Spatial Multiproduct Pricing: Empirical Evidence on Intra-European Duopoly Airline Markets

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Abstract

This paper estimates a model of spatial multiproduct duopoly pricing when the location patterns differ across markets. The theoretical model suggests that a neighbouring location pattern yields less competitive Nash prices than an interlaced location pattern. I apply this model to data for intra-European duopoly airline markets. The empirical results support the theoretical model since I find that fares are higher on intra-European markets which exhibit a neighbouring location pattern in the time domain: In accordance with intuition, price competition is reduced when each airline operates on a specific segment of the timetable (e.g., the first 12 hours of the day). This result has several implications for policy makers and/or airport authorities in charge of awarding slots. (JEL D43,L13,L40,L93)


*I am indebted towards Louis Phlips for detailed comments on the paper.
"On ne fait point de l'industrie entre ciel et terre; il faut se poser quelque part sur le sol."

L. Walras [1874], Eléments d'Economie Politique Pure.

1 Introduction

Leon Walras was indeed right. A firm or an industry must be located somewhere in geographical space if it is to assemble inputs and reach consumers. Although Leon Walras could not foresee the Wright brothers’ flight of 1903 and the subsequent development of the airspace industry throughout the century, his quotation describes the essence of the air transportation industry, the industry of interest in this paper. An airline market requires well-defined geographic coordinates in the space domain and likewise, a scheduled airplane requires a well-defined departure time in the time domain. In airline markets, single product firms operating under perfect competition are rare. Actually, the airline industry, and modern businesses in general, show that multiproduct firms tend to compete among few rivals: Duopolists, each operating several flights, is a typical airline market structure. Since each flight has a well-defined location or ‘address’, a market is characterised by a particular location pattern of flights (see Greenhut et al.[1987] for a discussion on the analogy between space location, product differentiation and transport scheduling). The aim of this paper is to study the empirical implications of location patterns in a spatial multiproduct duopoly model using data on intra-European airline markets.

Within the traditional framework developed by Hotelling’s [1929] paper on spatial competition, Bensaid & de Palma [1994] first show that different organisational structures may theoretically arise in a two stage location-then-price game: An interlaced location, a neighbouring location and a mixed location pattern. A (horizontally) differentiated product industry characterised by an interlaced location equilibrium corresponds to a situation where each firm wishes to offer a ‘product line’
as broad as possible. On the contrary, a neighbouring outlet pattern characterises an equilibrium where all the outlets owned by a firm are located next to each other. In the latter, each firm wishes to specialise on a segment of the 'product line'. Finally, a mixed outlet pattern arises as a combination of interlaced and neighbouring locations in the case of three or more outlets per firm. From a theoretical point of view it has been shown that a neighbouring location pattern yields less competitive prices both in the two-outlet and three-outlet cases (see e.g., Nero [1995]). This arises because price competition is reduced when firms own adjacent (strategically dependent) outlets. The European airline industry provides a unique framework for empirically testing the location pattern effect. As emphasised by recent research, despite the current phase of liberalisation in Europe (Third Package), a large number of intra-European routes are served by only two airlines (most of the time the flag-carriers), indicating that duopoly is still the dominant market structure in the intra-European airline market industry. This unique market structure leads to a number of reasonable simplifications which in turn allow me to test the implications of location patterns (one important aspect of the organisational structure of airline markets) on pricing behaviour (market conduct). The empirical results support the theoretical model, since I find that fares are higher on intra-European markets which exhibit a neighbouring location pattern in the time domain: In accordance with intuition, price competition is reduced when each airline operates on a specific (specialised) segment of the timetable (e.g., the first 12 hours of the day). Clearly, this result has several implications for policy makers and/or airport authorities in charge of awarding slots. The message of this paper is that there is a potential for the neighbouring pattern to be a source of market power in the air transportation industry. Additionally, I find that, on average, European airlines price discriminate according to the income of origin. These original results constitute the main empirical contribution of the paper.

This paper is organised as follows. Section 2 presents a model for comparing prices across duopoly airline markets with different location patterns. Data and the econometric specifications are discussed in Section 3. Sec-
tion 4 presents and interprets the empirical findings. Finally, Section 5 concludes.

2 The Theoretical Structure

My principal objective in this paper is to estimate a model of spatial multiproduct duopoly pricing when the location patterns (in the time domain) differ across markets. I apply this model to data for intra-European duopoly airline markets, strictly defined, in that two carriers (principally flag-carriers) offer all of the (nonstop) direct services on a given city-pair. The empirical study covers the October 1993 period (the data are described more fully in Section 3).

In this article, I model intra-European airline markets as an one-dimensional (horizontally) differentiated industry. Rather than Hotelling's [1929] celebrated 'distance' assumption, we now have 'time'. I follow Panzar [1979] in modelling airline competition within the one-dimensional 'address' model framework. Therefore, it is assumed that airlines produce a homogeneous product (in the consumers' eyes) except for the time dimension. This seems reasonable if, as is postulated in the empirical model, duopolists are symmetric in the level of service frequency. Actually, many intra-European markets are characterised by a symmetric duopoly structure with both airlines providing an identical number of daily flights and capturing similar market shares. This market structure leads to a number of reasonable simplifications which in turn allow me to test the implications of location patterns in the time domain on pricing behaviour. Indeed, I consider the European airline industry as a unique and natural framework for testing the predictions of spatial multiproduct duopoly pricing. The theoretical model suggests that duopolist firms with neighbouring outlet locations choose higher (noncooperative) Nash prices than those resulting under interlaced locations. Therefore, I would expect that on

^1 Notice that contrary to most quality variables and/or other characteristics dimensions, airline scheduling time is (unambiguously) observable.
a given route (city-pair), duopolist airlines operating aircraft with interlaced departure times would charge lower equilibrium prices, ceteris paribus. The results of this paper suggest that there is a potential for the neighbouring pattern to be a source of market power in the European airline industry. Consequently, the present research suggests that policy-makers and airport authorities should cautiously consider the implications of departure times for market power and social welfare when awarding slots to competing duopolies.

