Modeling Consumer Preferences for Low-CO_2 Emissions Aircraft in China

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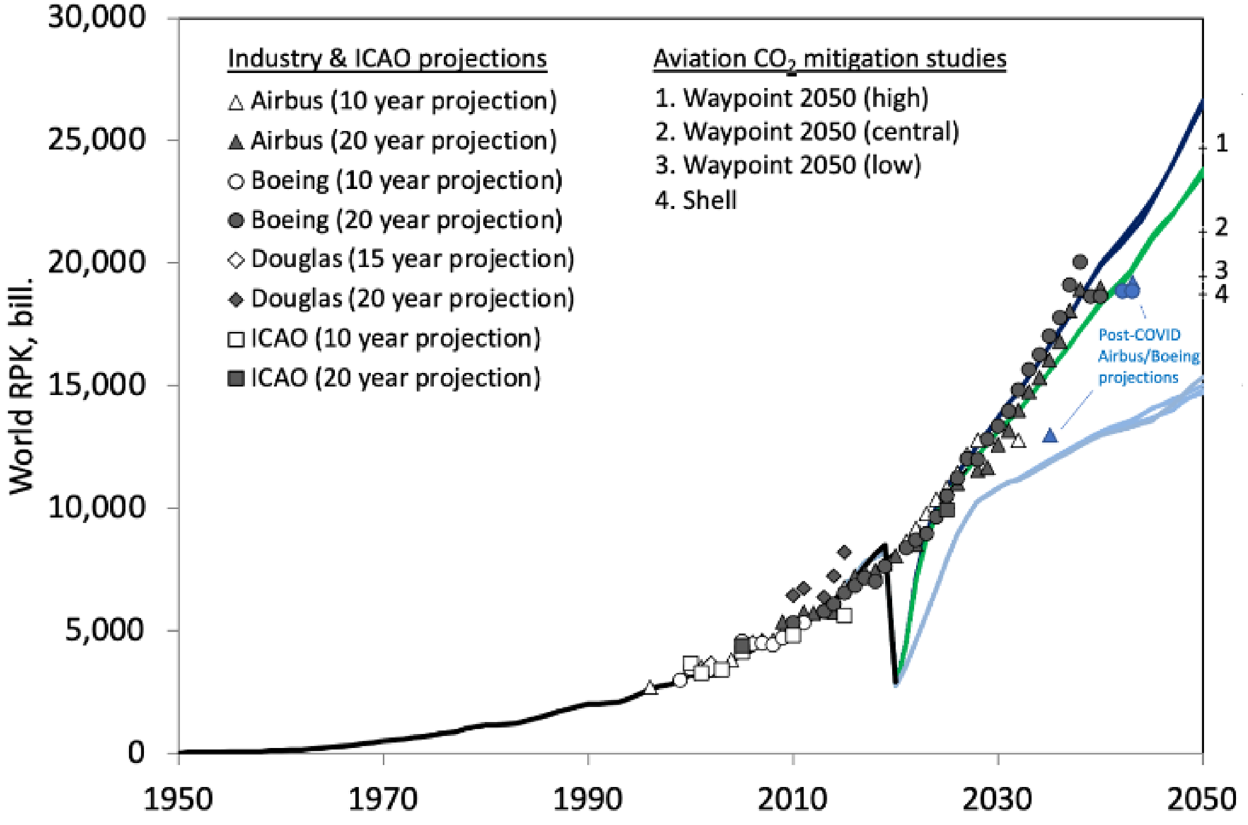
Introduction



World revenue passenger-km travelled (RPK)

Aviation: Technologies and fuels to support climate ambitions towards 2050. *Concawe.* Report No. 5/23, 2023, p. 4.

