Second-Degree Price Discrimination and Price Dispersion: The Case of the U.S. Airline Industry

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Abstract

This paper introduces a second-degree oligopolistic price discrimination model with consumer heterogeneity both on a horizontal and a vertical dimension. We find a *non-monotonic* relationship between market power and price dispersion. Using data from the U.S. airline industry, we find supportive empirical evidence for the theoretical prediction. To the extent that price dispersion is correlated with the degree of price discrimination, our exercise indicates that the relationship between market power and price discrimination can be nonmonotonic.

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Keywords: Price dispersion; Second-Degree Price Discrimination; Non-Linear Pricing; Airline Industry.

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1 Introduction

Non-linear pricing has attracted significant attention in recent years. The first papers in the non-linear pricing literature were concerned with a monopolist who designs his offers (prices and qualities or quantities) to sort consumers [e.g. Mussa and Rosen (1978) and Maskin and Riley (1984)]. More recent developments have extended these models to oligopolistic markets [e.g. Champsaur and Rochet (1989), Ivaldi and Martimort (1994), Stole (1995), Villas-Boas and Schmidt-Mohr (1999), Armstrong and Vickers (2001), Rochet and Stole (2002) and Yang and Ye (2005)].[1]

One of the main issues and a source of controversy in this literature [e.g. Stole (1995) pp.552–554] is the effect of market structure on price dispersion. Most of the empirical literature which has investigated the relationship between market structure and price dispersion, or the extent of price discrimination, has imposed a monotonic structure.[2] In a seminal paper, Borenstein and Rose (1994) study the price dispersion in the airline industry. They find that price dispersion increases as the market becomes more competitive (*negative* relationship; i.e., less concentration leads to higher dispersion) and argue that the data provide support for monopolistically competitive third-degree price discrimination models.[3] On the other hand, Busse and Rysman (2005) find that more competition leads to a lower price dispersion (*positive* relationship; i.e., less concentration leads to lower dispersion), using data from display advertisements in yellow page directories. These seemingly conflicting findings may suggest that the relationship between market structure and price dispersion is overall non-monotonic. Our main goal in this paper is to develop a second-degree oligopolistic price discrimination model and to test its predictions using data from the airline industry. We are interested in the relationship between the intensity of competition (market power) and price dispersion, both theoretically and empirically. We find theoretical and empirical evidence in favor of a non-monotonic relationship.

More specifically, we formulate a second-degree oligopolistic price discrimination model.[4] Our

[1] For a survey on the second-degree oligopolistic price discrimination literature, we refer the reader to Stole (2003).

[2] An exception is the work by Clerides and Michis (2006).

[3] Stavins (2001), using a data set with information on ticket prices and restrictions, also finds that more competition results in higher price dispersion.

[4] In a second-degree price discrimination model firms do not observe the preferences of the consumers and they offer a menu of products which are designed in such a way so that consumers self-select. In a third-degree price discrimination model firms do observe the consumers' preferences and make targeted offers. Hence, the main difference between the two types of price discrimination is an incentive compatibility constraint that must be satisfied in the second-degree case to ensure that consumers choose the product that has been designed for them. For example, business travelers (the high-end consumers), who value time more, choose the more expensive ticket

theoretical set-up is similar to the models in Stole (1995), Villas-Boas and Schmidt-Mohr (1999) and Yang and Ye (2005). We assume that neither the vertical nor the horizontal location of a consumer is known by the firms, which offer the same non-linear pricing menu regardless of a consumer's horizontal location. Any given consumer can choose any price-quality choice offered by one of the two firms. We look at how the horizontal length of the interval (which measures the degree of market power and is inversely related to the intensity of competition) affects equilibrium price dispersion.

Our theoretical model uncovers a *non-monotonic* relationship (inverse U-shape) between the intensity of competition (or market power) and price dispersion (as measured by the Gini coefficient), suggesting that low price dispersion may be associated with either high or low market power. This prediction is also supported by our empirical exercise that uses data from the U.S. airline industry. This is one of the first studies that predicts a non-monotonic relationship between price dispersion and the intensity of competition, using a second-degree price discrimination model and finds supportive empirical evidence for this prediction in the airline industry, which (based on casual empiricism) is replete with second-degree price discrimination.[5] To the extent that price dispersion is correlated (positively or negatively) with the degree of price discrimination, then the implication is that there is no clear connection between market power and price discrimination.[6] This is in line with recent contributions on this topic. For instance, McAfee, Mialon and Mialon (2006) demonstrate, in a third-degree price discrimination model, that there is no theoretical connection between the extent of price discrimination and the extent of market power.

There is a growing empirical literature that studies second-degree price discrimination in an oligopolistic setting. Busse and Rysman (2005) test for second-degree price discrimination in display advertising in yellow page directories. The relationship they assume between market structure and the extent of price discrimination is monotonic. They find that an additional competitor causes the price of the full page advertisement (high quality product) to fall by more

which comes with fewer restrictions (i.e., "restricted fares" vs. "unrestricted fares"). To guarantee this, firms set a lower price (discount) for the high-end product (ticket) than what they would have charged had they known the exact preferences of the consumers.

