Will they stay or will they go?

Competitive RM with Loyal and Fully Flexible Customers

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Agenda

1. Motivation
2. Review of demand models
3. Class-based forecasting with market information
4. Class-based market priceable model with loyal customers
5. Classes market priceable model with loyal customers

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Motivation

- Competitive information perceived as a perennial value driver with a lot of undeveloped potential
- Much better availability of competitive information nowadays
  - Specialized third parties such as Infare
  - Data lakes to store large amounts of information
  - More processing power, include competitive information in real time

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DEMAND MODELING IN RM

RM Models with Competitive Information

Dichotomy in model settings:

- Current RM models typically assume monopolistic setting
  - All or some customers are price-sensitive
  - No concept of switching to competition – i.e., all customers are loyal
- Game-theoretic literature typically assume all demand will go to a competitor with the lowest fare (“all or nothing”)
  - None of the customers are loyal – i.e., all customers are fully flexible
- Can an airline go directly from “all loyal” customers to “no loyal”?
- Is there a “happy middle”?

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RM Models with Competitive Information: Equilibria

Some results for a duopoly pricing game over a booking horizon with symmetric competitors and fully flexible customers:

- Nash equilibrium known to exist when customer valuation (WTP) is known, either with fixed or random market size
- Extended recently to random customer valuation and random market size
- Equilibrium requires a competitor with lower capacity to sell out first

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Monopolistic Models with Competitive Information

- Equilibrium pricing dominated by monopolistic pricing under some demand and capacity scenarios (“Prisoner’s dilemma,” Singh (2019))
- No pure strategy equilibrium when some of the customers are loyal
- Therefore monopolistic models with fully flexible (market priceable) customers are valuable and practical

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Modeling Contexts

Two main modeling contexts (both extend naturally to fare families):

- Class-based
  - Accommodates existing fare class structure, discrete demand curve
    - Discrete price points correspond to class fares
  - Two options:
    - All demand is price-oriented and buys the lowest available fare within a class block
    - Demand is a hybrid of product-oriented (“yieldable”) and price-oriented (“priceable”) customers
- Classless (“Continuous Dynamic Pricing”)
  - No existing fare class structure; price changes continuously within an interval
  - Demand is price-oriented and buys the lowest available fare within a class block

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Class-based Booking Models
Loyal Demand

- Assume that yieldable and priceable demands may co-exist in the same booking class

Yieldable

Demand	Availability		Result
Y Class	Y Class	115	$1000 Purchase
M Class	M Class	60	$600 Purchase
B Class	B Class	25	$450 Purchase
Q Class	Q Class	0	No Purchase

and

Priceable

Demand	Availability		Result
Y Class	Y Class	115	No Purchase
M Class	M Class	60	No Purchase
B Class	B Class	25	$450 Purchase
Q Class	Q Class	0	No Purchase