- Global passenger aviation demand forecast to grow 4%/year despite COVID-19 impact
- In 2019, passenger flights contributed to ~ 85% of CO_2 emissions in commercial aviation (ICCT,2020)
- Aviation sector facing increasing pressure to mitigate CO_2 and non-CO_2 impact
- Achieving industry net-zero targets requires disruptive technological change

Introduction

Challenges

Achieving aviation net-zero goals will likely require an increase in airfares

Opportunities

Consumer's willingness to pay for green aviation

Social acceptance

- *Consumer attitudes*
- *Consumer choices*
- *Willingness-to-pay*

↓

Airline behaviour

- *Airline choices*
- *Responses to new technologies*
- *Airline profitability*

- Public opinion can either facilitate or impede the deployment of these disruptive technologies and fuels

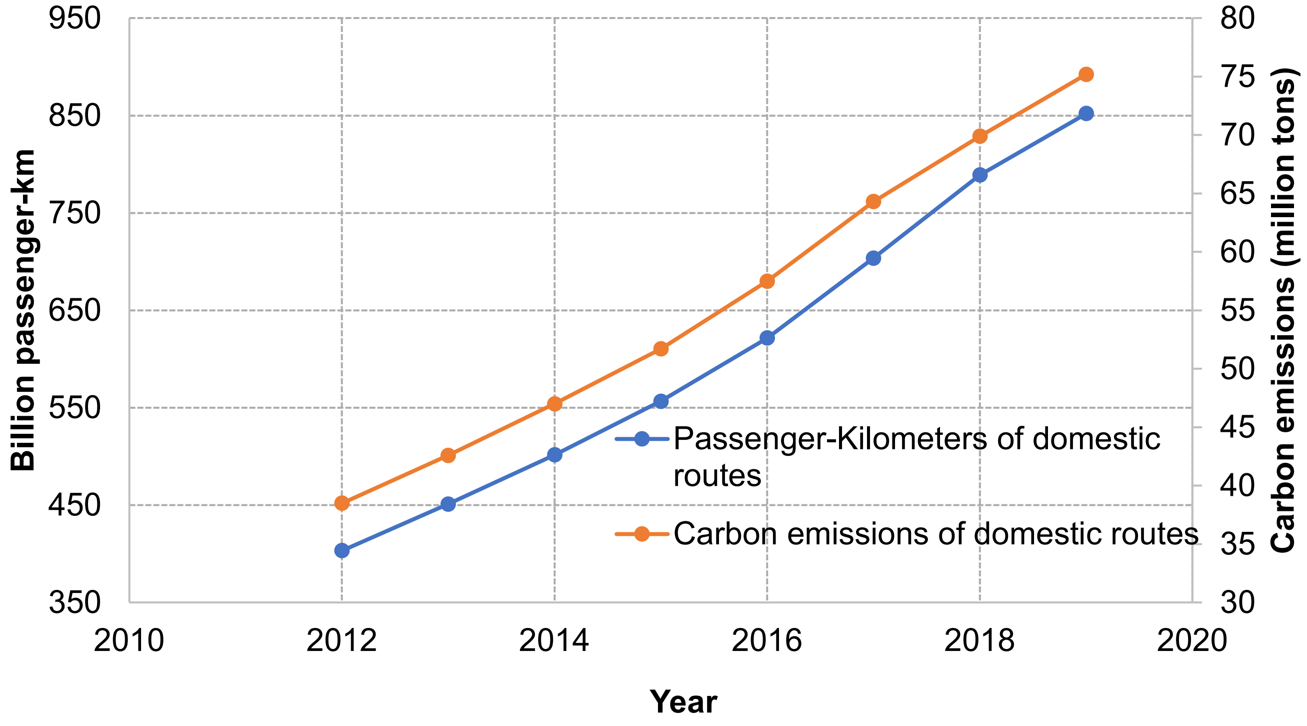
Introduction

- Study focuses on Chinese domestic market to investigate consumer preferences for low-CO_2 emissions aircraft

- 2012 - 2019, domestic passenger air travel grew by 111%, related CO_2 emissions have increased by 95%

Research Objectives:

- Identify preference heterogeneity across individuals and market segments
- Analyse characteristics of potential early adopters
- Quantify consumer willingness to pay