This work extends the already large body of literature that studies the determination of fares in airline city-pair markets\(^2\). Typically, the literature explores the connection between fares and market-specific variables, which include measures of demand (city populations, incomes, etc.), costs (flight distance, load factor, etc.) and market structure (number of competitors, market share, airport presence, etc.). Recently, the inclusion of network characteristics has given new insights. On the one hand, network characteristics play a significant role in consumer choice among competing airlines (e.g., Berry\(^3\) [1990]). On the other hand, network characteristics can play an important role on costs and therefore on fares. For example, Brueckner, Dyer & Spiller [1992] and Brueckner & Spiller [1994] emphasised that hub-and-spoke networks generate cost reductions through economies of traffic density. In comparison to the existing literature, the present work is differentiated in the following two major aspects. First, it focuses on intra-European airline markets\(^4\).


\(^3\)Berry [1990] estimates a discrete choice model of product differentiation for the U.S. airline industry. According to Berry [1990], air transportation services are differentiated because, on a given city-pair market, airlines’ network characteristics (e.g., airport presence, network size) vary.

\(^4\)Recently, Marin [1995] models European airline competition as a vertically and horizontally differentiated industry. However, contrary to the present work, Marin [1995] analyses the impact of liberal bilateral agreements on some European airline
Second, it focuses on one particularly important aspect of airline competition: The implications of the location pattern of daily flights in the time domain on pricing behaviour.

Airlines can be thought of as complex multiproduct firms. First, because each route can be considered a different product and second, because within each route an airline operates several air services. For the purpose of this analysis, a multiproduct airline is an airline operating several daily aircraft on a given intra-European route. Assuming that the intra-European air services market can be characterised by a model of spatial duopolistic competition, it is possible to represent the airline decision process as the following (schematic) two stage game:

1. At the very beginning, the airline decides whether to enter the intra-European market, and if so, it makes a choice about its technology. Then, the airline has to decide how many daily aircraft to operate on the market and at which departure time. The former is the product range decision and the latter the product selection (location) decision.

2. In the second stage of the game, the airline sets noncooperative prices given the decisions of the previous stage.

The first stage may be considered as long term decisions, whereas the last more flexible stage may be viewed as a short term decision (see Bresnahan [1989]). For the purpose of this analysis, I focus on the last stage of the decision process, when airlines take the departure times, the number of aircraft operated and the set of markets they operate in as given. One can argue that this assumption is rather restrictive on the grounds that airlines generally control both price and schedule simultaneously. However, in the case of intra-European airline markets, carriers do not always markets.

Theoretically it is costless to reschedule an airplane (‘capital is mobile’ according to the supporters of the [perfect] contestability theory (Baumol, Panzar & Willig [1982])). However, an airline typically operates several aircraft over its network and the relocation of a single flight generally induces the relocation of several other flights (given that aircraft are operated on a continuous basis). This suggests that the
control the schedule variable, because much of the infrastructure needed by airlines is publicly provided. Indeed, in most of the intra-European markets (city-pairs), the choice of the (offered) departure time greatly depends on local airport authorities which allocate available slots\(^6\). Typically, a slot of 10-15 minutes is allocated to the airline which must then make sure that its actual departure (and landing) time falls within this slot. At slot-constrained airports, a carrier is practically stuck within its allocated slot.

In the remaining of this section I closely follow the work of Dresner & Tretheway [1992] who propose a method for comparing prices across international airline markets. These authors test the pricing behaviour in international airlines markets according to whether the route is operated under a liberal bilateral environment or under a traditional (bilateral) regulatory agreement. Although the assumptions underlying our model are completely different, it turns out that their methodology provides an interesting framework for modelling intra-European duopoly airline competition. For the purpose of this analysis, I focus on the two benchmark cases: The interlaced location and the neighbouring location. In order to put more structure on the empirical model let us assume that the cost function of firm \(k\) operating an aircraft \(i\) on the route \(r\), \(TC_{kr}^i(\cdot)\), is given by

\[
TC_{kr}^i(f_k^i, S_{kr}^i, x_r) = f_k^i + VC_{kr}^i(S_{kr}^i, x_r),
\]

where \(f_k^i\) represents the fixed or overhead cost of operations allocated to each aircraft. Notice that \(f_k^i\) depends only on the carrier \(k\), and not on the route itself. This is justified on the grounds that on the (medium-haul) intra-European routes an airline typically uses similar aircraft. Hence the fixed cost of operating an aircraft are carrier-specific rather than carrier-and-route-specific. The second element of (1), \(VC_{kr}^i\), represents the variable cost of operating an aircraft on route \(r\). This variable cost depends on a vector of route \(r\) characteristics, \(x_r\) (such as the distance of relocation of an aircraft can affect part of the network. Most of the time, this is not a costless operation.

\(^6\)Several international European airports are severely slot-constrained due to airport and air space congestion.
the route and input prices the carrier faces), and on the level of output or traffic, \( S_{kr} \) (market shares), carried by the aircraft on that route. Equation (1) suggests that there are economies of scale from operating an aircraft on a particular route. Using (1) to characterise the cost function, airline \( k \)'s profit function from operating airplanes on route \( r \), \( \Pi_{kr} \), can be written as:

\[
\Pi_{kr} = D_r \left[ \sum_i \left( p_{kr}^i S_{kr}^i - V C_{kr}^i (S_{kr}, x_r) - f_k^i \right) \right],
\]

(2)

where \( D_r \) stands for market \( r \)'s customers (uniform) density, and \( p_{kr}^i \) is the price (strategy variable) chosen by airline \( k \) for its aircraft \( i \) in city-pair \( r \). Implicit to (2) is the idea that costs can be separated at the aircraft and route level and that there are no economies of scope from operating several airplanes on a given route. It is also important to note that the demand for travelling in market \( r \), \( S_{kr} \), does not depend upon prices in any of the other markets. Intuitively we can assume that customers who wish to travel from one city to another have no desire to travel anywhere else (i.e., zero cross-price elasticities between markets).