[5] We believe that second-degree price discrimination is the major source of price dispersion in the airline industry. Carriers make a range of tickets with different qualities (mainly restrictions) and prices available to everyone at the same time. The travelers depending on their individual preferences self-select [see also Varian (2006, pp.450-451)]. This does not mean that third-degree price discrimination (i.e., targeted offers) is absent. The advent of the Internet has certainly increased the incidence of targeted offers. Nevertheless, our data end in 1999 when the impact of the Internet was arguably low.

[6] We do not have good quality and cost data and therefore we cannot test the extent of price discrimination.

than 12%, while that of a quarter page (low quality product) falls by less than 6%. Since the high price falls more than the low price, Gini must fall as competition increases (i.e., positive relationship between market concentration and price dispersion).[7] This is consistent with our model. As we have shown, a positive relationship between market structure and price dispersion is consistent with a second-degree price discrimination model. Clerides and Michis (2006) test for the extent of second-degree price discrimination using data on detergent prices from six different countries. They find mixed results. In some countries the relationship between the intensity of competition and the extent of price discrimination is positive, while in other countries it is negative. This suggests that the overall relationship may be non-monotonic. Verlinda (2005), using airline data, finds that more competitive routes exhibit a tighter fare distribution. Verlinda utilizes the entire fare distribution rather than collapsing all the information in a single number.[8]

Other empirical studies on nonlinear pricing, that are nevertheless focusing on different issues, include, Verboven (1999), Clerides (2002), Miravete (2002), Seim and Viard (2004), Borzekowski, Thomadsen and Taragin (2005) and McManus (2006). A number of empirical studies, e.g. Seim and Viard (2004) and Borzekowski, Thomadsen and Taragin (2005), focus on the relationship between market structure and the number of contracts firms are offering, but they do not consider the relationship between market structure and price dispersion, which is the main focus of our paper.[9] Their main finding is that more competition is associated with "more" price discrimination.

Our results have some interesting policy implications. As we show the relationship between market structure and price dispersion is non-monotonic and in particular inverse U-shaped. Then, lower concentration leads initially to higher and eventually to lower price dispersion. Moreover, lower concentration lowers the average price. If we assume that consumer welfare increases as the average price and the price dispersion fall (the latter is due to risk aversion or search cost considerations), then an increase in concentration (due, say, to a merger) when the market is

[7] Their primary focus is on how the degree of competition affects the curvature of the non-linear pricing schedule. They show that more competition leads to a greater degree of curvature. In addition, it turns out that prices become less dispersed.

[8] There is also a large body of theoretical literature that addresses directly the issue of price dispersion. The theoretical literature on price dispersion can be separated into two groups. In the first of these, price dispersion is the outcome of price discrimination [second-degree: e.g., Dana (1998), Gale (1993), Gale and Holmes (1992, 1993) and Stole (1995), or third-degree: e.g., Borenstein and Rose (1994) and Stole (1995)]. In the second group of papers, price dispersion comes from costly capacity and uncertain demand [e.g., Dana (1999)], or simply randomization [e.g., Rosenthal (1980) and Varian (1980)]. Some papers in that literature analyze the relationship between competition and price dispersion and find either a negative or a positive relationship.

[9] Of course, the number of contracts offered by firms has an influence on equilibrium price dispersion, but this link is not pursued explicitly by those papers.

already competitive will result *both* in a higher average price and a higher price dispersion. Consumer welfare will decrease, all else equal. On the other hand, if the market becomes more concentrated, when it is already concentrated enough, the price dispersion will fall, which impacts the consumer welfare positively besides the negative effect from the higher average price.

The rest of this paper is organized as follows. In section 2, we develop a second-degree oligopolistic price discrimination model which serves as a theoretical basis for the empirical exercise. The empirical model is provided in Section 3. The main results are presented in section 4 and we summarize in section 5. In the appendix, we describe the data sets that we use and how we process the data.

2 The theoretical model

The theoretical model tries to capture the competition in prices and qualities when firms do not know the preferences of the consumers. In the airline context the horizontal dimension captures the travelers' preferences over different carriers and times of departure and the vertical dimension captures tickets of different qualities, e.g. "restricted fares" vs. "unrestricted fares." The single-crossing property is satisfied only in the vertical dimension. The firms' offers, as a result, sort consumers only in that dimension.

