International Center for Air Transportation

PODS

Continuous Pricing with Multiple Fare Quotes

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Speaker Bio

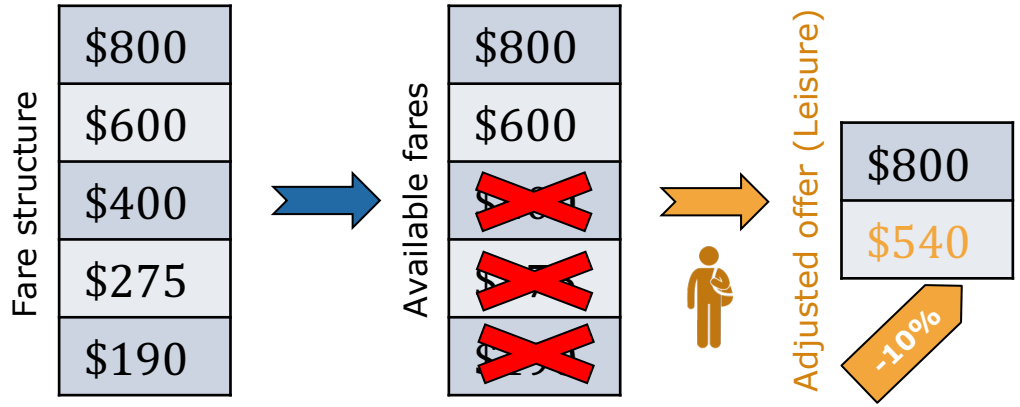
Bazyli Szymański is a Ph.D. candidate in Air Transportation Systems at the Massachusetts Institute of Technology (MIT) advised by Dr. Peter Belobaba. His work in the MIT-PODS Consortium focuses on continuous pricing for airline revenue management.

Prior to joining MIT, Bazyli gained 2 years of professional experience in the airline industry at LOT Polish Airlines and Star Alliance. He holds a Master's degree in Mathematics from University of Warsaw.

Prior PODS Research: Price Adjustment and Continuous Pricing

Dynamic Price Adjustment

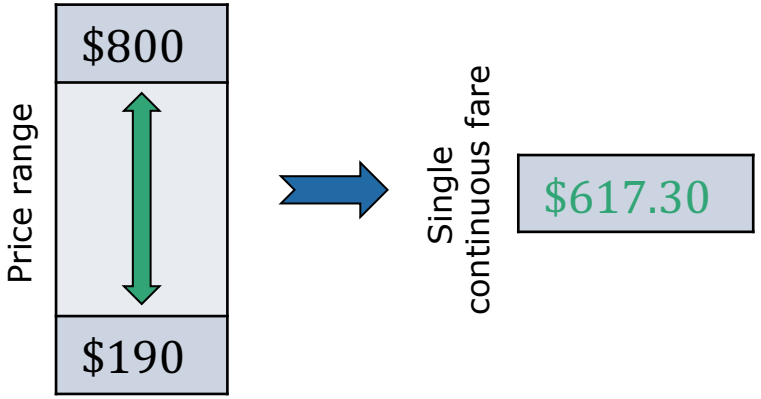
- Middle ground between Traditional and Continuous: use Traditional class-based RM to determine fare availability
- Adjust filed fares based on transactional data (passenger segment) and estimated WTP



Wittman and Belobaba (2019)
Wittman (2018)

Continuous Pricing with 1 fare quote

- No necessary reference to filed fares
- Continuous RMS determines OD quotes from forecasted demand volumes and WTP
- But only one product (no restrictions) offered – usable with fully unrestricted fares



Belobaba, Liotta and Hopperstad (2018)
Papen (2020)
Szymański, Belobaba and Papen (2021)

Framework for Continuous Pricing with Multiple Fare Quotes

- Goal: extend Continuous Pricing to multiple products to compete in general fare structures
- Combine **product differentiation** (rows) with **fare quote segmentation** (columns)
  - Focus on the bottom row – **multiple products** – in this presentation

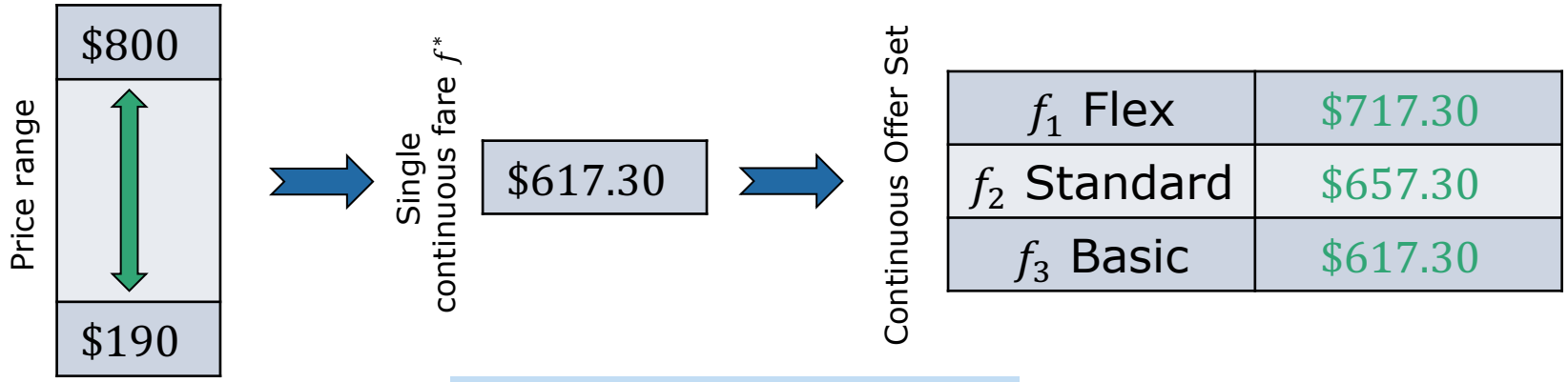
		Price for Business/Leisure	
		Identical	**Different**
Number of Products per customer	One	Continuous Pricing *with 1 fare quote*	Segmented Continuous Pricing
	Multiple	Unsegmented Continuous Pricing for Fare Families ★	Segmented Continuous Pricing for Fare Families

Continuous Pricing with Product Differentiation

Unsegmented Continuous Pricing for Fare Families

- **Product differentiation**: all customers are offered multiple products with different characteristics to choose between (Basic, Standard, Flex)
- Continuous RMS determines a single quote f^*, and offered products are adjusted by mark-ups