The price equation under an interlaced location

Two airlines are supposed to play Bertrand-Nash price competition with given departure times. For the sake of simplicity, let us consider the pricing equation which arises when both carriers, Firm A and Firm B, operate two airplanes each (i.e., \( i = 1, 2 \)) on a particular market. In this case, Firm A's first order conditions are:

\[
\frac{\partial \Pi_A}{\partial p_A^1} = D \left( S_A^1 + p_A^1 \frac{\partial S_A^1}{\partial p_A^1} - \frac{\partial V C_A^1}{\partial S_A^1} \frac{\partial S_A^1}{\partial p_A^1} + p_A^2 \frac{\partial S_A^2}{\partial p_A^1} - \frac{\partial V C_A^2}{\partial S_A^2} \frac{\partial S_A^2}{\partial p_A^1} \right) = 0,
\]

(3)

\( ^{7}\)In Europe, due to airport noise restrictions, most flights are scheduled between 6.00 a.m to 10.00 p.m. For the purpose of this work, I assume that demand is uniformly distributed over the 'market length'. Note that all consumers are assumed to have an identical perfectly inelastic demand. The assumption of the basic spatial model is that different travellers have different most preferred time departures. For example, it may be important for a businessman to travel in the morning while for travellers visiting friends it may be more convenient to travel later.

\( ^{8}\)Omitting the subscript for the market.
\[
\frac{\partial \Pi_A}{\partial p_A^2} = D \left( S_A^2 + p_A^2 \frac{\partial S_A^2}{\partial p_A^2} - \frac{\partial VC_A^2}{\partial S_A^2} \frac{\partial S_A^2}{\partial p_A^2} + p_A^1 \frac{\partial S_A^1}{\partial p_A^1} - \frac{\partial VC_A^1}{\partial S_A^1} \frac{\partial S_A^1}{\partial p_A^1} \right) = 0, 
\tag{4}
\]

where the slope of the variable cost curve, \( \frac{\partial VC_A}{\partial S_A} \), is defined as the marginal cost (\( mc_A \)). Because the airline is assumed to operate similar aircraft throughout its (European) network it stands to reason that the marginal cost of operating airplanes is identical, so that \( mc_A^1 = mc_A^2 = mc_A \). Moreover, in symmetric locations, the own price elasticities are equal such that \( \frac{\partial S_A^1}{\partial p_A^1} = \frac{\partial S_A^2}{\partial p_A^2} \). Put differently, the slope of the aggregate demand is similar across ‘outlets’. With an interlaced location, carrier A’s airplanes are surrounded by carrier B’s airplanes. In other words, there is no scope for carrier A (and carrier B) to “coordinate” its pricing policy between its own airplanes because airplanes of the same carrier are strategically independent. This is an important feature of the address model of (one-dimension) product differentiation which implicitly assumes localised competition. As a result, with an interlaced location, we have that \( \frac{\partial S_A^1}{\partial p_A^1} = \frac{\partial S_A^2}{\partial p_A^2} = 0 \). Accordingly, equations (3)-(4) can be rearranged with the dependent variables (i.e., prices) on the left hand side as follows

\[
p_A^1 = mc_A(\cdot) - S_A^1 \frac{\partial p_A^1}{\partial S_A^1}, \tag{5}
\]

\[
p_A^2 = mc_A(\cdot) - S_A^2 \frac{\partial p_A^2}{\partial S_A^2}. \tag{6}
\]

Equations (5)-(6) imply that mark-ups are inversely related to the elasticity of the aggregate demand faced by each airplane. Notice that in symmetric equilibrium, we have that carrier A would charge identical prices for its own airplanes.

**The price equation under a neighbouring location**

Assume that, on a given market, carrier A operates two morning flights and carrier B operates two afternoon flights. In such a situation, each carrier has an incentive to relax price competition because it faces less competition from the rival. In effect, under this neighbouring location, there is scope for carrier A (and carrier B) to “coordinate” its pricing policy since now its own airplanes are in direct competition.
Airplanes of the same carrier are now **strategically dependent**. As a result, under a neighbouring location, \( \frac{\partial S^1_A}{\partial p^1_A} = \frac{\partial S^2_A}{\partial p^2_A} \neq 0 \). In other words, carrier \( A \) can internalise the effect of a change in the price \( p^1_A \) on the profit derived from operating the second aircraft. Accordingly, equations (3)-(4) can be rearranged to yield

\[
\begin{align*}
p^1_A &= m c_A (\cdot) - S^1_A \frac{\partial p^1_A}{\partial S^1_A} - \frac{\partial S^2_A}{\partial p^1_A} \frac{\partial p^1_A}{\partial S^1_A} [p^1_A - m c_A], \quad (7) \\
p^2_A &= m c_A (\cdot) - S^2_A \frac{\partial p^2_A}{\partial S^2_A} - \frac{\partial S^1_A}{\partial p^2_A} \frac{\partial p^2_A}{\partial S^2_A} [p^1_A - m c_A]. \quad (8)
\end{align*}
\]

It can be observed, from examining equations (5)-(6) and equations (7)-(8), that the difference in prices charged by carrier \( A \) depends on the extra term

\[
- \frac{\partial S^i_A}{\partial p^i_A} \frac{\partial p^i_A}{\partial S^j_A} [p^i_A - m c_A] \quad i, j = 1, 2 \quad i \neq j. \quad (9)
\]

This extra term is positive for the following reasons. First, \( \frac{\partial S^1_A}{\partial p^1_A} \) is positive if substitutability between carrier \( A \)’s air services is assumed. Second, \( \frac{\partial p^1_A}{\partial S^1_A} \) is negative if I assume a downward sloping aggregate demand facing carrier \( A \)’s aircraft. Finally, the price cost margin is non-negative given profit maximisation and assuming no subsidies (across airplanes and across markets) in the model. Accordingly, prices must be higher under a neighbouring location pattern.