Consider Hotelling's model with two firms located at the two end points of a line of length L (points 0 and L, respectively). Firm i ($i = 1, 2$) produces two goods of different qualities which are endogenously chosen, q_{il} (low) and q_{ih} (high) with $q_{ih} > q_{il} \geq 0$. There is a fixed cost of producing a good of quality q, which is assumed to be $\frac{q^2}{2}$, and the marginal cost is aq ($a > 0$). There are two types of consumers with a quality preference parameter of θ_l (low type) and θ_h (high type), and $\theta_h > \theta_l$. The firms do not observe the consumer types. A consumer with quality preference parameter θ obtains utility $V + \theta q$ from consuming a good of quality q. The fraction of consumers of low type is σ and that of high type is $1 - \sigma$. Each type of consumer is uniformly distributed on the interval $[0, L]$. There is also a transportation cost that is quadratic in the distance that the consumer has to travel to the firm. The per-unit transportation costs are allowed to be different between a low type and a high type consumer, i.e., $t_h \geq t_l$. This captures the fact that a high valuation traveler finds it more costly to move away from his "ideal" time of departure than a low valuation traveler. Therefore, a low type consumer located at point x who buys firm 1's low quality product will enjoy a utility of $V + \theta_l q_{1l} - p_{1l} - t_l x^2$. If he buys firm 2's low quality product the utility is $V + \theta_l q_{2l} - p_{2l} - t_l (L - x)^2$. The utilities of the consumers who are buying high quality products can be derived similarly. We assume that V is sufficiently high so that the market is covered. Further, we also assume that in the equilibrium each firm will produce both qualities.

Our model builds on Stole (1995), Villas-Boas and Schmidt-Mohr (1999) and Yang and Ye (2005). Stole (in one of the cases that he studies) assumes that firms know the exact horizontal location of each consumer, but are unaware of the vertical preferences. In this case firms offer each consumer on the horizontal line a price-quality menu to choose from. We differ from Stole (1995) in that both the vertical and the horizontal location of a consumer are unknown to the firms. Moreover, Stole (1995) allows the transportation cost to interact with the quality preference, whereas, as in Villas-Boas and Schmidt-Mohr (1999) and Armstrong and Vickers (2001), we assume that the transportation cost is lump sum. Villas-Boas and Schmidt-Mohr (1999) also model vertical and horizontal differentiations. They are interested in how the degree of competition affects a bank's collateral requirements. Yang and Ye (2005) develop a second-degree price discrimination model with heterogeneity both at a horizontal and a vertical dimension and a continuum of consumer types on the vertical dimension. Our model is simpler than the model in Yang and Ye (2005) because we assume only two types of consumers on the vertical dimension [as in Villas-Boas and Schmidt-Mohr (1999)]. By assuming two types we are able to derive closed form solutions for the equilibrium prices and qualities.

Firm i's problem is

$$\max_{\langle q_{il}, q_{ih}, p_{il}, p_{ih} \rangle} \pi_i = \sigma[(p_{il} - aq_{il})d_{il}] - \frac{q_{il}^2}{2} + (1-\sigma)[(p_{ih} - aq_{ih})d_{ih}] - \frac{q_{ih}^2}{2}$$

$$\text{subject to:} \qquad p_{ih} - p_{il} \leq \theta_h(q_{ih} - q_{il}) \qquad \text{(IC high type)}$$

$$\text{and} \qquad p_{ih} - p_{il} \geq \theta_l(q_{ih} - q_{il}) \qquad \text{(IC low type)}$$

where d_{il} and d_{ih} are the demand functions for its low and high quality product respectively. For example, firm 1's demand functions are,

$$d_{1l} = \frac{\theta_l (q_{1l} - q_{2l}) - (p_{1l} - p_{2l}) + t_l L^2}{2Lt_l} \text{ and } d_{1h} = \frac{\theta_h (q_{1h} - q_{2h}) - (p_{1h} - p_{2h}) + t_h L^2}{2Lt_h}.$$

Equations (IC high type) and (IC low type) are the incentive compatibility (IC) constraints, which guarantee that the high type consumer does not have an incentive to misrepresent his type and buy the low quality product, and the low type consumer has an incentive to stay with the low quality product. Since V is sufficiently high and firms compete, the individual rationality constraints are automatically satisfied. This corresponds to the full-scale competition case in Villas-Boas and Schmidt-Mohr (1999).

Each firm chooses the level of the two qualities and the two prices to maximize its profits subject to the incentive compatibility constraints. We only look for an interior equilibrium, i.e., all qualities and prices must be strictly positive. Note that a firm's product faces competition from two fronts: directly from its rivals' products and indirectly from the firm's other product. We invoke the extension of the revelation principle to common agency games [e.g. Martimort and Stole (2002)].