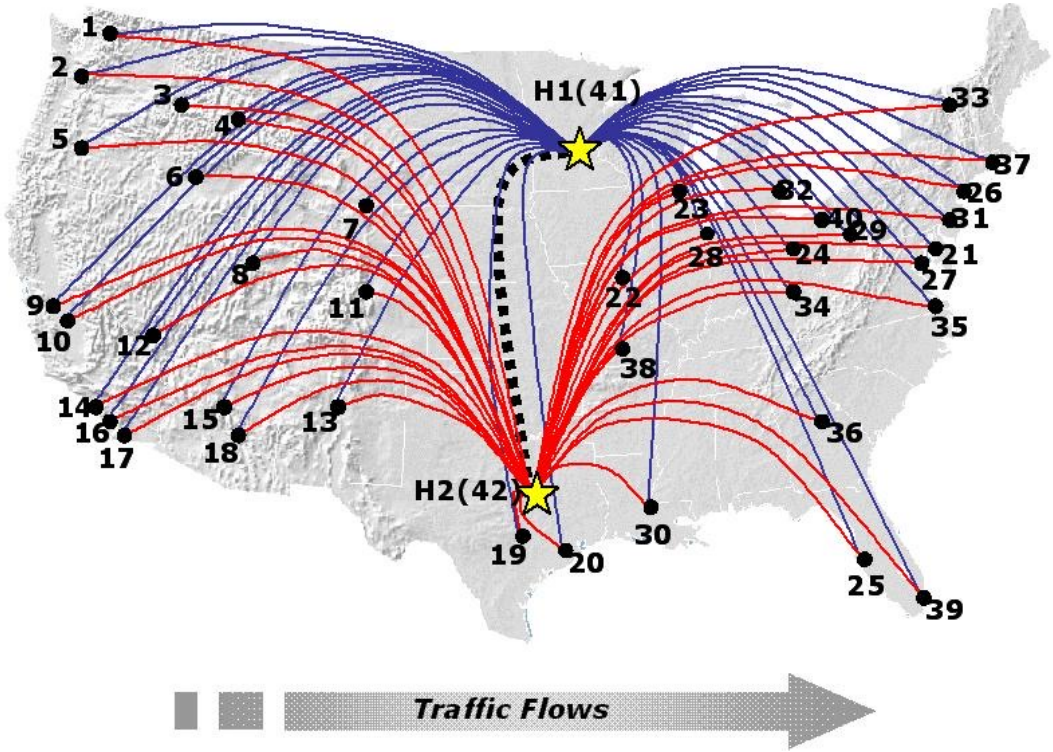
- **Currently applicable in "Matrix Pricing" fare structures** – mark-ups and product characteristics fixed throughout the time horizon
- Optimization based on assumptions on total WTP. Mark-ups added to the continuous f^*



Szymański and Papen (2020)
see also: Juhasz (2021)

Simulation Results from PODS Network D11

- 2 airlines
  - Highly symmetric networks
- 40 Spoke Cities
- 252 legs
- 482 OD markets
- Traditional class-based airlines use fare structures with 11 FCs



Unsegmented CP for Fare Families

PODS Simulation Assumptions

Passengers:

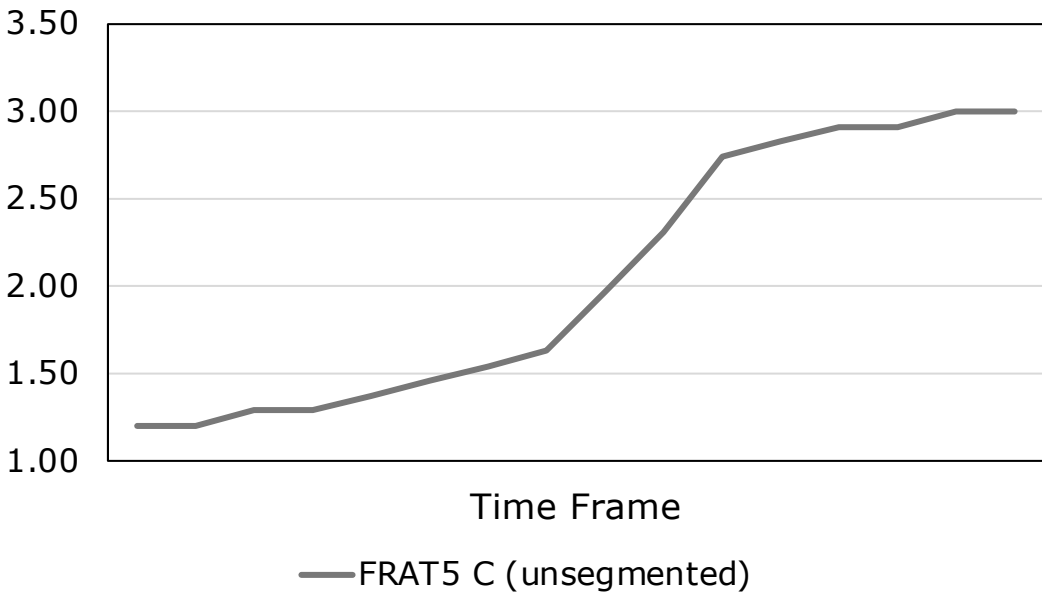
- belong to a unique segment (Business/Leisure)
- have a total maximum WTP θ drawn from a negative-exponential distribution
- incur disutilities for buying inferior products drawn from Normal distributions

	Business WTP	Leisure WTP
Max WTP	$\mathbb{P}(\theta_B > f) = \frac{1}{2}\wedge((\frac{f}{2.5*f_L} - 1)/0.6)$	$\mathbb{P}(\theta_L > f) = \frac{1}{2}\wedge((\frac{f}{f_L} - 1)/0.5)$
P1: Basic -> Standard	**μ: \$60** σ: \$18 r: 100%	**μ: \$40** σ: \$12 r: 75%
P2: Standard -> Flex	**μ: \$60** σ: \$18 r: 50%	**μ: \$40** σ: \$12 r: 25%

f_L is the fare that all Leisure pax can afford,
$2.5 * f_L$ is the fare that all Business pax can afford

Airlines:

- use a single median WTP curve (FRAT5) as a buy-up probability estimates across DCPs
  - FRAT5 value increases closer to departure given a higher proportion of Business pax
- have fixed \$35/\$100 mark-ups from Basic to Standard/Flex



Unsegmented CP for Fare Families

Fare Structures Used in Simulations

"Matrix Pricing" Traditional class-based RM				
FC	AP	Basic	Std	Flex
1	0	F_1	$F_1 + \$35$	$F_1 + \$100$
2	0	F_2	$F_2 + \$35$	$F_2 + \$100$
3	0	F_3	$F_3 + \$35$	$F_3 + \$100$
4	0	F_4	$F_4 + \$35$	$F_4 + \$100$
5	0	F_5	$F_5 + \$35$	$F_5 + \$100$
6	0	F_6	$F_6 + \$35$	$F_6 + \$100$
7	0	F_7	$F_7 + \$35$	$F_7 + \$100$
8	0	F_8	$F_8 + \$35$	$F_8 + \$100$
9	0	F_9	$F_9 + \$35$	$F_9 + \$100$
10	0	F_{10}	$F_{10} + \$35$	$F_{10} + \$100$
11	0	F_{11}	$F_{11} + \$35$	$F_{11} + \$100$

Unsegmented CP for Fare Families			
AP	Basic	Std	Flex
0	f^*	$f^* + \$35$	$f^* + \$100$

No additional restrictions apply on Fares

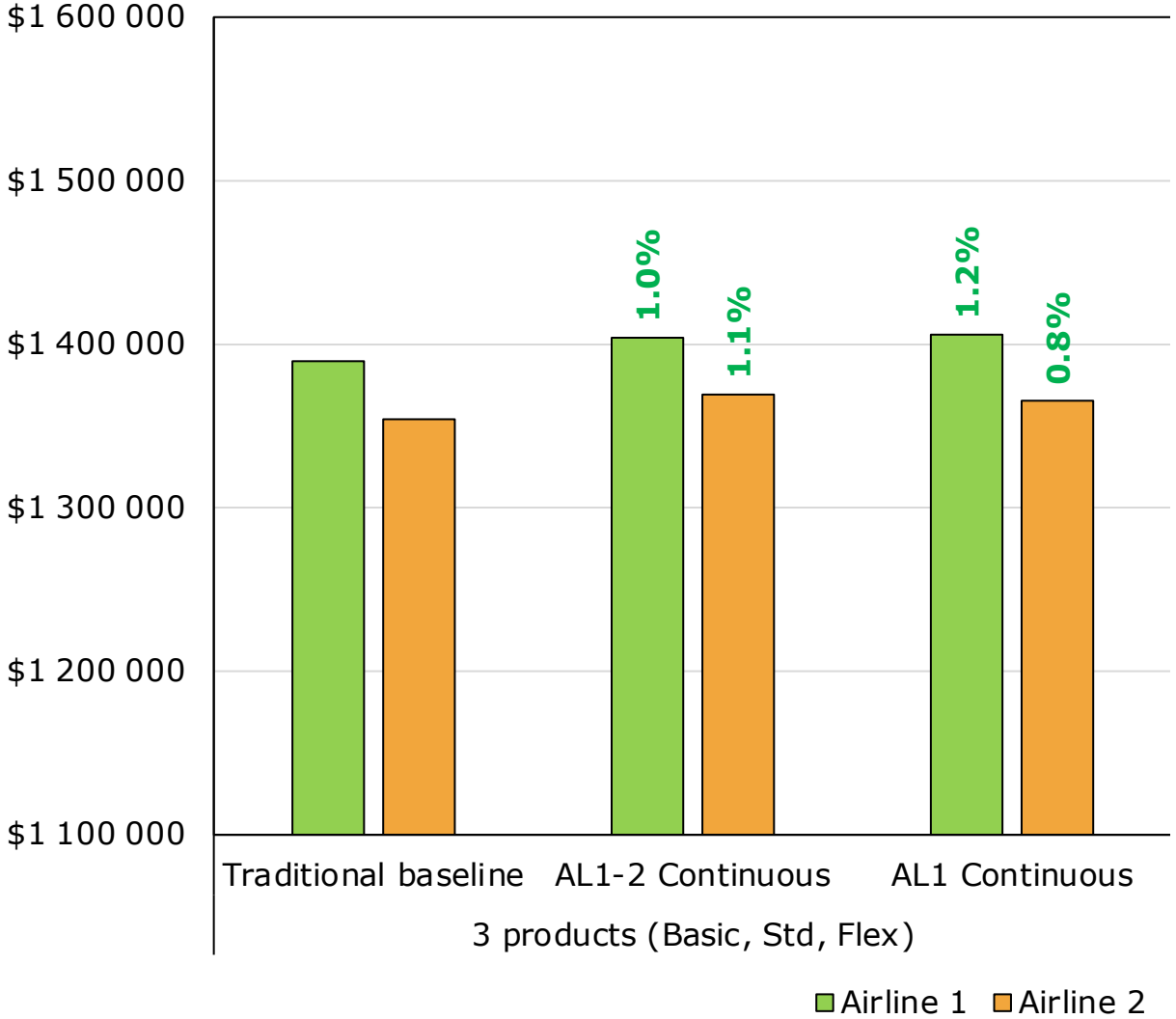
Same fare structure type across OD markets (but with different fare levels)

