On-line International Price Discrimination with and without Arbitrage conditions

Enrico Bachis

Nottingham University Business School

lizeb@gwmail.nottingham.ac.uk

Claudio A. Piga*

Economics Department, Loughborough University

c.a.g.piga@lboro.ac.uk

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Abstract

We present evidence of a form of on-line price discrimination where airlines charge, at the same time and for the same flight, fares expressed in different currencies that violate the law of One Price. Unexpectedly for an on-line market, we find that price discrimination may be accompanied by arbitrage opportunities and that both tend to persist for long periods before a flight's departure. Discrimination seems to be driven by competitive pressure, although some airlines practice it in routes where they have a monopoly position. Finally, discrimination is more likely within two weeks prior to departure, suggesting it is used to manage stochastic demand.

JEL classification: L11, L13, L93

Keywords: Law of One Price; sample selection; on-line pricing; dispersion; airlines, exchange rate.

*Contact Author. Address for correspondence: Economics Department, Loughborough University, Leicestershire, UK, LE11 3TU, Tel: +44 (0) 1509 222701; Fax: (+44)-(0) 1509 223910. Piga gratefully acknowledges receipt of the British Academy Larger Research Grant LRG-35378.

Recent empirical research on electronic commerce has consistently found evidence of price dispersion across on-line retailers, but has not reported any case where the same e-company engages in price discrimination on-line – see Glenn Ellison and Sara F. Ellison (2005) for a survey. The price transparency of the Internet, due its low search costs, is implicitly assumed not to be conducive to effective price discrimination (henceforth, PD) because the shoppers of a company setting a low and a high price for the same product (e.g., in two different parts of its website) would very quickly learn to buy only at the low price. To overcome this difficulty and extract surplus from their customers, on-line retailers may engage in obfuscation strategies by proposing add-ons to the product originally sought (Glenn Ellison and Sara F. Ellison, 2004). This is not the case in this paper, where we present evidence of different prices being posted by the same e-seller on the same website at the same time for exactly the same product.

Our data are taken from the websites of six European Low Cost Airlines (hereafter, LCCs) and pertain to both UK domestic flights and flights connecting the UK with the main continental European countries. A simple example illustrates the nature of the PD tactic employed by the LCCs in our sample. Consider a flight from London to Madrid. Normally, this corresponds to the first leg of a round trip by a British traveller, and to the return leg of a Spanish traveller who has just visited the UK. The location of the first leg determines the currency used by the LCCs to show the final fares, so the Spanish traveller will be offered a fare in Euro while the British one in Sterling. If the booking occurs at the same time, and in the absence of PD, the ratio of the two fares should be very close to the prevailing exchange rate and the Law of One Price should hold (Pinelopi K. Goldberg and Michael Knetter, 1997). However, about 23% of the almost two million observations in our dataset report a difference between the two fares of at least 7 British Sterling or more. Thus, our LCCs engage in PD in their own website, without resorting to any of the obfuscation strategies aimed at confusing the customer. What enables them to do so is simply that the two prices do not appear simultaneously on the same screenshot, and on-line customers have to be able to actively engage themselves in a search for better fares, the feasibility of which they might not be aware of. In addition to presenting a new way to conduct PD on-line, we show therefore that search costs play an important role even in the on-line market for air tickets in Europe.[1]

The above type of PD is innovative with respect to the traditional modes of discrimination associated with airlines, which often apply such ticket restrictions as Saturday night stay-over requirements, advance-purchase discounts or surcharges for one-way tickets

[1] Search engines, e.g. www.traveljungle.co.uk or www.skyscanner.net, are present but they are not capable of detecting the type of PD strategy we consider.

(Joanna Stavins, 2001; Stephanie Giaume and Sarah Guillou, 2004). Indeed, a feature of European LCCs is to have eliminated completely such restrictions: e.g., departing on a Monday and returning on a Thursday is likely to cost less than returning on a Sunday. In any case, each leg is priced independently and the same price would be shown on-line for the Monday flight if one tried to book a one-way ticket. Moreover, all LCCs offer "no-frills" flights with no class distinction for seats, thus excluding any form of discrimination based on quality (Michael Mussa and Sherwin Rosen, 1978). Finally, price variations due to the inclusion of connecting flights are ruled out by the fact that LCCs issue only "point to point" tickets (Eric Clemons *et al*., 2002).

We discuss how on-line PD may or may not be associated with arbitrage opportunities. When it is not, the airlines manage to segment the markets perfectly. However, for some of the airlines, about 8% of the observations offer the chance to save at least 14 Sterling via on-line arbitrage. This is surprising because, firstly, arbitrage is assumed to prevent discrimination (Jean Tirole, 1988). Secondly, one would hardly expect profitable arbitrage opportunities to be posted systematically on-line. More strikingly, we find strong empirical evidence of persistence over time being a characteristic of discriminatory cases and of arbitrage opportunities, which may remain posted for two or more weeks.

Marcus Asplund and Richard Friberg (2001) document how the exploitation of arbitrage opportunities, arising in cases of deviations from the Law of One Price, likely led to a change in the way prices were listed in Scandinavian Duty-Free shops. This does not seem to have happened for at least some of our LCCs. We complement our data set covering the period June 2002 - June 2004 with screen shots, retrieved as late as April 2006, showing examples of PD cases. We infer that at least one large low-cost carrier has been actively pursuing on-line PD strategies for many years even if they entailed offering arbitrage opportunities. We cannot however ascertain whether LCCs offer discriminatory prices and possible arbitrage opportunities because these are hardly found out or because the airlines are not worried if arbitrage is exercised.[2] In support to the last hypothesis the econometric analysis reports that the probability to observe a case with arbitrage conditions reduces as a route becomes more concentrated, thus suggesting that discounts via arbitrage may be a strategic weapon more likely used in competitive routes.

Dispersion in airline prices may arise from variations in costs of serving different passengers or from discriminatory pricing (Severin Borenstein and Nancy L. Rose, 1994). An important aspect in our study is that the research design limits the relevance of the former

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[2] It is possible that the airlines may tolerate arbitrage only to a certain extent, and programme their sites accordingly.

source of dispersion, as the two prices in different currencies were retrieved on-line within one hour from each other and are for a seat on the same flight (identified by a code). Thus, the dispersion in our data is, at each point in time, the result of PD only. Depending on the sample composition, the econometric analysis reveals that most LCCs post discriminatory fares in less concentrated routes, thus confirming the findings in Borenstein and Rose (1994) of dispersion increasing with competition. But for one airline, which is renowned for choosing smaller and secondary destination airports, the opposite result holds, thus suggesting the presence of monopoly-type forms of PD. When controlling for market (i.e., city-pairs) characteristics, we find size and the presence of charter competition to be positively associated with dispersion, a further indication of PD being driven by competitive pressure.

Some motivating examples, their related theoretical framework and the data collection strategy are defined in the next Section, while Section II draws a parallel between the deviations from the Law of One Price in Asplund and Friberg (2001) and those in our dataset. Section III identifies different types of discriminatory cases by distinguishing whether they present arbitrage opportunities. Such distinctions are further investigated in the econometric analysis of Section IV, and followed by the concluding remarks of Section V.

1. Looking for Price Discrimination on-line.

A. Motivating examples.

Examples from a LCCs's web site, exhibiting the type of on-line PD on which we focus, are shown in Figures 1 to 4. These are made up of two parts: the top one shows the fares in British Sterling (hereafter, GBP) for each leg of a flight departing from the UK and arriving in another European destination; the bottom part reports the fares (in the currency of the country from which the flight originates) for the inverted trip, where the outgoing flight is scheduled on the same day of the return flight in the top part. The same flight appearing in both parts is framed in an oval for ease of comparison.

Various features of the queries' results need to be specified. First, the queries reported in the two parts of Figures 1-4 were made only a few minutes after the other, therefore ruling out any bias arising from changes in prices due to changes in capacity availability.[3] Second, it is important to stress that the European LCCs we surveyed set prices for each leg independently and that these fares do not change when a customer books a round-trip or a one-way ticket. E.g., in Figure 1 the price of 119.99 GBP for the Ancona (AOI) - London Stansted flight on July 17th 2005 would have appeared identically even if the query had not been for a return flight. Third,

[3] See the Windows bar at the bottom of each part.

the programme issuing the queries yields fares expressed in the currency of the country where the first flight originates. Finally, to make their sites look familiar by appearing in the visitor's language the airlines' web sites automatically detect the nation in which the visitor is located. However, we believe that doing so does not affect the level of fares displayed. Indeed, we tried to access the sites using different languages, but the same fares were returned. Moreover, the hypothesis that each airline extracts the fares from the same dataset (or algorithm) is reinforced by the fact that for most airlines the query results are displayed on the same web page, regardless of the language used.[4]

Figure 1 reports the "normal" case where the ratio of the fare in Sterling (119.99 GBP) and in Euro (169.99 EUR) for the flight coded "FR 125" from Ancona to Stansted on July 17th 2005 is very close to the exchange rate on the date of the query, made on July 9th 2005. No attempt at price discriminating is highlighted in this example and possible differences between the fares are likely to be induced by the differences in the exchange rates used by us and by the airline.

Figure 2 captures the nature of the PD's strategy. It clearly shows how the price in GBP for the flight coded "FR2359" is higher than that in Euro. Consider a British traveller wishing to fly from Stansted to Dinard on Aug 25th 2005 and return on Sept 1st. In theory this person, instead of booking a round-trip ticket and pay 69.99 GBP for the first leg plus 9.99 GBP for the second, could buy two one-way tickets and pay only 0.45 EUR for the return. However, the benefit of such a form of arbitrage (about 9.5 GBP in this particular case) has to be weighed against the extra costs it would generate. Indeed, booking two separate tickets entails having: 1) to pay an extra credit card commission of about 4.5 GBP; 2) to print an extra ticket; 3) to fill in an extra on-line booking form; 4) to incur search costs to verify the presence of arbitrage possibilities; 5) to find out the exchange rate used by the credit card provider. The presence of these costs creates a "band of inaction" within which it is not worth pursuing arbitrage conditions (Asplund and Friberg, 2001). This notwithstanding, Figure 2, and the following examples, highlights an important difference with previous literature emphasizing how an airline's dominance of at least one endpoint of a route leads to market power (Severin Borenstein, 1989 and 1991). Indeed, the European LCCs in our sample do not practice any of the marketing strategies indicated as the source of airport dominance (i.e., Frequent Flyer Programme, Travel Agents' Commissions Override programme etc). Furthermore, the above-

[4] At the time of this draft (June 2006), Ryan Air and EasyJet allow the language to be selected by the visitor. Ryan Air and Bmibaby display the results in the same page regardless of the language selected - http://www.bookryanair.com/skylights/cgi-bin/skylights.cgi and http://www.bmibaby.com/bmibaby/skylights/cgi-bin/skylights.cgi respectively - while Easyjet's fares are shown on a URL that is language-sensitive.

mentioned invariance of fares when booking a round-trip or two one-way tickets implicitly impedes the possibility to take advantage of airport dominance.[5]

Figure 3 illustrates a case of PD, which is not associated with the possibility to engage in arbitrage. Note how the price in GBP for the flight coded "FR 195" from Bologna Forli to Stansted is about 33 GBP cheaper than the fare quoted in Euro.[6] However, no arbitrage conditions arise in this case because a British traveller would prefer to buy a return ticket and not two separate ones. A side effect of this is that Italian travellers are adversely discriminated as they are offered a higher fare for the same type of ticket.

