when the LCCs market share is small FSCs raise their airfares. In this market conditions an increase of the market price can be explained as an attempt to exploit the higher service quality offered by FSCs. The increasing airfare interval ends at the maximum of the concave function, that corresponds to a threshold of LCCs market share equal to about 19%. Beyond that point FSCs starts decreasing their prices, at an increassing rate in response to a constant additional importance of LCCs in the city pair. Hence, LCCs consolidation has generated a situation where, in European markets, as long as LCCs have a sufficiently high market share in the city pair, FSCs tend to match the lower price levels charged by low-fare airlines. The right panel of Fig. 6 presents the average marginal effect of LCCs market shares on FSCs airfares. It is positive before the threshold of about 19% LCCs market share, and then becomes negative.

The results of column (4) of Table 7 confirm that each additional competitor in the city pair reduces FSCs' airfares by about 8%. As before, the coefficients for the control variables in $\boldsymbol{X_1}$, and for the time and city pair dummies are also included in the model, but not reported due to space considerations.

Using the main econometric model shown in Eq. 1 and its empirical results reported in Table 6 it is possible to observe the effect on airfares in European non-stop routes of the possible entry of an LCC in a city pair. This effect is captured by the estimated coefficients of the dummy $LCCPRESENCE$, that takes value 1 if an LCC enters, and $TOTCOMP$, since a new competitor operates in the market. These coefficients, $\hat{\alpha}_1$ and $\hat{\alpha}_2$, are reported in column (3) of Table 6 and are, respectively, -0.11 and -0.12. Since we have a log-linear equation, the estimated percentage impact of the combined effect of $LCCPRESENCE$ and $TOTCOMP$ is equal to $(e^{\hat{\alpha}_1+\hat{\alpha}_2}-1)\cdot 100$, that corresponds to about -21%. The null hypothesis that $\hat{\alpha}_1+\hat{\alpha}_2=0$ can be rejected since the p-value is approximately 0, implying that the entry of a low-cost carrier on a city pair generates a robust and stronger decrease in airfares compared to the one that is observed in case of entrance of a FSC, which in this scenario is significantly lower, at 8%.

4.1. Robustness checks

A possible drawback of our empirical results is that in many city pairs LCCs do not compete with FSCs, but rather they are monopolists or compete only among themselves. Indeed, LCCs have still a tendency in Europe to operate secondary routes where they can capture the more price elastic consumers, and so the previous estimate of an -11% reduction in airfares due to the presence of LCCs may suffer of this bias, i.e., LCCs do not decrease the average level of airfares in a market but rather they operate in new markets charging lower fares to highly price elastic consumers.

To control for this problem we run a series of robustness checks where we include in the regressions an interaction term between $LCCPRESENCE$ and a dummy variable identifying monopolistic routes (i.e., where $TOTCOMP$ corresponds to one), denoted as $LCCMONOPOLY$. Table 8 reports the estimates for the $LCCPRESENCE$ and $LCCINTENSITY$ when the interaction term $LCCMONOPOLY$ is included.

Columns (3) and (5) display the CFA estimates and point out that the presence of LCCs in the European city pairs has still, even if we take into account that in some routes they are monopolists, a negative and statistically significant estimated coefficient, equal to -0.11, while $LCCINTENSITY$ has, as in the previous estimates shown in Table 6, a significant negative first-degree estimated coefficient and a significant positive second-degree coefficient. Interestingly, the estimated coefficient for the interaction variable $LCCMONOPOLY$ is not statistically significant, but it has a positive sign. There is a weak evidence that when LCCs are monopolists their fares are higher than those charged in markets where their market power is lower. However, after controlling for this possible effect, we can confirm that LCCs reduce airfares and that their market share has a U-shape relation with prices charged in direct European flights.