Passenger-km Data: Civil Aviation Administration of China
CO_2 emissions of domestic routes adapted from (Cui et al., 2022)

Methodology - Stated Preference (SP) Survey

Survey composition		
1	Air travel experiences	Flight frequency, trip purpose, frequent flyer program, etc.
2	Most recent air trip	Recent trip purpose, fare class, alternative mode choice etc.
3	Stated choice (SC) experiment	Hypothetical air itinerary choice, 9 choice tasks
4	Attitudinal statements	Environmental concern, social norm, openness to new technology, etc
5	Socio-demographic questions	Gender, age, income, etc.

Stated Choice (SC) Experiment

Sustainable Aviation Fuels (SAF) powered conventional aircraft

Zero-emission aircraft: all-electric aircraft and hydrogen powered aircraft

Which flight ticket would you choose for a short-haul trip in China?

Note: Short-haul flights are defined as those less than 700 km (e.g., Beijing to Shenyang)

	Option 1	Option 2	Option 3
Aircraft Type	Hydrogen aircraft	SAF powered conventional aircraft	Conventional aircraft
Life Cycle CO_2 Emissions Compared to The Conventional Aircraft	100 % reduction	60% reduction	0% reduction
Ticket Price (¥)	700	840	700
Flight Time (h)	2h15	1h30	1h30

	Option 1	Option 2	Option 3
Your choice:	○	○	○

Methodology - Modelling Techniques

- Apply discrete choice modelling to estimate data from the SC experiment
- Assume utility maximisation behaviour
- The observed discrete choices are dependent variable
- Identify factors influencing choices:
  - Characteristics of choice options
  - Characteristics of decision-maker (e.g., age, income, etc.)
- Multinomial logit model (MNL): the probability of individual n choosing air itinerary option

$$P_{ni} = \frac{e^{V_{ni}}}{\sum_{j=1}^{J} e^{V_{nj}}}$$ where J is the total number of air itinerary options

Methodology - Modelling Techniques

- Base model

$$V_i = ASC_i + \beta_{fare} * fare + \beta_{flight\ time} * flight\ time + \beta_{aircraft\ type} * aircraft\ type + \beta_{emission\ reduction} * emission\_reduction$$

- Incorporating systematic heterogeneity

$$V_i = ASC_i + (\beta_{fare} + \Delta_{\beta_{fare}} * business) * fare + (\beta_{flight\ time} + \Delta_{\beta_{flight\ time}} * business) * flight\ time....$$

- Latent class model

the probability of individual n choosing air itinerary option i:

$$P_{ni} = \sum_{s=1}^{S} P(i|X_n, s)\ P(s|X_n)$$

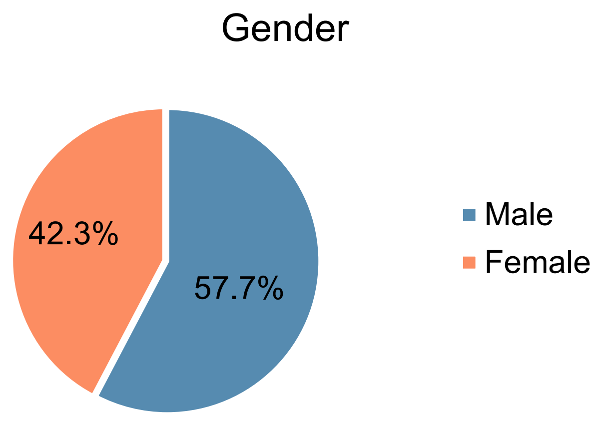
Class-specific choice probability

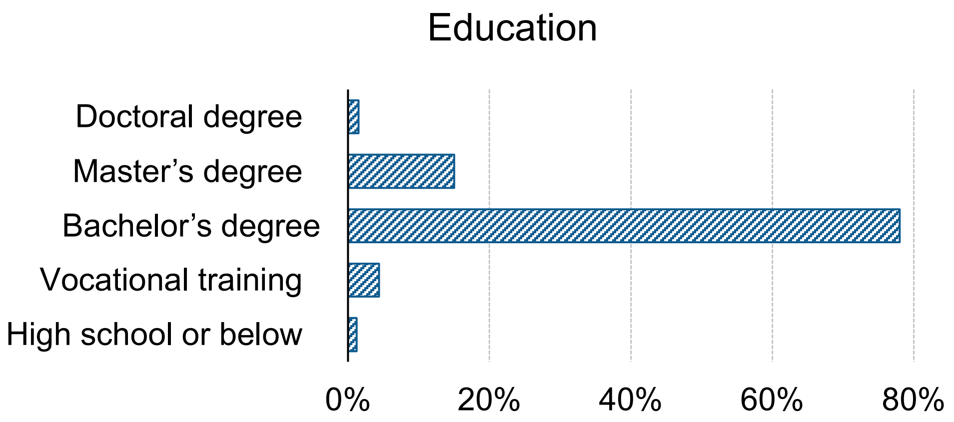
Class membership probability

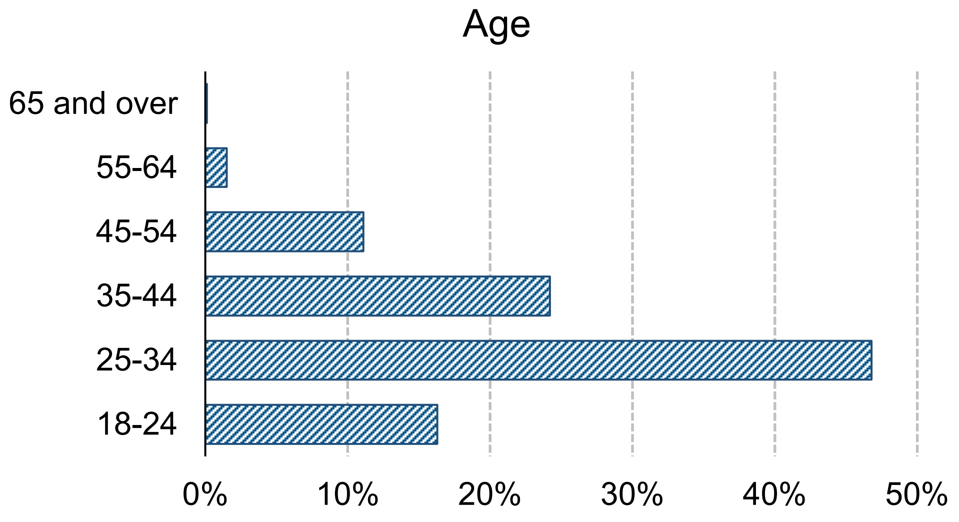
where X_n is characteristics of itinerary option i, s is latent class

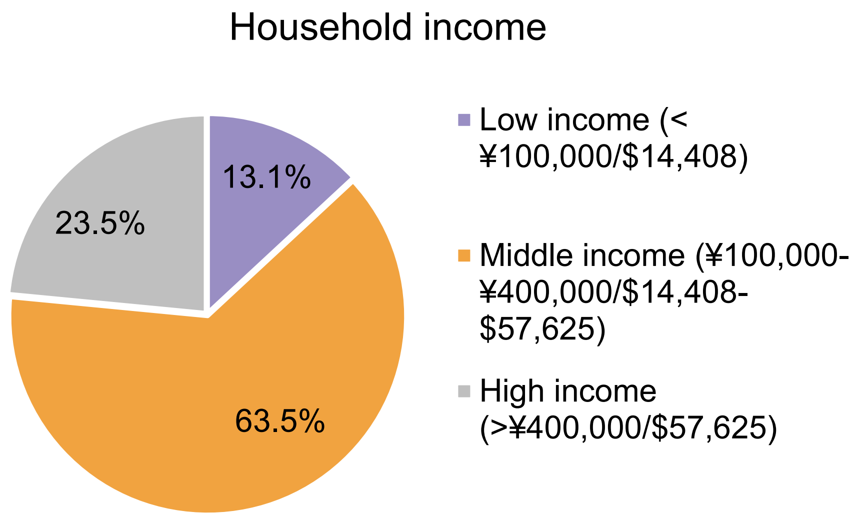
Data

Web-based survey: 3,187 respondents, who have flown before (28,683 SC observations)