The following single expression condenses carrier \( A \)’s pricing equations (5)-(6) and (7)-(8) under both location patterns, ceteris paribus:

\[
p^i_A = m c_A (S^i_A, x) - \frac{\partial p^i_A}{\partial S^i_A} S^i_A + \gamma_1 (N B O R), \quad i, j = 1, 2 \quad i \neq j, \quad (10)
\]

where,

\[
\gamma_1 = - \frac{\partial S^j_A}{\partial p^i_A} \frac{\partial p^i_A}{\partial S^j_A} [p^i_A - m c_A] > 0, \quad (11)
\]

and \( N B O R \) is a dummy variable defined as

\[
N B O R = \begin{cases} 
0 & \text{under an interlaced location pattern,} \\
1 & \text{otherwise.}
\end{cases} \quad (12)
\]
Clearly, if the pricing scenario of the theoretical model is true, then prices should be lower under an interlaced location pattern. From the empirical point of view, equation (10) indicates that the sign of the coefficient of the traffic variable \( S_A' \) may also be identified. Given the assumptions of the model, \( S_A' \) has two distinct effects on \( p_A' \). First, when a carrier operates on the upward sloping part of its marginal cost curve, higher traffic levels lead to higher marginal costs. This effect may reflect the short run capacity constraints faced by the carrier when traffic increases. Hence, as an argument in the determination of the marginal cost \( mc_A(\cdot) \) one would expect output to have a positive effect on price. Second, since aggregate demand is assumed to be downward sloping, the sign of \( (-\partial p_A' / \partial S_A') \) should be positive. As a consequence, since both the marginal cost effect and the demand effect should be positive, one would expect the coefficient of the traffic variable in the regression on price to be positive.

The idea now is to derive a route price equation using equation (10). Dresner & Tretheway [1992] propose an original way to do this. They argue that the use of route-specific variables may be reasonable when the analysis is focused on duopoly international airline markets, because prices and costs should be fairly similar between duopolists at the route level. Since one would expect carriers’ heterogeneity to be more important at the worldwide route level than at the intra-European route level, I follow Dresner & Tretheway’s methodology in specifying a price equation at the route level rather than carrier-and-route level\(^9\). The steps leading to this specification are carefully justified throughout the remainder of this section. What is key in Dresner & Tretheway’s analysis is the separation of the cost effects of output on price from the other route-specific cost effects. In other words, the variables representing those effects on the right hand side of (10) are entered separately (and additively). Carrier A’s equation (10) becomes

\[
p_A = \gamma_1(NBOR) + \gamma_2 S_A + \gamma_3 \mathbf{x},
\]

\(^9\)It is important to note that the route level specification requires less data. This is particularly useful given the lack of relevant data at the European carrier level.
where $\gamma_2$ is equal to $(-\partial p_A/\partial S_A)$ plus the cost effects of traffic $S_A$ on price. $\gamma_3$ is the vector representing the effects of the route-specific cost variables (other than traffic) on price $p_A$. Notice that in (13), the subscript standing for aircraft $i$ has been dropped since, at the equilibrium of the two airplane case, the carrier charges equal fares. Of course, there exists a similar expression for carrier $B$:

$$p_B = \theta_1(NBOR) + \theta_2 S_B + \theta_3 x,$$  \hspace{1cm} (14)

with $\theta_2$ representing $(-\partial p_B/\partial S_B)$ plus the cost effects of traffic $S_B$ on price and $\theta_3$ capturing the effects of the route-specific cost variables (other than traffic) on price $p_B$. The summation of (13) and (14) yields

$$p_A + p_B = (\gamma_1 + \theta_1)(NBOR) + \gamma_2 S_A + \theta_2 S_B + (\gamma_3 + \theta_3)x. \hspace{1cm} (15)$$

Implicit to (15) is that the route-specific costs for carrier $A$ are equal to the route-specific costs for carrier $B$. In other words, the $x$ vectors are assumed to be the same at a route level. Finally, following Dresner & Tretheway, it is assumed that the fares charged on the route by the two carriers are the same (i.e., $p_A = p_B = p$) and that the effect of traffic on fare is the same for both duopolists, i.e., $\gamma_2 = \theta_2$. Accordingly, equation (15) can be reformulated as

$$p = \alpha_1(NBOR) + \alpha_2 S + \alpha_3 x,$$  \hspace{1cm} (16)

with $\alpha_1 = (\gamma_1 + \theta_1)/2$, $\alpha_2 = (\gamma_2 + \theta_2)/2$, $\alpha_3 = (\gamma_3 + \theta_3)/2$, and $S$ is equal to the total passenger traffic on the route. The price equation (16) deserves several comments because the assumptions that allow us to derive it, in particular that duopolists charge equal fares and face equal costs at the route level, must be carefully justified.

First, note that (16) is a route-specific rather than carrier-and-route-specific equation. Therefore, using Evans & Kessides' terminology [1993a, 1993b], the present empirical study on airline pricing would be placed among the first-generation studies which have been developed by many researchers such as Graham, Kaplan & Sibley [1983], Bailey, Graham & Kaplan [1985], Hurdle et al.[1989] and Peteraf & Reed [1994] among
others. Recent empirical studies conducted on the domestic U.S. airline industry (Borenstein [1989], Berry [1990], Evans & Kessides [1993a,1993b], Abramowitz & Brown [1993]) indicate that the first-generation studies ignore important intra-route heterogeneity in firms characteristics. The latter authors argue that the most important firm characteristics that vary within the route are measures of airport dominance and network characteristics (e.g., size of the network). The second-generation studies undoubtedly constitute an improvement in explaining price differences among U.S. airlines serving domestic markets. However, since the present study focuses on duopolists carrier (primarily, flag-carriers) operating intra-European routes, it can be assumed that intra-firm differences in terms of market power (e.g., due to dominance at an airport) do not affect European airlines’ pricing behaviour in the same way as they affect the U.S. markets. First, because market shares on a given market are very similar between duopolists. Second, dominance at an airport plays a minor role on intra-European markets: The advantages (disadvantages) Swissair (Lufthansa) may enjoy on the Geneva-Frankfurt route are likely to be reversed on the Frankfurt-Geneva route.

