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Market expansion, cannibalization, and international airline pricing strategy

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Abstract

We analyze market response and pricing of air travel on the Paris–Abidjan, Ivory Coast route operated by a French airline, Union des Transports Aeriens (UTA). We measure the impact of price on the overall size of the market, and examine the nature, pattern, and extent of cannibalization using a set of econometric models for overall passenger volume and for each fare class share. Our analysis shows that (1) only one class of fares expands the market; (2) cannibalization is very significant and highly asymmetric; (3) even small deviations from optimal prices substantially reduce profit. Based on these estimated models, we forecast demand for air travel and calculate optimal fares. We discuss how these models and results were used by UTA and the impact they had on pricing strategy.

Keywords: Pricing; Market response; Air travel; Optimization

1. Introduction

In the mid 1980s, Union des Transports Aeriens (UTA) faced many of the same difficult forecasting and pricing problems in its Paris–Abidjan, Ivory Coast, route that other airlines faced in markets around the world. Air fares differed dramatically; the price of a seat could vary by as much as 150% on the same flight. Customers were a diverse lot, differing in price sensitivity with respect to the decision to travel and willingness to trade off lower prices for travel restrictions. Recognition of segment differences had produced a large and growing number of fares; in all, 20 different fares were offered on every flight. Competition was limited to one other scheduled airline, Air Afrique. Unlike some markets (e.g. US markets), Air Afrique and UTA jointly set prices and flight schedules.[1]

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[1] It is important to note that many airlines face very limited if any competition in many other markets worldwide, including US markets. Perceived as intensely competitive since deregulation (Kahn, 1989), many US markets are characterized by little if any competition. For example, seven of 20 major hubs can be reached from New York City on only one airline and competition on 12 of the remaining is severely limited in that two airlines control at least 84% of passenger volume (Pevsner, 1989).

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Large differences in price sensitivity across customer segments, limited competition, and many fares available in limited numbers created opportunities but also challenges for forecasting and pricing. Some fares might be raised without threat of competitive retaliation and without reducing the overall number of passengers (e.g. full fares without travel restrictions). However, if the difference between lower, more restrictive fares and full fares was sufficiently great, travelers might switch to less expensive fares, cannibalizing revenues without expanding the market. On the other hand, low discount fares might expand the market, but increase cannibalization. Forecasting the impact of prices on market size and the pattern of cannibalization, and then balancing these forces to design a set of optimal prices, is a very difficult managerial problem, especially given constraints such as fleet size, plane configuration, and government regulation.

This situation created a need for UTA to develop a system to forecast demand and then use this forecast to evaluate their current pricing strategy. In particular, UTA focused on developing a forecasting system that could be useful for gaining insights into important questions in three areas:

(1) Market expansion. Does each fare expand the market and, if so, by how much? With a large number of fares and diverse customers, it is quite likely that some fares will expand the market. Identifying which fares expand the market and by how much is important for forecasting and pricing.

(2) Cannibalization. What is the extent and pattern of cannibalization induced by different fares and the current fare structure? Cannibalization was an acknowledged factor, but little is known about its pattern (which fares were drawing travelers from which other classes of travel) and the size of these effects, which are central for both forecasting and pricing.

(3) Profits. How can pricing be improved to increase profit? This question raises both tactical and strategic issues. The tactical issue is, can the impact of prices be forecast so prices are better managed *within* the current pricing structure (number of fares, type of restrictions, etc.)? The broader strategic issue is, should a new pricing strategy be considered? If so, what deficiencies in the current one should it attempt to correct and, more generally, what features should it have?

This paper reports the results of our analysis of these issues in the context of the Paris–Abidjan route. Our analysis consists of response modeling, forecasting, and optimization. We first construct response models for total volume and for the fare class share. The models have a number of interesting features, including the ability to capture the impact of all prices on overall passenger volume and the highly asymmetric patterns of cannibalization, in a simple system of fare class share models flexible enough to accommodate seasonality and useful for forecasting and for calculating optimal prices.[2] We estimate these models to show the impact of fares on overall passenger volume, to identify the pattern and extent of cannibalization induced by the current fare structure, and we explore their usefulness in forecasting overall demand for air travel and for travel in each fare class.

Based on this system of response models, we calculate optimal air fares for the Paris–Abidjan route and forecast response at those optimal fares. Our approach relies on a model of airline profit based on our estimated response models, integrated with the prevailing constraints on fare availability and fleet size. We derive an optimal pricing rule for a line of air fares if the availability of each is limited, and then calculate optimal prices. Comparing optimal and actual prices in a forecast sample, we show that our results are useful for forecasting and for managing prices. Our models forecast well, and the optimal prices

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[2] More generally, our response models capture the impact of pricing on intrabrand competition in which cannibalization is substantial, an important issue as the number of line extensions increase. Others have addressed asymmetric competition (e.g. Carpenter et al., 1988; Blattberg and Wisniewski, 1989), but less has been done on the integration of market expansive effects, asymmetric intrabrand competition, and optimal pricing.

implied by them produce a substantial profit gain over actual prices in a forecast sample.[3]

We discuss how UTA management used our models and results at the tactical and strategic level. At the tactical level, we provide precise answers, such as what are optimal prices given market response and what will be the number of passengers traveling at each fare class, making our analysis suitable for use as a forecasting and decision support system. At the strategic level, we provide qualitative insights into one central question: is UTA's current pricing strategy optimal? We discuss how managers valued both the precise answers and qualitative insights generated by our analysis. This provides an important perspective into how managers use or do not use models such as the ones described here.

