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Scheduled Delays? Scheduled Time Competition and On-Time Performance In the Airline Industry

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Introduction

Firms compete aggressively against each other when demand is stagnant. They compete across the marketing mix to increase market share, retain customers, and improve profitability, such as the case of the airline industry. A lot of attention has been on the industry's overall financial performance and its increasingly cutthroat price competition after deregulation, as a result of multiple major airlines' in and out of bankruptcy protection and increased access of price information and comparison due to the emergence of online reservation services. Airline service performance has also become a focal point of the industry wide competition (Mazzeo 2003 for example). In particular, flight delays have attracted strong interest lately because of the large-scale breakdown of JetBlue's control systems and wide spread of delays in the busy markets across the U.S. While weather was to be partially blamed for the delays, JetBlue's management and customer service strategies play a more important role.

Time-based competition in the airline industry has been studied both from the perspective of airline strategies and from the perspective of customer services. In fact, research has found that airlines implemented "departure-time crowding" strategies in response to increased competition (Borentein and Netz 1999). Major airlines have been reported to have better on-time performance on the more competitive routes (Rupp, Owens, and Plumly 2003). These findings raise more questions about airlines' competitive behavior and strategies. For example, for airlines under tremendous pressure to improve financial performance after 9/11, their average on-time performance has actually declined since 2002, from 81.27% to 76.75% in 2005 (Bureau of Transportation Statistics 2005). Given that on-time performance is considered a main factor leading to customer satisfaction, why would airlines respond to the increased competition by a lower on-time performance level? Even if airlines have little control over a flight's actual travel time, they can choose to have a longer flight scheduled time to improve the perception and perhaps satisfaction of their customers for a given level of flight time variation (Mayer and Sinai 2003b). Since adjusting scheduled flight time costs close to nothing to the airlines but could increase airlines' on-time performance, this should have been the struggling airlines' dominant strategy in improving their service perception without hurting their bottom lines. However, this simple solution of increasing scheduled flight time seems to have two problems that might prevent it from being implemented—first, airlines may be constrained by the availability of aircraft and therefore tend to shorten flight scheduled times to improve turnaround times (Mayer and Sinai 2003b); second, increasing a flight's scheduled time may reduce its chance to be selected among a few similarly scheduled fights. For example, Northwest Airlines allows a potential traveler to sort online search results by price, scheduled flight time, and departure time. A longer scheduled flight time puts the flight at a less than favorite spot in the list. Many online service providers such as Orbitz.com also use this approach facilitate online search of flights.

The first issue is an efficiency issue while the second is a customer acquisition and retention issue—airlines set flight scheduled times to appeal to customers who are sensitive to time when selecting a flight, and the likelihood that this customer will be retained depends partially on how satisfied the customer feels after the trip is finished. Hence, reducing flight scheduled times to attract more time sensitive customers will more likely disappoint them because the flights tend to have poor on-time performance, for given actual flight times. This posts a tradeoff for airlines when competing to acquire customers and to retain existing customers. This issue also provides an opportunity for better understanding interactions between customer acquisition, which focuses on current market demand, and customer retention, which captures future values of customers. Despite the importance, little has been done to directly link decisions on scheduled flight time to airline on-time performance. In the broader marketing literature concerning customer relationship management, it has been shown that customer acquisition and customer retention can be related (Thomas 2001). However, the nature of such interactions and their effect on firm strategies are largely untapped. In this study, we focus on investigating this connection for the airline industry. We first establish a game theoretic framework, in which airlines compete on price and flight scheduled time to attract potential passengers. The airlines' on-time performance factors in as a form of future market payoffs, where any delay of a flight will reduce a passenger's willing to return to the airline. Therefore, each airline has to balance its scheduled flight time and expected on-time performance in the competition. In addition, we analyze airline-operating data to study empirically whether such a connection exists and in what pattern it exists.

The rest of the paper is organized as follows: The next section will review related literature. Section 3 will develop the basic game-theoretical model to capture the airline customer acquisition and retention trade-offs through schedule time and pricing competition. Section 4 extends the basic model to a two-dimensional utility function with scheduled time and expected delays. Section 5 develops some basic hypotheses through our analytical model results, and tests it with empirical airline data. Section 6 summarizes our findings.

Related Literature

This section reviews two main streams of research that is closely related to our study. The first is a stream of recent research in economics that studies airline on-time performance, pricing, competition, and other time related issues such as airline departure time. The second is a number of recent studies regarding customer acquisition and customer retention in the customer relationship management literature.

The research on airline on-time performance and scheduled time competition has attracted an increasing attention recently. Borenstein and Netz (1999) have found a negative and significant relationship between competition and scheduled time differentiation. This finding confirms a common observation that airlines tend to cluster their flights in a certain period of time, and is also consistent with predictions made by product differentiation theories, such as the Hotelling model. The fact that airlines and airline ticket online consolidators such Orbitz.com provide searches results sorted by departure time to certain extent validates the assumptions that travelers choose departure time in addition to price to book a flight, and that airlines respond by moving their scheduled departure time closer to each other. The recent research on airline on-time performance has reported mixed findings. Rupp et al. (2003) find that competitive routes tend to have slightly higher on-time performance and shorter fight delays. This result is supported by Mazzeo (2003), which also shows a positive relationship between competition and airline service quality. Both argue that airline on-time performance is a measure of airline customer service, which should improve under competition. On the other hand, Mayor and Sinai (2003a and b) find that delays are actually longer on more competitive routes and at hub airports. They argue that the increased delays on the more competitive routes are because of a scheduling strategy deployed by airlines to set a tight flight schedule to minimize labor costs and improve operating efficiencies. This scheduling strategy in fact sets scheduled travel time to average actual block time and does not allow for any variations due to weather or customer preferences. These conflicting empirical findings also limit their value in understanding airline behavior in price and quality competition because they provide little information to help explain the alternative findings.