As it is standard in these models, e.g. Villas-Boas and Schmidt-Mohr (1999), we assume that equation (IC high type) is satisfied with equality, i.e., the high type consumers are indifferent between choosing low quality or high quality products, but the low type consumers strictly prefer the low quality product.[10]

Proposition 1 (**Main theoretical result**). *The relationship between L (intensity of competition) and equilibrium price dispersion is inverse U-shaped.*

Next, we prove the proposition. We use the first order conditions and look for a symmetric equilibrium. We are able to obtain a unique closed form solution to the first order conditions. (The expressions are lengthy and are omitted). In our model, L is the distance between the two firms, and it captures the degree of product differentiation and the intensity of the competition in the market. An increase in L means that firms' products are more differentiated (or fewer firms are in the market) and the competition is less intense. Moreover, since firms are symmetric, we only need to calculate the Gini coefficient for just one firm. Then, we can see how the Gini changes when L varies. The Gini coefficient is given by,[11]

$$Gini = \frac{3L\theta_h\left(6t_h\theta_l - 3\theta_h t_h + t_l\theta_h - t_l a - 3t_h a\right)}{A_1L^2 + A_2L + A_3}, \tag{1}$$

where $A_1 \equiv -256t_lt_h$, $A_2 \equiv 4t_l\theta_h a - 12t_l\theta_h^2 + 8t_la^2 - 96t_h\theta_l a - 12t_h\theta_h^2 + 72t_ha^2 + 12t_h\theta_h a + 24\theta_h\theta_l t_h$ and $A_3 \equiv -6\theta_h\theta_l a^2 + 3\theta_h^2\theta_l a - 3\theta_h^3 a + 6\theta_h^2 a^2 + 3a^3\theta_l - 3a^3\theta_h$. It can be shown (details are omitted) that the Gini coefficient exhibits an inverse U-shape with respect to L, for *any* parameter

[10] When we later check for unilateral deviations, we also allow a firm to deviate to other structures, where separation still occurs and all consumers are served. There are two other such structures that we consider. In the first one, equations (IC high type) and (IC low type) are satisfied with strict inequality, i.e., low type consumers strictly prefer the low quality product, and high type consumers strictly prefer the high quality product. In this case, the low quality and the high quality products are essentially independent. In the second one, equation (IC low type) is satisfied with equality, i.e., the low type consumers are indifferent between choosing low quality or high quality products, while the high types strictly prefer the high quality product.

[11] Since the Gini expression is lengthy we set $\sigma = \frac{3}{4}$ in (1). Nevertheless, we would like to emphasize that the inverse U-shape result holds for *any* value of σ.

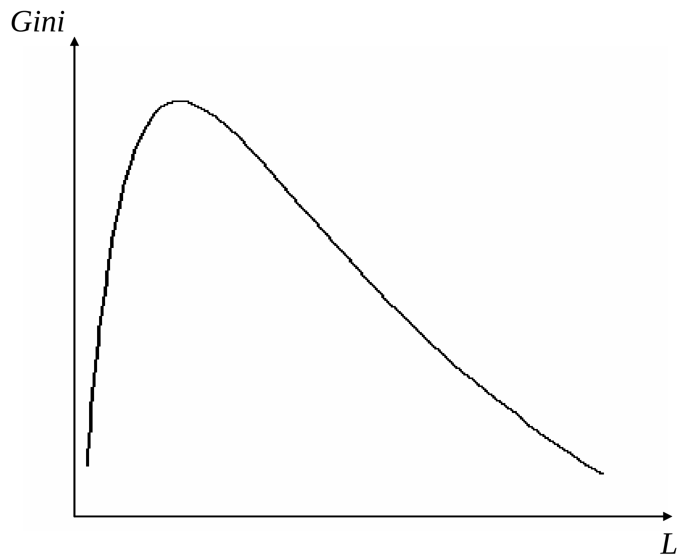

Figure 1: Gini as a function of the intensity of competition

configuration (see figure 1).

Of secondary importance is the issue of an existence of an equilibrium. To answer this question we have to examine all possible unilateral deviations. As long as a firm does not deviate to another structure, the solution to the system of first order conditions guarantees that a firm does not want to alter its prices or qualities (objective functions are concave). But a firm can also deviate to other structures (see footnote 10), or choose to pool, or serve only one type of consumers. Hence, we have to examine all these possible deviations if we want to be certain that the solution to the first order conditions is an equilibrium. This exercise is very difficult and to circumvent this problem we assigned specific numerical values to the parameters. The main finding is that an equilibrium exists, if the difference between the two quality taste parameters, θ_h and θ_l, is not too big.[12]

Remark: We believe that our modeling assumptions are plausible. However, the inverse U-shape result is not robust to alternative specifications. For instance, with a linear (instead of quadratic) transportation cost the Gini is independent of L. However, if we introduce firm asymmetry then the non-monotonicity relationship is restored (with linear transportation costs) but the shape may be a sideways-S rather than inverse U-shaped.[13]

Therefore, the main message is that in a second-degree price discrimination model the rela-

[12] Details are available upon request.

[13] Further details are available upon request.

tionship between market structure and price dispersion is *possible* to be non-monotonic and in particular inverse U-shaped. Then, it becomes a matter of an empirical investigation to determine the exact relationship between market structure and price dispersion in a particular market. Next, we turn to our empirical exercise which tests the non-monotonic (and in particular the inverse U-shape) relationship between price dispersion and the intensity of competition, using data from the U.S. airline industry.