The discussion on the examples in Figure 2 and 3 highlights how arbitrage may occur only: 1) if its benefits outweigh the sum of actual and psychological costs engendering the band of inaction; and 2) for the return leg of a two-way trip. A case satisfying both conditions is reported in Figure 4 for the flight coded "FR 373" from Biarritz to Stansted, where the difference between the two fares is about 19 GBP, a value above the threshold limit of 14 GBP that in the remainder of the paper we consider as the upper bound of the "band of inaction".

Although we find ample evidence of similar cases in our fares dataset, it is noteworthy how the possibility of arbitrage does not necessarily translate into its actual implementation. For instance, in this case as a British traveller should have issued two queries, one for each single leg. While this would take only little extra time to perform, most individuals would naturally issue a normal query for a return ticket and it is unlikely that even a very expert web-surfer could contemplate the possibility to control for arbitrage opportunities. Psychological inertia may thus be one reason why LCCs engage in PD even when arbitrage opportunities are present. This issue is further investigated below.

B. Data Collection

Since the start of this research project in May 2002, fares were collected using an "electronic spider", which connected directly to the websites of only the main LCCs (i.e., Ryanair, Buzz, Easyjet, GoFly) operating in Great Britain at the time.

The dataset includes daily flights information from June 2002 up to, and including, June 2004, for a total of 25 months. Over such a period, a number of important events took place, which are reflected in the dataset. First, a series of takeovers occurred: Easyjet acquired GoFly

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[5] Assume that airline 1 dominates airport A, and airline 2 airport B. Both airlines operate a service on the route. In the traditional case where airlines impose a penalty for one-way tickets, airline 1 could charge more for round-trip tickets originating in A, and airline 2 would do the same for round-trips originating in B. Absent the penalty and all else equal, arbitrage would significantly erode the airlines' market power.

[6] Interestingly, the fare in Euro for the other flight (coded FR 199) available on the same route and day is slightly cheaper, although it falls well within the band of inaction.

(December 2002) and Ryan Air took over Buzz (March 2003) – see Enrico Bachis and Claudio Piga (2006) for a further discussion. Second, new LCCs began their operations: the "spider" was upgraded to retrieve fares from the Bmibaby and MyTravelLite sites.

In order to account for the variety of fares offered by airlines at different times prior to departure, every day we instructed the spider to collect the fares for departures due, respectively, 1, 4, 7, 10, 14, 21, 28, 35, 42, 49, 56, 63 and 70 days from the date of the query. Henceforth, these will be referred to as "booking days". So, for instance, if we consider London Stansted-Rome Ciampino as the route of interest, and assume the query for the flights operated by a given airline was carried out on April 1st 2003, the spider would retrieve the prices for both the London Stansted-Rome Ciampino and the Rome Ciampino-London Stansted routes for departures on 2/4/2003, 5/4/2003, 8/4/2003, 11/4/2003 and so on (see Appendix A). The return flight for both types of directional journey was scheduled one week after the departure. For those routes where an airline operates more than one flight per day, all fares for every flight were collected. Thus, for every daily flight we managed to obtain up to 13 prices that differ by the time interval from the day of departure. The main reason to do so was to satisfy the need to identify the evolution of fares - from more than two months prior to departure to the day before departure – which has been noted to be very variable for the case of LCCs (Eric Pels and Piet Rietveld, 2004; Stephanie Giaume and Sarah Guillou, 2004).[7]

The collection of the airfares has been carried out everyday at the same time: in addition to airfares we collected the name of the company, the time and date of the query, the departure date, the scheduled departure and arrival time, the origin and destination airports and the flight identification code. In addition to UK domestic routes, flights to destinations in continental European countries were considered (see Table 3).

To complement the price data with market structure characteristics, secondary data on the traffic for all the routes and all the airlines flying to the countries indicated above was obtained from the UK Civil Aviation Authority (henceforth, CAA).[8] For each combination of company, route and departure period (i.e., month/year), the CAA provided the number of monthly seats, the number of monthly passengers and the monthly load factors.

Table 1 illustrates how the data retrieved from the Internet represent an accurate sample of the activity of each of the LCCs in the markets we consider. It compares the number of routes for which we have price data with the actual total number of routes by each airline. The latter figure is taken from the CAA dataset, which also provides the number of routes where our

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[7] While the spider could have retrieved any number of prices, in practice the need to reduce both the number of queries made to an airline server and the time of programme execution to a manageable level, led to the design above.

[8] See www.caa.co.uk

LCCs face competition by either a major FSC or another LCC. To test the spider's functionality, initially we limited the number of surveyed routes. Indeed, in August 2002 the percentage of routes with prices was 63% (37 over 59) of the total number operated by Ryan Air, 50% for Easyjet, 64% for Buzz and 46% for GoFly. However, thanks to the speed of the programme, within a few months such percentages could be increased significantly for all the airlines, to cover 80% or more of the total routes they operated. Considering that the spider took all the prices for all the daily flights, the price dataset provides an exhaustive illustration of the on-line pricing activity of each airline.

Table 1 also shows that the airlines differ in the amount of competition they face. For instance, in about 25% of EasyJet's routes at least another competitor (FSC or LCC) is also present. At the other extreme, Ryan Air (and Buzz to a lesser extent) faced competition in a very limited subset of routes. The other airlines lie somewhere in between, with competitive routes accounting for about 33% of the total. Such differences may be driven by the choice of the arrival destinations. Ryan Air and Buzz chose almost exclusively secondary airports that may be many miles away from the city of arrival, while the other airlines also fly to major airports where FSC also land.

C. Identifying Price discrimination on-line

The data collection above was carried out separately (but simultaneously) for the routes originating in UK and for those originating outside the UK.[9] The first procedure created a dataset with fares denominated in GBP, the second one with fares expressed in the currency of the originating country. These two datasets were then matched using a code combining the values of airline, departure airport, arrival airport, flight code, day of departure and booking day. Such a matching strategy enables the comparison of the on-line fares for the same flight available on the same booking day to two travellers, one trying to book the first leg of the trip, the other booking the second leg. Appendix A provides more insights into the matching procedure.

It was impossible to guarantee that the two fares were collected at exactly the same time. Thus, new ticket purchases occurring between the collections of the two fares may be responsible for the fares' difference. This potential problem was tackled in two ways. The "spider" was run overnight, thereby minimising the possibility of intervening purchases.

[9] For the UK domestic routes, in the second case we simply inverted the direction of the trip.

Further, the "spider" saved the exact time in which each fare was retrieved: the sample analysed in this study includes only pairs of fares collected within a one-hour interval.[10]

2. Deviations from the Law of One Price.

The above examples configure a situation very similar to the one described by Marcus Asplund and Richard Friberg (2001), where customers of Scandinavian duty-free stores could pay the same item choosing a catalogue nominal price expressed either in Swedish kronor (SEK) or in Finnish markka (FIM). Significant deviations from the Law of One Price (LOP) arose because nominal prices were fixed until a new catalogue was printed, while the exchange rate between SEK and FIM was free to fluctuate. Deviations were thus mostly due to the presence of high fixed "menu costs" which led the companies to issue a new catalogue only when arbitrage conditions had become particularly conspicuous and costly.

Figures 2 to 4 show cases of deviations from the LOP despite menu costs being negligible in electronic commerce, which begs the question of *whether* the airlines systematically engage in PD. We try to answer this by detecting the presence of deviations from the LOP, which, given our data collection strategy, can only be caused by PD.

Let f_{irtcb} be a flight offered by LCCs *i*, on route *r*, with departure scheduled on date *t*, code flight *c* and whose fares are posted *b* days before *t*. Route *r* is defined as an airport pair. The airlines post two prices, which can be expressed in the same currency for domestic flights, or in two different currencies depending on the country where the flight originates. The following analysis holds for both domestic and international flights. Let P_{irtcb}^{EU} identify the price for flight f_{irtcb} when offered in a continental European currency *EU*, and $\Phi = P_{irtcb}^{EU} / P_{irtcb}^{UK}$ its relative price in currencies *EU* and *UK* (i.e., GBP). Moreover, let $e_{EU/UK}^{b}$ be the nominal exchange rate, the currency *EU* price of currency *UK*, available on the date *(t-b)*. If LOP holds for flight f_{irtcb}, then:

$$\Phi = P_{irtcb}^{EU} / P_{irtcb}^{EU} = e_{EU/UK}^{b} \tag{1}$$

or

$$\Delta = \left[\left(P_{irtcb}^{EU} / e_{EU/UK}^{b}\right) - P_{irtcb}^{UK}\right] = 0\,, \tag{2}$$

[10] As Ellison and Ellison (2005) discuss, inertia in Internet prices is often observed, suggesting that companies do not continually monitor the market situation and reoptimize. Moreover, we casually noted that after buying tickets on-line from the LCCs in our study, fares remained unchanged despite the obvious reduction in the seat availability.

with Δ expressed in GBP. The LOP fails to hold if $\Phi / e^{b}_{EU/UK} \neq 1$ or $|\Delta| > 0$. For the latter case, Table 2 reports the percentile distribution of the absolute value of Δ by airline and type of flights. Even noting that small values of $|\Delta|$ may be induced by differences between the exchange rates used by us and by the airlines, more that half of the 1918424 observations for international airfares report a |Δ|>2, while the LOP holds unconditionally (i.e., |Δ|=0) for at least the 99% of the observed domestic fares, with the minor exception of fares posted by Ryan Air. Such a finding suggests two considerations. One, presumably the airlines try to avoid the bad publicity of being found out practicing price discrimination strategies, which can be more easily noted when the fares are in the same currency. Two, the comparability of two fares in different currencies entails the gathering of detailed information on $e^{b}_{EU/UK}$, which is a costly activity that not everyone is ready to undertake. Thus in international flights the airlines are more protected by the risk of negative publicity and have therefore more leeway in engaging in PD as a yield management strategy aimed at maximizing load factors. Finally, Table 2 shows that all the airlines, except EasyJet, have at least 5% of their fares with a |Δ|>*14*, which is the upper bound we chose to define the "band of inaction".