We begin with a discussion of the airline pricing issues, and the specific problems issues in the Paris–Abidjan market. Following that, the market response models are presented and estimated in Section 3. Section 4 discusses the results of that analysis, which are then used to calculate optimal prices in Section 5. In Section 6 we present forecasts based on actual and optimal prices. The impact the analysis had at UTA is discussed in Section 7, followed by a summary.

2. The Paris–Abidjan air travel market

2.1. Pricing issues

The fare structure in the Paris–Abidjan market shares much with other markets. A fare in this market is the price of a ticket that can be purchased for immediate travel or for future travel at current prices. The number of fares is large. Some fares have analogues in other markets, such as full fare without restrictions and discount fares with advance purchase and minimum-stay requirements. Other fares are controlled by the government (e.g. for medical and military personnel) as a result of UTA's partial government ownership. In all, over 20 fares exist; most are set by UTA. With additional background from UTA management we combined these 20 fares into three major categories.

2.1.1. Full fare

Full fare enables travel without restriction. This is the most expensive fare, and is often used by business travelers, including French executives living in Ivory Coast who travel on business and vacation to France. Other important users of this fare are French residents traveling to the Ivory Coast for vacation, especially in winter and summer months. Given the high level of prices, lowering these fares was not expected to expand the market, but differences with lower-priced fares raised an important cannibalization issue because this was their highest margin fare.

2.1.2. Discount fare

Discount fare enables travel at rates lower than full fare but with travel restrictions, including advance purchase and minimum-stay requirements (e.g. 7-day advance purchase, Saturday night stay required). Cannibalization of full-fare revenue by discount fares was likely, according to UTA. The discount over full fares can be substantial (40% below full fare was common), and the fare is widely available, subject only to requirements imposed by one's travel schedule. This fare was initiated to attract new customers to the route. However, the extent of the impact of discount fares on the size of the market or the cannibalization of revenues from full-fare passengers had not been measured.

2.1.3. Deep-discount fare

Deep-discount fares, required by government

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[3] Our pricing analysis provides results useful for managing intrabrand price competition. We derive a general rule for optimal product-line pricing that generalizes previous models and extends them to the case in which quantities of each item in the line are limited (e.g. Urban, 1969; Reibstein and Gatignon, 1984). Integrated with our market response models, this optimal pricing rule illustrates how cannibalization can be managed with prices.

regulation, enable travel at rates below discount fares but with additional restrictions. The actual restrictions vary by specific group, but in comparison with discount fares, deep-discount fares typically require longer advance purchase periods and a longer minimum stay. For these greater restrictions, the discounts are substantial; deep-discount seats could be purchased for less than half of the full fare, and larger discounts are available at times. Many deep-discount fares are limited to specific groups, such as members of the clergy, military, and medical personnel. Also, significantly, the deep-discount fare was available to families traveling together. In many cases, members of these special groups still had to satisfy travel restrictions.

This situation creates a fuzzy picture with respect to the impact of deep-discount fares on the market size and on the proportion of travelers flying at higher prices. Being cheaper, deep-discount fares were most likely to expand the market, but their ability to do that is limited by the restrictions imposed on who has access to the fares. The extent of cannibalization was likewise unclear. For instance, some corporations with French employees living in the Ivory Coast offered them vacation travel to France as a benefit. This may be offered as an allowance equivalent to full fare for the employee (and possibly other family members, depending on the employee's position) but use restricted for travel. So an employee may opt to use the allowance to pay full fare, or he or she may search for a less expensive fare and, travel restrictions permitting, receive the difference between full fare in cash. Thus, employees and other families in general have a strong incentive to shop for the lowest fare. Cannibalization of full-fare revenues may be substantial if a large number of families search for low fares, or it could be insignificant if too few travelers have access to these fares. In either case, cannibalization can not be ruled out a priori.

2.2. Data

Our data consist of monthly observations on fare class shares, fares for each class, and the total number of seats sold for the 48 months between January, 1981 and December, 1984. We will use the first 41 months of data as a calibration or development sample to estimate our market response models and the remaining 7 months of data as a forecasting sample. Average passenger volumes and fares (in deflated January, 1977 French francs) for the development sample (January, 1981 through May, 1984) appear in Table 1. The data show the substantial magnitude of discounts as reflected in the relative index or the percentage each fare is of the full fare. Discount fares average 59% of the full fare and deep discount seats average only 40% of the full fare. Five deep-discount tickets can be purchased for the same outlay as two full fare seats, which is attractive for families.