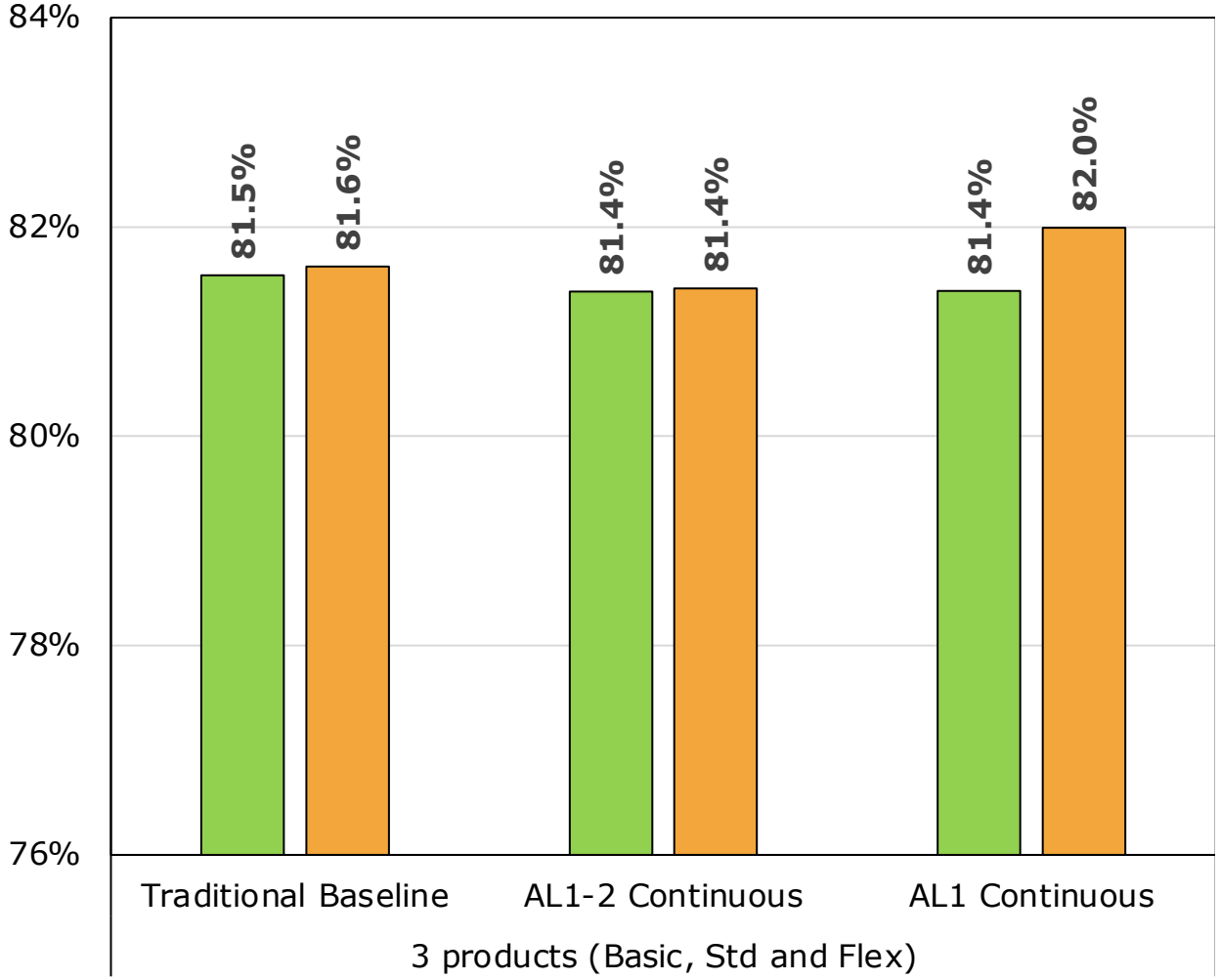
Continuous f^* bounded by $[F_{11}, F_1]$

PODS Simulations: gains of about 1% when CP for Fare Families applied symmetrically and 1.2% when applied by AL1 only

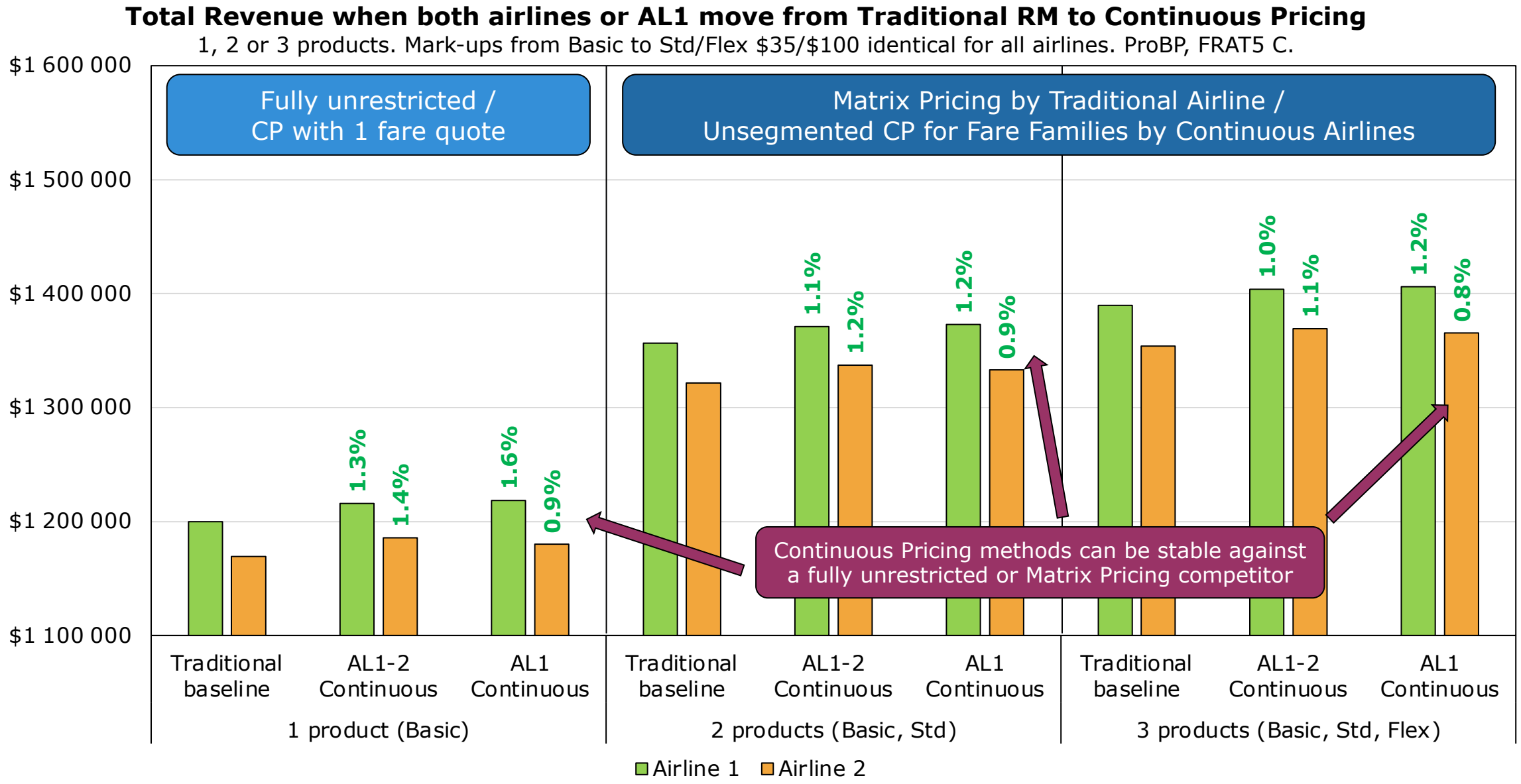
Total Revenue | **Load Factor**

Both airlines or AL1 move from Traditional RM (Matrix Pricing) to Continuous Pricing (Unsegmented CP for Fare Families).
$35/$100 mark-ups from Basic to Std/Flex. ProBP network optimizer, FRAT5 C.





