Price-formats as Sources of Price Dispersion: A Study of Online and Offline Prices in the Domestic US Airline Markets

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Abstract

Research in economics, information systems and marketing has sought to understand sources of price dispersion in both offline and online markets. Our research posits that extant empirical work on price dispersion has largely focused on studying the problem from a consumer perspective, i.e., their ability to search and compare, with additional explanations such as brands and shipping costs. We argue that while these consumer characteristics do play a role, price-related strategies such as price-images adopted by vendors (both online and offline) cannot be ignored in any analyses of online or offline markets, particularly in the study of price dispersion. We study pricing of U.S. airlines that compete in both online and offline markets using price data from over 80% of all domestic routes. Our study shows that even after accounting for all known heterogeneity in airline tickets, price formats adopted by vendors are important sources of price dispersion in both online and offline markets. Further, we find that not only do firms practicing EDLP (Everyday Low Price) strategies lower dispersion of prices by virtue of their consistent pricing approach, but they may also have an indirect effect that lowers price dispersion in the markets they compete in. Firms practicing promotional (HILO/PROMO) strategies tend to have a lower price-range in some types of markets served by EDLP competitors. Our results also find empirical support for oft-debated theoretical observations: First, along the lines of Varian (1980), we find that independent of price formats, price dispersion increases in reservation prices in the market. Second, we categorically show that while there is dispersion of prices online, consistent with lowered frictional cost theories online price dispersion is indeed smaller than that in offline markets.

1. Introduction

Studies of price dispersion provide rich insights into the prevalent heterogeneities in a market. An understanding of this phenomenon is particularly important for vendors who seek to engage in product segmentation, and price discrimination, in competitive markets, While dispersion itself is a core economic concept associated with any competitive market, renewed interested in price dispersion can be largely attributed to the advent of the Internet and online markets for a number of goods and services. It is generally supposed (and rightly to some extent) that on the Internet, consumer search costs would be lowered and a host of information asymmetry issues would go away and hence there would be near convergence in prices (Bakos 1997). However, an empirical truth about markets, electronic or otherwise, is that one always observes dispersion of prices even after controlling for many known sources of product heterogeneities (see (Pan, et al. 2003a) for a comprehensive discussion). The goal of our research is to add to the understanding of price dispersion in both online and offline markets. Our work contends that while an extraordinary amount of focus has been placed on consumer and product oriented explanations, empirical research has largely ignored the role of vendors' price image strategies in explaining price dispersion.

Literature in marketing suggests that firms proactively choose particular price formats as both positioning strategies and means to attract certain types of consumers. These choices are made by firms not necessarily as reactions to competitor prices of specific goods rather they are employed to deliver a certain "price image" to the consumer. For example, it is believed that consumers attach a certain price image to prices ending in 9 (e.g., 44^{49}, 99^{99}) and indeed there are shops called 99¢ stores entirely devoted to products with prices less than $0.99. Similarly another classic price-image strategy is to adopt either an "everyday low price" (EDLP) and

"promotional pricing" (HILO or PROMO) price format. While the goal of former strategy is to attract consumers on the promise that on an average they are likely to find low prices in the store, the strategy of the HILO firms has been to largely attract consumers through deals or discounts on certain featured products. Therefore just as production costs, competitor and market characteristics affect price and hence market-level price dispersion, it would be logical to expect that price dispersion in the markets are also a function of price formats chosen by vendors.

Hence an important task of this research is to examine if one source of price dispersion is the vendors' choice of price-images. Further, we are also interested in investigating how the co-existence of two or more firms each of which practices a different price-format, affects dispersion of prices in the said market. Two other questions that are central to our exercise revolved around empirically examining well known economic concepts. First, are there differences in dispersion of prices in online and offline markets when virtually identical firms compete in both setups? And second, is price dispersion affected by differences in consumers' reservation prices? While these questions have been of interest to researchers even prior to the existence of electronic markets, we would like to reinvestigate them both in the context of today's online markets as well as by accounting for vendors' price-image strategies.

For a number of reasons (discussed in detail in Section …), the US domestic airline industry lends itself to the study of the questions outlined above. Not only do the same firms participate in both online and offline channels, but there are at least two firms that have declared themselves to be adopting the EDLP price format while a majority of the rest engage in HILO strategies. We use a combination of privately-aggregated and publicly available pricing data of airline tickets to examine our research questions.

2. Literature Review

In a seminal work on pricing, Varian (Varian) observed that "… the 'law of one price' is no law at all," implying that there is unlikely to be a convergence of prices even for homogeneous products. There are many theoretical reasons for why price dispersion is likely to persist in any market; these can be broadly summarized into heterogeneity and information asymmetry regarding these differences.