Other factors affecting air travel during this period such as economic conditions were fairly stable. Flight schedules did vary from a winter schedule (17 round trips weekly) to a summer schedule (19 trips); we control for these seasonal differences. Passenger load factors varied from 57 to 61%. Advertising focused heavily on price and other factual information; no major cam-

Table 1
Data summary, Paris–Abidjan air travel market

	Full fare	Discount fare	Deep-discount fare
Average passengers	7045	4155	4016
Average real price	2346	1385	931
Relative index	100%	59%	40%
Average seat share	0.45	0.28	0.27

paigns or different appeals were launched during this period. Data on these other factors were only available at the annual level and, therefore, could not be included in this study. Because of the stability of these factors, excluding them should be of little consequence.

3. Modeling market expansion and cannibalization

To address the issues of central importance, the response model was required to have three key features:

(1) Differential impact of fares on market size. Given prior beliefs about the possibly different impact of full, discount, and deep-discount fares on the overall market size, the model must capture and estimate these differences if they exist.

(2) Asymmetric cannibalization. A central concern of UTA in this case is to measure the extent of cannibalization and to identify it's pattern. The expectation was that cannibalization would be highly asymmetric. Full fare passenger volume, for instance, may be more strongly affected by discount than deep-discount fares, given the greater access to discount fares and the fewer restrictions imposed. In terms of the model, this requires unique response parameters for each fare class, in addition to allowing for different or unequal cross-price coefficients to reflect asymmetries in response.

(3) Usefulness for optimal pricing. The ultimate objective of UTA was to evaluate their pricing structure and, depending on the results of the analysis, revise the fare levels or even the fare structure itself. Thus, the models as a whole must provide qualitative insights but at the same time be capable of producing optimal prices given the response structure.

The response model chosen to satisfy these conditions is a set of log-linear equations for the total volume of passengers and for the fraction traveling at each fare class:

$$Q_t = \exp(A_0 + \Sigma_j A_j p_{jt}) \qquad (1)$$

$$m_{it} = \exp(B_{i0} + \Sigma_j B_{ij} p_{jt}) \qquad (2)$$

where Q_t is the total passenger volume at time t, m_{it} is the fare class share or share of passengers flying at fare i at time t, p_{jt} its price, and A_j and B_{ij} are response parameters.

This system has a number of appealing properties for our application. The responsiveness of total volume can vary by fare class. The total volume elasticity with respect to fare j at time t for Eq. (1) is $D_{jt} = A_j p_{jt}$. Thus, different prices can have a different impact on total volume depending on both the response parameter and the price level. Furthermore, each fare class share has a unique price elasticity and cross-price elasticities that can be asymmetric. The elasticity describing the impact of the price of fare class j on the fare class share for fare class i based on Eq. (2) is $E_{ijt} = B_{ij} p_{ijt}$, which implies that the elasticity varies with the fare class's price and its response parameter. Moreover, it is generally asymmetric: $E_{ijt} = E_{jit}$ only if $B_{ij} p_{jt} = B_{ji} p_{it}$, which is unlikely. In addition, the elasticities can vary over time to reflect changes in the responsiveness of total volume, the pattern of cannibalization, or seasonality.

Though Eqs. (1) and (2) are well suited for this application, time series analysis of the data indicate they need modification because of strong seasonality. Inspecting the autocorrelation functions of passenger and air fares reveals that the autocorrelations persist at lags of 12-month intervals, so we reformulate the models in terms of seasonal ratios (differences in logs) that have well-behaved autocorrelation functions in this case. This approach ensures that the seasonality in demand and prices do not confound the results (Hanssens et al., 1990, p. 136). The reformulated model is

$$Q_t / Q_{t-12} = \exp\left[\alpha_0 + \Sigma_j \alpha_j (p_{jt} - p_{jt-12})\right] \qquad (3)$$

$$m_{it} / m_{it-12} = \exp\left[\beta_{i0} + \Sigma_j \beta_{ij} (p_{jt} - p_{jt-12})\right] \qquad (4)$$

where Q_{t-12} is total passenger volume lagged 12 months, m_{it-12} is fare class share lagged 12 months, α_i and β_{ij} are the new response parame-

Table 2
Parameter estimates*

Variable	Total volume	Fare class share		
		Full fare	Discount fare	Deep-discount
Constant	−0.047[b]	−0.016	−0.006	0.097[c]
Full fare	0.328	−1.033[a]	0.162	0.948[c]
Discount fare	0.254	0.800[a]	−1.299[b]	1.132
Deep discount fare	−0.657[a]	0.379[b]	0.518[b]	−0.711[c]
Lagged error term	−0.322[c]	−0.051	0.356[c]	0.351[c]
R^2	0.43	0.64	0.48	0.39

* One-tail statistical significance is indicated as [a]($P < 0.01$), [b]($P < 0.05$) and [c]($P < 0.1$), except for the intercept (two-tail). R^2s are for seasonal difference models, shown in Eqs. (3) and (4). Full fare, discount fare, and deep-discount fare coefficients are multiplied by 1000 for presentation.

ters where $i = 1$ for full fare, $i = 2$ for discount fare, $i = 3$ for deep discount, and other variables are as before.[4]

Eq. (4) lacks a natural sum and range constraint, but for this application that is an advantage. A sum and range constrained fare class share model, like the multiplicative competitive interaction (MCI) model, makes predictions in the [0, 1] interval that sum to one. However, seasonal transformations of the fare class share data can destroy their sum and range constraint properties. In contrast, Eq. (4) easily accommodates seasonality and, moreover, we can impose sum and range constraints as needed in the optimization. Therefore, Eq. (4) is a flexible and appealing system for the problem at hand.