Table 3 presents values of $\Phi = P^{EU}_{irtcb} / P^{UK}_{irtcb}$ and $e^{b}_{EU/UK}$ broken down by airline and country. It confirms that the LOP holds for UK domestic flights, while it generally does not for international flights, with the exception of those operated by EasyJet, for which the two statistics are very similar across countries. For Buzz and GoFly, deviations from the LOP are limited to specific countries, Switzerland and France, respectively. BmiBaby and MyTravel systematically violate the LOP as, in all the countries they serve, their fares expressed in the continental European currency are, on average, higher than the one expressed in GBP. On the other hand, Ryan Air, which Tables 2 and 3 reveal to be the airline which is more heavily reliant on international PD, tends to post a higher fare in GBP for flights to and from Ireland, Holland and Austria, with the opposite holding for all the other countries, except Sweden.

To further highlight the deviations from LOP in our dataset, Figure 5 shows, for each airline, the kernel density for $\Phi = P^{EU}_{irtcb} / P^{UK}_{irtcb}$ and $e^{b}_{EU/UK}$ for flights to countries adopting the European common currency, the Euro. The overlapping of the two distribution is indicative of adherence to the LOP: this only seems to be the case of EasyJet, while for all the other LCCs the two distributions are either disjoint (BmiBaby and MyTravelLite) or the distribution of Φ presents thicker and longer tails (Ryan Air, Buzz and GoFly). As Φ appears to be more disperse than the distribution of the exchange rate between the Euro and the GBP, Figure 5, as well as the other evidence in this section, provides supports to the notion that most LCCs have pursued PD strategies that have led to significant deviations from the LOP. Table 2 has also highlighted how fares differences for the same type of ticket may exceed the band of inaction, below which we deem it not worthy to engage in arbitrage.

However, it is still possible that the deviations from the LOP in our datasets are mostly due to situations equivalent to those described by Figures 2 and 3, in which arbitrage opportunities are either not profitable or not present. That is, if the Internet has created a "frictionless market" where arbitrage opportunities are instantly wiped away by costless search and negligible menu costs, we should expect very few cases of PD of the type represented in Figure 4. If, however, search costs were heightened by psychological inertia on the customer's behalf, then arbitrage opportunities would be offered because it would be highly unlikely that travellers would be aware of their presence.

III. Price Discrimination and Arbitrage

In this section we build on the discussion of the motivating examples from Figures 1 to 4 and investigate the extent to which LCCs allow the possibility of arbitrage opportunities to arise. To this purpose, we constructed the discrete variable "Discrimination Type", taking four values, each representing one of the four different situations depicted in Figures 1 to 4. More precisely, a value of "zero" is assigned to non-discriminatory observations, that is, those with $|\Delta|\leq 7$ (see also Figure 1). Although arbitrary, the value of 7 was chosen because 1) it is the middle point of the "band of inaction"; 2) there may be significant differences between the exchange rates we used and those used by the airlines. A value of "1" is for discriminatory observations that fall within the band of inaction, i.e., those with $7\leq|\Delta|<14$ (see Figure 2).[11] Discriminatory observations with no arbitrage conditions (as in Figure 3) are given the value "2", while those with arbitrage opportunities (as in Figure 4) are assigned the value "3".[12] It is noteworthy how for values "1" to "3" of "Discrimination Type", George Stigler's (1987) definition of price discrimination holds, as the marginal cost for a seat booked at the same time for the same flight has to be the same regardless of whether the booking takes place in UK or in continental Europe.

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[11] The only monetary factor contributing to the creation of the band of inaction is the payment of an extra credit card commission of about 4.5 GBP. Thus, travellers with a low opportunity cost of time, which is necessary to do the search and fill in the booking form, might be interested in taking advantage of these opportunities. This is why a value of 1 for "Discrimination Type" is for cases deemed as discriminatory. However, it does not distinguish between the situations highlighted in Figures 3 and 4. While in theory such a distinction would be feasible, we chose not to implement it given the low value associated with the arbitrage.

[12] Formally, and recalling that discrimination is possible only on the second leg of a round-trip, a value "2" is assigned when the flight departs from the UK and $\Delta\leq-14$ or when the flight departs from continental Europe and $\Delta\geq 14$. Similarly, a value "3" is given to observations departing from the UK and $\Delta\geq 14$ or when the flight departs from continental Europe and $\Delta\leq-14$.

In Table 4, the frequencies for the values of "Discrimination Type" are broken down by airline and departure location for the sample of international flights.[13] Overall, about 3.8% of the observations are associated with profitable opportunities of arbitrage, while 19% exhibit characteristics of PD without arbitrage. However, airlines show a different tendency in pursuing PD strategies on-line. The Total rows show how Ryan Air and GoFly are the companies reporting the lowest percentage of non-discriminatory fares (60.6% and 68.3%, respectively), and by far the highest percentage of cases with "Discrimination Type" equal or greater than 2, 14.8% and 15.9% respectively. Conversely, these are very rare for EasyJet, which reports 93% of non-discriminatory fares. For the other LCCs, discriminatory fares account for up to 25.6% of cases.

Recall from Table 3 how BmiBaby and MyTravelLite systematically recorded values of $P_{irtcb}^{EU} / P_{irtcb}^{UK}$ above the relevant exchange rate. Furthermore, recall that arbitrage opportunities arise only for the second leg, that is, the return flight. Table 4 shows that for BmiBaby, we retrieved 4070 cases of profitable arbitrage opportunities for flights departing from the UK, while only 162 were from continental Europe. That is, BmiBaby offers arbitrage opportunities almost exclusively to travellers residing in a continental European country. However, they are also almost exclusively the victims of PD (i.e., when "Discrimination Type" is equal to 2). Indeed, in 4979 cases departing from continental Europe, BmiBaby offered a fare $P_{irtcb}^{EU} / e_{EU/UK}^{b}$ for a first leg flight, which is at least 14 GBP higher than that offered to British travellers returning to their country. A similar analysis holds also for MyTravelLite, thus helping to shed further lights on the figures reported in Table 3.

Other similarities between Ryan Air and GoFly are shown in Table 4. For both airlines we retrieved a larger proportion of arbitrage opportunities for flights departing from continental Europe (thus possibly benefiting British travellers). These account for 9.5% and 10.1% of Ryan Air and GoFly cases, respectively. At the same time, for the same airlines a larger share of cases with "Discrimination Type" equal to 2 (respectively, 9.7% and 9.9%) is found to depart from the UK, thus adversely discriminating British travellers relative to their continental European counterparts returning from a visit to UK. However, we also found a significant amount of cases where non-UK resident travellers are either offered arbitrage opportunities (5.3% for Ryan Air and 6.2% for GoFly) or are the victims of PD (5.2% and 5.7%, respectively). While the distribution of cases with "Discrimination Type" equal or greater than 2 largely varies across

[13] From now on, only international flights are considered, given that domestic flights are generally not used for PD purposes.

airlines and departure location, for smaller values of "Discrimination Type" we observe a more even distribution.

The analysis of Table 4 has clearly highlighted how most LCCs have made extensive use of on-line PD strategies, even when these entail profitable arbitrage conditions. As in Asplund and Friberg (2001) we do not have information regarding whether the customers have taken advantage of the opportunities offered. However, the indirect evidence from their case and ours can provide interesting insights. Asplund and Friberg (2001) argue that the practice of dual price setting was abandoned because the high volatility of the exchange rate between SEK and FIM offered large arbitrage opportunities to consumers. In our case, the data covers the period June 2002-June 2004. However, the evidence we retrieved and report in Figures 1 to 4 was collected much later, in 2005 and in April 2006. This suggests that amongst the airlines that our evidence reveals to be heavily committed to PD strategies (namely, Ryan Air and GoFly), the one still active (i.e., Ryan Air) has carried on practicing the various forms of PD we have introduced in this paper. This is consistent with two distinct, but not exclusive explanations.

First, the enduring and systematic practice of PD hints that LCCs' customers have remained largely unaware of the presence of arbitrage opportunities, despite LCCs sell their tickets almost exclusively on-line. This is further evidence that the Internet is providing firms with new and imaginative price setting schemes. But unlike the firms selling computer RAM described by Glenn Ellison and Sarah F. Ellison (2004), LCCs do not need to implement "search obfuscation" techniques. Indeed, different prices for the same flight may be available on the same web site at the same time.[14] However, they can be found out only if the on-line customers run two queries, instead of one. The hurdle to overcome is thus not technical, or related to significant differences in the opportunity cost of time to run an extra query, which would only take a few more seconds. It is mainly associated with the natural propensity of the great majority of travellers to search for information on a round-trip ticket (which is the default option in the on-line query form). That is, we argue that there exists a psychological inertia reducing the likelihood of searching what the price of two single tickets could be. This is consistent with the presence of high, not low, search costs, broadly defined. The acid test is provided by Table 4: indeed, assume that half of the observations with "Discrimination Type" equal to 1 satisfy the condition of departing from the right airport and thus present opportunities

[14] Some airlines, however, have recently begun to engage in obfuscation practices similar to the ones described in Ellison and Ellison (2004). For instance, travel insurance is now automatically included in the order, and the customers have to unclick to avoid being charged for it. Moreover, uncertainty about the final price arises also because the charge for landing fees and airport taxes is not specified together with the fares.

for net savings via arbitrage. Then, about 20% of cases from Ryan Air present arbitrage conditions. This is quite a high proportion, hinting that these opportunities are seldom taken.