Product Heterogeneity

Product heterogeneity is the most obvious source of price dispersion. Products can be heterogeneous along various dimensions, such as differences in how closely they align with consumers' tastes and preferences (Hotelling 1929, Salop 1979), or differences in quality (Mussa and Rosen 1978). They can also be differentiated with the associated shopping experience, convenience, and services such as delivery and return policy (Smith, et al. 2000). Further, heterogeneity can be introduced into ex ante homogeneous products by incorporating elements that creates switching costs for consumers (Klemperer 1987), which lead to unwillingness of consumers to purchase an otherwise identical product from another seller. The concept of switching cost is closely related to consumer's brand loyalty.

Consumer Heterogeneity

Brand Loyalty and Awareness. Brand is a signal for quality or service levels (Lal and Sarvary 1999). Using game-theoretic analysis, Narasimhan (1988) shows that in a market where consumers are heterogeneous in brand loyalty, price dispersion results from seller arbitrage and randomizing strategies in equilibrium. The predictions of this model have been supported by

empirical findings on price dispersion in electronic markets. Brynjolfsson and Smith (2000) observe that branded retailers and retailers with whom a consumer visited previously hold significant price advantages, and conclude that price dispersion on the Internet may result from heterogeneity in consumer awareness or in retailer branding and trust. Chen and Hitt (2001) demonstrate that the necessary conditions for Bertrand competition to emerge and hence the resulting convergence of prices in a market are full brand awareness and the absence of brand sensitivity, which are unlikely in the Internet context.

Price Knowledge. Varian (1980) identifies two forms of price dispersion, namely spatial price dispersion and temporal price dispersion, that are closely related to the relative portions of consumers who are informed and uninformed about the distribution of prices in the market. In the market with temporal price dispersion, sellers intentionally vary prices over time so that consumers cannot learn by experience about sellers that consistently have low prices. Such randomized pricing strategy is an attempt to discriminate between informed and uninformed consumers; and as long as the cost of acquiring price information is positive, price dispersion persists. Spatial price dispersion occurs in a situation where multiple sellers contemporaneously offer a homogeneous product. An example is Salop and Stiglitz's (1977) study of the coexistence of these two types of consumers in a market of homogeneous products. Salop and Stiglitz show that market equilibrium takes the form with some fraction of sellers sell at competitive price (at average cost) while the rest sell at a higher price (monopolistic price). Although high-priced sellers sell only to uninformed consumers, sufficiently large number of such consumers keeps the business of these sellers. A direct interpretation of Salop and Stiglitz's result is that consumer heterogeneity in price knowledge can be a source of price dispersion.

Search Cost. Instead of assuming consumer types being exogenously determined, Baye and Morgan (2001) extend Varian's model by explicitly modeling consumer's choice of paying a fee to become informed (subscribe to the "information gatekeeper") or remain uninformed (not subscribing). The fees that consumers pay in gaining access to prices listed by different firms can be thought of as the costs associated with searching for these different prices and offerings. An interesting finding in their model is that equilibrium dispersion exists in the homogeneous product market even if all informed consumers purchase from the lowest price seller. The rationale behind this finding is that firms face the tradeoff between charging higher prices and earning higher profits from the uninformed consumers and losing sales from those who have access to prices from other sellers, and thus will randomize prices as long as there is a positive portion of uninformed consumers who will be purchasing at the monopoly price.

Bakos (1997) models the effects of electronic markets on lowering consumer search costs. His main idea is that an electronic marketplace such as the Internet facilitates the exchange of price and product information among participating buyers and sellers by serving three distinct market functions: matching buyers and sellers, facilitating transaction, and providing an institutional infrastructure (Bakos 1998). Bakos posits that electronic markets match buyers and sellers by reducing the costs involved in their search for the right products and the right buyers. Specifically on the buyer's side, such search costs are composed of the opportunity cost of time spent on searching, and the associated expenditures referred to as "access costs" (Bakos 1997). As a result of lowering such costs, market becomes more efficient in terms of decreased ability of sellers to extract monopolistic profits and increased ability of the market to optimally allocate

resources.

Vendor Heterogeneity

Cost. Reinganum (1979) observes that when firms differ in their marginal costs and have perfect information on buyers' reservation prices and demand functions, they behave as monopolistic competitors and offer a distribution of prices that creates price dispersion in the market. Spulber (1995) find that when vendors' costs are different but are known to all competitors in the market, vendors with lower costs will undercut the prices set by others with higher costs, eventually forcing high-cost vendors out of the market and leading to convergence in prices. However, in the more realistic case where asymmetry of information exists, price dispersion would result. Some argue that by making rivals' prices observable, the Internet can potentially increase cost transparency (Sinha 2000) and thus reduce price dispersion.