This research attempts to extend the above literature by establishing an airline competition model that includes both price and scheduled fight time, with a belief that the above findings might very well be different outcomes of an airline behavioral pattern under different conditions. We also conduct an empirical analysis to further study this issue.

The second line of research is the customer acquisition and customer retention literature in marketing that has gained much attention recently. Customer acquisition and customer retention are critical components of customer relationship management (CRM) (Gupta, Lehmann, and Stuart 2004), with a goal to attract new customers and to retain the existing customers who might leave (Verhoef 2003; Bowman and Narayandas 2004). The current studies in the related literature have indicated that both customer acquisition and customer retention aim to increase a firm's market share by selling products to more customers subject to marketing resource constraints (McGahan and Ghemawat 1994; Thomas 2001). Therefore balancing and allocating resources between customer acquisition and customer retention can be a challenge (Reinartz et al. 2005). Aggressive marketing actions of some carriers in the cellular phone industry to attract customers by offering them exclusive deals might reduce customer satisfaction of their existing customers and encourage these customers to leave. Similarly, in the airline industry, a shorter scheduled fight time may appeal to potential customers by setting up a higher expectation. However, since the actual flight time is constrained by technical and efficiency factors, particularly on a short route, a shorter scheduled flight time increases the possibility of delay and therefore reduces customer satisfaction and discourages customer retention. While marketing literature has recognized the existence of a connection between customer acquisition and customer retention, it is unclear how such a connection could affect airlines' decisions and strategies in the competition at route level.

This research contributes to marketing literature by focusing on the potential affect of customer acquisition decision—reducing scheduled flight time on customer satisfaction and customer retention performance—increasing airline delays under airline competition. We examine customer preference and market conditions under which airline competition on price and scheduled flight time would lead to different scenarios that could explain strategic behavior of airlines.

The Basic Model

We consider a market where two airlines (i = 1, 2) compete on price (p_i) and scheduled flight time (T_i). Consumer utility function is modeled in the following two formats. First, the utility function depends only on price p_i and scheduled time T_i, both known to the consumer as public information. Such information is available on most airline websites and other major air ticket booking websites such as Orbitz.com. Second, more and more websites have included average on time percentages on past flights that indicate expectations of on time performance of future flights. To reflect this change, we will add expected delays in the consumer utility function. We will focus on the simple utility function first and expand discussions based on results from the two dimensional, e.g. scheduled time and expected delay, utility function.

The actual flight time, t_i, is random and can either be t^H or t^L. The joint distribution of the actual flight times, t_1 and t_2, is given in Table 1. It is reasonable to assume that $t^L \le T_i \le t^H$. In other words, airlines only schedule their flight times within the actual range of flight times. Barring any other reasons beyond the scope of this study, it is unnecessary to schedule flights too long or too short. (since many of our results are dependent on this assumption, we should further justify it and speculate a bit about what might happen if this assumption is not true).

The utility function is given as $U = V - \theta T_i - p_i$, where V is the reservation price. Consumer preferences over scheduled flight time are distributed uniformly over $[\underline{\theta}, \overline{\theta}]$. This utility function contains only consumer's scheduled time but will also include expected delays in the following section as an extension of the current model. The consumer population is normalized to one and the marginal consumer is indifferent at $\tilde{\theta} = (p_2 - p_1)/(T_1 - T_2)$. It is assumed that $T_1 \ge T_2$, to follow the convention.

The demand function for the airlines can be derived as $D_1 = (\tilde{\theta} - \underline{\theta})/(\bar{\theta} - \underline{\theta})$ and $D_2 = (\bar{\theta} - \tilde{\theta})/(\bar{\theta} - \underline{\theta})$.

In addition to the price competition, we examine the following three aspects of flight times that affect customer value, airline operations and therefore airline strategies. As the results indicate, these three aspects play significant roles in airline decisions, market differentiation, and on-time performance.

Sources of Flight Time Uncertainty:

For any given scheduled flight time, delay may occur due to the intrinsic uncertainty of the flight. In our simplified case, delay is possible when the scheduled flight time is less than t^H. There are various factors affecting the actual flight time of a flight. Some are common factors shared by all airlines on a route, such as weather conditions and security reasons, while some others are specific to individual airlines, such as aircraft delays due to mechanical problems and labor dispute. According to BTS, weather delays accounted for 0.92% of all flights in the U.S. in September 2006; delays for security reasons were 0.06%; aircraft delays were 5.74% (Figure 1). The nature of uncertainty, common vs. airline specific, may contribute to airlines' strategy when scheduling for their respective flights (Mazzeo 2003). In this study, the uncertainty in the actual flight times of the two flights is represented in a joint distribution (Table 1), although some main results are drawn from the cases of perfectly correlated flight times and independent flight times. Specifically, when the actual flight times are perfectly correlated, $\gamma_{LH} = \gamma_{HL} = 0$, $\gamma_{HH} = \gamma$, and $\gamma_{LL} = 1 - \gamma$. When the flight times are independent, $\gamma_{LH} = (1-\gamma_1)\gamma_2$, $\gamma_{HL} = \gamma_1(1-\gamma_2)$, $\gamma_{HH} = \gamma_1\gamma_2$, and $\gamma_{LL} = (1-\gamma_1)(1-\gamma_2)$.