Second, arbitrage chances may be intentionally "up for grabs". That is, LCCs post them specifically for the purpose of being exercised or are not too worried if some savvy Internet-surfer recognizes them. This leads to the natural question of *why* LCCs engage in PD. In the next section we adopt an econometric approach to shed some light on the characteristics associated with the different values of the variable "Discrimination Type".

IV. Empirical model

We begin investigating what drives the different values of "Discrimination Type" by looking at Table 5, where each cell reports the percentage number of observations by seasons (identified by the Summer – April to October - and Winter – November to March - timetables), booking day, classes of fares for P_{irtcb}^{UK} expressed in GBP and classes of fares for P_{irtcb}^{EU} converted in GBP. Within each of these categories, significant differences can be observed. Discriminatory cases are more likely during the Summer season. Non-discriminatory observations increase with the booking day, while generally arbitrage opportunities are more likely for late booking fares, those available from 14 up to 7 days prior to departure. Both findings reflect the fact that summer and late booking fares are generally higher and thus provide more scope for large differences between P_{irtcb}^{UK} and P_{irtcb}^{EU}. Indeed, when $P_{irtcb}^{UK} \geq 70$, more than 45% of the observations are discriminatory in nature, with almost 8% offering profitable arbitrage opportunities. Similar but slightly smaller figures are observed when $P_{irtcb}^{EU} / e_{EU/UK}^{b} \geq 70$. Relatedly, note how the incidence of values "2" and "3" for "Discrimination Type" increases monotonically with the category of P_{irtcb}^{UK} prices.

A. Econometric methodology and dependent variables

In the econometric investigation, we are interested in studying the different characteristics between non-discriminatory and discriminatory cases, and, for the sub-sample of discriminatory cases, the distinguishing traits of the groups of cases with and without arbitrage opportunities. To model these two discrete variables and take account of the sample selection problem arising because arbitrage can only occur within discriminatory cases, we employ a bivariate probit model with censoring setting (William Greene, 1998 and 2003, pp.713-714; Piga and Vivarelli, 2004). Formally the model can be represented as follows:

$$y^1_{irtcb} = \beta_1' X^1 + \varepsilon^1,\ y^1_{irtcb} = 1\ if\ \ y^{1*}_{irtcb} > 0,\ 0\ otherwise$$
$$y^2_{irtcb} = \beta_2' X^2 + \varepsilon^2,\ y^2_{irtcb} = 1\ if\ \ y^{2*}_{irtcb} > 0,\ 0\ otherwise \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$
$$(\varepsilon^1, \varepsilon^2) \sim BVN(0,0,1,1,\rho)$$
$$(y^1_{irtcb}, X^1)\ observed\ only\ if\ \ y^2_{irtcb} = 1.$$

The discrete variable y^2, which will be denoted as "Discriminatory", assumes the value of zero when "Discrimination Type" is also zero; "Discriminatory" is equal to 1 for values of "Discrimination Type" greater or equal to 1. The other discrete variable y^1, which we denote as "Arbitrage", is zero when "Discrimination Type" is equal to 1 or 2, and takes the value 1 when "Discrimination Type" is equal to 3. No value is attributed to "Arbitrage" when "Discrimination Type" is zero, as arbitrage conditions should be studied only within the sub-sample of cases where "Discriminatory" is equal to 1. Failing to take this sample selection into account by applying a standard bivariate probit model where "Arbitrage" is estimated on the full sample would result in biased estimates. That is, in a standard bivariate probit approach the factors affecting the probability to observe a non-discriminatory case would not be separated from factors influencing the likelihood of posting a discriminatory fare that is not associated with arbitrage opportunities.[15] Furthermore, estimating two independent equations could lead to wrong inference if their residuals were correlated. Finally, to account for the fact that for each daily flight we have repeated observations, the estimated standard errors are robust to heteroschedasticity and serial correlation within each (*irt)* cluster.

B – The regressors

One way to test if the airlines specifically choose particular flights to practice PD is to check if discriminatory observations persist over time. Recall how for each *irtc* group, where *i* identifies the airline, *r* the route, *t* the date of departure and *c* the flight code number, we have up to 11 observations of fares' pairs collected from 70 until 7 days prior to departure. We create the dummy "Persistence" equal to 1 if at least four observations for the same flights have $|\Delta| \geq 14$.[16] A strictly positive value for "Persistence" indicates that the fares posted for a specific flight departing on date *t* exhibit characteristics of PD for a period of at least 14 days (i.e., booking period of 21, 14, 10 and 7) or more. A positive coefficient for "Persistence" would

[15] Greene (1998) uses this model to distinguish the factors affecting the probability of default in credit card loans from the determinants of the antecedent decision to obtain a credit card. Similarly, Piga and Vivarelli (2004) argue that the sample of firms engaged in collaborative R&D activity is not randomly selected, but depends on the firms' decision to conduct R&D.

[16] This implies that at least four observations in a *irtc* group have a value of "Discrimination Type" equal to 2 or 3. This is the reason why we do not include "Persistence" in the equation for "Arbitrage, although its impact can still be evaluated via the marginal effects.

suggest that only certain flights are specifically chosen to implement PD strategies of the kind we have introduced in this article. This would be indicative, for instance, of deviations from the LOP being more likely for flights where the airlines expect to have a low load factor. A positive coefficient would not, however, allow to distinguish if, on the one hand, airlines engage in PD because they feel protected from arbitrage opportunities (up to the point that they leave them posted for long periods of time) or, on the other, if they intentionally maintain them on-line for so long just because they want Internet savvy travellers to find those opportunities out.

Table 6 shows some descriptive statistics for “Persistence”, of the variable used to generate it (“N of PD cases per flight”) and of the other regressors, broken down by the values of the dependent variables. The way “Persistence” and “N of PD cases per flight” were constructed is reflected in Table 6, where persistence over time seems to be a characteristic of the discriminatory cases. Note, however, how “Persistence” equal to 1 is assigned also to those non-discriminatory observations that belong to a group where we observe at least four discriminatory observations. Thus, up to seven observations in a group may have “Persistence” equal to 1 but “Discriminatory” equal to zero. Therefore, the econometric procedure may still reveal no differential impact of “Persistence”.

We use the monthly number of flights by an airline in a route to obtain the Herfindahl Index in a route (henceforth, “HHI route”).[17] Following Borenstein and Rose (1994), if discrimination is of a “monopoly-type”, then the coefficient in the “Discriminatory” equation should be positive. If however, discrimination increases as the route becomes more competitive, then we can infer that the airlines use it as a strategic weapon to enhance their market shares. By the same token, arbitrage opportunities should be more likely in more competitive markets. Table 6 does not reveal any significant difference, although it indicates the airlines in our sample operate in highly concentrated routes.

The monthly share of all flights in a route over the total flights operated in a city-pair (hereafter, “Shr Flights in route”) captures the extent to which a route has substitutes within a market.[18] A smaller share would imply a higher degree of substitutability for the travellers, lower market power for the airlines and hence less scope to engage in PD.

Large markets have been dominated for long by established carriers, possibly former national `flag-carriers', which may remain protected by such barriers to entry as the "grandfather" rights which post-liberalisation allocated slots in the main European, most congested airports to airlines on the basis of previous use. “Market Size”, obtained as the share

[17] To calculate market shares, flights are preferable to number of passengers as flights are decided in the previous season and are therefore less influenced by pricing considerations.

[18] The terms city-pair (which includes all the airports in a city pair) and market are used interchangeably.

of total flights in a city-pair over the total flights in a nation's sub-area,[19] is likely to affect positively the likelihood to post discriminatory fares, but to influence negatively an airline's propensity to offer arbitrage opportunities, e.g., because too many customers may be available to find them.

The presence of competition from charter operators may boost the need to engage in PD and to offer arbitrage opportunities. We expect the monthly share of charter passengers over the total number of passengers in a city-pair ("Shr charter pass.") to be positively correlated with discriminatory conditions and arbitrage opportunities.

If an airline is offering a service to a given destination from many UK departure airports, then the need to realise a sufficiently high load factor in every route is likely to provide a strong incentive to implement PD strategies, although its impact on the decision to offer arbitrage opportunities is less clear-cut.

Although for each observation collected *b* days prior to departure price dispersion is caused by price discrimination, stochastic peak-load pricing may still be responsible for dispersion over time. Indeed, the airlines may want to adjust their price as demand is revealed over time to reflect the shadow cost of capacity. We can control for stochastic peak-load pricing by including a set of dummy variables for each booking day (Borenstein and Rose, 1994). These are discussed in Table 5. Few days before departure the airlines can more precisely gauge if the flight will be full. Both decisions to engage in PD and to offer a discount via arbitrage may be therefore motivated by a high probability of a low load-factor. Thus, we expect them to be positively associated with the dummies identifying the fares posted only a few days before departure. The previous discussion has also highlighted company specificities, which are captured by a set of airlines' dummies.

Apart from "Persistence", Table 6 shows no significant difference between the statistics of each regressor across the values of the dependent variables. This may be the consequence of the regressors' monthly frequency, while the dependent variables refer to daily flights. Thus, in the econometric analysis, we also include dummy variables for the destination nations and the days of the week the flight departs although, to save on space, these are not reported in Table 7. Full sets of estimates are available on request.

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[19] The UK, as well as the largest destination countries, Italy, France, Germany and Spain, were divided in three sub-areas: North, Centre and South. This variable is calculated as the share of total flights in a city-pair (say, London to Rome) over the total flights to the Centre of Italy (the sub-area where Rome is located). For smaller countries, the denominator is given by taking the whole country.

C. Results

To estimate equation (3), only the sample of flights to and from continental Europe was used, i.e. UK domestic flights were not considered given their strict adherence to the LOP. Model 1 includes all the airlines; Model 2 excludes EasyJet because of its limited involvement in pursuing PD strategies; Model 3 considers Ryan Air exclusively. For each model, the marginal effects of the regressors on Pr(Arbitrage=1|Discriminatory=1) are shown. The discussion will hinge around the coefficients in Model 3, which are qualitatively similar to those in Model 2, and on their difference with those in Model 1.

Persistence over time characterizes discriminatory cases: the extremely high z-statistics indicates that a large proportion of observations for the same flight, collected at different times prior to departure, are discriminatory in nature. Notably, a change of "Persistence" from zero to one leads to a 26% increase in the probability to observe an arbitrage opportunity in the sub-sample of discriminatory cases.