Branding and Trust. Since transactions on the Internet typically do not involve simultaneous exchange of money and goods, branded retailers and those with whom the consumers trust may extract a premium from consumers who are reluctant to purchase a product from an unknown retailer (Smith, et al. 2000). Therefore, heterogeneity in retailer trust may lead to price dispersion online. Smith and Brynjolfsson (2001) argue that consumers indeed search more among the dominant firms of whom they are aware, allowing such firms to maintain higher prices. This speculation is supported by Bryjnolfsson and Smith's (2000) finding that branded retailers tend to be able to charge higher prices.

In sum, while existing theories have identified various sources of price dispersion, it is apparent from existing empirical studies that heterogeneity alone does not fully explain price dispersion.

The limiting role of heterogeneity in the understanding of price dispersion has been acknowledged at least as far back as the 1960s by Stigler: "a portion of the observed dispersion is presumably attributable to such differences. But it would be metaphysical, and fruitless, to assert that all dispersion is due to heterogeneity." (Stigler, 1961 p.214).

The Role of Price Format

Most product vendors do not price products only with a myopic view of one-time sale and neither do they necessarily react to their competitor's prices in a manner suggesting Bertrand equilibrium. Their practical approach is somewhere in between and one such approach widely discussed in marketing literature is that of maintaining a certain "price image." One way in which firms provide a price image to consumers is through maintaining a certain price format. Existing literature in marketing identifies two basic price formats, namely "Everyday Low Price" (EDLP) and "Promotional Pricing" (HILO). Although researchers argue that these formats are more appropriately regarded as a continuum rather than a dichotomy (Bell and Lattin 1998, Hoch, et al. 1994, Shankar and Bolton 2004), it is commonly agreed that sellers who declare to adopt EDLP tend to charge relatively stable, below average prices with little or no temporary price discounts. These sellers aim to attract consumers who expect "good deals" by creating credibility and a low price image (Bell and Lattin 1998). On the other hand, HILO sellers are promotion-oriented and charge higher prices on average, but engage in frequent promotions that allow prices to fall temporarily below the EDLP price level (Lal and Rao). These sellers aim to price discriminate consumers of different preferences and price knowledge (Blattberg, et al. 1981). Therefore, researchers suggest that EDLP and HILO are more than mere price formats but rather important positioning strategies that attract different types of consumers, e.g., time-

constrained consumers versus cherry-picking consumers (Lal and Rao 1997, Ortmeyer, et al. 1991), and large basket shoppers versus small basket shoppers (Bell and Lattin).

In summary, the goal of an EDLP firm is to give the impression to the consumer that the firm does not vary its prices often and on an average it charges a low price for the goods it sells while that of a HILO firm is to provide the impression to the consumer that it often runs promotions and offers deals that are very lucrative to the buyer. The main goal of the firms adopting these complex price formats is to keep the consumer as less informed as possible. Such conscious strategies are important sources of price dispersion. To study these issues we choose the U.S. airlines operating in the domestic market. The following section presents a set of testable hypotheses related to price dispersion in this market.

3. Conceptual Development

The marketing literature (Bell and Lattin 1998, Ho, et al. 1998, Hoch, et al. 1994) suggests that retailers adopt different price formats to target different consumer segments. Empirical studies have found significant differences in the range and variability in prices offered by sellers adopting different price formats (Ho, et al. 1998, Shankar and Bolton 2004). Moreover, price formats are also positioning strategies (Alba, et al. 1997, Lal and Rao 1997, Ortmeyer, et al. 1991). Differences in sellers' positioning create differentiations among sellers, which potentially enable them to extract price premiums from consumers and therefore increase price dispersion in the market. Therefore, we should expect to see two phenomena: First, the extent to which prices are dispersed differ between vendors who adopt EDLP and those who adopt HILO. Second, markets in which both types of price formats are present exhibit different degrees of price

dispersion compared to markets in which only one type of price format exists.

Hypothesis 1: *The price-image of a firm is a significant source of price dispersion in both online and offline markets.*

In markets where sellers adopting both types of price format coexist, consumer's reservation value could be lower compared to that in markets where only HILO sellers compete. Because EDLP sellers charge relatively consistent prices and make their prices more transparent to consumers, consumers may use them as "references" and the basis for evaluating the "fairness" of prices charged by HILO sellers (Alba, et al. 1997, Ortmeyer, et al. 1991). This implies intensified price-based competition and HILO sellers may react by matching, undercutting, or reducing the discrepancy between their prices and the everyday low prices, leading to decrease in price dispersion in the market. Further, Shankar and Bolton (2004) find that variability in prices of a seller decreases as competitors' prices are lower and more consistent. This suggests that HILO firms may react to the presence of EDLP sellers, who offer lower prices with higher consistency, by lowering their own price variability and hence leading to lower overall price dispersion. Further, their results indicate that a seller's relative brand price increases in competitors' relative price level, implying the range of prices offered a seller would also decrease in the presence of low-price competitors. Therefore:

Hypothesis 2 (H2): *The presence of EDLP competitors constrains the reactions of HILO firms and lowers price dispersion in that market relative to other markets in which EDLP firms do not compete.*