3 The empirical model

The descriptions of the variables that we use in this section and how we process the data can be found in the appendix. An observation in our empirical work is the price dispersion (measured by Gini)[14] of fares offered by a carrier i on a route j (a city pair) at time t (quarter). In the model, GINI is specified as a function of route characteristics, market structure, population, carrier dummies and time dummies. The benchmark model is,

$$\begin{aligned} \text{GINI}_{ijt} &= \beta_0 + \beta_1 \text{MILEAGE}_j + \beta_2 \text{POP}_{jt} + \beta_3 \text{ENDDOM}_{ijt} \\ &\quad + \beta_4 \text{MKTSH}_{ijt} + \beta_5 \text{HHI}_{jt} + \beta_6 \text{HHI2}_{jt} + \\ &\quad \sum_{k=1}^{9} \gamma_k \text{DUM\_C}_k + \sum_{l=1}^{4} \delta_l \text{DUM\_T}_l + u_j + \epsilon_{ijt} \qquad (2) \end{aligned}$$

where HHI is the Herfindahl-Hirschman Index and HHI2 is the square of HHI. We are mainly interested in the signs of β_5 and β_6. In particular, to confirm the inverse U-shape relationship between market structure (as it is captured by HHI) and price dispersion (as it is captured by Gini), β_5 must be positive and β_6 must be negative. Moreover, DUM_C's are carrier dummies, and DUM_T's are time dummies.

We specify the error term to have a route effect (u_j) common to all carriers on a given route, and a "white-noise" error specific to the observation (ϵ_{ijt}). The models are estimated by instrumental variables generalized least squares (IVGLS).

Our test suggests the existence of significant route effects, and a Hausman test rejects the random effects assumption. We estimated both a fixed effects model and a random effects model, but only the results from fixed effects model are presented.[15] Note that in the fixed effects model,

[14] We provide a first order correction for the small sample downward bias of the Gini coefficient. See Deltas (2001) for detailed information on this small sample bias, its consequence and how it can be corrected.

[15] The fixed effects model and the random effects model lead to qualitatively the same results. The only major difference is that, ENNDOM is negative and insignificant in the fixed effects model, but becomes positive and insignificant in the random effect model. In the next section we offer more details.

the variable MILEAGE is dropped, since it does not vary across time. Moreover, HHI varies more across routes than across time on the same routes. Fixed effects estimates of the coefficient for HHI would ignore the information contained in the first variation.

Besides route effects, we assume fixed time and carrier effects, which are absorbed in time and carrier dummy variables respectively. If the ability to price discriminate raises the number of passengers traveling with the carrier and thus its market share, then MKTSH will be endogenous. We did a Durbin–Wu–Hausman test, which confirmed the endogeneity of MTKSH.[16] Following Borenstein and Rose, we use a carrier's geometric share of the enplanements at the two end cities of the route (GEOSHARE) as instrument for MKTSH. It is highly correlated with MKTSH, and is not likely so with price discrimination, since GEOSHARE and price dispersion are calculated from different data, and price dispersion is for a given route while GEOSHARE involves many other routes. Thus GEOSHARE can be assumed to be exogenous.

The summary statistics for the full sample are presented in Table 1. The average fare (AVG_FARE) ranges from $50 to $1047 with a mean of $321 and a standard deviation of $137. The mean of the Gini is approximately .23, which implies that the expected difference in prices paid by two passengers selected at random on a route is about 46 percent of the airline's mean ticket price on the route. This is higher than the 36 percent found in Borenstein and Rose who used 1986 data. Tables 2 and 3 provide summary statistics by groups of Mileage, Population, Market share and HHI. We can see that price is more dispersed for carriers with higher market shares, on routes with longer distance, higher concentration and more population. Price level follows a similar trend.

Next we turn to the estimates of the empirical model, where we focus on how the HHI affects the Gini coefficient.

4 Main empirical results

Table 5 reports the estimates (numbers in parentheses are standard errors). Model (A) includes the quadratic term (HHI2) [see (2)], while model (B) does not.

First, the empirical evidence suggests that the relationship between market structure and price dispersion is non-monotonic. Second, if we wish to impose a more precise structure, then the estimates are broadly consistent with an inverse U-shape. The estimate for the coefficient of

[16] Since HHI is the sum of squares of MKTSH, it is also likely to be endogenous, although not as serious as MKTSH. Borenstein and Rose (1994) find that no bias was indicated in treating HHI as exogenous.

HHI (i.e., for β_5) is positive (equal to .062 and significant at the 8% level) and that of HHI2 (i.e., for β_6) is negative (equal to $-.069$ and significant at the 2% level).[17]

The partial derivative of Gini with respect to HHI [using the estimates from model (A)] is $.062 - .138 \times$HHI. At HHI$= .449$ the Gini attains its maximum with respect to HHI. For any route with HHI$> .449$, an increase in the competition will increase the Gini coefficient, with all else held constant. For any HHI$< .449$ an increase in the competition, lowers the Gini. About 20 percent of carrier-routes (1382 out of 7104 total observations) have HHI lower than .449. This implies that 80% of our observations lie on the downward sloping part of the inverse U-shape curve.