PODS Simulations: Continuous Pricing ahead in revenues & stable in competition with fully unrestricted or matrix pricing fare structures

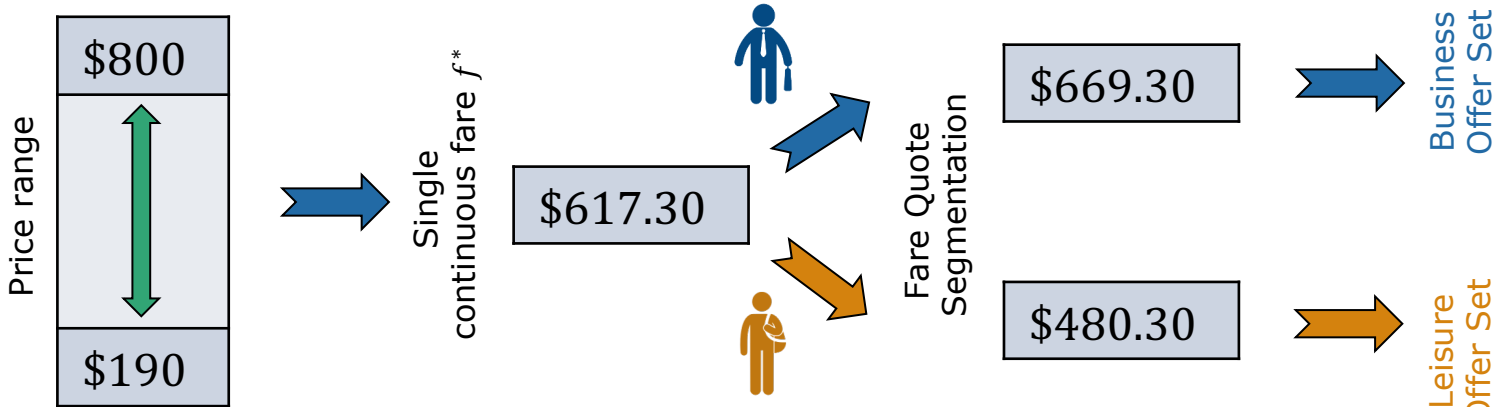


Adding Fare Quote Segmentation to Product Differentiation

Segmented Continuous Pricing for Fare Families

- **Fare Quote Segmentation**: based on transactional data and estimated segment WTP, adjust the continuous fare (e.g., to Business/Leisure pax)
- Different offer sets may be constructed based on the passenger type

- Currently, the optimizer generating f^* unaware of two segments and multiple products; fare quotes are heuristically adjusted at quotation



Business Offer Set

f_1 Flex	$769.30
f_2 Standard	$694.30
f_3 Basic	–

Leisure Offer Set

f_1 Flex	$580.30
f_2 Standard	$515.30
f_3 Basic	$480.30

Szymański and Papen (2020)

Segmented CP for Fare Families
PODS Simulation Assumptions

Passengers:

- belong to a distinct segment (Business/Leisure)
- have a total maximum WTP θ drawn from a negative-exponential distribution
- incur disutilities for buying inferior products drawn from Normal distributions

	Business WTP	Leisure WTP
Max WTP	$\mathbb{P}(\theta_B > f) = \frac{1}{2}\wedge((\frac{f}{2.5*f_L} - 1)/0.6)$	$\mathbb{P}(\theta_L > f) = \frac{1}{2}\wedge((\frac{f}{f_L} - 1)/0.5)$
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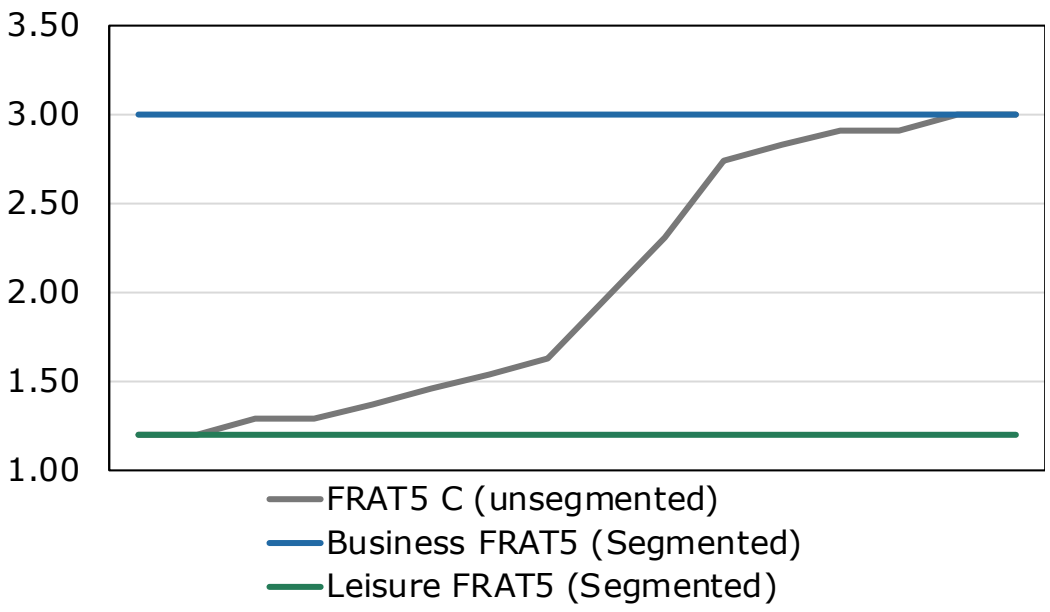
f_L is the fare that all Leisure pax can afford,
$2.5 * f_L$ is the fare that all Business pax can afford