Dynamic price discrimination is characterized by randomized pricing strategies, which is found to be most profitable for vendors selling products that exhibit two characteristics: First, the product is perishable, or expires at a point in time. Second, capacity is fixed well in advance and can only be changed at a relatively high marginal cost (McAfee and te Velde 2004). Airline tickets are an example of products that possess both characteristics, and hence randomized pricing by airlines is generally observed. Further, based on Varian's (1980) model of sales, Baye and Morgan (2004) demonstrate that price dispersion in best-selling consumer electronics products sold in an online intermediary increases as consumers' reservation increases. Since consumers' reservation value for airline tickets increases as the departure date approaches, it is expected that prices of tickets that are closer to the departure date would exhibit higher dispersion, regardless of the specific price formats adopted by the carriers.

Research on price format also yields similar insights. Lal and Rao's (1997) numerical illustration shows that the deal offered by the HILO store increases in the willingness to pay by the consumers. Further, the EDLP store increases its overall discount even at a faster rate compared to the price cut offered by their HILO counterpart. This result implies that not only do price dispersions increase for both EDLP and HILO firms, but the difference also becomes smaller as consumers' reservation increase. For example, the difference in dispersions between EDLP prices and HILO prices are more salient for four-week advance purchase tickets than that of one-week advance purchase tickets.

Hypothesis 3 (H3): *Price dispersion increases with increasing consumer reservation prices in a market.*

Empirical research in online price dispersion concludes that prices remain dispersed over time in various types of electronic markets (Baye, et al. 2002, Baye, et al. 2004, Pan, et al. 2003b, Rachford, et al. 2003). Further, studies that compare the relative magnitudes of price dispersions across online and offline channels find that the dispersion is either more pronounced online compared to offline (Bailey 1998, Brynjolfsson and Smith 2000) or is not significantly different across the two channels (Clay, et al. 2002, Lee and Gosain 2002). Even though price dispersion – by virtue of vendors' constant attempt to price discriminate and their conscious adoption of different pricing strategies – may not completely vanish in electronic markets, lowering of search costs and increased price transparency in the online environment should result in lower price dispersion compared to that in physical markets, ceteris paribus. Controlling for the identical types of markets and products, prices offered by the same sellers that operate in both channels are expected to be less dispersed online than offline.

Hypothesis 4: *Price dispersion will continue to exist in an online market but will be significantly less than that observed in the corresponding offline market.*

4. Data and Method

Two sets of data are employed in this research. The first data set contains prices and descriptions of airline tickets obtained from both online travel agents and individual airline websites. This data includes one- to four-week advance purchase tickets with weekday as well as weekend

departures from the 500 busiest routes in the U.S. As a result, we have collected a total of 1,137,500 individual tickets written by fourteen largest domestic carriers and three regional airlines; accounting for over 86% of all domestic passenger enplanements in the U.S. The second data set is a collection of the Origin and Destination Survey provided by the U.S. Bureau of Transportation Statistics. The data consists of transacted prices of 10% sample of all airline tickets that originate in the U.S. on domestic carriers. To eliminate variations in prices for flights flying the same origin-destination pair due to different number of stops, only direct flights are considered in both samples. We control for four major factors that affect pricing of airline tickets, namely market power, competition, market structure, and cost. Table 1 summarizes the set of variables that are included in the model.

Factor	Variable	Related Literature	Explanation
Price-image Strategy	EDLP	(New variable in the airline context)	**EDLP** = 1 if the observed ticket is written by a carrier adopting the "everyday low price" strategy; 0 otherwise.
Market Power	Hub origin (origihub) or destination (desthub) airport	(Berry et al. 1997; Hayes and Ross 1998, Borenstein 1989,1991)	**origihub (desthub)** = 1 if the origin (destination) airport is a hub for the particular airline offering the ticket; 0 otherwise. Flights originating at hubs appeal to price-inelastic consumers. Hubbing airlines may offer superior service through their control over airport resources, such as more convenient gates and better departure times, most likely valued by business travelers. Further, hub increases entry barriers and drive up prices for hub-originating passengers. It has also been used as a price