Expected Delay:

Given the joint distribution in Table 1, the expected delay for airline 1 relative to airline 2 can be written as

$$\delta_1 = \gamma_{HL} \max[(t^H - T_1), 0] + \gamma_{HH} \max[(t^H - T_1) - (t^H - T_2), 0] = \gamma_{HL}(t^H - T_1) .$$

Similarly, the expected delay for airline 2 relative to airline 1 can be written as

$$\delta_2 = \gamma_{LH} \max[(t^H - T_2), 0] + \gamma_{HH} \max[(t^H - T_2) - (t^H - T_1), 0]$$
$$= (\gamma_{LH} + \gamma_{HH})(t^H - T_2) - \gamma_{HH}(t^H - T_1) .$$

The relative delay will increase the likelihood of the consumer who is dissatisfied with the delay to switch to the other airline in this duopoly market. Therefore, the potential costs of delay should include the potential loss of long-term value of the consumer (Thomas, Blattberg, and Fox 2004; Blattberg 1981). Define this lost customer value as $c_i \delta_i^2$. This convex cost function is consistent with existing marketing literature.

<u>Efficiency of Scheduled Flight Time</u>:

In addition to the cost of relative delays, the airlines also incur potential efficiency loss due to long scheduled flight times. As indicated earlier (Mayer and Sinai 2003), longer than operationally optimal scheduled flight times lead to higher labor and other costs. For simplicity, we further assume that t^L is the most cost efficient for a scheduled flight time so that any time longer than t^L will increase costs of operations for the airlines. Therefore, reducing scheduled flight times leads to efficiency gains for the airlines. Denote the marginal cost of a longer scheduled time as e_i. The total cost of efficiency loss of a scheduled flight time T_i is $e_i (T_i - t^L)$.

The airlines first choose their scheduled flight times and then decide on their prices to maximize the following objective functions.

$$\max_{T_i, p_i} \Pi_i = p_i D_i - c_i \delta_i^2 - e_i (T_i - t^L) .$$

The equilibrium prices are given as follows,

$$p_1 = \left\{(\bar{\theta} - 2\underline{\theta})(T_1 - T_2)\right\}/3.$$
$$p_2 = \left\{(2\bar{\theta} - \underline{\theta})(T_1 - T_2)\right\}/3.$$

The airlines solve for the equilibrium scheduled flight times from

$$\pi_1 = \left\{(\bar{\theta} - 2\underline{\theta})\right\}^2 \frac{(T_1 - T_2)}{9(\bar{\theta} - \underline{\theta})} - c_1[\gamma_{HL}(t^H - T_1)]^2 - e_1(T_1 - t^L), \text{ and}$$

$$\pi_2 = \left\{(2\bar{\theta} - \underline{\theta})\right\}^2 \frac{(T_1 - T_2)}{9(\bar{\theta} - \underline{\theta})} - c_2[(\gamma_{LH} + \gamma_{HH})(t^H - T_2) - \gamma_{HH}(t^H - T_1)]^2 - e_2(T_2 - t^L).$$

The Nash equilibrium scheduled flight times for the two airlines are

$$T_1 = t^H + \frac{(\bar{\theta} - 2\underline{\theta})^2}{18(\bar{\theta} - \underline{\theta})c_1\gamma_{HL}^2} - \frac{e_1}{2c_1\gamma_{HL}^2}, \text{ and}$$

$$T_2 = t^H + \frac{-(2\bar{\theta} - \underline{\theta})^2 c_1\gamma_{HL}^2 + (\bar{\theta} - 2\underline{\theta})^2 c_2(\gamma_{LH} + \gamma_{HH})\gamma_{HH}}{18(\bar{\theta} - \underline{\theta})c_1c_2(\gamma_{LH} + \gamma_{HH})^2\gamma_{HL}^2} - \frac{e_2c_1\gamma_{HL}^2 + e_1c_2(\gamma_{LH} + \gamma_{HH})\gamma_{HH}}{2c_1c_2(\gamma_{LH} + \gamma_{HH})^2\gamma_{HL}^2}.$$

These results indicate that the potential efficiency gains from a shorter scheduled time (e_i) and correlation between the flight times (γ_{ij}) drive the airlines' scheduled time decisions. When the flights are perfectly correlated, or $\gamma_{LH} = \gamma_{HL} = 0$, $\gamma_{HH} = \gamma$, and $\gamma_{LL} = 1 - \gamma$, the results can be simplified and derived as follows. For Airline 1, whose scheduled flight time is longer, if $\frac{(\bar{\theta} - 2\underline{\theta})^2}{9(\bar{\theta} - \underline{\theta})} - e_1 > 0$, $T_1 = t^H$, and if $\frac{(\bar{\theta} - 2\underline{\theta})^2}{9(\bar{\theta} - \underline{\theta})} - e_1 < 0$, $T_1 = t^L$. For Airline 2, since the First Order Condition indicates that $\frac{-(2\bar{\theta} - \underline{\theta})^2}{9(\bar{\theta} - \underline{\theta})} + 2c_2\gamma^4(T_1 - T_2) - e_2 = 0$, when $T_1 = t^L$, $T_2 = t^L$ as well. If $T_1 = t^H$, however, $T_2 = t^H - \frac{(2\bar{\theta} - \underline{\theta})^2}{18(\bar{\theta} - \underline{\theta})2c_2\gamma^4} - \frac{e_2}{2c_2\gamma^4}$ when

$\frac{-(2\bar{\theta} - \underline{\theta})^2}{9(\bar{\theta} - \underline{\theta})} + 2c_2\gamma^4(t^H - t^L) - e_2 \geq 0$, otherwise $T_2 = t^L$.