We also obtained estimates without the quadratic term HHI2, see model (B). Previous literature [e.g. Borenstein and Rose (1994), Stavins (2001) and Busse and Rysman (2005)] has assumed a monotonic relationship, because their theory did not generate a non-monotonic one. We find that the effect of HHI on Gini (without the quadratic term) is negative, $-.032$, (and significant at the 2% level), which is consistent with Borenstein and Rose (1994) and Stavins (2001).[18] This is not surprising given that almost 80% of our observations have HHI that belongs in the downward sloping part of the inverse U-shape relationship (see the discussion in the previous paragraph). Therefore, if we force a linear relationship, then it is very likely that it will yield a negative estimate. Busse and Rysman (2005), on the other hand, find that more intense competition leads to lower price dispersion, which is consistent with the increasing part of the inverse U-shape.

The effect of the other explanatory variables on price dispersion is of secondary importance and it is not discussed here. Nevertheless, the estimates are presented in table 5.

All the time dummies have negative estimates. That is, compared to the second quarter of 1999, all other quarters have lower price dispersion, and 1995, 1997 have the lowest dispersion, with all else held constant.

To check the robustness of the non-monotonic relationship between Gini and HHI, we employed a semiparametric regression method by estimating a kernel-weighted local polynomial in HHI. The relationship between Gini (after controlling for all other variables) and HHI is plotted in figure 2.[19] First, there is clear evidence that the relationship is non-monotonic. Second, it is more difficult to determine the exact functional form of the relationship. If we smooth the part of the graph which corresponds to HHI's that are roughly greater than .5, then it looks like a double

[17] The random effects model yields very similar results. The estimate for β_5 is .051 (and significant at the 10% level) and the estimate for β_6 is $-.045$ (and significant at the 8% level). The other estimates from the random effects model are not presented in this paper.

[18] In the random effects model this estimate is $-.012$ (significant at the 10% level).

[19] The Gini in figure 2 is the residual of Gini after controlling for all other variables except HHI

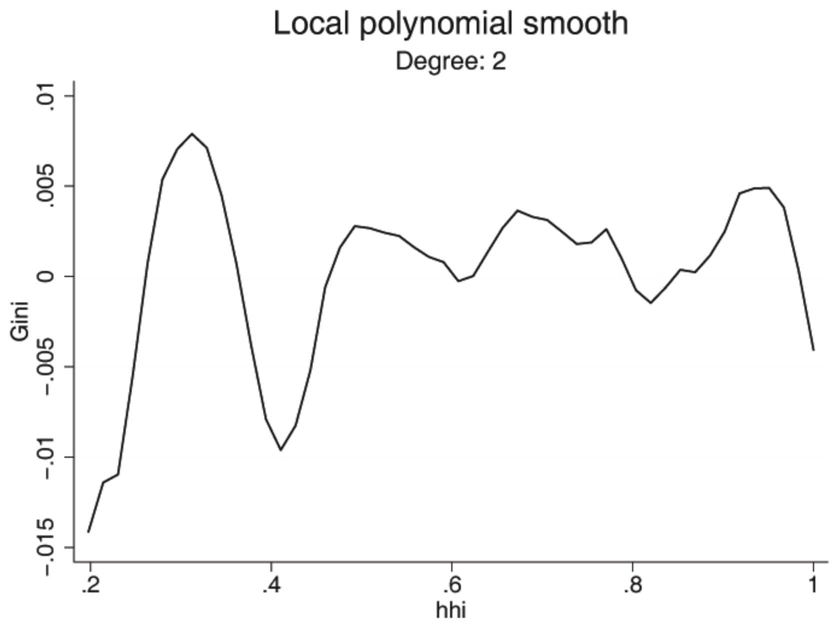

Figure 2: Relationship between Gini and HHI based on a semiparametric regression

hump shape. Finally, the evidence presented in figure 2 is not inconsistent with the inverse U-shape prediction that we obtained from the parametric regression. For instance, starting from high levels of concentration (i.e., HHI close to 1) and moving to a less concentrated structure, the price dispersion can increase. When we move to even lower levels of concentration (i.e., HHI less than roughly .3) price dispersion decreases (although, obviously, the overall transition is not so smooth).

5 Concluding remarks

Oligopolistic second-degree price discrimination models have recently attracted significant attention. One question of interest and a source of controversy is how price dispersion is affected by market structure. This is a very important issue because, among other things, consumer welfare greatly depends on price variability. Therefore, policy makers would like to know whether a more concentrated market structure (due to, say, a merger) will impact price dispersion positively or negatively.