			mark-up proxy by Hayes and Ross (1998). On the other hand, hub increases cost efficiency and may reduce price for non-business travelers. Prior literature has found that the earlier effect dominates the latter.
	Frequency (freq)	(Hayes and Ross 1998; Borenstein and Rose 1994)	**freq** is the number of flights scheduled for departure from the origin to destination on a given route by the carrier writing the ticket. Hayes and Ross 1998 use number of scheduled flights as a proxy for average endpoint Herfindahl to capture market share. Higher flight share reflects higher market share, hence market power.
Ticket Characteristics	Number of days of advance purchase (DD7, DD14, DD21)	(Clemons et al. 2002; Stavins 2001; Danna 1998; Gale and Holmes 1993)	**DD7** = 1 if the observed ticket is characterized by 7 to 13 days of advance purchase; 0 otherwise. **DD14** = 1 if the observed ticket is characterized by 14 to 20 days of advance purchase; 0 otherwise. **DD21** = 1 if the observed ticket is characterized by 21 to 27 days of advance purchase; 0 otherwise. Weekend stay-over and advance purchase are restrictions that airlines impose on tickets to discriminate price inelastic consumers (business travelers) from relatively more price elastic consumers (tourists). Baseline comparison is four weeks (28 days or more) advance purchase.
Market Characteristic	Market concentration (mktcon)	(Hayes and Ross 1998; Stavins 2001)	**mktcon** is the total number of airlines offering services (non-stop or indirect) on the observed route. Number of carriers serving a route has been used as a proxy for route Herfindahl to capture market share and as an alternative measure of market competition. The

			higher the concentration in a route, the more intense the competition.
	Slot-constrained airports (slot)	(Berry et al. 1997; Fournier and Zuehlke 2004; Stavins 2001; Verlinda and Lane 2004)	**slot** = 1 if either/both origin and destination airports on the observed route are slot-controlled; 0 otherwise. Slot is a measure of the extent to which one or both the endpoint airports are congested, hence leading to higher opportunity cost of operating in that airport is higher. On the other hand, competition in slot-controlled airports is higher (due to more carriers offering services at these airports). Prior studies find that the effect of slot on price to be inconclusive.
	Distance (shorthaul)	(Hayes and Ross 1998; Berry et al. 1997; Borenstein 1989; Stavins 2001)	**shorthaul** = 1 if the non-stop distance between origin and destination airports on the observed route is equal to or less than 500 miles; 0 otherwise. Costs are directly associated with flight distance, hence longer the distance, higher the price. On the other hand, total distance of a flight varies by intermediate point. As length of a flight increase, there can be more variability in carriers' choices of intermediate airports and lead to higher price dispersion.
Cost	Frequency (freq)	(Berry et al. 1997; Borenstein 1989)	(see definition under "market power") Higher the frequency, lower the per-flight cost; because aircraft utilization is generally greater for the aircraft used on such routes.

Table 1: Explanation of Variables

Empirical Method

We employ hierarchical modeling (HM) for this research as opposed to the traditional least square approach due to potential violation of two critical assumptions of OLS – the independence and homoscedasticity of random errors. Prices of tickets offered by a particular carrier are likely to be correlated because they are written by the same airline with the specific cost structure and pricing strategy. The dependence among observations is also referred to as Intra-Class Correlation (ICC). The OLS assumption of independent errors is violated in the presence of ICC (Kreft and De Leeuw 1998) and the standard errors of the coefficients are underestimated. This raises the risk of type-I error (Pedhazur 1997). Further, since unit-level random error varies across airlines, the assumption of homoscedasticity is also likely to be violated. Hierarchical models extend traditional regression models by taking into account the partial independence of individual observations within the same group as well as the fact that these observations may be more similar to one another compared to those belong to another group.

Two maximum likelihood methods are commonly used in estimating hierarchical models: the full maximum likelihood (ML) and the restricted maximum likelihood (REML). In ML, both fixed effects and variance components are included in the likelihood function. Variance-covariance parameters and second-level fixed coefficients are estimated by maximizing the joint likelihood. In REML, variance-covariance components are first estimated with maximum likelihood that integrates over all possible values of the fixed effects, which are then recovered using generalized least square (GLS) given the variance-covariance estimates obtained from the first step (Goldstein 1995, Raudenbush and Bryk 2002, Raudenbush, et al. 2001). REML

minimizes the deviance of the least squares residuals as opposed to minimizing deviance of the data.

We choose to adopt REML in this research because ML, though consistent and asymptotically efficient, does not adjust for the number of fixed effects that are being estimated; as a result the variance components will tend to be underestimated with small sample sizes or when the number of groups is small (Jones and Steenbergen 1997). Although the data sets we use in this research do not fall into the "small sample size" category, our dependent variables are aggregated measures (such as range and coefficient of variation), the number of observations in some cases reduce to only several hundreds. As a precautionary measure and to be consistent with the majority of research using hierarchical models, REML is employed in our analyses.

Measuring Price Dispersion

The dispersion of prices can be reflected in a variety of measures, such as the difference between the highest and the lowest price, the variance or standard deviation of the distribution. Among the various measures of dispersion, the most representative ones are range and coefficient of variation. These two measures have been widely used in prior literature on price dispersion (Baye and Morgan 2004, Baye, et al. 2003, Carlson and Pescatrice 1980, Sorensen 2000). Although the "raw" measure of variability such as variance and standard deviation have also been used by prior studies on price dispersion (Dahlby and West 1986, Pratt, et al. 1979), the scaled measure, coefficient of variation, is more robust because it is expressed as a ratio to the average price. While two markets may exhibit the same variance in prices, the dispersion is considered more significant in the one where the average price is lower. The rationale is there is

more room for differences in prices when the average price in the market is high, thus the same variance would mean more severe dispersion in a market where prices are comparatively lower.