Quite interestingly, the coefficient for "HHI route" varies across models. It is negative in the full sample, hinting that price dispersion is more likely in less concentrated routes, insignificant in the second model, and positive in the third. It would seem, therefore, that Ryan Air practices a "monopoly-type" form of discrimination, while EasyJet uses it to compete against other airlines in the same route. Such a result may be due to the heterogeneity characterising the features of routes operated by each airline. Indeed, Ryan Air tends to choose secondary, regional airport where no other airline flies. On the contrary, EasyJet (and GoFly before the takeover) operates from main airports and therefore faces tougher competition from full service and low-cost carriers alike (see Table 1). Arbitrage opportunities are less likely in concentrated routes as well as in larger markets, possibly a reflection of the dominant position enjoyed by the airline in the former case, and the presence of more potential arbitrageurs in the latter. However, the size and the presence of charter operators in a market seem to boost the incentives to pursue PD strategies. The latter findings suggest a positive association between the use of PD and competition in the market.

Similarly, the number of UK departures used by an airline to serve a destination increases a firm's need to use a wider range of pricing tactics, although a change in "N UK departures" from one to its mean value has a negligible impact on Pr(Arbitrage=1|Discriminatory=1). The marginal effect for "Shr charter pass." is on the contrary quite high (15%), and noticeable for "Shr Flights in route" (3%). The latter two variables are also positively correlated with the decision to post discriminatory fares. Although not in Model 1, the high demand in the Summer season probably explains why less discriminatory cases are posted during this period, and why this variable does not significantly affect the probability to observe arbitrage opportunities, although its coefficient is significant in the "Arbitrage" equation. Finally, all else equal, discriminatory cases and arbitrage opportunities seem to be more likely in the last 14 days before a flight departs, when the airlines have been able to gauge quite accurately the demand for a flight.

V. Conclusions

The low search costs of the Internet facilitate price comparisons on-line that may even lead to lower off-line prices (Jeffrey R. Brown and Austan Goolsbee, 2002). To protect themselves from Bertrand-type competition, e-retailers may either try to build brand allegiance or engage in obfuscation strategies (Eric Brynjolfsson and Michael D. Smith., 2000; Ellison and Ellison, 2004 and 2005). Given the high price transparency of the Internet, it would therefore seem unlikely to observe the same company offering two different prices for the same product on-line. The thrust of this paper is to show, through a particular data collection design, how some important European Low Cost Carriers systematically post fares on-line that violate the Law of One Price (Fred S. McChesney *et al.* , 2004). Our analysis still supports the notion of low search costs on-line. Indeed we find airlines do not practice PD for U.K. domestic flights, because their fares, being expressed in the same currency, can be more easily compared. As discrimination is applied only to international flights, we argue that other forms of search costs remain important, even if the transaction takes place on-line: an obvious example is learning about the current exchange rate that credit card companies will apply. However, the strongest factor facilitating PD is probably related to the inability of an on-line customer to control for the presence of arbitrage opportunities, which are often observed in our dataset. Assuming that all these difficulties are overcome, we also argue that airlines may actually benefit from having customers acting as arbitrageurs, as discrimination may help increase a flight's load-factor. Indeed, the evidence indicates discriminatory cases are more likely within the two weeks prior to a flights' departure, when the airlines have better information about demand realization. When associated with the offering of discounts via arbitrage, the form of on-line price discrimination we present is therefore likely to be welfare-enhancing, as it does not penalize the airlines and allows consumption by customers that otherwise would not have purchased the ticket.

We use a bivariate model with sample selection to study the factors affecting the decisions to both post discriminatory fares and offer arbitrage opportunities. We generally find that their likelihood increases with the degree of competition in the route or in the market, thereby suggesting the airlines use PD as a competitive weapon. A striking result is that over a period of 70 days discriminatory cases for a flight are often observed four times or more at regular time intervals. Even more strikingly for an on-line market, arbitrage opportunities tend to persist over time and remain posted for 14 days or more. This is in shark contrast with the conventional wisdom of arbitrage being incompatible with discriminatory pricing, especially in markets with low search or transportation costs. On the whole, the evidence seems to suggest how airlines do not seem particularly worried by the price transparency of the Internet, but, rather, use it to maximize their yield in a route.

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Figure 1: The “standard” case with no price discrimination.

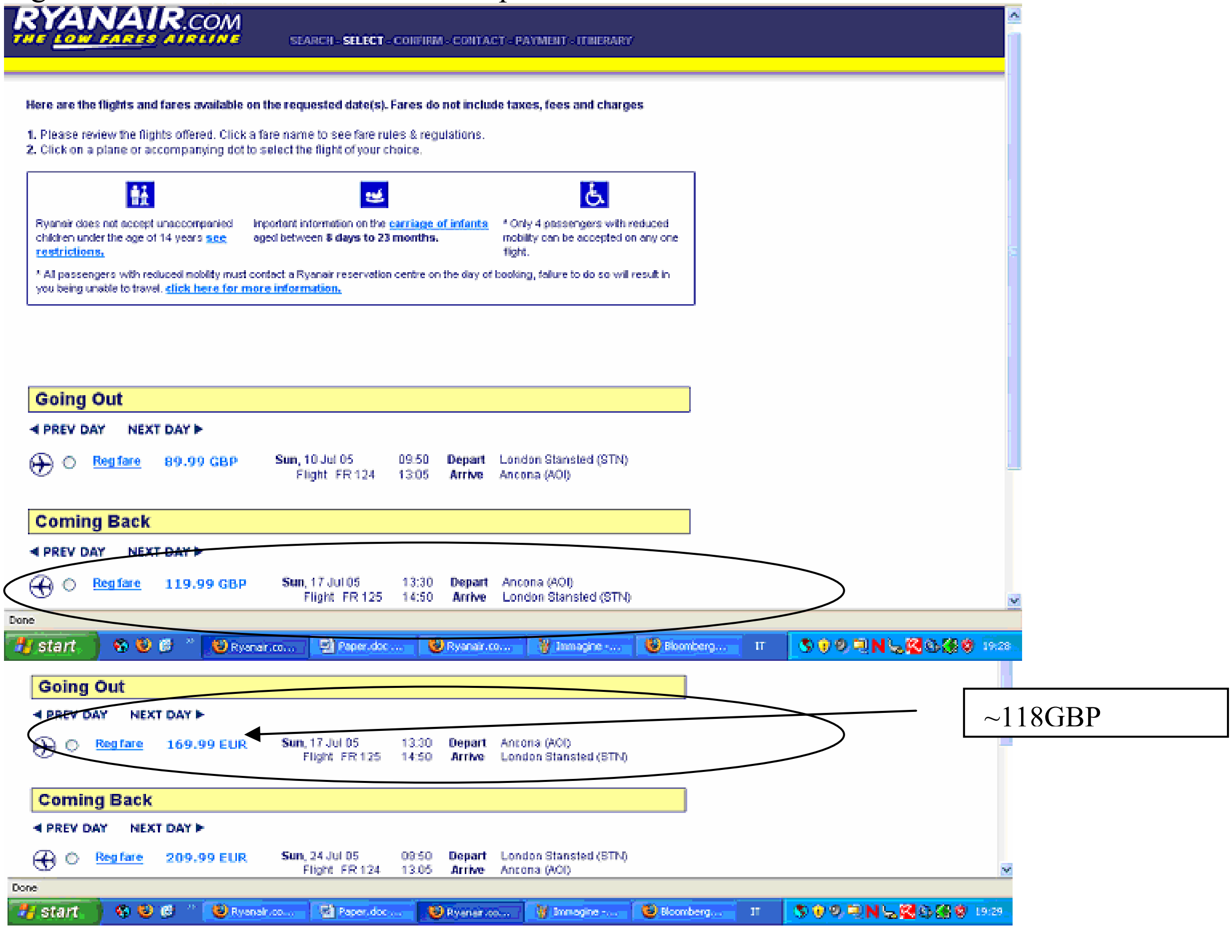

Figure 2: An example of price discrimination with low value of arbitrage

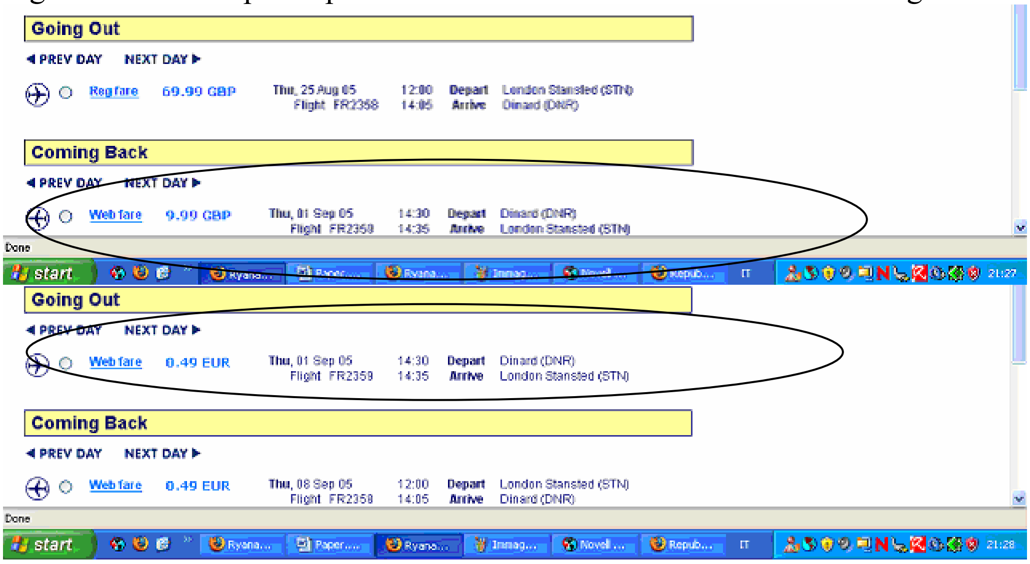

Figure 3: An example of price discrimination without the possibility of arbitrage.

Figure 4: An example of price discrimination with possibility of arbitrage.