In the following, we discuss some of the important findings and implications.

Proposition 1. When Airline 1's ($T_1 \geq T_2$) efficiency gains from a shorter scheduled time are sufficiently large, (a) both airlines set their scheduled flight times as (t^L, t^L) if their actual flight times are perfectly correlated; and (b) the airlines differentiate their scheduled flight times, if the actual flight times are independent.

This result indicate that the nature of flight uncertainties can lead to different patterns of scheduled flight times at equilibrium—one differentiated and the other not, under sufficient but modest potential efficiency gains from a shorter scheduled flight time. When this benefit of shorter scheduled times is less overwhelming, the attributes of consumer preferences in scheduled times and airlines' long term customer value reach a delicate balance determined by the nature of flight uncertainties. When the actual flight times are highly correlated, the airlines become less different, other things being equal. Under the forces of reducing scheduled flight times to gain efficiency and satisfy customers, the airlines follow similar strategies by moving to the lowest scheduled times possible. The potential benefits of retaining customer by reducing expected delays are undervalued and therefore eliminated as both choose the same scheduled times (no relative delays). On the other hand, when the actual flight times are more independent, the airlines become less similar, amplifying the benefits of using customer retention, via fewer delays, as a differentiation strategy. This finding emphasizes the importance of understanding nature of uncertainty airlines are facing and the potential outcomes such uncertainty may lead to in a competitive market.

The balance between consumer preferences, of a shorter scheduled time, and airlines' interests of keeping customers satisfied, by fewer delays, is destroyed when the airlines become highly sensitive to potential gains from its improved operational efficiency due to a shorter scheduled time. Airlines may be under substantial financial pressure so much so that any efficiency boost is highly valued and desired, particularly when they are under Chapter 11 protection, for example. Airlines may be operating on a busy route connecting from, and/or to, an overly congested airport, leading a disproportional efficiency gain from a small reduction in scheduled time. The following result indicates a different outcome of the airline competition.

Proposition 2. When efficiency gains from a shorter scheduled time are sufficiently large for both airlines, both will reduce their scheduled flight times to (t^L, t^L), regardless of correlations of their actual flight times.

This result in consistent with the empirical findings reported in Sinai and Mayor (2003), where the authors attribute increased flight delays as a result from airlines increased efforts to improve efficiency, rather than an outcome of market competition. Our result, however, shows that this outcome can be a scenario of market competition (on price and scheduled time in particular) when potential efficiency gains from shorter flight scheduled times are dominant. Furthermore, our results predict a more differentiated outcome of this competition, when the potential efficiency gains from shorter scheduled times are much less dominant.

Proposition 3. When Airline 1's efficiency gains from a shorter scheduled flight time are sufficiently small, both airlines differentiate their scheduled flight times to a similar degree, regardless of correlations of their actual flight times.

The nature of flight time uncertainties again does not determine the degree of differentiation as an outcome of the competition. In this case, when the airline that has longer scheduled flight time (Airline 1) cannot generate sufficient gains from a shorter scheduled time, airlines differentiate their scheduled times so that they can fully benefit from the tradeoff between consumer preferences of a shorter scheduled time and the expected delays caused by the shorter scheduled time. When the pressure of the efficiency gains from shorter scheduled times is less intense, the flights on a route should present more diversity in terms of scheduled time, to the extent to which market competition is played out. This result is consistent with the empirical findings in Mazzeo (2003), Rupp, et al (2003), both of which report significant effect of competition in airlines' scheduled time decisions, and to a certain degree, Borenstein and Netz (1999), which finds effect of horizontal differentiation as an outcome of competition on scheduled time allocation. This effect of competition is to the contrary of what Sinai and Mayor (2003) reports where efficiency concerns are found to be the only reason why scheduled times are consistently shorter than they should be, and delays are prevalent in the airline industry.

The above set of results provide a more complete picture as to what airlines could do to respond to their needs to improve efficiency, satisfy customers who prefer shorter scheduled times, and maintain or improve customer satisfaction and retention by reducing delays. The previous empirical findings, though appearing to be contradicting to each other in some cases, actually represent different possible outcomes of airline competition that involves price and scheduled time. In other words, competition does matter, leading shorter but varied scheduled times depending on nature of flight uncertainty and efficiency gains for shorter scheduled times. However, uniformly short scheduled times can also be a likely outcome of the competition when efficiency concerns and expectations from shorter scheduled times become dominant against other balancing factors. Finally, a fully differentiated market, in terms of scheduled time, is still a possibility if the potential efficiency gains from shorter scheduled times are not overwhelming. These results provide some implications that are empirically testable. However they are based on a simplifying assumption that consumers are not aware of expected delays of possible flights they are choosing from. This assumption, while helpful in allowing clear and closed form solutions, may limit the strength of the findings. In the following sections, we first expand the model to replace the consumer utility function with one that is two-dimensional in a consumer's evaluation of scheduled flight time (scheduled time and expected delay). We then empirically test implications of some of the findings.