Models

If sellers' conscious adoption of different price formats contributes as a source of price dispersion as hypothesized, we shall obtain two observations: first, the extent of price dispersion differs between EDLP and HILO sellers (model 1a); second, at the market level, the degrees of dispersions in prices differ between markets in which both types of sellers coexist and those in which only HILO sellers compete (model 1b). Therefore:

Model 1a (Firm-level Variance):

$$\begin{aligned} Disp_{km} = {} & \alpha + \beta_1 DD7 + \beta_2 DD14 + \beta_3 DD21 + \beta_4\, freq_{km} + \beta_5 hub_{km} \\ & + \beta_6 shorthaul_m + \beta_7 slot_m + \beta_8 mktcon_m + \beta_9 \left(EDLP_k \times DD7\right) \\ & + \beta_{10} \left(EDLP_k \times DD14\right) + \beta_{11} \left(EDLP_k \times DD21\right) + \varepsilon_{ikm} \end{aligned} \qquad (1)$$

where

$$\alpha = \gamma_0 + u_{0k} + u_{0m} \qquad (2)$$

$$u_{0m} \sim N\left(0, \varphi\right) \qquad (3)$$

$$\varepsilon_{ikm} \sim N\left(0, \sigma^2\right) \qquad (4)$$

Consistent with Borenstein and Rose (1994), route effects (u_{0m}) are treated as random while airline effects (u_{0k}) are fixed. The dependent variable is separated into two measures of price

dispersion, range[1] and coefficient of variation, at the carrier-route level (*km*). Separate estimations are performed with respect to each of the measures.

Model 1b (Market-level dispersion):

$$Disp_m = \alpha + \beta_1 DD7 + \beta_2 DD14 + \beta_3 DD21 + \beta_4 shorthaul_m + \beta_5 slot_m + \beta_6 mktcon_m + \beta_7 EDLPmkt_m + \varepsilon_m \quad (5)$$

where

$$\varepsilon_{ikm} \sim N\left(0, \sigma^2\right) \quad (6)$$

Similar to model 1a, the dependent variable is separated into two measures of price dispersion, range and coefficient of variation. However, the measures in this model are at the route level (*m*) since the focus of this model is on examining how dispersions differ between markets in which both EDLP and HILO sellers coexist and those where only HILO sellers are present. For this purpose, an additional independent variable ($EDLPmkt$) is introduced to identify the two types of markets. Again, separate models are tested with respect to each of the two measures of dispersion. Notice that since the level of analysis is at the route level (i.e. one observation per route), route and airline fixed-effects are excluded from this model.

Model 2 (HILO firms' reactions):

$$Disp_{km} = \alpha + \beta_1 DD7 + \beta_2 DD14 + \beta_3 DD21 + \beta_4 freq_{km} + \beta_5 hub_{km} + \beta_6 shorthaul_m + \beta_7 slot_m + \beta_8 mktcon_m + \beta_9 EDLPmkt_m + \varepsilon_{ikm} \quad (7)$$

where

$$\alpha = \gamma_0 + u_{0k} + u_{0m} \quad (8)$$

[1] Range at the carrier-route level is adjusted as a ratio to the range of prices in the market.

$$u_{0m} \sim N(0, \varphi) \quad (9)$$

$$\varepsilon_{ikm} \sim N(0, \sigma^2) \quad (10)$$

Though structurally very similar to model 1a, the objective of model 2 is to examine whether there are any differences in the pricing behaviors between the HILO firms in markets where EDLP sellers are present and those where only HILO competes. Again, the *EDLPmkt* dummy is included to identify identifies the types of competitors in the market. Further, since only tickets offered by HILO sellers are included in this model, no EDLP-specific effects are being analyzed.

5. Results

Price Formats as Sources of Dispersion

The results of model 1a are summarized in the first four columns in Table 2. Dispersions in prices of the two EDLP sellers are significantly lower than those of the HILO sellers at the carrier-route level, in both business and leisure tickets. The finding is robust for both dispersion measures, range and coefficient of variation[2]. At the route level, price dispersion in markets where both EDLP and HILO sellers compete are significantly lower than that in markets where only HILO sellers are present (columns 5 to 8). This finding is robust to different dispersion measures and for both business and leisure tickets.

From these results, we can conclude that price format is a significant source of online price dispersion. To show the second part of the hypothesis on offline price dispersion, we perform

[2] With the exception of one of the EDLP sellers (EDLP2) for whom the range of prices for three-week advance purchase business tickets is indeed wider than that of HILO sellers

similar analyses on a different set of data that consists of purchased price data from both online and offline channels.