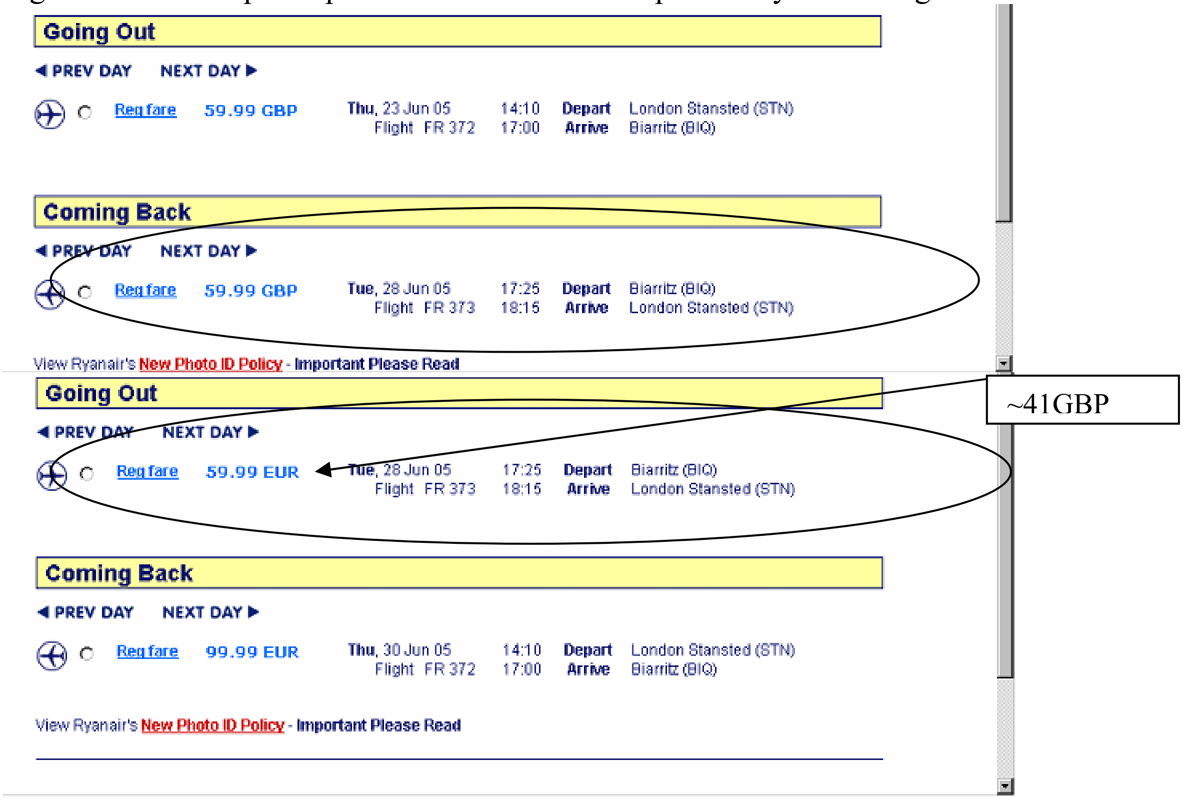

Figure 5 – Kernel Densities of $\Phi = P_{irtb}^{EU} \,/\, P_{irtb}^{UK}$ and $e_{EU/UK}^{b}$.

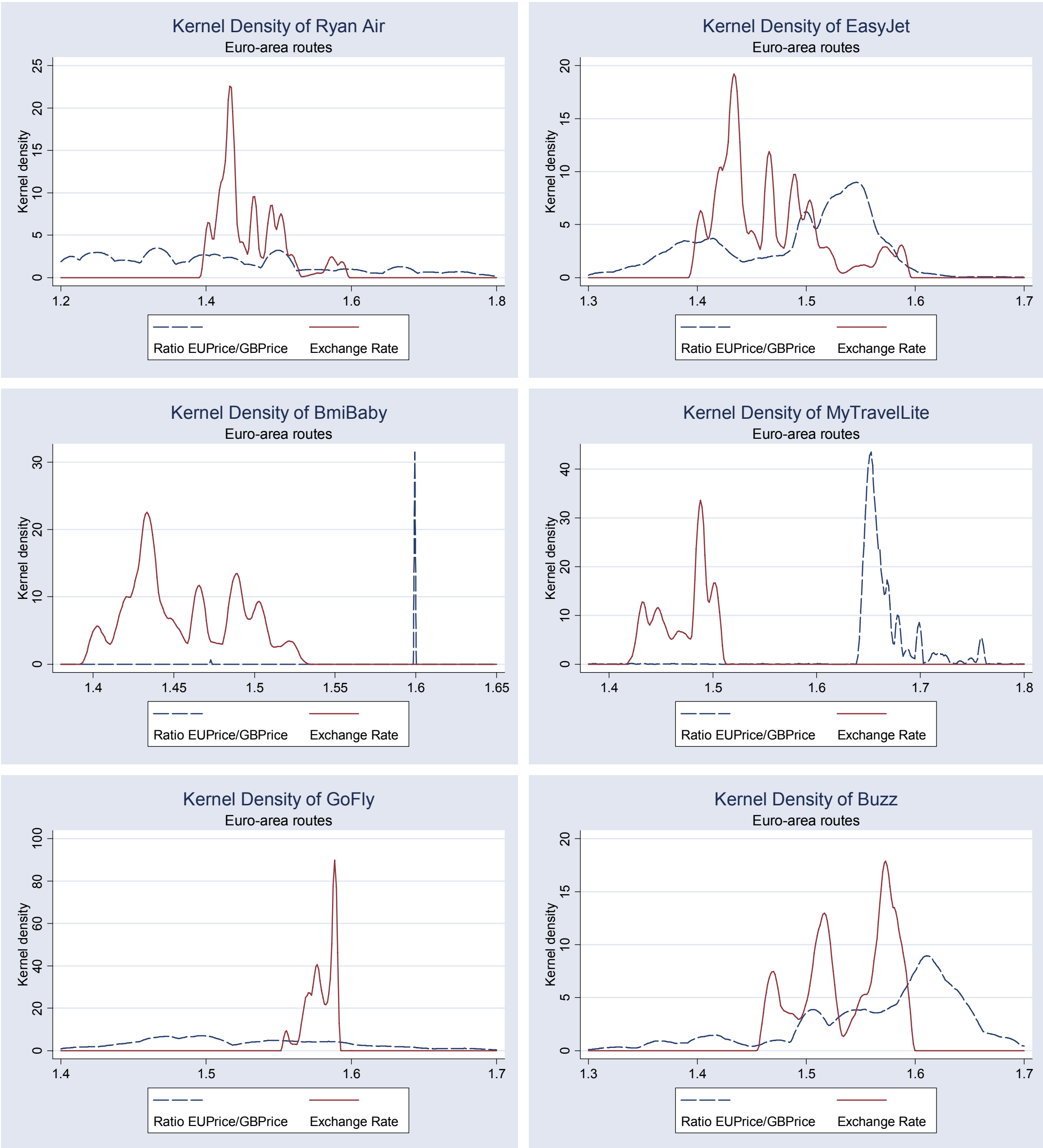

Table 1 – Number of routes by type of sample, airline and period.

	BMIBABY			RYAN AIR			EASYJET		
Year_ month	Routes Price Sample	Routes CAA Sample	Comp. Routes CAA Sample	Routes Price Sample	Routes CAA Sample	Comp. Routes CAA Sample	Routes Price Sample	Routes CAA Sample	Comp. Routes CAA Sample
02_07				34	59	7	19	38	9
02_08				37	59	8	19	38	9
02_09				37	59	7	28	40	9
02_10				37	59	7	28	41	10
02_11				37	60	8	29	41	9
02_12				37	60	8	61	79	20
03_01	26	35	10	49	61	9	61	80	20
03_02	26	35	11	50	64	7	63	82	21
03_03	30	37	12	50	64	7	66	84	22
03_04	26	37	9	56	65	7	66	88	19
03_05	31	40	10	69	88	6	67	89	19
03_06	32	43	10	69	88	6	67	89	20
03_07	33	45	11	69	88	6	67	89	21
03_08	34	45	11	83	89	8	88	92	24
03_09	35	44	11	83	89	6	88	92	23
03_10	35	48	13	84	92	8	89	96	26
03_11	37	42	12	87	93	8	88	95	23
03_12	38	47	15	87	94	8	88	98	25
04_01	33	49	15	42	98	8	46	98	25
04_02	36	47	14	84	94	8	88	98	25
04_03	38	43	13	84	94	8	89	101	25
04_04	34	48	17	87	99	10	89	107	27
04_05	34	50	16	81	94	9	89	110	27
04_06	34	55	18	84	96	9	88	114	29
	BUZZ			GOFLY			MYTRAVELLITE		
02_07	21	33	3	17	37	11			
02_08	21	33	5	17	37	11			
02_09	21	33	5	30	35	9			
02_10	21	32	5	30	39	11			
02_11	20	20	0	32	38	11			
02_12	22	22	0	32	38	11			
03_01	22	22	1						
03_02	22	21	0						
03_03	22	26	4						
03_12							13	14	5
04_01							13	14	5
04_02							13	13	5
04_03							13	11	4
04_04							13	11	4
04_05							10	9	3
04_06							9	9	3

Source: Price sample is retrieved from the airlines' web sites, Total routes and competitive routes are from the Civil Aviation Authority dataset.

Table 2: Descriptive statistics of $|\Delta| = \left|\left(P^{EU}_{irtcb} / e^{b}_{EU/UK}\right) - P^{UK}_{irtcb}\right|$ by company and destination.

	Company						
Statistic	Bmibaby	RyanAir	EasyJet	Buzz	GoFly	MyTravel	Total
			International Flights				
p1	0.60	0.06	0.05	0.03	0.05	0.50	0.06
p5	1.23	0.39	0.24	0.23	0.29	0.91	0.32
p10	1.67	0.88	0.46	0.45	0.62	1.37	0.63
p25	2.56	2.32	1.07	1.03	1.91	2.53	1.50
p50	4.25	5.32	2.35	2.05	3.62	4.20	3.41
p75	7.15	9.93	4.15	3.45	9.56	6.32	6.53
p90	10.67	17.20	5.92	8.17	16.95	10.13	12.13
p95	14.58	23.51	8.53	14.01	23.23	14.35	17.50
p99	22.79	36.81	17.58	29.50	42.21	32.96	34.08
mean	5.56	7.68	3.17	3.65	7.05	5.53	5.38
min	0.00	0.00	0.00	0.00	0.00	0.01	0.00
max	79.99	79.84	79.97	79.91	79.98	79.36	79.99
sd	4.85	8.08	3.81	5.62	8.65	5.94	6.53
N	168750	803782	849313	42333	30957	23289	1918424
			Domestic Flights				
p1	0	0	0	-	0	0	0.00
p5	0	0	0	-	0	0	0.00
p10	0	0	0	-	0	0	0.00
p25	0	0	0	-	0	0	0.00
p50	0	0	0	-	0	0	0.00
p75	0	0	0	-	0	0	0.00
p90	0	0	0	-	0	0	0.00
p95	0	2.52	0	-	0	0	0.00
p99	0	10	5.00	-	10	0	5.00
mean	0.05	0.40	0.12	-	0.26	0.00	0.18
min	0	0	0	-	0	0	0.00
max	55.50	63.00	75.00	-	39.15	3.99	75.00
sd	0.88	2.05	1.39	-	2.20	0.13	1.54
N	54601	71408	137083	-	7534	1772	272398
Total N	223351	875190	986396	42333	38491	25061	2190822

Source: the airlines' web sites.