Two-Dimensional Utility Function with Scheduled Time and Expected Delays

A more informed and sophisticated consumer will consider both scheduled flight time and expected on-time performance, when such information is available, when making a decision to choose between two flights. On-time performance information has been made available on many websites such as Travelocity.com and Orbitz.com, where a flight's on-time performance history is summarized to provide an estimate that could form an expectation of its future on-time performance. A potential traveler then could make a more informed decision based on more available information.

To incorporate the on-time performance information into consumer's decision-making, we consider a two-dimensional utility function that retains the scheduled flight time from the previous model, and includes expected delay as an additional factor. The new utility function can be written as

$$U = V - \theta T_i - \lambda\beta(t^H - T_i) - p_i = V - \lambda\beta t^H - (\theta - \lambda\beta)T_i - p_i ,$$

where $\beta(t^H - T_i)$ is the consumer perceived amount of airline delay, with the consumer perceived probability of High flight time as β while the perceived probability of Low flight time as $1-\beta$. The consumer's perceived High flight time probability could be different from the airline's actual flight time probability γ_1 or γ_2. Assume consumer's scheduled time preference indicator, θ, and the delay preference indicator, λ, are both distributed uniformly over the interval [0,1]. Define $\rho = \theta - \lambda\beta$, which will follow a triangular distribution with a probability density function (p.d.f.) of

$$g[\rho] = \begin{cases} 4(\rho+\beta)/(1+\beta)^2, & \text{if } -\beta \le \rho \le (1-\beta)/2 \\ 4(1-\rho)/(1+\beta)^2, & \text{if } (1-\beta)/2 \le \rho \le 1 \end{cases},$$

and cumulative distribution function (c.d.f.) of

$$G[\rho] = \begin{matrix} 2(\rho+\beta)^2/(1+\beta)^2, & \text{if } -\beta \le \rho \le (1-\beta)/2 \\ 1-2(1-\rho)^2/(1+\beta)^2, & \text{if } (1-\beta)/2 \le \rho \le 1 \end{matrix} .$$

Using the convention that $T_1 \ge T_2$, the demand functions of the airlines can be written, respectively, as

$$D_1 = G[\tilde{\rho}] = G[(p_2 - p_1)/(T_1 - T_2)],$$

$$D_2 = 1 - G[\tilde{\rho}] = 1 - G[(p_2 - p_1)/(T_1 - T_2)].$$

With the airline profit functions unchanged, the First Order Conditions can be stated as

$$G[(p_2 - p_1)/(T_1 - T_2)] - g[(p_2 - p_1)/(T_1 - T_2)] * p_1/(T_1 - T_2) = 0,$$

$$1 - G[(p_2 - p_1)/(T_1 - T_2)] - g[(p_2 - p_1)/(T_1 - T_2)] * p_2/(T_1 - T_2) = 0.$$

From the First Order Conditions,

$$\frac{(p_2 - p_1)}{(T_1 - T_2)} g[(p_2 - p_1)/(T_1 - T_2)] = 1 - 2G[(p_2 - p_1)/(T_1 - T_2)],$$

or more generically, $\tilde{\rho} g[\tilde{\rho}] = 1 - 2G[\tilde{\rho}]$.

Applying the distribution forms stated earlier, we have two possible results:

(1) For $-\beta \le \tilde{\rho} \le (1-\beta)/2$, $\tilde{\rho} * 4(\tilde{\rho}+\beta)/(1+\beta)^2 = 1 - 2*2(\tilde{\rho}+\beta)^2/(1+\beta)^2$. Since $-\beta < \tilde{\rho}$, $\tilde{\rho} = -3/4\beta + \sqrt{(3/4\beta)^2 + (3\beta+1)(1-\beta)/8}$.

(2) For $(1-\beta)/2 \le \tilde{\rho} \le 1$, $\tilde{\rho} * 4(1-\tilde{\rho})/(1+\beta)^2 = 1 - 2 + 2*2(1-\tilde{\rho})^2/(1+\beta)^2$, and $\tilde{\rho} = 3/4 - \sqrt{(3/4)^2 - (3+\beta)(1-\beta)/8}$.

Given this distribution, the objective functions can be rewritten as

$\pi_1 = G^2(\tilde{\rho})/g(\tilde{\rho})(T_1 - T_2) - c_1[\gamma_{HL}(t^H - T_1)]^2 - e_1(T_1 - t^L)$, and

$\pi_2 = [1 - G(\tilde{\rho})]^2/g(\tilde{\rho})(T_1 - T_2) - c_2[(\gamma_{LH} + \gamma_{HH})(t^H - T_2) - \gamma_{HH}(t^H - T_1)]^2 - e_2(T_2 - t^L)$.

Airlines' Nash equilibrium scheduled flight times are therefore solved as

$$T_1 = t^H + \frac{G^2(\tilde{\rho})/g(\tilde{\rho}) - e_1}{2c_1\gamma_{HL}^2} \text{, and}$$

$$T_2 = t^H - \frac{[1-G(\tilde{\rho})]^2/g(\tilde{\rho}) + e_2}{2c_2(\gamma_{LH}+\gamma_{HH})^2} - \frac{\gamma_{HH}}{(\gamma_{LH}+\gamma_{HH})}(t^H - T_1).$$

While similar results can be derived once the specific distribution is applied in the above equations, the use of multi-dimensional utility function, which has both scheduled flight time and expected delay factored into the consumer's choices, can provide the following additional implications.

Proposition 4. If the efficiency gains from shorter scheduled times are sufficiently small (large) for both airlines, the degree to which the airlines differentiate their scheduled times is smaller (larger) when the utility function includes expected delay than when the utility function is one-dimensional.