Class	Y	M	B	Q
Fares	$1000	$600	$450	$250

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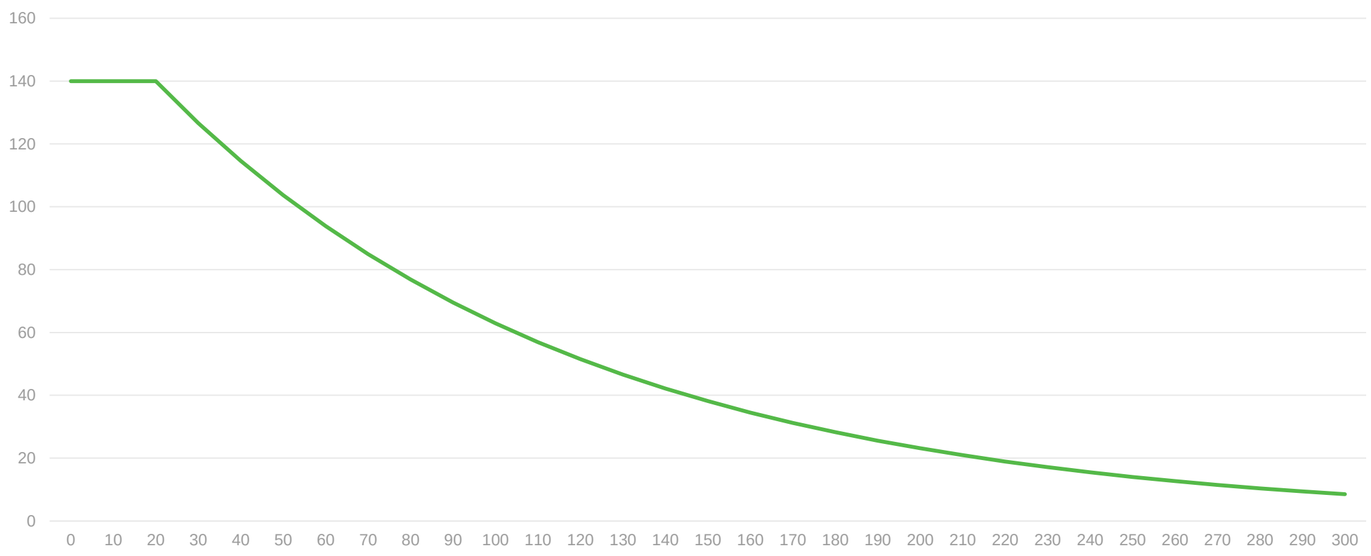
Classless Structure (Continuous Demand Curve)
Loyal Demand

- Assume all demand is price-sensitive (price-oriented, priceable)
- Willingness to pay (WTP) has a continuous distribution
- Forecast the parameters that determine the shape of the exponential curve that contains elasticity of demand (no classes)
  - λ- volume parameter; α - price elasticity/WTP-related parameter
- Determine dynamic price based on willingness-to-pay parameter and the bid price

$$D(p) = \lambda e^{-\left(\frac{p-p_0}{\alpha}\right)}$$



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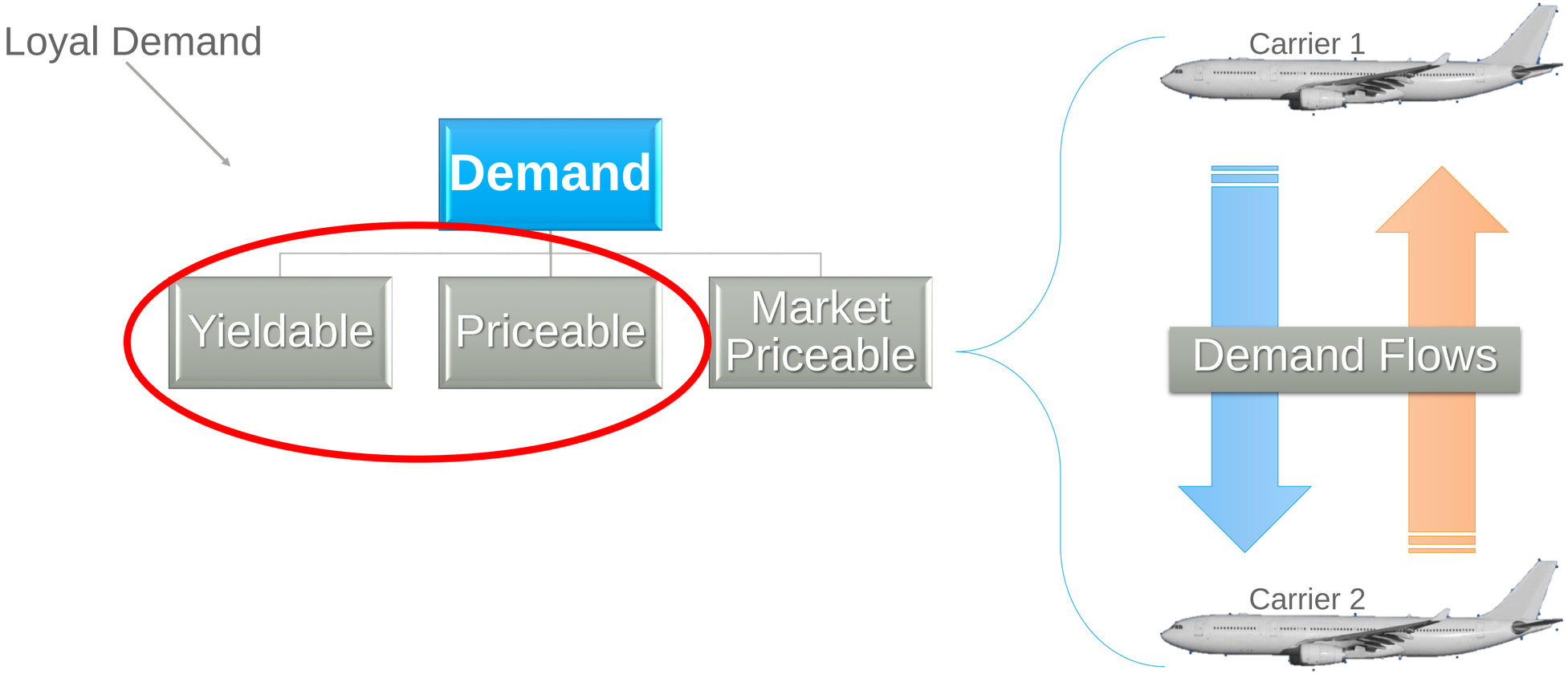
CLASS-BASED FORECASTING WITH MARKET INFORMATION (MARKET HYBRID)