We formulate a model of oligopolistic second-degree price discrimination. Consumers are heterogeneous both on the horizontal and the vertical dimension. We find that price dispersion (measured by the Gini coefficient) is *possible* to exhibit an inverse U-shape with respect to the intensity of competition (market power). For low levels of competition, price dispersion increases as the market becomes more competitive, but eventually price dispersion decreases.

We test the predictions of our model using data from the U.S. airline industry, which is arguably replete with second-degree price discrimination. The empirical estimates are broadly consistent with the theoretical prediction. More specifically, there is plenty of evidence that the relationship between market structure and price dispersion is non-monotonic and if we wish to impose a more precise structure then it is inverse U-shaped. To the extent that price dispersion is correlated with the degree of price discrimination, our exercise indicates that there does not exist a monotonic relationship between market power and second-degree price discrimination.

Further work needs to be done, both theoretical and empirical, before we can draw a more clear picture about the role of market structure on equilibrium price dispersion. We hope that this paper will spawn more research papers on this interesting issue.

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A Appendix: Data and variable description

The data set we use is DB1A and T-100 from the Department of Transportation. DB1A is compiled from a 10% sample of airline tickets as reported by air carriers participating in the Origin & Destination Survey. The data include the full itinerary and the dollar amount paid by each passenger, and are summarized by routing and dollars paid.

T-100 contain data reported by US air carriers operating between airports located within the boundaries of the United States and its territories. T-100 Segment data contain information by aircraft type and service class for departures performed, available capacity and seats, passengers transported, scheduled departures etc. T-100 Market data contain information on passengers *enplaned* at the origin airport of the flight and *deplaned* at the destination airport of the flight.

A.1 How we process the data

We use 5 quarters of DB1A and T-100, including second quarter of year 1991, 1993, 1995, 1997 and 1999.[20] Since we focus on the same quarter we minimize any seasonal price variation. Each quarter of DB1A data has about 2–3 million (2.3 million for 1991 and 3.0 million for 1999) observations. Each observation in this data include *class, carrier, fare, number of passengers who pay at this fare, detailed information about the routes.* We include only the domestic routes with at least 50 passengers reported in that quarter. We have only analyzed direct economy class round-trip fares.[21] Next, for travels on these routes, we pick only observations that satisfy the following conditions:

(i) The carriers and the classes are the same on both coupon segments (both A→B and B→A);

(ii) The fares are greater than $25 and less than 8 times of SIFL – Standard Industry Fare Level[22] (12 times for distance below 1000 miles, and 10 times for distance between 1000 and 3000 miles). Fares not in this range are assumed to be frequent flyers or punch errors and are excluded;

(iii) We regard round trip flights at different directions as the same route, i.e., we view A→ B→A and B→A→B as the same market and combine the observations together.

These selection criteria leave us with a data set of 10603 carrier-route-time observations, representing 971 routes. Some observations have no price dispersion, i.e., Gini is zero. We can not take log when Gini equals zero. A close look at these observations suggests that they are suspicious, as most of them report only one passenger for an entire quarter. Also, we do not have data of ENDDOM or GEOSHARE for some carrier-routes. These observations are dropped and our final data contain 7104 observations on 946 routes.

A.2 Other data

(i) Route mileage data is from airfare consumer report by the Department of Transportation.

(ii) Population data is available from:

[20] We do not use data from more recent years because we wanted to avoid any "post-September 11" issues.

[21] There are business travelers in economy class. Business class tickets are very few for many routes in the data set. Borenstein and Rose also analyze only coach class, direct flights.

[22] The Department of Transportation posts the fare (per mile) formula, depending on the distance of the route.

"http://eire.census.gov/popest/archives/place/placest.php"

We use the average of the populations of the two end cities for each route.

(iii) Income data for places with a population of 50,000 or more is available at:

"http://www.census.gov/popest/archives/"

A.3 Variable descriptions

1) *Dependent variables*

GINI: GINI is calculated from the following formula:

$$GINI = \frac{2}{n^2 \bar{x}} \sum_{i=1}^{n} \left(\left(i - \frac{n+1}{2} \right) x_i \right)$$

where $\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i$ with x_i the price each passenger pays in ascending order and i is the rank.

2) *Explanatory variables*

MILEAGE: nonstop mileage between the two end cities on a route multiply by two (round-trip), in 1000 miles.

POP: average of populations of the two end cities on a route, in millions.

ENDDOM: carrier's share of all originating passengers at the end cities on a route, as a proxy for FFP effectiveness.

MKTSH: market share of an operating carrier on a route, calculated based on the number of passengers traveled.

HHI: route Herfindahl-Hirschman Index, calculated as the sum of the squares of MKTSH.

DUM_C1–DUM_C9: dummies for 9 major carriers: AA, CO, DL, HP, NW, TW, UA, US and WN respectively. The base is non-major carrier.

DUM_T1–DUM_T4: dummies for second quarter of 1991, 1993, 1995 and 1997 respectively. The base year is 1999.