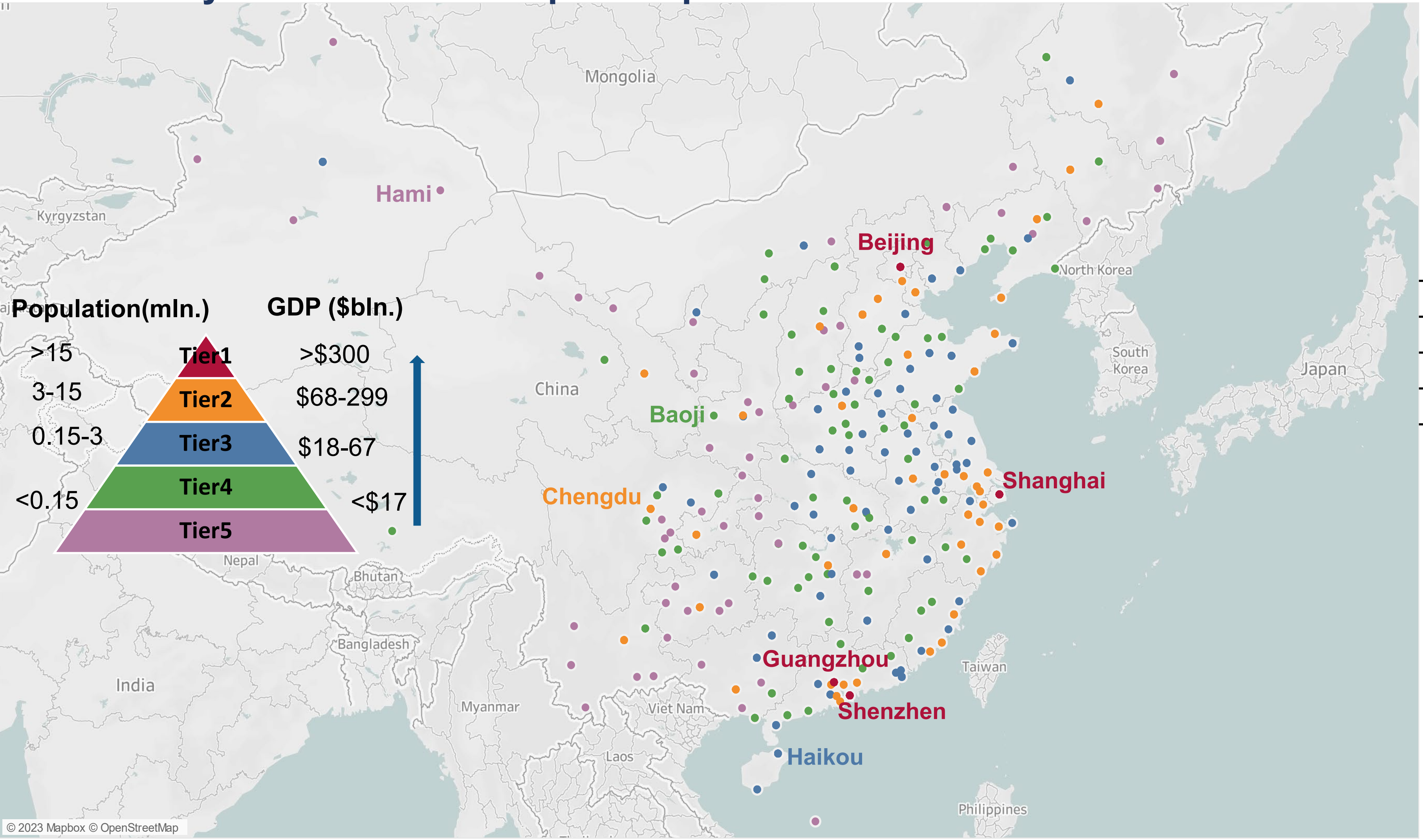




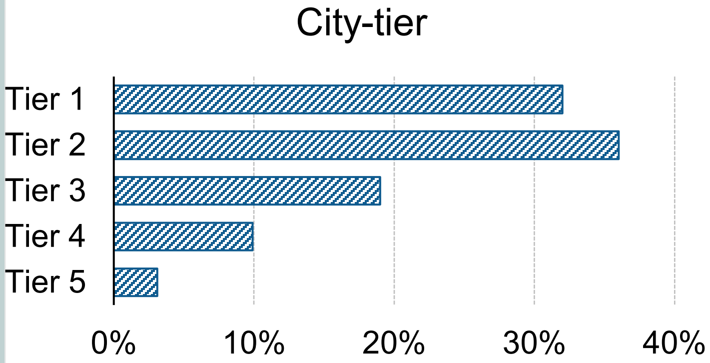


Data

City Locations of Sample Respondents



Tier1: Beijing, Shanghai, Shenzhen, Guangzhou
Tier2: e.g., Chengdu
Tier3: e.g., Haikou
Tier4: e.g., Baoji
Tier5: e.g., Hami



- Sample Coverage: All 31 Chinese administrative regions, with 63% residing in Tier 1 and Tier 2 cities

Estimation results

- Preference order (all respondents):

  Electric aircraft > Hydrogen aircraft > SAF-powered conventional aircraft > Conventional aircraft

  Corresponding WTP for alternative aircraft: $89, $63, $44

- Preference order (business travelers):