Second, I treat the output of duopolists as homogeneous (except in the time dimension of course). It can be argued that airlines compete both in terms of price and quality of service. The main aspect of the quality of service likely to influence the pricing behaviour of European airlines is the frequency of service. In order to avoid any bias due to the frequency of service, I only consider duopoly routes with symmetric frequencies.

Finally, implicit to the equation (16), is that the price equation at a route level is independent of carriers’ network characteristics (e.g., size and configuration of the overall network). This can be justified on the grounds that the European network operated by each duopolist presents similar characteristics in terms of size and shape (hub-and-spoke) and that, in the data set, the number of routes operated by a particular

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10It is acknowledged that European airlines fly airplanes of equal comfort, serve similar refreshments and increasingly important, provide comparable frequent flyer programmes.
airline corresponds to a small part of its overall network. More details on data are provided in the next section.

3 The Data and the Econometric Specification

Data were gathered from the official ABC World Airways Guide (ABC WAG) for the month of October 1993 on intra-European duopoly city-pairs or markets. About 380 unidirectional\(^1\) intra-European markets are operated by two carriers, indicating that duopoly is still the dominant market structure in the intra-European airline industry. This is not very surprising since in Europe, despite the European packages of measures for promoting liberalisation of the industry, most of the international routes are served by the two flag-carriers or some subsidiaries (see Nero [1994]). In order to estimate the theoretical (spatial) model analysed in Section 2, I only consider markets where both duopolists operate the same number of daily aircraft, i.e., symmetric frequencies. This allows me to preserve the symmetrical structure of the model and to focus only on the location pattern (diminishing any bias due to market and/or airport power in the econometric analysis). A sample of 122 unidirectional city-pair markets satisfying the requirement of symmetry is used\(^2\). In this sample, 4 daily aircraft are operated on 71 markets, 6 daily aircraft are operated on 35 markets, 8 daily aircraft are operated on 8 markets, 10 daily aircraft are operated on 6 markets and finally, 12 daily aircraft are operated on 2 markets. To ensure meaningful observations, the sample includes only markets offering (nonstop) direct services. The minimum daily service level in the sample is 132 passengers and the maximum is 1,968.

The ABC WAG provides a detailed description of the timetable and

\(^1\)Travel from point A to point B is taken as a different market from travel from point B to point A (see e.g., Borenstein [1990], Berry [1990]).

\(^2\)A potential problem with this sample selection rule is that the sample may suffer from selection bias. The assumptions of the theoretical model, however, prevent me from formally correcting this problem (see e.g., Heckman [1979]).
flight patterns on each market which allows me to construct the $NBOR$ dummy variable. In order to understand how this variable is constructed, let us consider the two markets described in Table I.

Table I: Example of Location Pattern

<table>
<thead>
<tr>
<th>Market</th>
<th>Flight Number</th>
<th>Departure Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>MILAN-STUTTGART</td>
<td>LH5347</td>
<td>0745</td>
</tr>
<tr>
<td></td>
<td>AZ452</td>
<td>1110</td>
</tr>
<tr>
<td></td>
<td>LH5343</td>
<td>1650</td>
</tr>
<tr>
<td></td>
<td>AZ1442</td>
<td>2030</td>
</tr>
<tr>
<td>STUTTGART-MILAN</td>
<td>AZ1443</td>
<td>0805</td>
</tr>
<tr>
<td></td>
<td>AZ453</td>
<td>1300</td>
</tr>
<tr>
<td></td>
<td>LH5342</td>
<td>1450</td>
</tr>
<tr>
<td></td>
<td>LH5330</td>
<td>2035</td>
</tr>
</tbody>
</table>

Table I reports the typical daily flight pattern on the Milan-Stuttgart and Stuttgart-Milan markets for the month of October 1993. Both markets are operated by Alitalia (AZ) and Lufthansa (LH) and both flag-carriers operate two daily aircraft on each market. However, it appears from Table I that on the Milan-Stuttgart route the flights are interlaced (i.e., $NBOR = 0$), while the Stuttgart-Milan route displays a neighbouring flight pattern. In effect, in the latter market Alitalia (AZ) operates the first two (morning) flights while Lufthansa’s (LH) flights are scheduled in the afternoon and early evening. When more than 2 flights per airline are provided on a given market, a mixed location pattern may arise resulting in one or more neighbouring flights. For the purpose of the empirical model, mixed locations and neighbouring locations are identically treated since it has been shown that the equilibrium prices under a mixed location are higher than under an interlaced location (see e.g., Nero [1995]). Under the above assumption, 61 observations exhibit a neighbouring location pattern, i.e., half the sample data.

On each route, a number of different fares were available in the ABC WAG, ranging from “First Class” fares to several types of “Discount” fares. The latter category is difficult to consider in an empirical model since the conditions related to the “Discount” fares vary signifi-
canty across airlines and markets. Moreover, given that “First Class” services are virtually suppressed in intra-European routes, I focus on the “Economy/Coach” fares\textsuperscript{13}. Economy/Coach fares can be considered as the basic price in the airline industry with the other fares being determined as either a mark-up or a discount of economy fares. More importantly for the empirical model, economy fares are considered to be more closely linked to costs\textsuperscript{14}. At this point, three remarks are in order. First, on a given market, the basic economy fares as reported by the ABC WAG are the same between airplanes of a given airline. In other words, an airline charges identical fares across its own airplanes. Second, the fares data suggest that duopolists charge very similar fares on a given market\textsuperscript{15}. Third, published fares are directional, i.e., they depend on the direction of travel. The above remarks are important in the light of the assumptions used to derive the price equation (16).