Airlines:

- use a single median WTP curve (FRAT5) as a buy-up probability estimates across DCPs
  - **adjust fare quotes according to pax type identification** assuming a constant Business FRAT5 of 3.0 and Leisure FRAT5 of 1.2

New

- for both Business/Leisure use the same \$35/\$100 mark-ups to Standard/Flex as in Unsegmented tests



Segmented CP for Fare Families

Fare Structures Used in Simulations

Fully restricted
Traditional class-based RM

FC	AP	R1	R2	R3	R4
1	**0**	0	0	0	0
2	**0**	0	0	0	1
3	**3**	0	0	1	0
4	**3**	1	0	0	1
5	**7**	0	1	1	0
6	**7**	1	1	0	1
7	**10**	1	1	0	1
8	**10**	0	1	1	1
9	**14**	1	1	1	0
10	**14**	1	1	1	1
11	**21**	1	1	1	1

Fully unrestricted
Traditional class-based RM

FC	AP	R1	R2	R3	R4
1	**0**	0	0	0	0
2	**0**	0	0	0	0
3	**0**	0	0	0	0
4	**0**	0	0	0	0
5	**0**	0	0	0	0
6	**0**	0	0	0	0
7	**0**	0	0	0	0
8	**0**	0	0	0	0
9	**0**	0	0	0	0
10	**0**	0	0	0	0
11	**0**	0	0	0	0