Current O&D Enhancements Competitive Science



Measure market elasticity by examining demand flows based on the cheapest market fare

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Class-based Forecasting

- Use availability as covariates to identify yieldable, priceable, and market priceable mix
  - The Open proportion within the DCP → Open%
  - The Lowest Open proportion within the DCP → LA%
  - **The Market Lowest Open proportion within the DCP → MLA%**

- Consider these availability conditions:
  - Open but not lowest open
    - All bookings are yieldable
  - Open and lowest open
    - Both yieldable and priceable bookings
  - **Open, lowest open, and lowest open in the market**
    - **Yieldable, priceable, and market priceable bookings**

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Modeling with Three Hybrid Covariates

- Let the observed vector bookings at departure date t be

$$\boldsymbol{X}_t = \left(x_{t,1}, x_{t,2}, \dots, x_{t,n}\right) \text{ for DCP = 1, 2, ..., n}$$

- Three covariates for Open%, LA% and MLA%

$$\boldsymbol{Open}_t = \left(Open_{t,1}, Open_{t,2}, \dots, Open_{t,n}\right)$$
$$\boldsymbol{LA}_t = \left(LA_{t,1}, LA_{t,2}, \dots, LA_{t,n}\right)$$
$$\boldsymbol{MLA}_t = \left(MLA_{t,1}, MLA_{t,2}, \dots, MLA_{t,n}\right)$$

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Market Hybrid Forecasting

- Condition the forecast on the future covariate vector:

$$E[\mathbf{X} \mid \mathbf{C} = \mathbf{c}]$$

To get Unconstrained Yieldable Forecast, set

Open% = 1
LA% = 0
MLA% = 0

To get Unconstrained Priceable Forecast, set

Open% = 1
LA% = 1
MLA% = 0

*Subtract off yieldable forecast

To get Unconstrained Market Priceable Forecast, set

Open% = 1
LA% = 1
MLA% = 1

*Subtract off yieldable and priceable forecast

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CLASS-BASED MARKET PRICEABLE WITH LOYAL CUSTOMERS – SIMPLE EXAMPLES

Forecast Example

	Fare	Yieldable	Priceable	Market Priceable
Y Class	$1,000	7	5	1
B Class	$600	10	7	2
M Class	$450	21	13	21
Q Class	$250	20	15	12

Any combination of the components is possible

- The “Yieldable” column could be set to zero (and effectively removed)
- If all demand is market priceable then only the last column with nonzero entries

Many economics contexts assume that all demand is what we call market priceable, but:

- We provide a more precise picture and actually show what the real market demand consists of
- Knowledge of the market priceable component allows the airline to assess what portion of demand is affected by competitors’ actions

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Example

	Fare	Yieldable	Priceable	Market Priceable
Y Class	$1,000	7	5	1
B Class	$600	10	12	3
M Class	$450	21	25	24
Q Class	$250	20	30	36

Assume a static and deterministic market scenario: the lowest price in the market is $500, no capacity constraints