If scheduled time differentiation is small under the one-dimensional utility function based on scheduled flight time, a result from sufficiently large efficiency gains airlines may expect from shorter scheduled times, the addition of expected delay to the utility function should reduce the pressure for the airlines to shorten their scheduled times motivated by the potential efficiency gains. This is because the consumer prefers a shorter expected delay when choosing flights, and shorter expected delays require longer scheduled times, which works against the other dimension of consumer preference (scheduled flight times). The balance established with the one-dimensional utility between a longer scheduled time, which reduces the chance and costs of delays, and a shorter scheduled time, which improves airline operational efficiency and is preferred by the consumer, is tipped toward the longer scheduled time, allowing for more likely differentiation of scheduled time. By the same token, if the marketing is already differentiated in schedule flight time under the one-dimensional utility function, resulted from sufficiently small efficiency gains from shorter scheduled times, the difference between the scheduled times will be reduced when both scheduled times are moved toward the upper limit of scheduled times (t^H). This finding suggests that the declining differentiation in scheduled flight times, as reported by many (Sinai and Major 2003, for example), may also be related to the increasing availability of airline delay information.

The following results apply to both utility functions.

Proposition 5. The larger the customer value lost from delays for Airline 1, the longer the scheduled flight times for both airlines. The larger the efficiency gains from a shorter scheduled time for Airline 1, the shorter the scheduled flight time for both airlines.

The pressure for Airline 1, who has the longer scheduled time, to schedule a shorter flight in order to achieve efficiency gains is alleviated when the airline also faces a higher potential loss of customer value when delays occur, which is more possible with shorter scheduled times. The balance for Airline 1 therefore shifts toward a longer scheduled time. This increase in Airline 1's scheduled time offers an opportunity for an increase in scheduled time by Airline 2, who has a shorter scheduled time than Airline 1, without changing the degree of differentiation. Similarly, when the efficiency gain from a shorter scheduled time is greater for Airline 1, who has a longer scheduled time, Airline 1 naturally tends to reduce its scheduled time. It is interesting that when Airline 1 reduces its scheduled time, Airline 2 will reduce its own scheduled time as well. This is because by doing so, Airline 2 can improve its efficiency gains from a shorter scheduled time, and it can do so without losing additional customer value since it maintains the same expected delay relative to Airline 1.

Proposition 6. The larger the customer value lost from delays for both airlines, the less differentiated the scheduled flight times when Airline 1 has a higher efficiency gain from a shorter scheduled time, but the more differentiated when Airline 2 has a higher efficiency gain.

When both airlines have higher customer values to lose when delays occur, a higher efficiency gain by Airline 1 can compensate to a certain extent the force that drives Airline 1's scheduled time longer. However, the same force does not exist for Airline 2, whose scheduled time therefore will move closer to where Airline 1's scheduled time is with the motivation to gain customer value from reduced delays. Alternatively, when only Airline 2 faces a higher efficiency gain, Airline 1 is better off moving its scheduled flight time even longer while Airline 2's incentive to increase scheduled time is limited by the loss of efficiency, which is higher for Airline 2, from the longer scheduled time.

In summary, the above findings have shown airlines' potential efficiency gains from shorter scheduled times play an important role to lower scheduled times, and when such gains are sufficiently large, they could push the scheduled times to the lowest possible and eliminate scheduled time differentiation, which is consistent with Sinai and Mayor (2003). However, scheduled time differentiation remains a likely outcome of airline competition when efficiency gains from shorter scheduled times are not dominant. In fact, airlines can find, in equilibrium, scheduled times to differentiate the market and benefit from improved customer retention. Furthermore, the nature of flight uncertainty and consumer utility function can also lead to differentiation of scheduled times, reported in Mazzeo (2003) and Rupp, et al. (2003). In the following section, we draw some empirical implications from the above results and test them with airline operations data. The empirical results provide a certain degree of validation to some results and some additional observations of firm strategies in the airline industry.

Theoretical Implications and Empirical Analysis

The implications from the above results can be further examined empirically to either provide validation of these results or to create relevance of these results to the airline industry. Specifically, we focus on a few important aspects of the previous results to generate some empirical implications. First, our previous results have identified the potential importance of efficiency gains from shorter scheduled times to an airline, and demonstrated that when such gains increase airlines tend to reduce their scheduled times, which ultimately reduces scheduled time differentiation. Although all airlines value efficiency improvement if scheduled time can be reduced, some may be more sensitive to such gains than others, and we argue that those under higher financial pressure to improve operational performance tend to benefit more from any efficiency boost a reduced scheduled time may provide. Therefore, airlines under financial pressure should be more willing to reduce scheduled flight times at a cost of losing customers and customer value in the long term. Furthermore, for airlines operating on a certain route, the more airlines under such financial pressure, the shorter the scheduled flights for all airlines on the route.

Second, as the previous results indicate, different long-term customer values to the airlines lost due to delay have a direct impact on airline decisions of scheduled times and the outcome of airline competition. On a route where most travelers are business travelers, scheduled times are more important but delays could cost much more than on a route where most are leisure travelers. According to our earlier findings, customer value lost due to delay may more likely increase scheduled flight times at equilibrium so that potential delays can be reduced. Empirically, we identify routes by the extent to which the travelers on these routes are tourist travelers. We believe that such travelers have a generally lower sensitivity to delays, a lower level of loyalty, and a lower long-term value to airlines since they are likely bargain hunters. Therefore, flights on these routes tend to be scheduled at shorter flight times but have a higher level of delays.