4. Measuring market expansion and cannibalization

We estimate Eqs. (3) and (4) using the 41 months of data from our development sample (January, 1981 through May, 1984). Eqs. (3) and (4) form a set of linear (in logarithms) seemingly unrelated equations all of which contain identical explanatory variables. For such systems, ordinary least square methods produce unbiased, efficient estimates. However, since the OLS residuals were not always free of autocorrelation, the models were reestimated using an additional lagged error term using the Cochrane–Orcutt method. Table 2 shows the parameter estimates and goodness of fit measures. The models fit well. Although reported R^2s based on the seasonal difference models are modest, R^2s for the untransformed models exceed 0.90.

To illustrate volume and seat share sensitivities to fare changes, we simulated the effects of various 10% fare increases, using the average fares, seat shares and passenger volumes for comparison. We discuss the results below, along with presenting the qualitative significance of the parameter estimates.

4.1. Passenger volume

The total volume of passengers responds principally to the deep-discount fare. Lower deep-discount fares evidently expand the market, attracting more families and other special groups of travelers. This remains true even though not all travelers have access to deep-discount fares. Discount fares, within the range observed, do not significantly increase the market size even though discount fares average 60% of full fares. This result was surprising. It suggested that the discount fares did not achieve

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[4] It is possible that air fares 'lead' passenger volumes so that a distributed lag relationship exists between the two. We checked this hypothesis empirically by formulating a response model with current and one-period lagged prices. The F-test on the joint significance of lagged prices was not significant in three of four cases. In the one exception (full-fare passengers) the response parameters were not distinguishable between the contemporaneous and distributed-lag models, suggesting that the latter are affected by collinearity. We therefore retained the more parsimonious model.

their objective of expanding the market. As expected, full fares did not affect market size.

In quantitative terms, reducing the deep-discount fare 10% produces a modest 6.2% increase in volume. The limited availability of these seats to all travelers is an important factor in limiting the size of this effect. In US markets where super-saver fares are available subject only to purchase and minimum stay restrictions, one might expect a larger impact. However, the estimate was reasonable in UTA's view. Moreover, its small size was especially meaningful.

4.2. *Full fare class share*

The share of full-fare passengers depends on all fares. Higher full fares drive flyers to other fares, and lower discount and lower deep-discount fares attract full-fare passengers. This pattern of cannibalization was not completely expected. Some full-fare/discount cannibalization was thought likely, but the impact of deep-discount fares on full-fare passengers was not known.

Full-fare share depends most importantly on full-fare prices. Increasing full fares by 10% reduces full-fare passengers by 23%—without increasing the number of passengers. Travelers simply switch to lower deep-discount fares. Thus, in addition to being statistically significant, the cannibalization involved a potentially large number of passengers. This result, one of the most important from UTA's perspective, showed the existence of full fare–deep discount cannibalization, and implied a significant profit consequence. The significant cannibalization of the full fare class share does not suggest that full-fare passengers are the most price sensitive. They are evidently insensitive with respect to deciding whether or not to fly, but are smart shoppers when it comes to deciding which fare to purchase.

4.3. *Discount fare class share*

Discount fare class share depends on discount fares and deep-discount fares to a lesser degree. Higher discount prices shift customers towards other fares, and lower deep-discount prices significantly reduces discount fare class share. Thus discount revenues, like full fare revenues, can be cannibalized by low deep-discount fares. This was somewhat surprising, given that deep-discount seats are not available to all who may wish them. These parameters also reveal an important asymmetric price effect: full fare class share is affected by discount fares but discount share is unaffected by full fares. Thus, increasing full fares drives buyers to less expensive fares, but reducing full fares does not draw discount flyers. Capturing an asymmetry such as this is possible because our response models are not sum constrained. However, this result raises the question about why this asymmetry exists. It may suggest that travelers treat price increases and decreases differently or that travelers are using reference prices to evaluate discounts or premiums.

In quantitative terms, the cannibalization caused by lower discount fares is substantial, but more limited than those induced by full fares. Raising discount fares 10% from the average decreases discount fare class share by 17% and drives travelers to other fares including full fares. In fact, 10% increase in discount fares increases full fare class share by 11%. This result demonstrates the fundamental asymmetry in cannibalization. Discount fares significantly affect full fare class shares, but full fare prices do not affect discount fare class shares. It also suggests that, like full fare flyers, discount passengers 'fly smart'—making a trade-off between the savings associated with discount fares and the convenience of full fare. It also raises intriguing issues associated with asymmetries in price increases and decreases and reference prices.