The last four columns in Table 2 present the results from the DB1B data. When both online and offline channels are considered, differences in price dispersions between EDLP and HILO sellers are still observable. However, the results are slightly different compared to the previous analysis with online pricing data. While the coefficients of variation remain lower for EDLP sellers, the range of prices offered by EDLP sellers is either not significantly different exceeds that by HILO sellers. One potential explanation could be that for EDLP1, majority of business tickets sales are made one or three weeks prior to departure, which contribute to increase in price dispersion as measured by price range according to the results reported in models 1a and 1b. Unfortunately, without information on Saturday-night stay restriction and the actual purchase and departure dates of the tickets, this cannot be verified.

In terms of overall price dispersion in the market (last two columns), the results from transacted prices suggest that dispersion in markets where both EDLP and HILO sellers coexist is lower, by both measures of dispersion. This result is consistent with that found in online pricing data. In sum, results from these four analyses show that price format is a significant source of price dispersion in both online and offline contexts. Therefore, hypothesis 1 is strongly supported.

HILO Reactions

Results of model 2 are summarized in Table 3. Only limited evidence is found on the speculation that pricing patterns of HILO sellers differ with respect to the presence of EDLP

competitors. Except for price range in business tickets, no significant difference is observed among the dispersions in HILO prices in markets where EDLP sellers participate and those they do not. Therefore, hypothesis 2 is not supported.

Consumers' Reservation

Results from model 1a and 1b (columns 1 to 8, Table 2) allows us to draw inferences on the hypothesized relationship between online price dispersion and consumer's reservation. According to results in Table 2, price dispersion is found to be higher as the departure date approaches at the carrier-route level (columns 1 to 4). However, this result is observed in business tickets only. While the dispersion measured by coefficient of variation increases with consumer reservation for both business and leisure tickets, there is no evidence that the range of prices varies across the four weeks of advance purchase. Further, the relative dispersions of EDLP prices and HILO prices do not vary systematically with respect to increasing reservation; there is no evidence that EDLP prices become more or less dispersed compared to HILO prices as departure date approaches.

On the other hand, there is strong evidence that price dispersion increases with consumer's reservation at the route level (Table 2, columns 5 to 8). Both measures of price dispersion increase as the departure date approaches. This observation is robust with respect to both business and leisure tickets. The results validate the theoretical predictions of Varian's (1980) model of sales and the interpretation by Baye (2003) that as consumer reservation increases, so does dispersion of prices in the market. Hypothesis 3 is partially supported.

Online vs. Offline Price Dispersion

To test the last hypothesis, analyses were performed separately on each of the price dispersion measures. First, t-test is performed on the range of prices for each carrier-route observation between the two data sets. Second, F-test is performed on the ratio of variances. Variance is used in place of coefficient of variation as the second measure of price dispersion because of its desirable distributional properties. Variance for large sample has a Chi-square distribution, and the ratio of variances has an F-distribution, allowing for a straight forward statistical test of the equality of variances drawn from the two samples. The results are summarized in Table 4.

Range of purchase prices in both online and offline channels are significantly wider compared to posted prices on the Internet; the variance of the former is also higher than that of the latter majority of the time (averaging over 80%). The results are robust at both route and carrier-route level measures of dispersion, offering strong support for hypothesis 4.

6. Discussion

Our analyses yield two important observations on the relationship between price format and online price dispersion. First, dispersions in prices of sellers who adopt the EDLP strategy are lower compared to those who adopt the HILO strategies. Second, price dispersions in markets where EDLP sellers are present are lower compared to those where only HILO sellers compete. Both of these results are found to be robust for both online and offline contexts and thus offer strong support to the hypothesis that price format is a source of price dispersion in both online and offline markets.

While the majority of research in online price dispersion focuses on attributing the differences among online vendors' pricing behaviors to their reactions to consumer heterogeneity and competitive forces in the market, the analysis on dispersion in HILO sellers' prices presented in this study shows that dispersions in HILO prices do not vary across markets where EDLP competitors are present and those where they are not. This finding suggests that conscious adoption of price formats is a choice that sellers *proactively* make, rather than a reactive response. The results offer support for the theoretical argument of random pricing theory in explaining price dispersion, which largely lack empirical support in the existing literature.

Results from the analysis on the relationship between consumer's reservation value and price dispersion indicate that price dispersion is higher among products for which consumers have higher willingness to pay, demonstrating that this holds true also in the context of perishable products, such as airline tickets, that are typically characterized by promotional pricing. This suggests that though a firm's pricing behavior is largely governed by the price format it chooses, there are similarities in the pricing patterns of firms regardless of their price formats, in that all firms tend to extract as much surplus from the consumers as possible by discriminating against those who are less price-elastic.