Third, while our models based on airline competition lead to scenarios in equilibrium where airlines on a route reduce scheduled times to the minimum without differentiation, therefore supporting the empirical findings in Sinai and Mayor (2003), other scenarios point to differentiated outcomes that are sensitive to competition, supporting the findings in Mazzeo (2003) and Rupp, et al. (2003). It would be useful then to empirically examine the direct impact of airline competition after controlling for the above factors. The empirical findings could potentially contribute to more complete understandings of airline competitive strategies in terms of scheduled time planning.

The empirical model used is as follows.

$$\begin{aligned} \textit{Scheduled Time} = {} & b_0 + b_1 \textit{Distance} + b_2 \textit{HHI} + b_3 \textit{Hub-O} + b_4 \textit{Hub-D} + b_5 \textit{Tour-O} \\ & + b_6 \textit{Tour-D} + b_7 \textit{Congestion-O} + b_8 \textit{Congestion-D} + b_9 \textit{Bankruptcy} \\ & + b_{10} \textit{Bankruptcy-Other} + \Sigma\beta_\iota \textit{Day} + \Sigma\beta_\varphi \textit{Hour} + \Sigma\beta_\kappa \textit{Airline} + \varepsilon \end{aligned}$$

Table 2 shows the details of variable definition.

The data used for this analysis were collected from three sources. The data regarding airline operations, including routes and distances, flight schedules and times, airport information, etc., are from Department of Transportation, Bureau of Transportation Statistics (On-Time Performance). Information of daily flights in June 2006 was collected and used in the analysis. The final dataset consists of the 8 major airlines and top 50 U.S. domestic markets/routes that were direct and served by multiple airlines. Airline financial status data were collected from 2nd Quarter 2005 to 2nd Quarter 2006, from DOT, Bureau of Transportation Statistics (Airline Financial Data). Origin and destination travel and tourism contributions to the respective city's

Gross Metro Product (GMP) were obtained from a report submitted to the US Conference of Mayors by DRI-WEFA (2002?). The report ranks the top 100 metropolitan areas based on their percentages of GMP generated from travel and tourism sectors. Table 3 provides a summary statistics of the data.

Regression results are presented in Table 4. First, Herfindahl Index is negative and significant, indicating competition does lead to shorter scheduled times, others thing being equal. This result supports the findings in Mazzeo (2003) and Rupp, et al. (2003), and is consistent with our analytical result. The importance of this finding is it confirms the role of competition in airline scheduled time decision while accounting for the possibility that airlines choose to minimize their scheduled times in response to serious financial pressure. This result integrates two contrasting arguments under the framework of vertical competition, and provides insights into airline competition with respect to price, time, and customer satisfaction and retention.

Second, an airline's financial pressure may not be sufficient for the airline to significantly reduce scheduled time, as indicated by the insignificant Bankruptcy. However, as such pressure increases, with more airlines under Chapter 11 protection, airlines begin to reduce scheduled times to compete for customers and improve efficiency. This result also provides support to Sinai and Mayor (2003), which argues that cost efficiency airlines can gain from reducing scheduled times drives shorter scheduled times and more delays. Our results indicate that this argument is valid when the efficiency gains become more critical as airlines fight for survival under substantial financial pressure.

Third, on routes with more tourists airlines determine their scheduled times in an interesting way. Flying into a tourist city, for example, airlines tend to have shorter scheduled times. Tourists value shorter scheduled times to start their vacations more than higher possibilities of delay because the cost of delay is less important. This shows an effect of customer value to airline decisions. Tourists tend to have lower loyalty toward a certain airline and can be more price sensitive. This tendency reduces their long-term value because their next trip is more uncertain as to when, where, and flying which airline. Delays at the tourist destination therefore will not cause much damage to the airlines. On the other hand, returning from a vacation may increase a tourist's value toward delays because they are well award of the regular schedules they are facing back from vacations. The positive and significant coefficient shows this is the case.

Finally, the coefficient of Distance is positive and highly significant, which is expected. Airport congestion, as measured by average taxi time in and out of an airport, is also positive and highly significant, indicating the airlines' approach to increase scheduled times to respond to airport congestion. It is also interesting to notice that the scheduled times are affected much more when a flight leaves a congested airport than when it arrives in one. The reason can be that the arriving flight can make adjustment in the air given the scheduled time and the degree of congestion while the departing flight is not close to be as flexible. After controlling for airport congestion, the role of Hub in explaining scheduled times becomes a matter of connecting flights. And the coefficients of the destination airport being a hub, positive and significant, and the origin airport being a hub, negative and significant, show this connecting effect. When the destination airport is a hub or gateway airport, more customers tend to be connecting travelers, and therefore more sensitive to flight delays because they have connection time constraints. On the other hand, customers leaving a hub are more likely to arrive at the final destination of the trip, and therefore are less sensitive to potential delays and may value on time performance less. This finding is hence another evidence that customer value toward delay plays an important role in airline scheduled time decisions.

Conclusion

This research studies airline competitive strategies, through game theoretic and empirical analysis, regarding airline decisions in scheduled flight times. The importance of this decision is it not only allows airlines to attract customers, with a shorter time, but it also helps airlines retain the potentially lost customers, with a longer time. The balance of the two forces is further affected by airlines' potential gains from reducing scheduled times to achieve better efficiency. Past research has found conflicting results when some showed strong evidence of airline competition while others argued that scheduled times had been reduced to minimum and there had been no room for competition (Mazzeo 2003; Rupp, et al. 2003, Sinai and Mayor 2003, etc). Our results indicate that, while airlines may be under substantial pressure to improve their efficiency and therefore could choose to minimize their scheduled times, airline competition, over price and scheduled time, can still be very much in play. In fact, the shortest and indifferent scheduled times in a highly competitive market can be a natural outcome of the competition when the financial pressure faced by the airlines is sufficiently strong. This finding, analytical as well as empirical, integrates the previously contradicting findings and provides a significant contribution to understanding airline, and generally firm, behavior in time-based competition.