Table 3 – Ratio of prices in different currencies and exchange rates, by company and country.

	countries		Bmi baby	Ryan Air	Easy Jet	Buzz	Go Fly	My Travel	Total	N
No Euro-Zone	UK	$e^{b}_{EU/UK}$	1.00	1.00	1.00	-	1.00	1.00	1.00	272398
		$P^{EU}_{irtcb} / P^{UK}_{irtcb}$	1.00	1.01	1.00	-	1.00	1.00	1.01	
	Switzerland	$e^{b}_{EU/UK}$	2.22	-	2.23	2.22	-	-	2.23	108534
		$P^{EU}_{irtcb} / P^{UK}_{irtcb}$	2.49	-	2.26	3.29	-	-	2.26	
	Sweden	$e^{b}_{EU/UK}$	-	13.45	-	-	-	-	13.45	57275
		$P^{EU}_{irtcb} / P^{UK}_{irtcb}$	-	13.41	-	-	-	-	13.41	
	Norway	$e^{b}_{EU/UK}$	-	11.80	-	-	-	-	11.80	19849
		$P^{EU}_{irtcb} / P^{UK}_{irtcb}$	-	16.99	-	-	-	-	16.99	
	Czech Rep.	$e^{b}_{EU/UK}$	48.24	-	48.42	-	-	-	48.37	10933
		$P^{EU}_{irtcb} / P^{UK}_{irtcb}$	56.69	-	44.88	-	-	-	48.12	
Eurozone	Italy	$e^{b}_{EU/UK}$	1.44	1.46	1.46	-	1.58	-	1.46	266918
		$P^{EU}_{irtcb} / P^{UK}_{irtcb}$	1.61	1.75	1.48	-	1.64	-	1.68	
	France	$e^{b}_{EU/UK}$	1.46	1.46	1.47	1.54	1.58	-	1.47	287646
		$P^{EU}_{irtcb} / P^{UK}_{irtcb}$	1.61	1.57	1.46	1.61	1.73	-	1.53	
	Spain	$e^{b}_{EU/UK}$	1.45	1.46	1.46	1.54	1.58	1.47	1.47	501131
		$P^{EU}_{irtcb} / P^{UK}_{irtcb}$	1.61	1.47	1.50	1.68	1.60	1.67	1.52	
	Holland	$e^{b}_{EU/UK}$	1.46	1.45	1.47	1.52	-	-	1.47	151541
		$P^{EU}_{irtcb} / P^{UK}_{irtcb}$	1.60	1.25	1.46	1.65	-	-	1.46	
	Germany	$e^{b}_{EU/UK}$	1.45	1.46	1.45	1.54	1.58	-	1.47	109645
		$P^{EU}_{irtcb} / P^{UK}_{irtcb}$	1.60	1.50	1.46	1.57	1.53	-	1.51	
	Belgium	$e^{b}_{EU/UK}$	1.45	1.47	-	-	-	-	1.46	25006
		$P^{EU}_{irtcb} / P^{UK}_{irtcb}$	1.61	1.41	-	-	-	-	1.46	
	Greece	$e^{b}_{EU/UK}$	-	-	1.47	-	-	-	1.47	18941
		$P^{EU}_{irtcb} / P^{UK}_{irtcb}$	-	-	1.51	-	-	-	1.51	
	Ireland	$e^{b}_{EU/UK}$	1.46	1.46	-	-	-	1.47	1.46	300059
		$P^{EU}_{irtcb} / P^{UK}_{irtcb}$	1.61	1.17	-	-	-	1.74	1.22	
	Portugal	$e^{b}_{EU/UK}$	1.48	-	1.46	.	1.58	1.47	1.47	35268
		$P^{EU}_{irtcb} / P^{UK}_{irtcb}$	1.60	-	1.49	.	1.57	1.67	1.51	
	Austria	$e^{b}_{EU/UK}$	1.50	1.47	-	-	-	-	1.47	25678
		$P^{EU}_{irtcb} / P^{UK}_{irtcb}$	1.60	1.32	-	-	-	-	1.33	

Source: Datastream for the exchange rates, price data from the airlines' web sites.

Table 4 – Type of discrimination by company and departure location.

		Variable "Discrimination Type" – Frequency (row %)				
	Departure From	0 Non Discri-minatory	1 Discrimin. – within band	2 Discrimin. - no arbitr.	3 Discrimin. - w/ arbitr.	Total
Bmi Baby	Cont.Europe	61609 (73.2)	17370 (20.6)	4979 (5.9)	162 (0.2)	84120
	UK	64024 (75.7)	16476 (19.5)	60 (0.1)	4070 (4.8)	84630
	Total	125633 (74.4)	33846 (20.1)	5039 (3.0)	4232 (2.5)	168750
Ryan Air	Cont.Europe	244160 (60.8)	98523 (24.5)	20806 (5.2)	38268 (9.5)	401757
	UK	243175 (60.5)	98832 (24.6)	38911 (9.7)	21107 (5.3)	402025
	Total	487335 (60.6)	197355 (24.6)	59717 (7.4)	59375 (7.4)	803782
Easy Jet	Cont.Europe	382425 (91.2)	28556 (6.8)	5569 (1.3)	2559 (0.6)	419109
	UK	407750 (94.8)	17236 (4.0)	2197 (0.5)	3021 (0.7)	430204
	Total	790175 (93.0)	45792 (5.4)	7766 (0.9)	5580 (0.7)	849313
Buzz	Cont.Europe	18513 (88.2)	1492 (7.1)	612 (2.9)	367 (1.7)	20984
	UK	19097 (89.5)	1106 (5.2)	581 (2.7)	565 (2.6)	21349
	Total	37610 (88.8)	2598 (6.1)	1193 (2.8)	932 (2.2)	42333
Go Fly	Cont.Europe	10517 (68.5)	2419 (15.7)	876 (5.7)	1551(10.1)	15363
	UK	10615 (68.1)	2466 (15.8)	1548 (9.9)	965 (6.2)	15594
	Total	21132 (68.3)	4885 (15.8)	2424 (7.8)	2516 (8.1)	30957
MTL	Cont.Europe	8636 (79.2)	1694 (15.5)	461 (4.2)	116 (1.1)	10907
	UK	9858 (79.6)	1864 (15.1)	95 (0.8)	565 (4.6)	12382
	Total	18494 (79.4)	3558 (15.3)	556 (2.4)	681 (2.9)	23289
	N	1480379	288034	76695	73316	1918424
	%N	77.17%	15.01%	4.00%	3.82%	100.00%

Source: airlines' web sites.

Table 5

			Variable "Discrimination Type" – Row %			
Type		N	0 Non Discri-minatory	1 Discrimin. – within band	2 Discrimin. - no arbitr.	3 Discrimin. - w/ arbitr.
	Summer	1419069	75.65%	15.84%	4.36%	4.16%
	Winter	499355	81.48%	12.68%	2.98%	2.86%
Booking Days	7	173358	73.27%	16.88%	5.15%	4.71%
	10	206143	74.10%	15.56%	5.27%	5.07%
	14	229889	75.00%	15.63%	4.71%	4.66%
	21	165725	77.97%	14.56%	3.99%	3.48%
	28	165957	76.58%	15.78%	3.96%	3.68%
	35	160698	77.49%	15.35%	3.78%	3.38%
	42	161806	78.08%	14.89%	3.48%	3.54%
	49	154176	78.93%	14.52%	3.27%	3.28%
	56	154252	79.24%	14.13%	3.23%	3.39%
	63	196572	79.50%	14.04%	3.26%	3.19%
	70	149848	80.63%	13.28%	3.17%	2.92%
Class P^{UK}	0-9.99	204601	89.19%	7.79%	1.53%	1.49%
	10-19.99	328400	83.97%	12.51%	1.84%	1.68%
	20-39.99	562978	75.84%	17.28%	3.41%	3.47%
	40-69.99	540862	81.57%	9.81%	4.43%	4.20%
	>=70	281583	54.71%	28.65%	8.66%	7.98%
Class $P^{EU}/e_{EU/UK}$	0-9.99	201857	83.92%	10.26%	3.14%	2.67%
	10-19.99	321818	82.28%	13.77%	1.98%	1.96%
	20-39.99	569651	77.79%	16.33%	2.99%	2.90%
	40-69.99	495194	83.16%	8.36%	4.17%	4.31%
	>=70	329904	57.97%	26.85%	7.98%	7.20%

Source: airlines' web sites.

Table 6 – Mean and Standard Deviation of main regressors.

	Discriminatory			Arbitrage		
	=0	=1	Total	=0	=1	Total
Persistence	0.01 (0.1)	0.20 (0.4)	0.05 (0.23)	0.15 (0.36)	0.46 (0.5)	0.20 (0.4)
N of PD cases per flight	0.19 (0.7)	1.87 (2.44)	0.57 (1.49)	1.45 (2.17)	3.93 (2.64)	1.87 (2.44)
HHI route	0.89 (0.2)	0.90 (0.2)	0.90 (0.2)	0.90 (0.2)	0.90 (0.18)	0.90 (0.2)
Shr Flights in route	0.78 (0.3)	0.81 (0.26)	0.79 (0.3)	0.81 (0.26)	0.85 (0.25)	0.81 (0.26)
Market Size	0.22 (0.2)	0.22 (0.2)	0.22 (0.2)	0.21 (0.2)	0.23 (0.2)	0.22 (0.2)
Shr charter pass.	0.11 (0.2)	0.11 (0.2)	0.11 (0.2)	0.12 (0.2)	0.09 (0.2)	0.11 (0.2)
N UK departures	4.74 (4.2)	4.99 (5.7)	4.80 (4.6)	5.17 (5.7)	4.11 (5.35)	4.99 (5.7)
N	1480379	438045	1918424	364729	73316	438045

Source: Civil Aviation Authority; “Persistence” and “N. of PD cases per flight” were calculated using the price data from the airlines’ web sites. Note: SD in parentheses.