3)*Instrumental variables*

GEOSHARE: carrier's geometric share of the enplanements at the two end cities of the route, calculated as

$$GEOSHARE = \frac{\sqrt{ENP_{x1} \cdot ENP_{x_2}}}{\sum_y \sqrt{ENP_{y1} \cdot ENP_{y_2}}}$$

where x is the observed carrier, and y indexes all carriers that operate on the route, and ENP_{y1} and ENP_{y2} are carrier y's quarterly enplanement at the two end point cities. This is used as instrument for MKTSH.

4) *Miscellaneous*

AVG_FARE: average of the fares for each route carrier and time combination, in 100 dollars.

Table 1. Summary statistics for full sample (N=7104)

Variable	Mean	Std Dev	Minimum	Maximum
Price and dispersion				
GINI	.236	.078	.001	.669
AVG_FARE	3.219	1.373	.507	10.473
Route characteristics				
MILEAGE (10^3)	1.759	1.141	.190	5.448
POP (10^6)	1.260	1.166	.031	5.530
HHI	.676	.248	.197	1
Carrier characteristics				
ENDDOM	.182	.132	.0006	.923
MKTSH	.565	.359	.00008	1
GEOSHARE	.408	.281	.0009	1

Table 2. Summary statistics by groups of MILEAGE and POPULATION

	MILEAGE			POPULATION		
Variable	≤ 1	(1,3]	≥ 3	$\leq .5$	(.5,1]	≥ 1
Price and dispersion						
GINI	.219	.240	.257	.223	.235	.247
AVG_FARE	2.364	3.335	4.547	2.942	3.230	3.422
Route characteristics						
MILEAGE (10^3)	.655	1.781	3.954	1.580	1.710	1.933
POP (10^6)	1.221	1.182	1.630	.355	.760	2.325
HHI	.662	.678	.694	.768	.729	.566
Carrier characteristics						
ENDDOM	.201	.178	.162	.219	.196	.144
MKTSH	.533	.574	.598	.690	.615	.433
Obs	2165	3887	1052	2158	2118	2828

Table 3. Summary statistics by groups of MKTSH and HHI

	MKTSH			HHI	
Variable	$\leq .2$	(.2,.8]	$\geq .8$	$\leq .555$	$> .555$
Price and dispersion					
GINI	.211	.241	.245	.232	.239
AVG_FARE	2.785	3.214	3.492	3.039	3.352
Route characteristics					
MILEAGE (10^3)	1.724	1.718	1.829	1.711	1.795
POP (10^6)	1.843	1.336	.812	1.661	.964
HHI	.570	.493	.953	.435	.854
Carrier characteristics					
ENDDOM	.082	.165	.265	.133	.219
MKTSH	.082	.471	.973	.351	.724
Obs	1584	2960	2560	3021	4083

Table 4. Correlation coefficients (N=7104)

Variable	GINI	MILEAGE	POP	ENDDOM	MKTSH	GEOSHARE	HHI
GINI	1	.145	.080	.156	.148	.206	.082
MILEAGE	.145	1	.149	-.109	.036	-.104	.023
POP	.080	.149	1	-.245	-.342	-.344	-.389
ENDDOM	.156	-.109	-.245	1	.558	.792	.414
MKTSH	.148	.036	-.342	.558	1	.685	.704
GEOSHARE	.206	-.104	-.344	.792	.685	1	.554
HHI	.082	.023	-.389	.414	.704	.554	1

Table 5. Price dispersion regression results

Variable	**with HHI2**	**w/o HHI2**
model →	(A)	(B)
CONSTANT	.042	.073
	(.051)	(.048)
Route characteristics		
POP	.101	.100
	(.038)	(.038)
HHI	.062	-.032
	(.035)	(.013)
HHI2	-.069	
	(.029)	
Carrier characteristics		
ENDDOM	-.065	-.056
	(.044)	(.041)
MKTSH	.085	.079
	(.020)	(.019)
Time dummies		
DUM_T1 (1991)	-.013	-.013
	(.002)	(.002)
DUM_T2 (1993)	-.030	-.030
	(.002)	(.002)
DUM_T3 (1995)	-.042	-.041
	(.002)	(.002)
DUM_T4 (1997)	-.005	-.005
	(.002)	(.005)
Observations	7104	7104
R^2 (overall)	.2161	.2128

Note. Numbers in parentheses are standard errors.

We did all the tests for model A and B. But only test statistic for model (A) is reported below. The test of route effects and the test of random vs. fixed effects are done with and without instrumental variable for MKTSH (market share). Test results: Hausman test statistic for endogeneity: $F(1, 7083) = 72.80$, $\Pr ob > F = 0.0000$. Test statistic for route effects (IV vs. IVGLS (FE)): $F(945, 6140) = 5.46$, $\Pr ob > F = 0.0000$. Hausman test statistic (RE vs. FE): $\chi^2(18) = 176.81$, $\Pr ob > \chi^2 = .0000$.