In the comparison of the degrees of price dispersion in online versus offline contexts, both the range and variance of prices are found to be significantly lower in electronic markets. This study is one of the first to show that while price dispersion still exists online, the dispersion is indeed smaller compared to that in the offline context. The results offer support to the theoretical prediction that due to lowering costs of search and increased price transparency, prices in

electronic markets are less dispersed compared to those in physical markets. Our study demonstrates that in relatively mature online markets such as those observed in the airline industry, frictional costs continue to exist. Our findings confirm that part of these frictional costs is attributed by the fact that firms adopt different price formats that can effectively prevent consumers from gaining full knowledge on available prices despite the low search costs in electronic markets.

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	Offered Prices								Transacted Prices[3]			
	Model 1a				Model 1b				Model 1c (N=1837)		Model 1d (N=497)	
	BUSINESS (N=6491)		LEISURE (N=6526)		BUSINESS (N=1844)		LEISURE (N=1844)					
	Range	CV	Range	CV	Range (raw)	CV	Range (raw)	CV	Range	CV	Range (raw)	CV
Intercept	0.8480***	0.0278	0.9406***	0.1306***	13.46	0.0473***	55.29*	0.1068***	0.4587***	0.3860***	776.42***	0.4726***
DD7	0.0442***	0.0779***	-0.0081	0.0738***	130.91***	0.0634***	155.62***	0.0705***	--	--	--	--
DD14	0.0629***	0.05054***	-0.0112	0.0632***	45.54***	0.0357***	110.10***	0.0670***	--	--	--	--
DD21	0.0138	0.02812***	-0.0137	0.0007	28.28*	0.0227**	2.55	0.0068	--	--	--	--
freq	0.0017***	0.000222***	0.0022***	0.0003***	--	--	--	--	0.0012***	0.0000	--	--
hub	0.0287*	0.02326***	0.0679***	0.0139**	--	--	--	--	0.4118***	0.1034***	--	--
shorthaul	-0.0295	-0.0060	0.0040	-0.0039	-30.76***	-0.0074	-51.37***	-0.0077	0.0716***	-0.0146	-457.63***	-0.0409***
slot	-0.1462***	0.02566***	-0.1079***	0.0341***	72.23***	0.0559***	90.09***	0.0656***	0.0726***	0.0314**	53.59	0.0151
mktcon	-0.0219***	0.0019	-0.02524***	-0.0020	11.50***	0.0057***	12.38***	0.0038*	-0.0109**	-0.0006	67.80***	0.0077**
DD7*EDLP	0.1277**	-0.03692**	0.0655	-0.0430**	--	--	--	--	--	--	--	--
DD14*EDLP	0.0775	-0.0316*	0.0455	-0.0497***	--	--	--	--	--	--	--	--
DD21*EDLP	0.1661***	-0.0019	0.1041**	0.0265	--	--	--	--	--	--	--	--

[3] Since there is no information on when the tickets were purchased (in terms of days prior to departure) in the DB1B data, all time dummies (DD7, DD14, DD21) and their interactions with EDLP are excluded from the modified models

EDLP1	-0.3490***	-0.0587***	-0.3457***	-0.112***	--	--	--	--	0.0971**	-0.1712***	--	--
EDLP2	-0.1415**	-0.0158	-0.2113***	-0.0743***	--	--	--	--	0.0756	-0.1039***	--	--
EDLPmkt	--	--	--	--	-82.29***	-0.0294***	-99.19***	-0.0475***	--	--	-549.43***	-0.1926***

Table 2: Price Dispersion and Price Format

	BUSINESS		LEISURE	
	Range	**CV**	**Range**	**CV**
Intercept	0.7004***	0.0300	0.7795***	0.1304***
DD7	0.0441***	0.0779***	-0.0079	0.0738***
DD14	0.0630***	0.0506***	-0.0110	0.0632***
DD21	0.0136	0.0281***	-0.0137	0.0008
freq	0.0036***	0.0003**	0.00335***	0.0004***
hub	0.0070	0.0239***	0.0528***	0.0149**
shorthaul	-0.0513	-0.0066	-0.0282	-0.0087
slot	-0.1422***	0.0250**	-0.0801***	0.0363***
mktcon	-0.0091	0.0012	-0.0117*	-0.0027
EDLPmkt	-0.1531***	0.0145	-0.0261	0.0258

Table 3: Results of Model 2 – Reactions by HILO Sellers

	Range (H_0:Equal Ranges)	**Variance Ratio (H_0: Equal Variances)**	
		5% significance	**1% significance**
Route Level	Rejected (p<0.001)	Rejected (Variances are different 79.49% of the time)	Rejected (Variances are different 81.20% of the time)
Carrier-Route Level	Rejected (p<0.001)	Rejected (Variances are different 82.20% of the time)	Rejected (Variances are different 84.20% of the time)

Table 4: Online vs. Offline Price Dispersion

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