The main concern of this empirical study is to estimate the price equation (16). The specific form chosen is the following log-linear function\textsuperscript{16}

\[
\ln(\text{FARE/MILE}) = \alpha_0 + \alpha_1(\text{NBOR}) + \alpha_2\ln(\text{DISTANCE}) + \alpha_3\ln(\text{PAX}) + \alpha_4\ln(\text{INCORIG}) + \epsilon, \quad (17)
\]

where $\epsilon$ measures independently and identically distributed (i.i.d.) errors in each market and:

- $\text{FARE/MILE}$ = One-way economy fare per mile as reported in the ABC;
- $\text{NBOR}$ = Dummy variable for a neighbouring location pattern;

\textsuperscript{13}As in the theoretical model, it is assumed that airlines do not price discriminate across passengers. Note also that the use of October data diminishes the typical high season factor that affects pricing in the vacation-oriented routes.

\textsuperscript{14}Note that, in my sample data, the correlation between “First Class” fares and “Economy” fares is equal to 0.9496.

\textsuperscript{15}In about 70% of the sample data, fares were identical. On average, the difference between duopolists’ fares is inferior to 1.5\% (some 6 US$ on the average fare sample).

\textsuperscript{16}The model was estimated in both linear and log-linear forms with similar results. Only the log-linear results are presented in Section 4, since the estimated coefficients may be readily interpreted as elasticities.
\begin{align*}
\text{DISTANCE} &= \text{Airport to airport miles;} \\
PAX &= \text{Number of daily passenger seats available on a route;} \\
\text{INCORIG} &= \text{Per capita income of the origin city-country (1993 GDP in $US at market exchange rates).}
\end{align*}

Except for \( PAX \), it is assumed that the explanatory variables in equation (17) are exogenous. The \( \text{FARE/MILE} \) variable represents the one-way economy fare (expressed in $US) per mile. Notice that all fares published in the ABC WAG are expressed in the currency of the country of origin. The IATA Neutral Unit of Construction (NUC) is used to express all fares with a common unit ($US) and is found in the Currency Conversions section of the ABC WAG. The mileage are airport to airport miles as reported in the Ticketed Point Mileage section of the ABC WAG. With respect to the cost variables, I expect both \( \text{DISTANCE} \) and \( PAX \) to have significant coefficients. Since the endogenous variable is \( \text{FARE/MILE} \), I expect the \( \text{DISTANCE} \) variable to have a negative coefficient showing that the average cost per mile falls with distance given the fixed costs of endpoint operations such as take-off and landing. \( PAX \) is a proxy for the passengers carried \( S \) given the lack of information of the load factor \( (lf) \) on a given route (we have that \( S = lf PAX \)). Therefore, \( PAX \) corresponds to the total daily capacity provided by the two duopolists. Information on the type of aircraft used and general aircraft’s characteristics are provided in the ABC WAG\(^{17}\). The \( PAX \) variable is expected to have a positive coefficient if carriers face short run capacity constraints. Notice that if marginal cost is falling (due e.g., to economies of traffic density) then the sign could be negative; see the previous section for the interpretation of the coefficient in the price equation (10)). The \( \text{INCORIG} \) variable controls for the ability of carriers to charge higher fares if the per capita income is higher in the country of origin, ceteris paribus. As an example, given that per capita income is about 10

\footnotetext{\( ^{17} \)First, note that on most markets, both duopolists use very similar, if not identical, aircraft. Second, assuming a constant load factor across routes and carriers of about 58\%, as stated in the AEA Year book for 1993, one would have an estimation of the revenue passengers carried.}
times larger in England than in Turkey, one would expect duopolists\textsuperscript{18} to charge a higher (lower) one-way economy fare in the London-Istanbul (Istanbul-London) market, all other things being equal\textsuperscript{19}. Finally, the main motivation of this empirical study is to test for the location pattern hypothesis: I expect the coefficient of the $NBOR$ variable to be positive, indicating that the basic economy fare is higher under a neighbouring location pattern, ceteris paribus.

Following many empirical studies of airline pricing (see, \textit{inter alia}, Dresner & Tretheway [1992], Abramowitz & Brown [1993], Peteraf & Reed [1994]), the empirical model is estimated using simultaneous two-stage least squares (2SLS) due to the endogeneity of the passengers variable $S$ in the price equation (16) (or $PAX$ in equation (17)). Although the demand side modelling is not the primary focus of this paper, it is still necessary to control for the factors which affect the output in order to obtain consistent estimates of the price equation. As usual in the case of empirical analysis on transport industries, it is assumed that the market demand is a function of the price and some exogenous variables representing an underlying “gravity model”. These latter variables are some measures of the economic size of the two route endpoints and the distance between them. The market demand $S$ can then be specified in log form as follows

$$
Ln(PAX) = \beta_0 + \beta_1 Ln(FARE/MILE) + \beta_2 Ln(AVGPOP) + \\
\beta_3 Ln(DENSITY) + \beta_4 Ln(DISTANCE) + \\
\beta_5 Ln(RELTRAVTIME) + \varepsilon, \tag{18}
$$

where $\varepsilon$ measures i.i.d. errors in each market and:

$AVGPOP$ = The average population of the two route endpoints;

$DENSITY$ = The sum of the aircraft movements at the two endpoints;

$RELTRAVTIME$ = The ratio of train to flight journey time.

\textsuperscript{18}In this case, British Airways (BA) and Turkish Airlines (TK).