  Hydrogen aircraft > SAF-powered conventional aircraft > Conventional aircraft

  Corresponding WTP for alternative aircraft: $98, $69

- Business travellers: Higher flight time sensitivity, lower fare sensitivity

	Panel effect model		Panel effect model with interaction	
Number of Parameters	9		15	
Number of Respondents	3187		3187	
Number of Observations	28683		28683	
LL (Log likelihood)	-27668.45		-26980.11	
Adj. Rho-squared	0.122		0.143	
AIC	55354.91		53990.22	
BIC	55429.28		54114.18	
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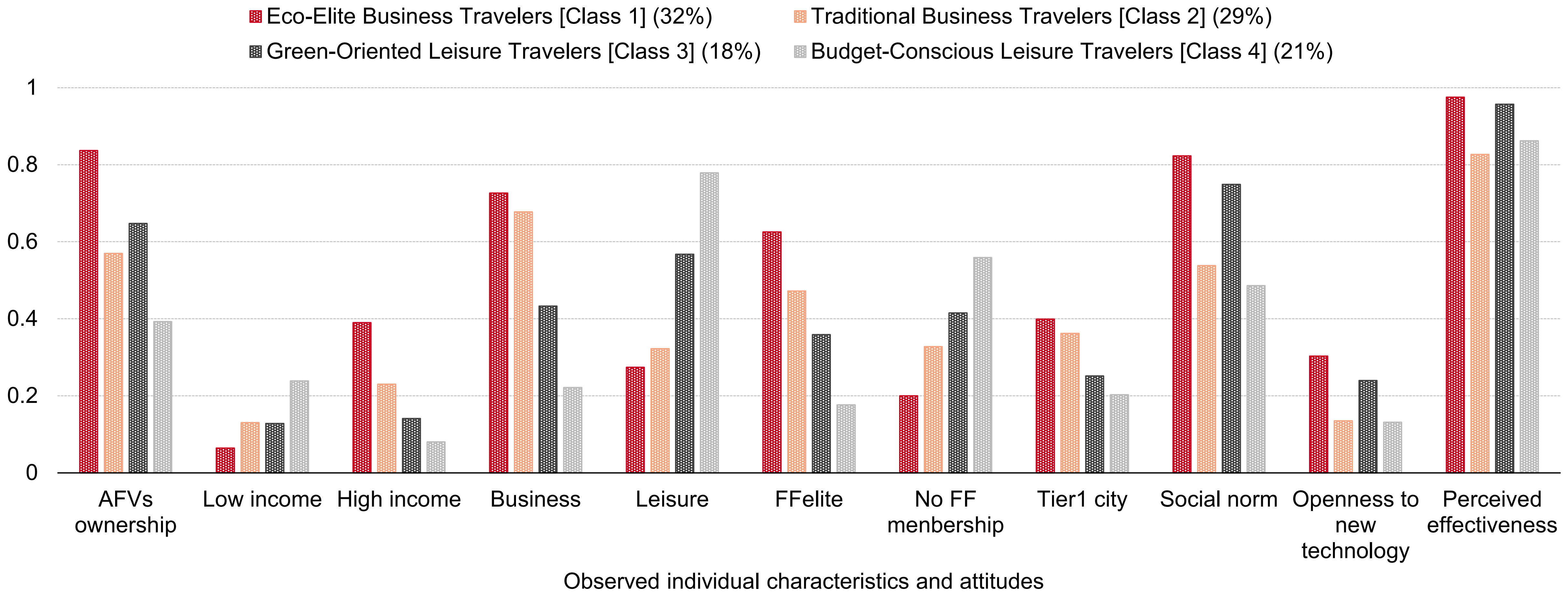
ASC1	0.1743	10.74	0.1587	9.61
ASC2	0.1412	8.49	0.1373	7.94
ASC3(base)				
Fare (¥)	**-0.0014**	**-32.63**	-0.0023	-21.39
Business travelers			0.0009	7.86
Flight time (min)	**-0.0034**	**-4.41**	-0.0025	-2.41
Business travelers			-0.0110	-6.91
SAF powered conventional aircraft	**0.4119**	**11.22**	0.2271	3.95
Business travelers			0.4345	5.79
Electric aircraft	**0.8353**	**13.44**	0.8455	9.06
Business travelers			0.1225	0.97
Hydrogen aircraft	**0.5962**	**10.61**	0.3800	4.46
Business travelers			0.5504	4.82
Conventional aircraft(base)				
Life-cycle CO2 emissions compared to the conventional aircraft (%)	**0.0053**	**11.18**	0.0062	8.36
Business travelers			0.0001	0.08
Sigma panel	0.1938	9.02	0.2121	10.11

Estimation results

- Business travelers’ interaction with employer-paying option
  - Employer-paying: Reduced fare sensitivity, higher value of time (VOT) ($152 vs. $27 self-paying)