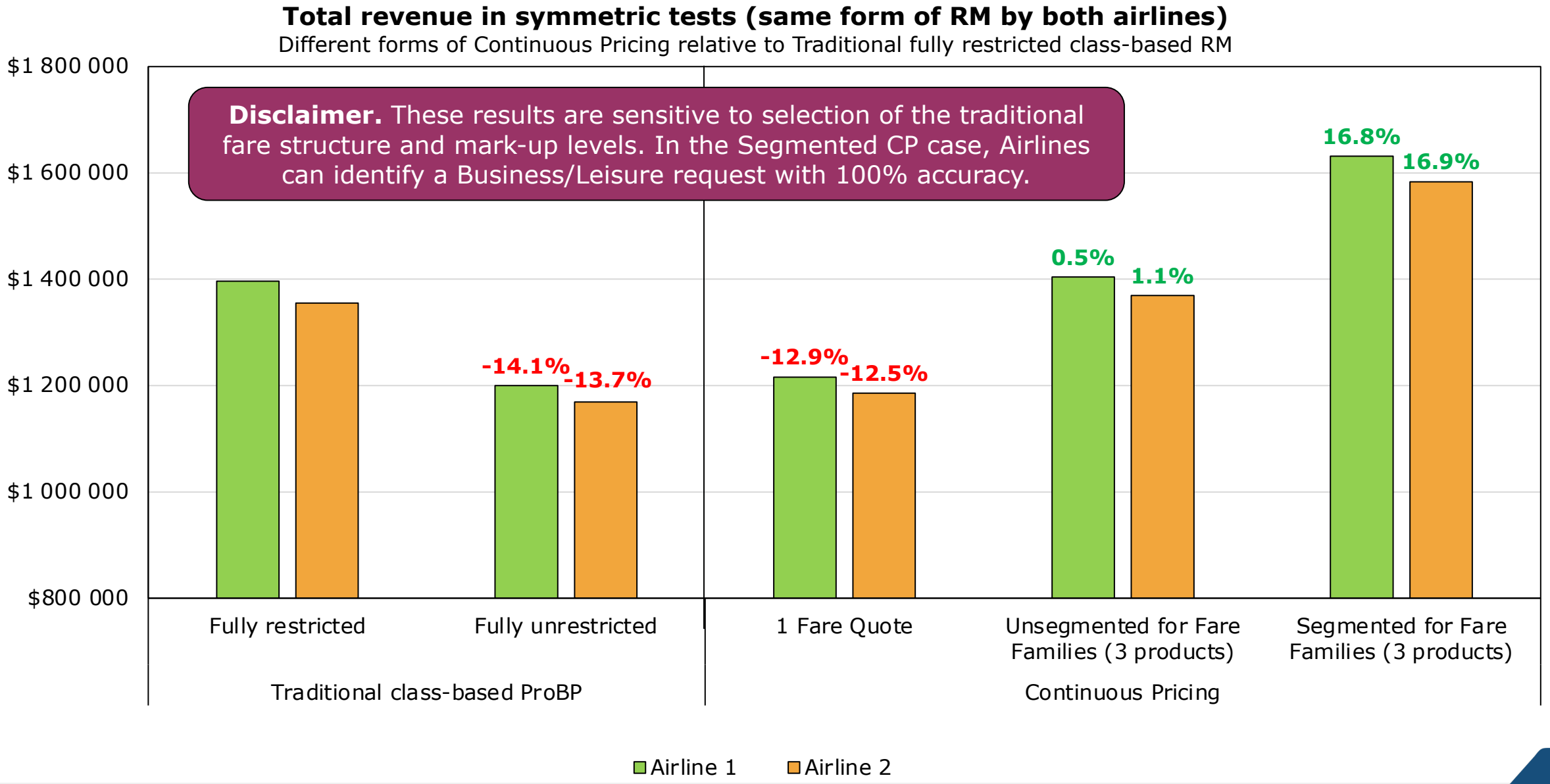
Segmented CP for Fare Families

AP	Basic	Std	Flex
0	f_B^*/f_L^*	f_B^*/f_L^* + \$35	f_B^*/f_L^* + \$100

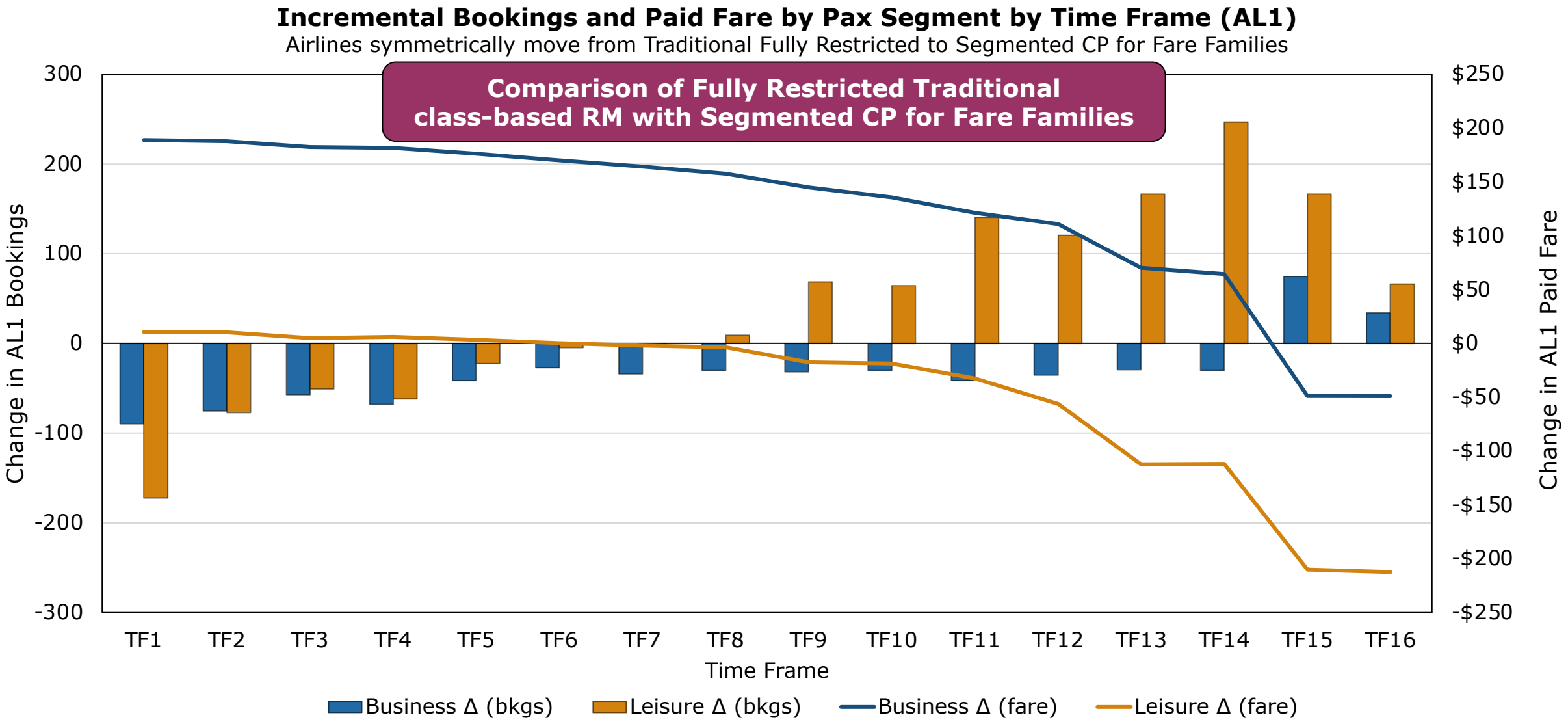
Continuous f_B^*/f_L^* **bounded by** $[F_{11}, F_1]$

Same fare structure type across OD markets (but with different fare levels)

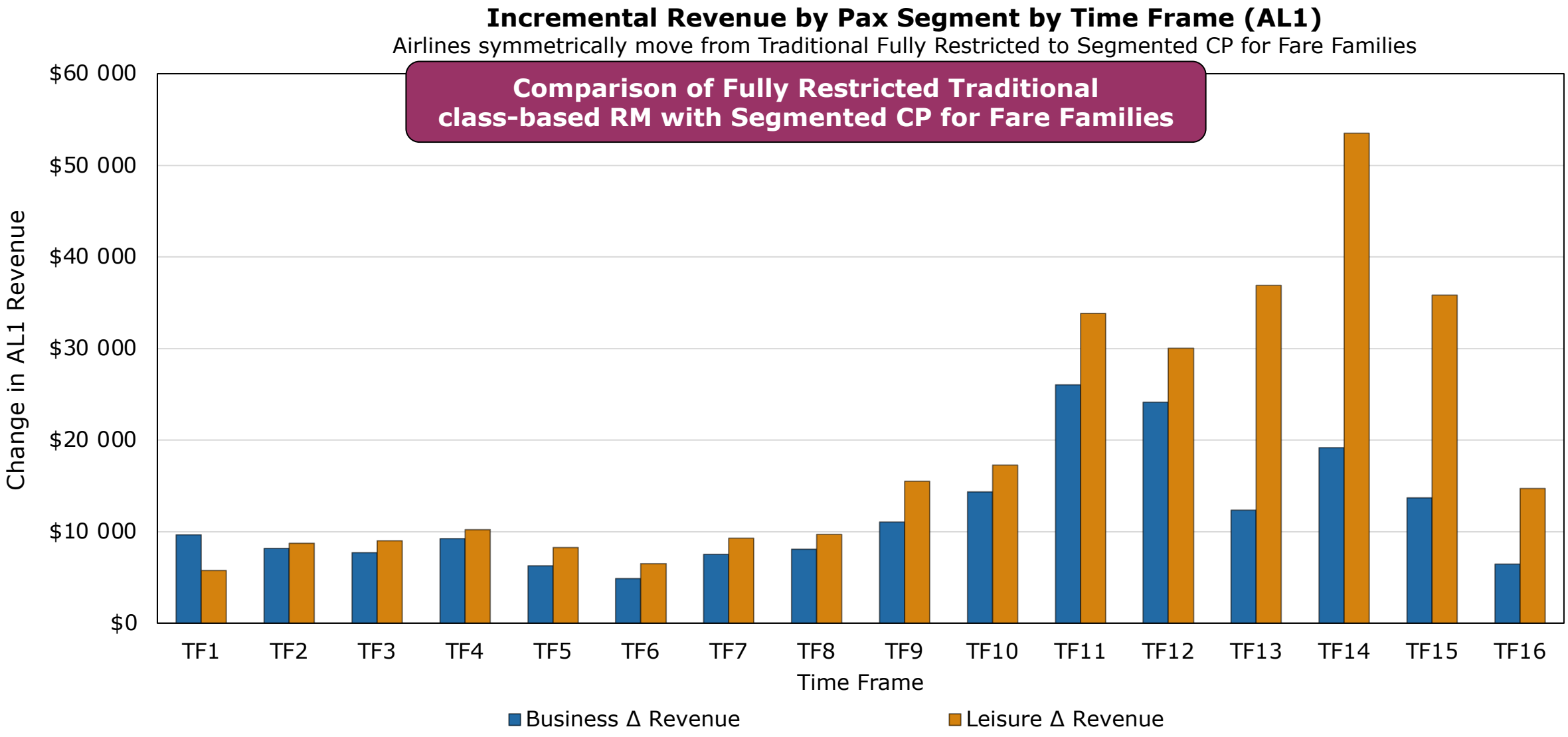
PODS Simulations: Fare Quote Segmentation with Product Differentiation could lead to hefty revenue gains when applied by all airlines