- Under this scenario we will not capture the market priceable component if we open Y, or Y and B
- We will capture the market priceable component if we open Y, B, and M or if we open all classes

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Example

	Fare	Yieldable	Priceable	Market Priceable	Nest Open	Expected Revenue
Y Class	$1,000	7	5	1	Y	$12,000
B Class	$600	10	12	3	Y, B	$20,200
M Class	$450	21	25	24	Y, B, M	$44,500
Q Class	$250	20	30	36	Y, B, M, Q	$43,950

Assume a static and deterministic market scenario: the lowest price in the market is $500

- Y lowest open: E[Revenue]= (7+5)*1000 = 12,000
- B lowest open: E[Revenue]= 7*1000 + (10+12)*600 = 20,200
- M lowest open: E[Revenue]= 7*1000 +10*600 + (21+25+24)*450 = 44,500
- Q lowest open: E[Revenue]= 7*1000 +10*600 + 21*450 + (20+30+36)*250 = 43,950

The expected revenue-optimal decision under this market scenario is to open Y, B, and M

The optimal decision will change depending on what the lowest available price in the market is

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Etihad Data

- XXX-YYY
- POS: AA
- DCP 4
- Dept Date: 6 Sep 2019

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Scenario 1: Dominant Market Position

- Large Market Share
  - Due to brand recognition, quality of service, scheduling, capacity, etc.
  - Implies that market priceable component of demand is relatively small compared to the airline priceable and yieldable components

	Fare	Yieldable	Priceable	Mkt Priceable
V	603	2.58	0.33	0.02
U	529	3.77	0.65	0.07
E	464	2.26	0.00	0.00
T	351	0.00	0.18	0.04

- Aggressive Low Cost Carrier in the market
  - The market fare is at $360

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Scenario 1: Dominant Market Position

	Fare	Yieldable	Priceable	Mkt Priceable	Nest Open	Expected Revenue
V	603	2.58	0.33	0.02	V	1751.90
U	529	3.77	0.65	0.07	V, U	4067.32
E	464	2.26	0.00	0.00	V, U, E	5050.96
T	351	0.00	0.18	0.04	V, U, E, T	5045.83

- Assuming zero bid price
- The optimal decision is to open V, U, and E, closing T
  - In this case, the extra demand that could be generated by matching in the market **does not** overcome the fare dilution of our priceable demand

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Scenario 2: Medium Market Position

	Fare	Yieldable	Priceable	Mkt Priceable	Nest Open	Expected Revenue
V	603	2.58	0.33	0.03	V	1751.90
U	529	3.77	0.65	0.10	V, U	4067.32
E	464	2.26	0.00	0.00	V, U, E	5050.96
T	351	0.00	0.18	0.05	V, U, E, T	5069.42

- Assuming zero bid price
- The optimal decision is to open all classes
  - In this case, the extra demand that could be generated by matching in the market **does** overcome the fare dilution in priceable demand

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Scenario 3: Medium Market Position

	Fare	Yieldable	Priceable	Mkt Priceable	Nest Open	Expected Marginal Rev
V	603	2.58	0.33	0.03	V	1461.37
U	529	3.77	0.65	0.10	V, U	3334.50
E	464	2.26	0.00	0.00	V, U, E	4092.43
T	351	0.00	0.18	0.05	V, U, E, T	4074.11

- Assuming bid price = 100
- The optimal decision is to open V, U, and E, closing T
  - In this case, the extra demand that could be generated by matching in the market **does** not overcome the fare dilution in priceable demand