  - Employer-covered business travelers have a greater WTP for flying on an alternative aircraft
- Four distinct groups were identified from the latent class model:
  - Class 1 (32%), Class 2 (29%), Class 3(18%), Class 4(21%)
  - Class 1 and Class 2: business travelers, similar VOT values (141$/h vs. 140$/h), Class 1 shows higher preference for alternative aircraft
  - Class 3 and Class 4: leisure travelers, similar VOT values (22$/h vs. 23$/h), Class 3 shows higher preference for alternative aircraft

Estimation results

Class membership probabilities



Conclusions

- Chinese respondents exhibit a preference for low-CO_2 emissions aircraft over conventional aircraft
- Identified four potential segments
  - Significant variations in WTP for flying on alternative aircraft across four segments:

    $36 ~ $177 for SAF powered conventional aircraft, $13 ~ $208 for electric aircraft, $9 ~ $219 for hydrogen aircraft
- Early adopters are likely to be affluent individuals who have prior experience with AFVs. They tend to embrace new technologies, believe in the positive impact of adopting low-CO_2 emissions aircraft, and are susceptible to social influence
- Limitations include selection bias, hypothetical bias due to SP data
- Establishes groundwork for future research into interactions between airline decision making and consumer preferences in emerging markets

More information:

http://www.atslab.org/