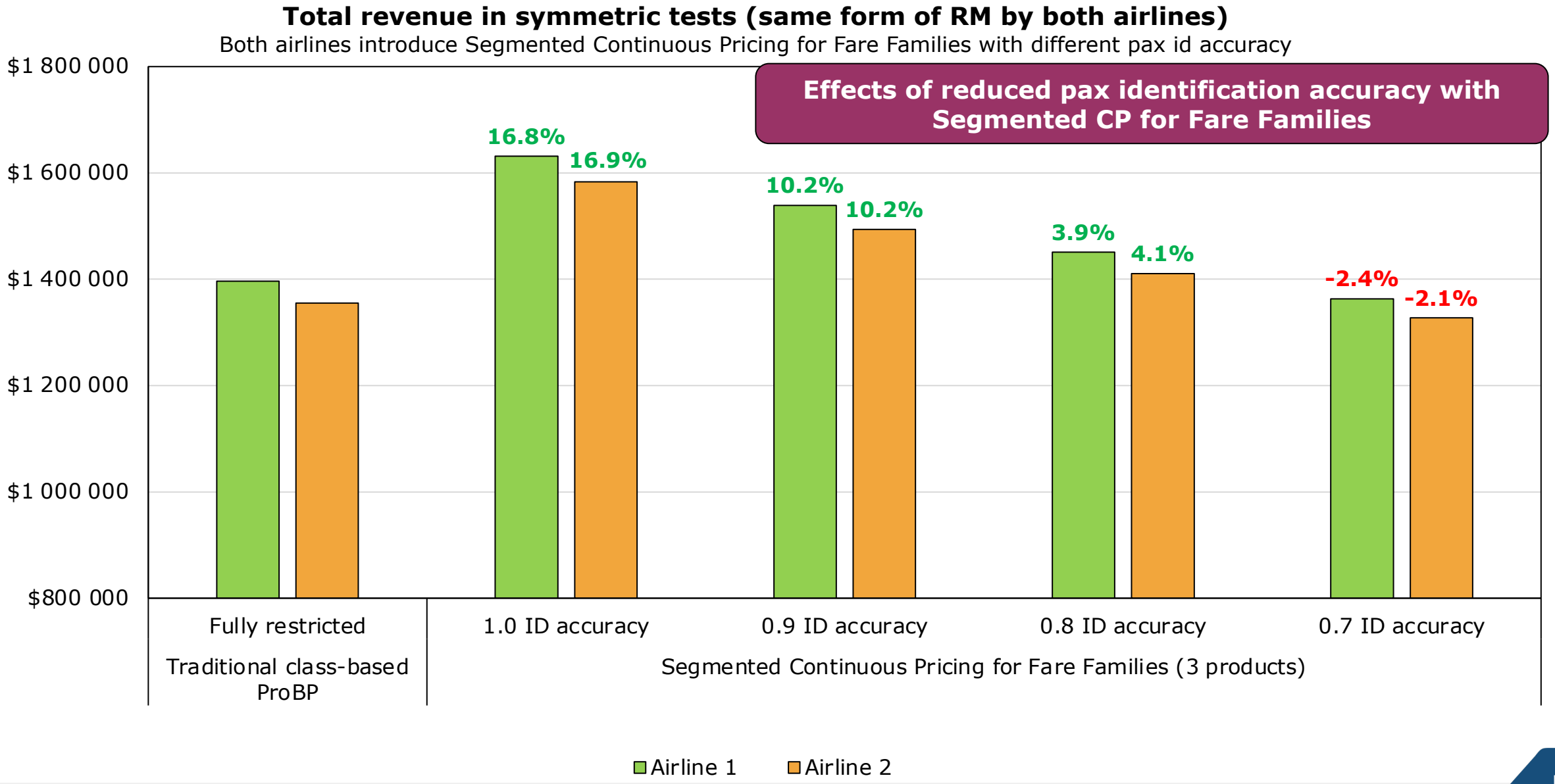
PODS Simulations: Less Business bookings as a function of higher Business fare, and more late Leisure bookings due to lower fares



PODS Simulations: Segmented CP for Fare Families extracts incremental revenue over Traditional Fully Restricted RM across all time frames



PODS Simulations: Gains of Segmentation are contingent on good passenger identification accuracy



PODS Simulations of CP with Multiple Fare Quotes

Summary

- Sustained 1-1.6% revenue gains of Continuous Pricing over Traditional class-based RM with no restrictions / matrix pricing in PODS Network D11
  - Achieved without excess competitive feedback and harm to the traditional competitor using CP with 1 fare quote / **Unsegmented CP for Fare Families**

- When applied by all airlines in the simulation, **Segmented CP for Fare Families** (with multiple products priced differently to Business/Leisure passengers) results in hefty incremental revenue (up to 17%) over Fully Restricted Traditional class-based baseline
  - Segmented CP for Fare Families points to large amount of consumer surplus, but it is sensitive to the ability of correctly identifying the segment of an incoming booking request
  - Further research required whether the method can be used by one airline in competition with general/Fully Restricted fare structures without excess competitive feedback

Future Research

- Presented heuristics rely on the *1 fare quote continuous pricing algorithms*
- Segmentation and Product Differentiation are adjustments/mark-ups to the single f^*

Optimization: improve current algorithms by integrating multiple products and segments into the continuous Bid Price computation

- We can show competitive stability of Continuous Pricing in fully unrestricted/matrix pricing fare structures
- Large revenue gains when all airlines simultaneously move to Segmented CP for Fare Families

Traditional competition: how to use fare quote segmentation with product differentiation to compete in general fare structures?

- When tests with reduced pax identification accuracy were performed, airlines continued to assume the same segmented FRAT5 as with perfect identification

Robustness: what WTP estimates to use under errors in pax identification and in competition?

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See also:

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Thank you!

Questions?

Feedback and suggestions welcome!

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