Table 8
Fare estimates from different specifications - explicitly controlling for the effect of LCC monopoly - full sample

	Dep. Variable *log(FARE)*			
	(2) OLS	(3) CFA	(4) OLS	(5) CFA
LCCPRESENCE	-0.171***	-0.114***		
	(-13.36)	(-8.01)		
LCCINTENSITY			-0.891***	-0.894***
			(-13.77)	(-12.75)
LCCINTENSITY_SQ			0.529***	0.500***
			(10.3)	(7.97)
$\hat{u}$		-0.322***		-0.479***
		(-9.73)		(-4.97)
LCCMONOPOLY	-0.058***	0.023	-0.013	-0.011
	(-3.42)	(1.22)	(-0.78)	(-0.59)
TOTCOMP	-0.045***	-0.138***	-0.050***	-0.137***
	(-8.91)	(-15.96)	(-10.21)	(-15.84)
$\hat{e}$		0.148***		0.147***
		(14.96)		(14.9)
F-statistic (*HUB*)		127.70		178.49
F-statistic (*AVGCOMP*)		619.71		648.00
Observations	189,073	189,073	189,073	189,073
Adjusted R-squared	0.70	0.71	0.70	0.71
Route and Time FEs	✓	✓	✓	✓

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

5. Conclusions

In this paper we investigate whether, after about three decades since liberalization of European skies, significant market consolidation by some LCCs (e.g., *Ryanair, easyJet*) and their acquisition of a high degree of market power, they are still offering flights at prices cheaper than those practiced by FSCs in European non-stop city pair routes.

Utilizing comprehensive data on marketed transactions in the period 2016-19 we provide some evidence on the effects of LCCs on fares and on the FSCs price behavior in response to increasing levels of market share of LCCs in a route. Our primary findings are as follows: first, fares are about 11% lower if at least one LCC is operating in the route in comparison to markets where only FSCs are present. Using as a reference the average fare for European non-stop flights observed in our data set, this equates to savings of about 11 US dollars. Second, we observe that fares decrease as LCCs presence in a market becomes more relevant, but only up to a LCCs market share threshold equal to 86%; after this level LCCs dominate the market and fares increase. This implies that LCCs exploit their market power when they are monopolist (or quasi-monopolist). Third, FSCs response to different levels of LCCs market share is non-linear: if the low-fare airlines' market share is lower than 19% legacy carriers increase their prices, and exploit the higher service quality offered, granting protection in case of delays, seats with more legroom, etc. However, beyond that market share threshold FSCs decrease their prices and try to match the LCCs lower airfares. Last, we show that the combined effect of (1) a new airline entering a route, and (2) this airline being a LCC, yields a 21% reduction in the route's airfare. To the best of our knowledge these insights are the first evidence of the general impacts of LCCs in Europe, taking into account real market transactions, all routes and airlines.

These results have some interesting policy implications. First, our empirical evidence implies that, after more than 25 years since the beginning of skies liberalization in Europe, LCCs are still a factor contributing to lower fares. Hence, policy makers have available some insights confirming that open skies have long-run price effects. The elimination of entry barriers generates a long-lasting competitive pressure on the airlines, granting the possibility to travel within Europe at reasonably low fares and choosing among multiple carriers. Second, since we show that FSCs tend to lower their prices only if the LCCs market share in a route is sufficiently high, policy makers will have to further increase the degree of openness of the skies, eliminating dominant positions as much as possible, i.e., granting to all airlines a level playing field in European routes. It may be necessary, for instance, to reduce the legacy carriers dominance in some European big airports, so that new airlines may also provide operations. Furthermore, the ongoing consolidation of European FSCs (informal negotiations are ongoing between *Air France-KLM* and *TAP*, while the European competition authority is evaluating the proposed merger between *Lufthansa* and *Ita Airways*) may be authorized by the European competition authority only if some slots in important airports are made available to new entrants. This is an opportunity requested by many LCCs for some time, and it is important that it is at least partially implemented in the event of conditionally authorized mergers, bearing in mind that where LCCs have robust market shares they are able to generate lower prices on routes connected to the freed slots. Last, the evidence we provide regarding the LCCs charging higher prices when their market share is close to monopoly implies that policy makers have also to carefully monitor some LCCs market power in the different routes, especially when their market share becomes very high.

Although the findings from this paper offer new and updated insights to help shape the European airline markets, the COVID-19 pandemic might have changed the competitive scenario. For this reason, future research should evaluate the post pandemic situation. Additionally, this paper exclusively focuses on non-stop flights only, while the expansion of the analysis to connecting flights might reveal different results. These extensions are left for future research.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Andrea Gualini: Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft. **Gianmaria Martini:** Conceptualization, Data curation, Methodology, Writing – original draft. **Flavio Porta:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing.

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