4.4. *Deep-discount fare class share*

Even more surprising, at first, were the estimates for deep-discount seat share. Higher full fares increase deep-discount fare class share, as do lower deep-discount fares. This indicates the trade-off available to some people (full fare for one versus discount fares for the entire family) was a more significant factor than expected. It also suggests that cannibalization is likely to have a significant profit impact. Full fare, of course, is the highest margin fare and deep-discount the lowest. It also shows that asymmetric cannibalization is limited to discount and full fares. Between full fare and deep-discount fares, cannibalization is symmetric.

Deep-discount fares affected all shares, but had the smallest effect. Increasing deep-discount fares from the average to 10% above it reduces deep discount volume by 5.4% and increases discount and full fare shares by approximately 3%. The small size of these effects is due to the limited segment of travelers who are able to select among all three fare classes.

4.5. Summary

Together, these results present an interesting but complex pattern of price effects.

(1) High full fares can drive travelers to deep-discount fares, indicating that while some travelers may not be price sensitive with respect to their decision about whether or not to travel, they are price sensitive with respect to what fare class they select.

(2) Low discount fares can draw full fare customers, cannibalizing revenue, without increasing the market.

(3) Deep-discount fares principally affect volume, and have little effect on shares of other fare classes.

5. Optimal prices for the Paris–Abidjan route

Based on the estimated response models, we model UTA profit as

$$\Pi_t = \hat{Q}_t \sum_{j=1}^{3} (p_{jt} - c_j)\hat{m}_{jt} \qquad (5)$$

where Π_t is profit at time t, $\hat{Q}_t$ is the estimated market volume at time t, c_j is the variable cost of fare class j, and $\hat{m}_{jt}$ is the estimated fare class share at time t. Optimal prices are found by maximizing Eq. (5) subject to capacity limitations. However, the deep-discount fare is regulated by the government so we treat p_{3t} as exogenous and allow m_{3t} to vary. In addition, we impose a sum constraint so that fare class shares add to one to ensure the logical consistency of the system.

This produces the following optimization problem:

$$\max_{p_{1t}, p_{2t}} Z_t(p_{1t}, p_{2t}, p_{3t}) \qquad (6)$$

where

$$Z_t = \left[\sum_{j=1}^{3} \hat{Q}_t (p_{jt} - c_j)\hat{m}_{jt} + \lambda_{j-}\left(\hat{m}_{jt} - m_{j-} - s_{j-}^2\right) + \lambda_{j+}\left(\hat{m}_{jt} - m_{j+} - s_{j+}^2\right)\right] + \lambda_Q\left(\hat{Q}_t - Q_+ - s_Q^2\right) + \lambda_s\left(1 - \sum_{j=1}^{3} \hat{m}_{jt}\right)$$

m_{j-} are minimum seat shares; m_{j+} are maximum seat shares; Q_+ is the maximum number of seats available, and s_{j-}, s_{j+}, and s_Q are slack variables associated with the constraints imposed by minimum and maximum seat shares and the total number of seats available, and λ_{j-}, λ_{j+}, λ_Q, λ_s are Lagrange multipliers. The seat share and volume restrictions are imposed due to plane configurations, fleet size, and other constraints such that $m_{1-} = 0.25$, $m_{1+} = 0.70$, $m_{2-} = 0.17$, $m_{2+} = 0.42$, $m_{3-} = 0.09$, $m_{3+} = 0.54$, and $Q_+ = 24\,500$. All response coefficients that were statistically indistinguishable from zero are set equal to zero to simplify the numerical analysis.

To solve for the optimal prices in Eq. (6), denoted $p^0 = (p_{1t}^0, p_{2t}^0)$, it is helpful to derive the solution to a simpler problem for a two-fare market as follows (suppressing the subscript t for the moment):

$$\max \Pi(p_1, p_2) = \sum_{j=1}^{2} Q m_j (p_j - c_j) \text{ subject to } m_1 \leqslant m_{1+} \text{ and } Q \leqslant Q_+ \qquad (7)$$

where m_{1+} is the maximum share devoted to share of fare 1 (e.g. full fare), and Q_+ is the maximum passenger volume. Optimal prices exist if Eq. (7) is concave (Franklin, 1980, p. 196), which is satisfied by many response models (e.g. Lilien et al., 1992, appendix C). We can derive an expression for optimal prices if both constraints in Eq. (7) are strictly binding so that $Q = Q_+$ and $m_1 = m_{1+}$. For fare class 1 we show in the appendix (available from the authors) that

$$p_1^0 = \gamma_1 / \{1 + [1 + \mu_1 + L_2(D_1 + E_{12}) \times (R_2/R_1)]/[D_1 + E_{11}]\} \tag{8}$$

where $\gamma_1 = c_1 + \lambda_2/m_1 + \lambda_1/Q$ is the cost of fare class 1 adjusted by the Lagrange multipliers for fare class share (λ_1) and volume (λ_2); $\mu_1 = (D_1\lambda_1 m_1 - E_{11}Q\lambda_2)/R_1$ is a parameter where D_1 is fare 1's market expansion elasticity, E_{11} is fare 1's fare class share elasticity, $R_1 = m_1 Q p_1$ is its revenue, and $L_2 = (p_2 - c_2)/p_2$ is fare class 2's price-cost margin. A similar expression can be derived for p_2^0.