Second, the nature of uncertainty faced by firms, airlines in our case, can be an important factor. That is, different sources of uncertainty between competing airlines may lead to a more differentiated outcome from the scheduled time competition, while similar sources tend to result in less differentiation. Our analysis shows that when financial pressure to improve efficiency is not as dominant, the nature of uncertainty in airline flight times becomes significant in determining how airlines choose to set their scheduled times.

Third, lost long-term values dissatisfied customers may cause due to delays also have a profound impact on firm strategies—scheduled flight times in the airline industry. Our game theoretic analysis shows that this long-term value plays a role that balances the force from the efficiency pressure to reduce scheduled times, allowing for more differentiated outcomes of the competition. This finding is supported by the empirical results based on the effects of airline hubs and tourist routes on scheduled time differences.

This research contributes to marketing literature as follows. First, it proposes a time-based game theoretic model based on the vertical differentiation framework with regard to price and scheduled time, applying to the airline industry. The modeling approach combines different factors such as price, scheduled time, delay, and efficiency gain/loss in the game and results in insightful strategic implications for the airline industry and other similar industries (examples). Second, this study incorporates customer retention effects into consumer preferences and firm decision processes. Airline delays affects consumer choices of flight and customer value from retention airlines can capitalize in the long-term. Therefore consideration of this customer retention method changes firm behavior and optimal strategies. Third, using airline industry as a background, this research provides in-depth understandings into airline strategies and competition. Specifically, the analytical and empirical findings confirm the argument that firm competition is still a driving force for airline performance and strategies, contrary to other arguments that efficiency concerns may be the only reason for the increasing delays in the airline industry.

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Table 1: Joint Distribution of Actual Flight Times

t_1 \ t_2	t^L	t^H	
t^L	γ_{LL}	γ_{LH}	$1-\gamma_1$
t^H	γ_{HL}	γ_{HH}	γ_1
	$1-\gamma_2$	γ_2	

Figure 1: Sources of Flight Delays

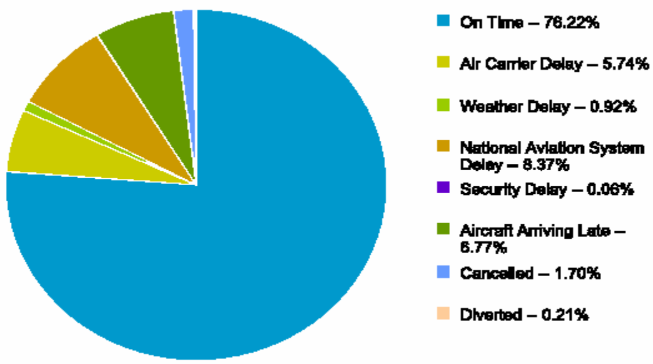

Table 2. Definition of Variables in the Empirical Analysis

Variable	Definition
Scheduled Time	The scheduled flight time between the flight's scheduled departure time and scheduled arrival time
Distance	The non-stop Radian measured distance of a city pair
HHI	Herfindahl Index based on flight frequency shares
Hub-O	Origin airport is a hub of an airline or a gateway airport
Hub-D	Destination airport is a hub of an airline or a gateway airport
Tour-O	Origin city's travel and tourism contribution in the city's Gross Metro Product (GMP)
Tour-D	Destination city's travel and tourism contribution in the city's Gross Metro Product (GMP)
Congestion-O	Origin airport's average taxi time
Congestion-D	Destination airport's average taxi time
Bankruptcy	Airline under Chapter 11 protection
Bankruptcy-Other	Number of other airlines on the same route under Chapter 11 protection
Day	Day of week
Hour	Hour of day (from 5am to 11pm)—arrival time block
Airline	Airline dummies

Table 3. Descriptive Statistics

	Mean	Standard Deviation	Maximum	Minimum
Scheduled time (Min)	149.56	74.94	549	45
Distance (Mile)	912.66	622.34	4,243	95
HHI	0.4861	0.1430	0.9865	0.1862
Hub-O	0.6323	0.4822	1	0
Hub-D	0.6301	0.4828	1	0
Tour-O	0.0622	0.0569	0.0273	0.0220
Tour-D	0.0622	0.0569	0.0273	0.0220
Congestion-O				
Congestion-D				
Bankruptcy	0.5439	0.4981	1	0
Bankruptcy-Other	0.5152	0.6068	3	1

Table 4. Regression Results (Standard Deviation in Parentheses)

	Parameter Estimates
Intercept	16.1156*** (0.2039)
Distance (Mile)	0.1184*** (0.0000)
HHI	-2.1657*** (0.1594)
Hub-O	-2.7724*** (0.0458)
Hub-D	4.2906*** (0.0506)
Congestion-O	1.1836*** (0.0039)
Congestion-D	0.1727*** (0.0109)
Tour-O	-4.5606*** (0.3565)
Tour-D	7.3576*** (0.3558)
# of Bankruptcy	-1.5041*** (0.0435)
N Adjusted R^2	16,7966 0.9895