\textsuperscript{19}For a similar argument, see Brueckner, Dyer & Spiller [1992].
The AVGPOP variable represents the average population of the two metropolitan areas as stated in the Statesman's Year Book\textsuperscript{20}. The DENSITY variable is assumed to be a proxy for economic activity at the two route endpoints (income city-specific data are not available). DENSITY is calculated as the sum of the weekly departures at the two endpoints cities\textsuperscript{21}. I expect to observe that demand rises with both AVGPOP and DENSITY, i.e., economic size variables. For the DISTANCE variable, two contrasting effects are at work. First, large distance implies lower ‘attraction’ between cities and therefore lower demand. Second, as distance increases, surface transportation is less attractive which should increase air transport demand. So the net effect of DISTANCE is hard to predict and has to be determined empirically. Finally, I include the RELTRAVTIME variable which controls for intermodal substitution between train and airplane transportation. Because Europe is provided with an extensive rail network and because the average distance is not as great as elsewhere (as, e.g., in the U.S. which is about 1,000 miles compared to some 500 miles in Europe), travelling by train provides an effective alternative to airplane. It is assumed that demand increases as the ratio of train to flight journey time increases. The train journey time is computed using the information available on the Thomas Cook European Timetable, Railway and Shipping Services throughout Europe. The flight journey corresponds to the difference between the scheduled arrival and departure time (ABC WAG).

Table II (see Appendix on page 26) presents the carriers (with the airline code) and the number of markets in which they appear in the sample data. Notice that all 17 airlines are so-called flag-carriers. Note also that Lufthansa (LH) appears in 43 different (directional) markets, which is the largest number of markets operated by any flag-carrier of the sample data. The main descriptive statistics for the sample data are represented in Table III (see Appendix on page 27). The average one way economy fare is 402 $US, while the average distance is 540 miles. The average


\textsuperscript{21}Since some cities have several airports, I consider the total departures at the city level.
scheduled flight time is 104 minutes. Note that the train journey is, on average, some 9 times larger than the flight journey. In summary, the empirical model is a cross-section study for the month of October 1993. Accordingly, in contrast to previous studies on European airline pricing (Abbott & Thompson [1991], Marin [1995]), the present study does not account for structural changes due to regulatory modifications or different time periods. Data consists of a sample of 122 directional routes. On each market, both duopolists provide the same number of aircraft such that the data satisfy the symmetry requirement of the theoretical model. Finally, the flight pattern has been identified in each market and characterised by the dummy variable $NBOR$.

4 The Empirical Findings

The objective of the paper is to provide an estimation of the price equation (17). Given the endogeneity of the $PAX$ variable, the Instrumental Variable technique (or 2SLS) is performed using Limdep’s econometric package. The results of the 2SLS of the price equation (17) and the demand equation (18) are reported in Table IV (see Appendix on page 28). The results suggest the following comments. First, $NBOR$, $DISTANCE$, and $INCORIG$ all have the expected sign, while $PAX$ has a negative and statistically significant sign. Second, the flight location pattern has a significant effect on intra-European airline pricing: The sign of the coefficient for $NBOR$ is positive and statistically significant at the 5 % level. This result suggests that, on average, duopolists are able to charge a higher fare under a neighbouring location pattern, all other things being equal. Routes with a neighbouring location pattern have a premium of 0.0689 or about 7 % above fares on routes with purely interlaced location patterns. Third, as shown in the bulk of studies on airline pricing, distance has the greatest effect on fare per mile. A 10 % $DISTANCE$’s increase produces a 3.8 % fare per mile’s decrease, ceteris paribus. Similarly, a 10 % $INCORIG$’s increase generates a 1 % increase in fare. This latter result is likely to be an important feature of intra-European airline markets. It illustrates carriers’ ability to charge
higher fares on routes with high income origins. Fourth, the negative sign of the coefficient for the output variable, \( PAX \), indicates that a 10% increase in output generates a 1.8% decrease in fare (per mile). As mentioned before, the coefficient for the output variable consists of two distinct effects: (1) A positive demand effect \((-\partial p^i/\partial S^i)\) when the aggregate demand is downward sloping and (2) a positive cost effect when carriers operate under short run capacity constraints. Accordingly, a negative coefficient of the output variable could arise if European airlines operate in their declining part of the marginal cost (i.e., under excess capacity and/or due to economies of traffic density), such that the negative effect outweighs the positive demand effect. The strong evidence of the 'persistent overcapacity situation' of European flag-carriers in 1993 (see e.g., AEA Yearbook 1994) tends to support the excess capacity interpretation. Finally, the goodness of fit is high.

The estimates of the output equation of Table IV suggest the following. The coefficients of \( AVGPOP \) and \( DENSITY \) have the expected sign. Surprisingly, \( FARE/MILE, DISTANCE, \) and \( RELTRAVTIME \) have an unexpected, although not statistically significant, sign. The effects of the ratio of train to flight journey time (which controls for intermodal competition) and distance on output are insignificant. Note that the sum of the weekly departures at the two endpoints cities (proxy for economic activity at the two route endpoints), measured by \( DENSITY \), has the greatest effect on output. As found in other empirical studies, the fit for the output equation is quite poor\(^{22}\). Nevertheless, the F statistic suggests that the joint test of the null hypothesis is rejected (the critical value at 1% significance is 3.02).

The next step is to explore whether the empirical results are sensitive with respect to both \( DISTANCE \) and \( RELTRAVTIME \) variables. Table V (see Appendix on page 29) presents the result of the 2SLS model when both \( DISTANCE \) and \( RELTRAVTIME \) are omitted. The results of

\(^{22}\)This could indicate that a relevant variable is omitted in the output specification. However, it is beyond the scope of the present study to fully explain the output variance.
this ‘constrained’ model show that the exclusion of $DISTANCE$ and $RELTRAVTIME$ does not affect the price equation’s estimates. The change in the estimates of the output equation suggest the following comments. First, the coefficient of the $FARE/MILE$ has now the expected negative sign, although still not statistically significant. Second, the coefficients controlling for the economic activity, $AVGPOP$ and $DENSITY$, have coefficients of similar magnitude with respect to the ‘unconstrained’ model. Finally, the goodness of fit of the ‘constrained’ model is better.

All in all, these results are plausible. Most of the estimated coefficients of economic interest agree with our expectations.

5 Concluding Remarks

This paper studies the empirical implications of location patterns in a spatial multiproduct duopoly model. In a nonspatial context, a neighbouring location pattern arises when, for example, in a given duopoly market an airline provides all of the morning flights and its rival provides all of the afternoon flights. The empirical model explicitly controls for the location pattern effect using data on intra-European duopoly airline markets.