Table 7 – Estimates from the Bivariate Probit model with Sample Selection. Marginal Effects calculated as Pr(Arbitrage=1|Discriminatory=1)

	Model 1 – Full Sample			Model 2 – without EasyJet			Model 3 – Only Ryan Air		
	Discrimi-natory.	Arbitrage	Marginal Effects	Discrimi-natory	Arbitrage	Marginal Effects	Discrimi-natory.	Arbitrage	Marginal Effects
Persistence	1.48 (129.9)		0.30 (56.5)	1.47 (125.8)		0.27 (63.5)	1.42 (116.7)		0.26 (58.1)
HHI route	-0.11 (5.65)	-0.05 (2.13)	-0.03 (6.06)	0.02 (0.61)	-0.13 (4.80)	-0.03 (5.16)	0.11 (3.00)	-0.24 (7.03)	-0.05 (5.95)
Shr Flights in route	0.03 (2.07)	0.07 (4.35)	0.02 (6.35)	0.21 (11.7)	-0.02 (1.18)	0.03 (7.34)	0.33 (16.2)	-0.09 (5.1)	0.03 (6.06)
Market Size	0.42 (18.7)	-0.33 (13.7)	-0.02 (3.36)	0.42 (15.3)	-0.35 (13.1)	-0.03 (4.23)	0.46 (14.7)	-0.38 (13.0)	-0.03 (4.51)
Shr charter pass.	1.05 (49.5)	-0.67 (24.5)	0.00 (0.31)	1.25 (37.5)	-0.41 (12.7)	0.10 (13.4)	0.91 (14.1)	-0.04 (0.92)	0.15 (13.2)
N UK departures	0.01 (9.76)	-0.02 (11.1)	0.00 (6.33)	0.02 (11.5)	-0.02 (11.4)	0.00 (5.53)	0.01 (5.88)	-0.02 (9.02)	0.00 (6.30)
Season	0.07 (9.12)	-0.06 (6.47)	0.00 (1.76)	0.01 (0.88)	-0.01 (0.95)	0.00 (0.54)	-0.10 (9.24)	0.05 (4.78)	0.00 (0.00)
10 days	0.01 (2.22)	0.06 (7.66)	0.02 (8.56)	0.05 (7.37)	0.01 (1.60)	0.01 (5.32)	0.05 (7.09)	0.01 (1.45)	0.01 (5.21)
14 days	-0.03 (5.31)	0.04 (4.97)	0.01 (2.59)	-0.02 (2.24)	0.03 (3.63)	0.01 (2.59)	0.00 (0.35)	0.02 (2.32)	0.01 (2.72)
21 days	-0.18 (24.8)	-0.01 (0.52)	-0.03 (13.3)	-0.21 (24.5)	-0.02 (2.11)	-0.04 (17.6)	-0.20 (19.3)	-0.03 (2.67)	-0.04 (15.3)
28 days	-0.12 (15.9)	-0.02 (2.32)	-0.02 (10.6)	-0.25 (26.7)	0.03 (2.99)	-0.03 (12.2)	-0.22 (20.6)	0.03 (2.42)	-0.03 (9.56)
35 days	-0.16 (20.5)	-0.04 (3.56)	-0.03 (15.3)	-0.28 (29.4)	-0.01 (0.86)	-0.05 (19.9)	-0.26 (22.9)	-0.02 (1.35)	-0.05 (16.6)
42 days	-0.19 (24.1)	0.02 (1.40)	-0.03 (11.1)	-0.29 (29.0)	0.05 (4.26)	-0.03 (12.6)	-0.25 (21.7)	0.05 (3.59)	-0.03 (9.21)
49 days	-0.23 (27.2)	0.01 (0.48)	-0.03 (14.3)	-0.31 (30.3)	0.00 (0.15)	-0.05 (19.5)	-0.27 (22.7)	-0.01 (0.81)	-0.05 (15.5)
56 days	-0.25 (28.9)	0.03 (3.01)	-0.03 (12.1)	-0.30 (28.3)	0.05 (4.43)	-0.03 (12.2)	-0.25 (20.3)	0.05 (3.96)	-0.03 (7.98)
63 days	-0.22 (27.3)	0.00 (0.18)	-0.03 (15.6)	-0.24 (23.9)	0.00 (0.21)	-0.04 (15.2)	-0.22 (18.3)	0.00 (0.27)	-0.04 (11.6)
70 days	-0.31 (34.5)	0.02 (1.68)	-0.04 (16.9)	-0.33 (29.9)	0.04 (2.81)	-0.04 (15.3)	-0.28 (21.6)	0.04 (2.51)	-0.04 (10.5)
Ryan Air	0.50 (41.0)	0.06 (3.63)	0.10 (26.1)	0.55 (41.5)	0.14 (7.56)	0.11 (40.9)			
EasyJet	-0.88 (67.2)	0.75 (42.9)	0.05 (12.9)						
Buzz	-0.34 (17.5)	0.66 (22.8)	0.15 (13.7)	-0.37 (17.9)	0.79 (26.3)	0.22 (16.8)			
GoFly	0.00 (0.24)	0.57 (23.4)	0.21 (21.6)	0.01 (0.26)	0.62 (24.7)	0.25 (23.7)			
MyTravelLite	-0.24 (10.3)	0.35 (10.1)	0.06 (5.55)	-0.18 (7.31)	0.34 (10.0)	0.08 (6.58)			
Wald Test Indep. equations (ρ=0)	χ^2=5262.75			χ^2=5251.9			χ^2=4083.11		
N	1918424	438045		1069111	378907		803782	316447	

Note: z-statistics in parentheses. Dummies for Nations and Day of the week included in all samples but not included to save space. Full set of estimates available on request.

Appendix

Table A1 illustrates two main features of the data collection strategy, that is, the matching of records and the control for the booking day. We begin with the latter. The first column identifies the date of the query for a round-trip journey: the second leg is normally due seven days after the first leg, with one exception on which we shall focus shortly. The second and the third column describe the dates of departure of each leg for trips originating in UK, when the date of departure is assumed to be respectively, 1, 4, 7, 10, 14, 21, 28, 35, 42, 49, 56, 63, 70 days from the date of the query (booking days are reported in brackets). The fourth and fifth column do the same for trips originating in Italy, as we chose the route London Stansted – Rome Ciampino for example. Note the exception of bookings made four days prior to the departure of the first leg, which are combined with a second leg due ten (not eleven) days from the time of the query.

As for the matching of records, consider the third row. It reports the dates of departure when the first leg is booked 7 days before. Now consider the first row. The second legs are booked exactly the same number of days as the first legs in the third row.

For convenience, we have used Greek capital letters to identify the match of the two fares available, for each booking day, for the Stansted-Ciampino flight, and Greek lowercase letters for the two fares available for the Ciampino-Stansted flight for each booking day. Note how the procedure makes it impossible to match fares for departures 1, 4, 17 and 77 days from the date of the query. Finally, it is worth clarifying how each row identifies a distinct query for each "directional" round-trip. Repeating the same procedure every day yields the possibility to collect up to eleven prices for each flight.

Table A1. Strategy for data collection.

date of booking	***Booking from UK***		***Booking from Italy***	
	First Leg Flight (£)	***Second Leg Flight (£)***	***First Leg Flight (€)***	***Second Leg Flight (€)***
	Stansted-Ciampino	*Ciampino-Stansted*	*Ciampino-Stansted*	*Stansted-Ciampino*
	date of departure (days from booking day)	***date of arrival (days from booking day)***	***date of departure (days from booking day)***	***date of arrival (days from booking day)***
01/04/2003	*02/04/2003 (1)*	*08/04/2003 (7)*[α]	*02/04/2003 (1)*	*08/04/2003 (7)*[Α]
01/04/2003	*05/04/2003 (4)*	*11/04/2003 (10)*[σ]	*05/04/2003 (4)*	*11/04/2003 (10)*[Σ]
01/04/2003	*08/04/2003 (7)*[Α]	*15/04/2003 (14)*[β]	*08/04/2003 (7)*[α]	*15/04/2003 (14)*[Β]
01/04/2003	*11/04/2003 (10)*[Σ]	*18/04/2003 (17)*	*11/04/2003 (10)*[σ]	*17/04/2003 (17)*
01/04/2003	*15/04/2003 (14)*[Β]	*22/04/2003 (21)*[χ]	*15/04/2003 (14)*[β]	*22/04/2003 (21)*[Χ]
01/04/2003	*22/04/2003 (21)*[Χ]	*29/04/2003 (28)*[δ]	*22/04/2003 (21)*[χ]	*29/04/2003 (28)*[Δ]
01/04/2003	*29/04/2003 (28)*[Δ]	*06/05/2003 (35)*[ε]	*29/04/2003 (28)*[δ]	*06/05/2003 (35)*[Ε]
01/04/2003	*06/05/2003 (35)*[Ε]	*13/05/2003 (42)*[ϕ]	*06/05/2003 (35)*[ε]	*13/05/2003 (42)*[Φ]
01/04/2003	*13/05/2003 (42)*[Φ]	*20/05/2003 (49)*[γ]	*13/05/2003 (42)*[ϕ]	*20/05/2003 (49)*[Γ]
01/04/2003	*20/05/2003 (49)*[Γ]	*27/05/2003 (56)*[η]	*20/05/2003 (49)*[γ]	*27/05/2003 (56)*[Η]
01/04/2003	*27/05/2003 (56)*[Η]	*03/06/2003 (63)*[ι]	*27/05/2003 (56)*[η]	*03/06/2003 (63)*[Ι]
01/04/2003	*03/06/2003 (63)*[Ι]	*10/06/2003 (70)*[λ]	*03/06/2003 (63)*[ι]	*10/06/2003 (70)*[Λ]
01/04/2003	*10/06/2003 (70)*[Λ]	*17/06/2003 (77)*	*10/06/2003 (70)*[λ]	*17/06/2003 (77)*