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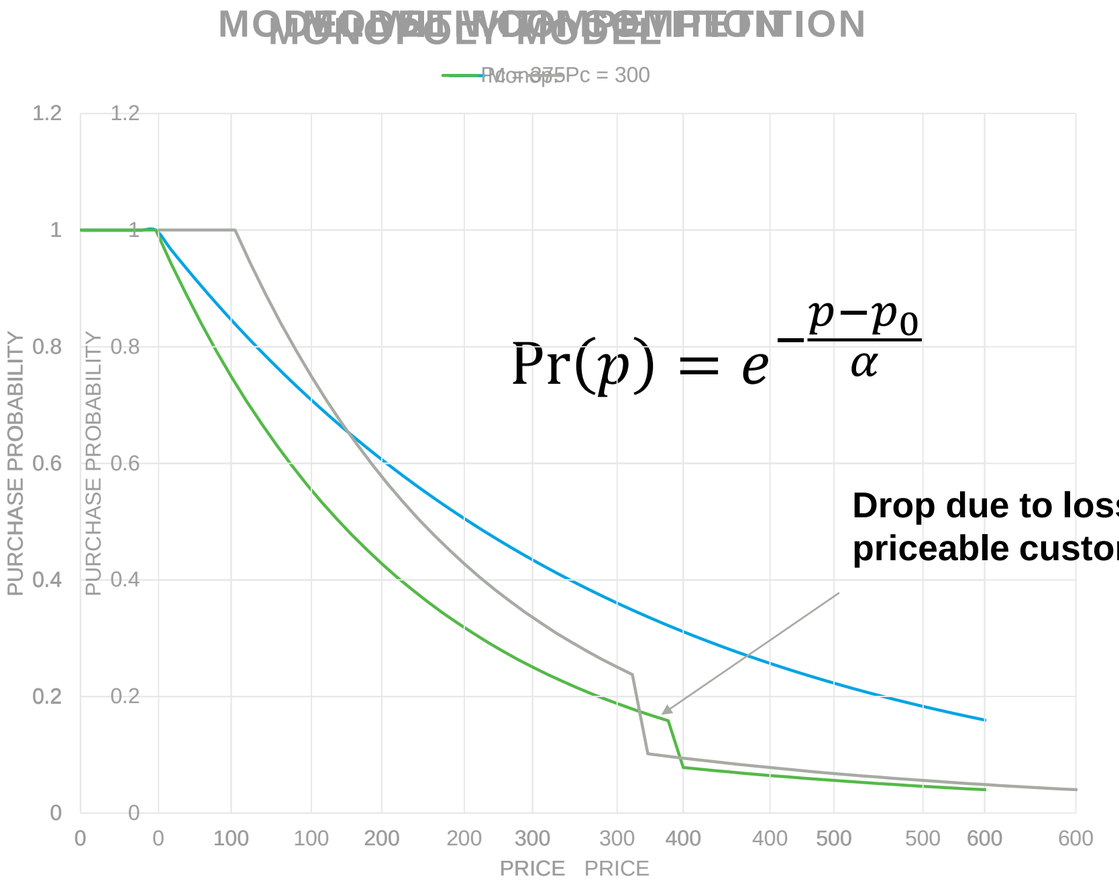
CLASSLESS MODEL WITH LOYAL CUSTOMERS – EXAMPLES

Model to Incorporate Competitor Prices



$$\Pr(p) = e^{-\frac{p-p_0}{\alpha}}$$

Drop due to loss of market priceable customers

Demand Drops as we price higher than the competition

Purchase Probability
(driven by customer WTP and Competitor's Price)

mean WTP for AL1 loyal customers = $\alpha_l + p_0$
mean WTP for other customers = $\alpha_m + p_0$
Fraction of AL1 loyal customers = δ

$$\Pr(p, p_c) = \begin{cases} \delta e^{-\frac{(p-p_0)}{\alpha_l}} + (1-\delta) e^{-\frac{(p-p_0)}{\alpha_m}} & if\ p \le p_c \\ \delta e^{-\frac{(p-p_0)}{\alpha_l}} & if\ p > p_c \end{cases}$$

$$\mathrm{d}(\mathrm{p}, \mathrm{p}_c) = \lambda \cdot \Pr(p, p_c)$$

Developed Bayesian forecasting methodology to estimate the parameters of this model