Because the empirical model is derived from a theoretical (spatial) model, the methodology allows us to be confident about the predictions on the signs of the regression coefficients. The principal empirical result suggests that the neighbouring location pattern hypothesis cannot be rejected with data on intra-European airline markets. In effect, after controlling for the principal variables that affect intra-European airline fares, I find that duopoly airline markets experience, on average, higher fares under a neighbouring location. This result has several policy implications. In particular, given that duopoly is the dominant structure in intra-European airline markets, policy-makers and airport authorities should cautiously consider the implications of location patterns for market power and social welfare when awarding slots to competing airlines.
Additionally, I find that, on average, European airlines price discriminate according to the income of origin.

The methodology developed in this paper could be applied in other contexts. The first obvious extension would be to apply it to another scheduling industry. One could test, for example, whether the neighbouring pattern is also a source of market power in the U.S. (deregulated) airline industry. In a purely spatial context, it would be interesting to test the location pattern effect in some retail industries (e.g., petrol stations around a lake or along a highway). In a product differentiation context, one can think of firms specialised in a segment of the 'product line'. For example in the luxury watch industry, some firms mainly produce ‘elegant’ watches (e.g., Rolex), while others concentrate on sophisticated ‘sports’ watches (e.g., Breitling). The basic empirical model could be extended in two obvious ways. First, Feenstra & Levinsohn [1995] have recently provided a framework to estimate markups and market conduct with multidimensional product attributes. Although the implementation of their econometric model is rather complex, their framework could provide some insight into modelling the airline industry as a multidimensional differentiated industry. Second, an interesting extension when explaining markups would be to allow for two key issues in the European airline industry: Multimarket contact and cross-ownership.

References

ABC WORLD AIRWAYS GUIDE (ABC WAG), 1993, October, No 712.


## Appendix

Table II: Airlines and Markets in the Data Set

<table>
<thead>
<tr>
<th>Airline</th>
<th>Markets</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIR FRANCE (AF)</td>
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</tr>
<tr>
<td>AIR PORTUGAL (TP)</td>
<td>4</td>
</tr>
<tr>
<td>ALITALIA (AZ)</td>
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</tr>
<tr>
<td>AUSTRIAN AIRLINES (OS)</td>
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<tr>
<td>BRITISH AIRWAYS (BA)</td>
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<tr>
<td>CZECHOSLOVAK AIRLINES (OK)</td>
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<tr>
<td>FINNAIR (AY)</td>
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<tr>
<td>IBERIA (IB)</td>
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<tr>
<td>KLM (KL)</td>
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<tr>
<td>LUFTHANSA (LH)</td>
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<td>LUXAIR (LG)</td>
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<td>MALEV (MA)</td>
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<tr>
<td>OLYMPIC AIRWAYS (OA)</td>
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<tr>
<td>SABENA (SN)</td>
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<tr>
<td>SAS (SK)</td>
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<tr>
<td>SWISSAIR (SR)</td>
<td>22</td>
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<tr>
<td>TURKISH AIRLINES (TK)</td>
<td>6</td>
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<tr>
<td>Variable</td>
<td>Mean</td>
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<tr>
<td>----------------</td>
<td>----------</td>
</tr>
<tr>
<td>ECONOMY FARE (One-way, $US)</td>
<td>402.4</td>
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<tr>
<td>DISTANCE (Mile)</td>
<td>540</td>
</tr>
<tr>
<td>FARE/MILE ($US/Mile)</td>
<td>0.8645</td>
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<tr>
<td>PAX</td>
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<tr>
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<tr>
<td>DENSITY (Departures)</td>
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<tr>
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<td>FLIGHT TIME (Minute)</td>
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Table IV: 2SLS Coefficient Estimates (Model I), Obs=122

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<tr>
<th>Dependent Variable:  $\ln(FARE/MILE)$</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-value</th>
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<tbody>
<tr>
<td>INTERCEPT</td>
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<td>4.658</td>
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<td>NBOR</td>
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<td>0.03545</td>
<td>1.945</td>
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<tr>
<td>$\ln(DISTANCE)$</td>
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<td>0.03845</td>
<td>-9.921</td>
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<tr>
<td>$\ln(PAX)$</td>
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<td>-2.565</td>
</tr>
<tr>
<td>$\ln(INCORIG)$</td>
<td>0.10197</td>
<td>0.03016</td>
<td>3.381</td>
</tr>
</tbody>
</table>

| Std. Dev. of Residuals                | 0.1856404   |
| Sum of Squares                       | 4.032097    |
| R-squared                            | 0.687318    |
| Adjusted R-squared                   | 0.676628    |
| $F[4,117]$                           | 64.29552    |
| Log-likelihood                       | 34.88329    |

<table>
<thead>
<tr>
<th>Dependent Variable: $\ln(PAX)$</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-value</th>
</tr>
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<td>$\ln(RELTRAVTIME)$</td>
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| Std. Dev. of Residuals                | 0.4402385   |
| Sum of Squares                       | 22.48195    |
| R-squared                            | 0.2852232   |
| Adjusted R-squared                   | 0.2544139   |
| $F[5,116]$                           | 9.257686    |
| Log-likelihood                       | -69.9407    |


Table V: 2SLS Coefficient Estimates (Model II), Obs=122

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<tr>
<th>Dependent Variable: $\ln(\text{FARE/MILE})$</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-value</th>
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<tbody>
<tr>
<td>$\text{INTERCEPT}$</td>
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</table>

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<td>0.54205</td>
<td>0.1125</td>
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| Std. Dev. of Residuals                     | 0.4285485   |
| Sum of Squares                             | 21.67115    |
| R-squared                                  | 0.3226793   |
| Adjusted R-squared                         | 0.3054593   |
| $F[3,118]$                                 | 18.73862    |
| Log-likelihood                             | -67.70011   |
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