Eq. (8), a generalization of the well known Dorfman and Steiner (1954) optimal pricing rule, can be used to examine the impact of cannibalization of the optimal fares. It shows, for instance, the importance of the cannibalization elasticity (E_{12}) and the constraints on the optimal price for fare 1. One can demonstrate the impact of E_{12} on p_1^0, for instance, using Eq. (8). More important for our purposes here, it can be used to calculate optimal prices.

5.1. Optimal prices

Using the estimated parameters from the development sample, we solved the system of 13 non-linear equations implied by Eq. (6) for optimal prices for each month in the forecast sample (June, 1984 through December, 1984). This produces p_{1t}^0 and p_{2t}^0 and produces fare class shares, total passenger volume and profits at those optimal prices given p_{3t}. A summary of the actual versus the optimal values appears in Table 3.

Table 3 shows that profits can be increased by our analysis, even though actual and optimal prices are, on average, quite close. Actual full fares on average exceed optimal full fares by just over 3%, and discount fares are suboptimal by less than 1%. Average actual fare class shares are accordingly close to their optimal values.

Table 3
Average optimal and actual prices, fare class, and profits[a]

	Actual	Optimal
Full-fare price	2185	2260
Full-fare class share	0.50	0.48
Discount-fare price	1337	1328
Discount fare class share	0.24	0.28
Total profits (in thousands)	92493	100063

[a] For June, 1984 through December, 1984. Prices and profits in deflated French francs. The results were obtained by first computing optimal fares and then optimal fare class shares at these fare levels.

Despite these similarities, profits under the optimal prices exceed actual profits by over 7 million French francs (an 8% increase) amounting to about $1.3 million at recent exchange rates.

6. Forecasting

We examine the predictive performance of the model, Eqs. (3) and (4), over a seven-period forecast sample of the data (from June to December, 1984) in two ways. First, we forecast total passenger volume and full and discount fare class shares using actual prices. We evaluate the results to assess the ability of our model to reasonably predict travel demand. Second, we forecast total passenger demand and demand for each fare class using optimal prices. We show above that optimal prices increase profit at UTA within the current pricing structure. Our analysis in this section addresses the larger strategic question, is the current pricing strategy suitable?

6.1. Forecasts with actual prices

Our forecasts based on actual prices appear in Fig. 1. The models appear to forecast well, especially with respect to fare class shares in the later months of the forecast sample. The average error percents for the seven periods are low, ranging from 2.5% (full-fare seat shares) to 13.7% (total volume). We can further illustrate

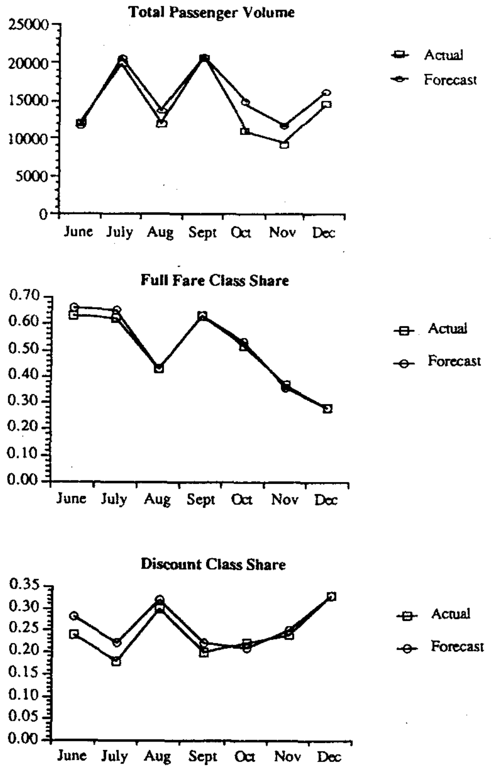

Fig. 1. Actual and forecast total passenger volume, full-fare class share and discount fare class share in forecast sample.

the predictive ability of our response model by benchmarking them against a time-series model, in this case a 'same as last year' model. Using the same seven forecasting periods, the seasonal model average error percents range from 6.4% (full-fare seat shares) to 16.8% (deep-discount seat shares). Thus, the inclusion of price patterns is not only significant in-sample, it also improves out-of-sample prediction of passengers and seat shares, generally about 50%. Following Granger's definition of causality, we conclude that air fares Granger cause passengers and seat shares (see e.g. Hanssens et al., 1990, p. 164).

6.2. *Forecasts with optimal prices*

Our forecasts based on optimal prices appear in Fig. 2. Two results shown in Fig. 2 are especially important. First, even though actual and optimal prices are, on average, quite similar, month-to-month differences are quite substantial. Fig. 2(A) shows that in some months (June, July, September, and October) full fares were underpriced by as much as 25%. In August, but especially November and December, these same seats were overpriced by as much as 20%. Over or underpricing of full fare seats resulted in under or overselling of other seats as shown in Fig. 2(B). When full fare seats were underpriced in June and July, actual full-fare class share exceeded the optimal by nearly 20%, and overpricing in December reduces full-fare share by an even greater fraction. Similar, though less dramatic, patterns are shown in Figs. 2(C) and 2(D).