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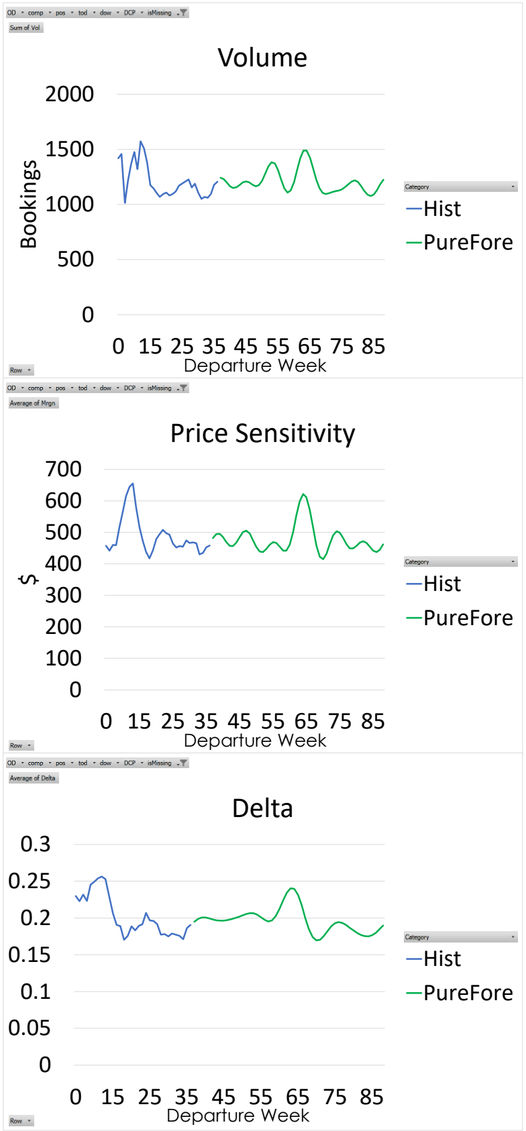
Forecast of Demand Curve Parameters

Market Volume

Price Sensitivity

Loyal Demand Fraction



$$E[Bookings] = f(\lambda, \alpha, \delta)$$

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Price Generation

The "**optimal price"** is computed by maximizing the margin contribution given the prevailing **bid price** and competitor's price p_c

$$contr^*(x,t,p_c) = max_p \;\; Pr(p,p_c,t) \cdot \big(p - BP(x,t)\big)$$

Leads to a pricing policy that either "matches" the competitor price by pricing at p_c or chooses to price at one of the following prices

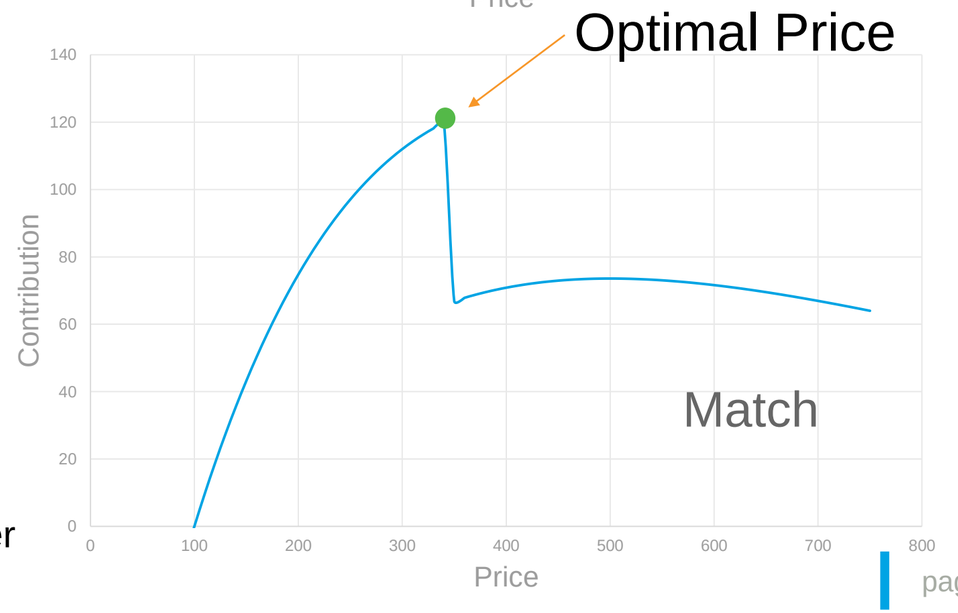
$$p^* = argmax\{contr(p_c), contr(p_m^*), contr(p_l^*)\}$$