Second, and most important, our results show that managing this pricing structure, given the impact of prices on market size and cannibalization, requires great precision. Even small deviations from optimal prices can lead to dramatic reduction in profit. For example, in October, full-fare seats were underpriced by 6.5% and discount seats overpriced by 3.5% (see Figs. 2(A) and 2(C)). These are small price differences, but their impact was to undersell discount seats by 13.6% with no corresponding gain in full-fare sales. The profit consequence of this 'near optimal' pricing was substantial: profits were 22% under profits associated with optimal prices even though actual and optimal fares were slight.

7. Implementation

7.1. *UTA reaction*

These results were presented to UTA in two stages. First, the market response models were developed and the results presented to top managers. The empirical results in Table 2, a central output of this project, were well received by UTA. However, UTA was surprised by the size of cannibalization effects. To validate our findings, they instructed the technical staff to conduct further analysis using new data. This analysis produced similar qualitative results, and gave greater credence to our findings.

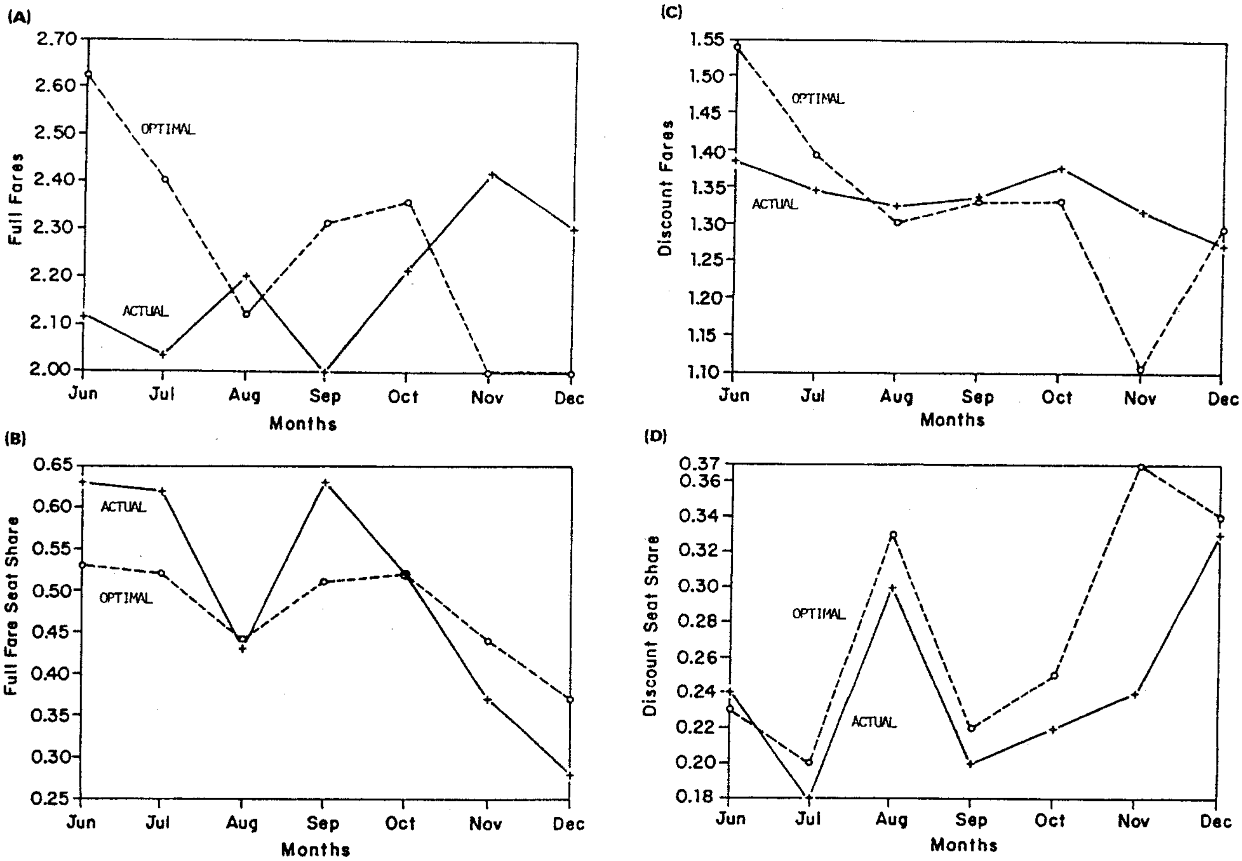

Fig. 2. Actual and optimal fares full fares (A), associated full-fare class shares (B); actual and optimal discount fares (C), and associated discount fare class shares (D) for forecast sample.