Match

Undercut

Ignore: Price Higher

High BP



Low BP

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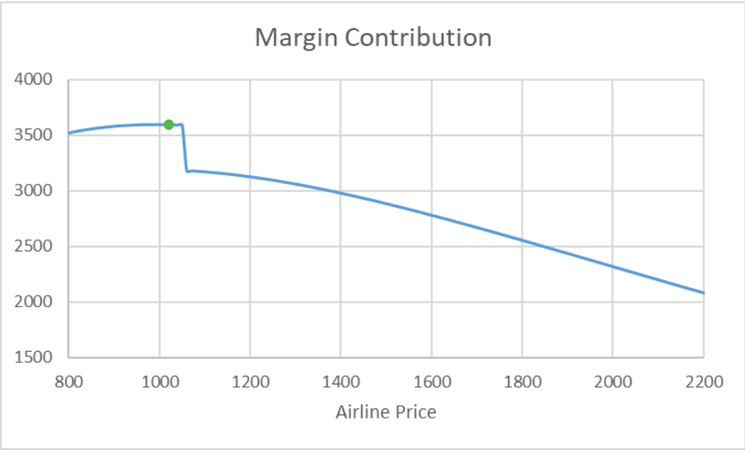
Effect of Bid Price on Pricing Strategy

OD	XXX-YYY
Block	Y
TOD	EY ZZZ
Dept Date	2/6/2018
DCP	7

Volume (λ)	α_m	α_l	p_0	Fraction Market Priceable (δ)
4.4	990	1185	800	0.4

Low Bid Price

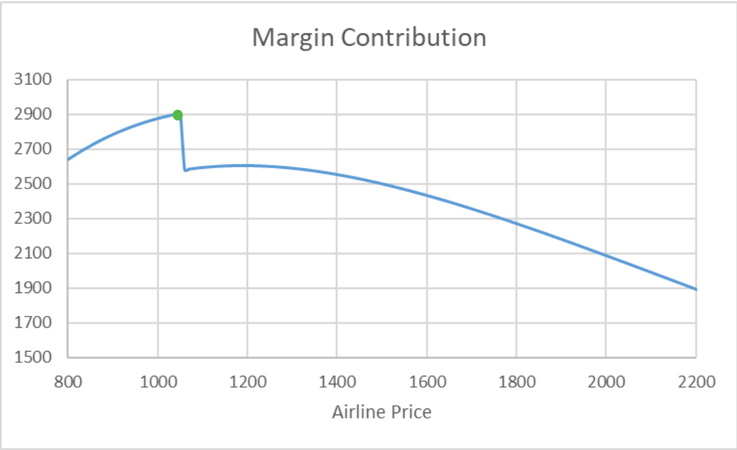
Bid Price = 30, $p_c = 1050$



$p_{AL}^* = 1030$ (Undercut)

Medium Bid Price

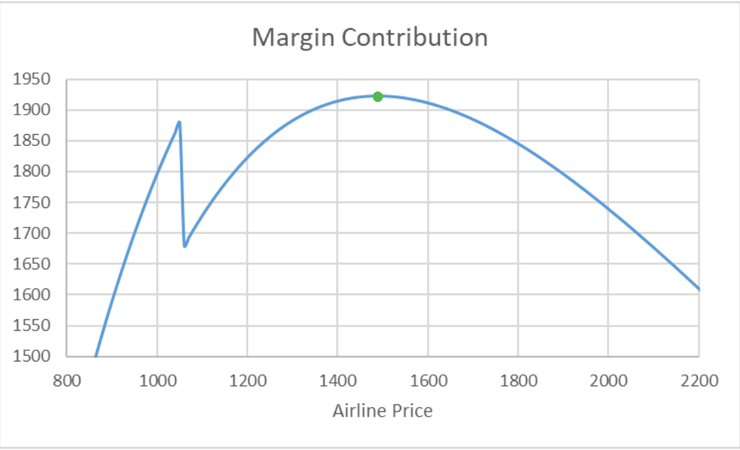
Bid Price = 200, $p_c = 1050$



$p_{AL}^* = 1050$ (Match)

High Bid Price

Bid Price = 500, $p_c = 1050$



$p_{AL}^* = 1490$ (Ignore)

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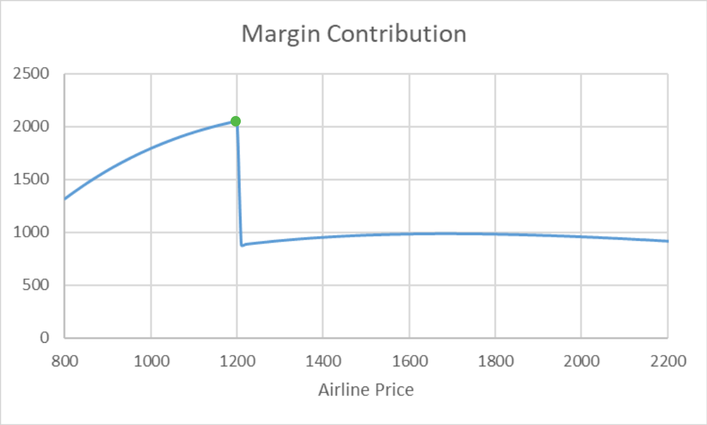
Effect of Fraction Loyal on Pricing Strategy

OD	XXX-YYY
Block	Y
TOD	EY ZZZ
Dept Date	2/6/2018
DCP	7

Volume (λ)	α_m	α_l	p_0
4.4	990	1185	800

Low Fraction Loyal

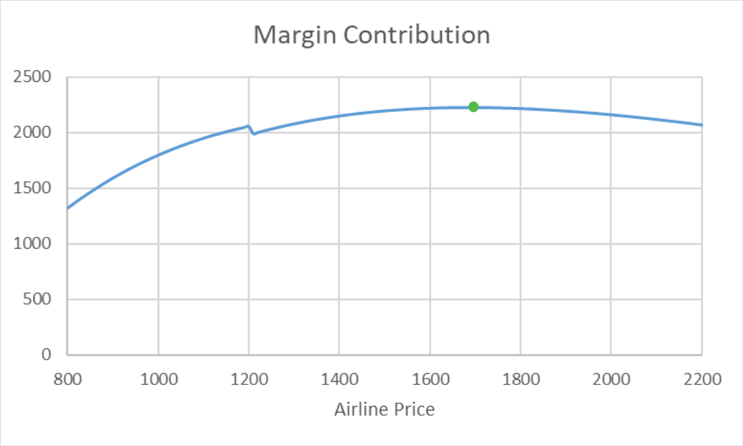
Bid Price = 500, $p_c = 1200$, $\delta = 0.4$



$p_{AL}^* = 1200$ (Match)

High Fraction Loyal

Bid Price = 500, $p_c = 1200$, $\delta = 0.9$



$p_{AL}^* = 1690$ (Ignore)

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Competitive vs. Monopolistic Approach

Most results obtained under duopoly assumption – two symmetric competitors:

- Dudey (1992)
  - Known customer valuation v, n-time periods, customer request in every period
- Talluri (2003)
  - Dynamic setting with competitors offering sets of products, general discrete choice model
- Dudey (2007)
  - Random customer valuation with known probability distribution and known market size, continuous demand function
- Walczak (2007)
  - DP pricing game, discrete demand curve, examples of multiple equilibria
- Isler & Imhof (2008)
  - Continuous demand curve, detailed solution for exponential demand functions
- Martinez-de-Albeniz & Talluri (2011)
  - Generalization of Dudey (1992) to random market size, but still with known customer valuation
  - Many insights and suggestions for extending the model
- Walczak & Singh (2017):
  - Nash equilibrium exists with probabilistic customer valuation and market size, customers fully flexible
  - No pure strategy equilibrium when some of the customers are loyal
- Singh (2019): *Explicitly Incorporating Competition under Flexible Models of Demand in Dynamic Pricing*
  - Equilibrium strategy analysis: equilibrium pricing dominated by monopolistic pricing under some demand and capacity scenarios

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Conclusions

- For class-based and classless models, the optimal decision can be undercutting, matching, or ignoring the lowest market price, depending on
  - The percentage of the market priceable demand
  - The bid price

- On-going research and development

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