After validating our results one conclusion was inescapable: cannibalization was a major factor. The large cannibalization of full-fare revenues—their most important source of profits—by travelers switching to discount but, surprisingly, also deep-discount fares made this issue a central one for management. As a result, UTA management devoted considerable effort to considering ways to reduce the impact of cannibalization. Our optimal pricing results, reviewed later by management, suggested a somewhat different insight. Given the current fare structure, managing cannibalization is difficult. Great precision is required given that small deviations from optimal prices can lead to substantial losses in profit. This suggested that the current pricing structure, in addition to being not well suited to the segment structure, was also difficult to manage optimally.

Of both portions of the analysis, the market response modeling received greater attention and played a larger role in decisions regarding future pricing strategy. The empirical results were intuitively appealing, and they were validated by UTA analysts using different data. This gave managers a considerable degree of confidence in them. The optimization results were presented later to UTA, after a consensus had begun to form about what should be done with respect to the cannibalization issue. That consensus was moving toward a decision to substantially revise the current pricing structure rather than try to manage the current one more precisely. The optimization highlighted further the sensitivity of profits to deviations from optimal prices. This provided additional evidence suggesting that the current pricing structure may need revision or at least substantial modification.

7.2. New pricing strategy

Given these results, UTA restructured fares to better address the segments served and shifted toward a manageable system designed to reduce cannibalization and expand the market where possible. To achieve this, UTA retained three classes of fares—full, discount, and deep-discount seats—with restrictions as described earlier, but moved away from having every fare available on every flight. The new system is designed to offer full-fare seats on every flight, but eliminate discount and deep-discount seats on some flights. Other flights have a mix of fares.

To implement this system, UTA classified all flights according to a red–yellow–green coding: red flights are peak business travel flights (e.g. early morning and late afternoon weekdays). Reservations are accepted only at full fare; discount and deep-discount seats are accepted but on essentially a stand-by basis. This structure gives non-full fare travelers access to peak travel flights, but that access is significantly reduced, reducing cannibalization and thus offering the prospect of substantial improvements in profits.

Yellow flights are near-peak flights (e.g. early afternoon weekdays) where one would find a mix of business and other travelers. Full fare is of course available with reservations and, unlike red flights, limited reserved seats are available for travelers flying at lower fares.

Green flights are off-peak flights (e.g. late night, mid-day Saturday). Discount and deep-discount fares are given full access with reservations. Low discount fares can also be used on green flights to expand the market with the gain in profit associated with a larger market offsetting small cannibalization.

The implementation of these changes have enabled UTA, since merged with Air France, to reduce cannibalization significantly. The policy effectively limits the cross-price elasticities without significantly reducing the overall volume of travelers.

7.3. Future work

Our results and our experience in implementing these models suggest a number of avenues for interesting future work. First, and most obvious, is an evaluation of the newly implemented pricing strategy. Is it easier to manage and does it lead to consistently higher profit? These questions, however, raise a more fundamental issue. UTA has revised their pricing strategy by shifting toward a capacity management system in which the capacity constraints are strategic decision variables. Our analysis takes these as fixed and then determines optimal prices. Expanding the analysis to allow both prices and capacity as strategic variables, while not straightforward, appears to be an important area for future work. Second, the further exploration of the source of the asymmetries in cannibalization appears fruitful. Asymmetries in market response have been documented empirically in other contexts (e.g. Blattberg and Wisniewski, 1989; Carpenter et al., 1988), but the fundamental sources have not been explored. Recent advances in behavioral decision theory suggest that consumers may view gains and losses differently. If so, this may give rise to asymmetric evaluation of price discounts or premiums. Incorporating these aspects of decision making in forecasting and optimization models would appear to have a significant payoff.

8. Summary

Forecasting and pricing air travel is a challenging problem. Market segments differ significantly in price sensitivity; dropping fares may increase the size of the market for some fare classes, whereas cannibalization may result for others. The pattern and size of cannibalization is hard to predict, but it has a significant impact on overall demand and on optimal prices. Pricing must account for these demand factors, balancing market expansion and cannibalization, while operating within available constraints.

Our analysis provides insights into those issues in the Paris–Abidjan market. We develop and estimate a system of market response models to forecast the impact of price changes on the number of passengers traveling and the share traveling at each fare class. Based on this system of response models, we are able to assess the current fare structure and pricing. Our analysis provides insights into three important questions through both precise answers to tactical questions as well as qualitative insights into strategic issues:

(1) Market expansion: does each price expand the market? No, only deep-discount prices increase overall passenger volume.

(2) Cannibalization: what is the extent and pattern of cannibalization? Cannibalization is significant, asymmetric, and largely confined to full-fare and deep-discount classes and full-fare and discount classes.

(3) Profit: is the current pricing optimal? Nearly so, but managing the cannibalization through prices is very difficult because small deviations from optimal prices produce surprising decreases in profits. Another pricing structure may be easier to manage and thus more suitable.

The changes adopted by UTA suggest that in this case the strategic insights were of greater value. However, many of those insights are possible because of the richness of the analysis with respect to the tactical information, such as the impact of fare changes on demand for each fare class. Thus, our analysis shows that the precise answers provided by our forecasting system can provide both important tactical insights as well as qualitative insights useful for strategic change.

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