Sustainable Pathways in the Aircraft Manufacturing Industry

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Introduction

- PhD student at Norwegian School of Economics (NHH), 2020-2025.
- Visiting TSE.
- Area of Research: Empirical Industrial Organisation, Transportation, Environment.
- Topics: Airlines and Electric Vehicles (EVs).
  - Pass-through of Passenger Taxes in the Aviation Industry.
  - Impact of the supply side shocks on pricing (Boeing 737Max), with Anantha Divakaruni (University of Bergen).
  - Local polution and tax incentives for Electrical Vehicles, with Morten Saethre and Mateusz Mysliwski (supervisors).

Setting

- Focus on commercial passenger aircraft
- Two main manufacturers: Airbus and Boeing
- Buyers: Airlines and lessors

Motivation

Major industry:

- Economy:
  - European industry is **world leader in the production of civil aircraft** and it generates: **405K jobs, €130 billion revenues** and plays a **leading role in exports,** amounting to **€109 billion** in 2019 (EU Commission)
- Environment:
  - Each new generation of aircraft is up to 20% more fuel efficient than the previous one: "80% less CO2 per seat in today's modern aircraft than in the first jets in the 1950s." (Air Transport Action Group)
  - Worldwide: 2.5% of global CO2 in 2018 (*Our world in Data, Ritchie 2020*)
  - US aviation emissions are rising, $\sim$ 2.3% per year from 1990 to 2019 (*IEA 2023*)

Benkard, C. Lanier (2000): *"Massive entry costs, dynamically increasing returns, imperfect competition, the fact that many countries consider it"strategic" that make it important from a policy perspective, and the industry has frequently been the target of industrial policy, most notably in Europe."*

Objectives

- Evaluate climate change mitigation policies while considering:
  - Firms optimal pricing strategies
  - Interactions between firms (competition)

Examples:

- Impact of the introduction of new aircraft models:
  - *e.g. more fuel efficient, uses 'Sustainable Aviation Fuels' (SAF), or hydrogen.*
- Emission standards on manufacturers to reduce CO2 emissions
  - at national or at supra-national level, *e.g. local carbon taxes, CORSIA*.
- Market power,
  - e.g. *should there be more cooperation among manufacturers to develop greener aircraft?*

Outcomes

- Diversion rates (consumer switching behaviour)
- Cost pass-through of shocks to prices

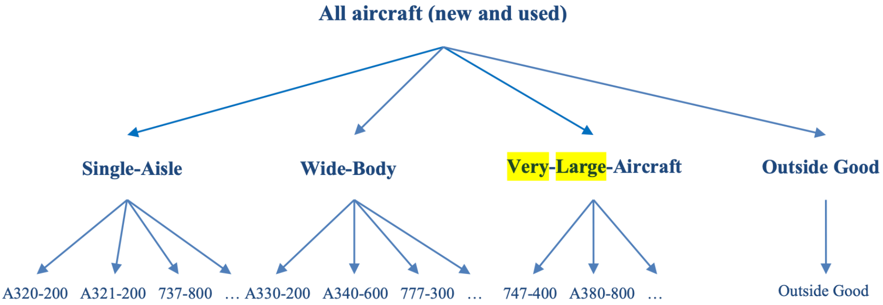
Literature Review

- Airline literature focuses on passenger fares (mostly using DB1B data from the DoT)
- Competition in the aircraft manufacturing:
  - Benkard (2000), "Learning and Forgetting: The Dynamics of Aircraft Production", *AER.*
  - Irwin and Pavcnik (2003), "Airbus versus Boeing revisited: international competition in the aircraft market", JIE.
  - Benkard (2004), "A Dynamic Analysis of the Market for Wide-Bodied Commercial Aircraft", ReStud.

Data

- Coverage (t): From 1995 - 2018(9)
- Firms (f): Airbus, Boeing
- Variables:
  - p_{jft}: List prices in millions (large unkown discounts, can be as big as 50%)
  - X_{jft}: Technical characteristics* (seats by class, MTOW, range, fuel consumption and cash operating costs)
  - M_t: Aircraft in operation (obtained from Airbus and from leasing data)

*constant over time


All aircraft (new and used)
Single-Aisle
Wide-Body
Very-Large-Aircraft
Outside Good
A320-200
A321-200
737-800
…
A330-200
A340-600
777-300
…
747-400
A380-800
…
Outside Good

Descriptive Statistics

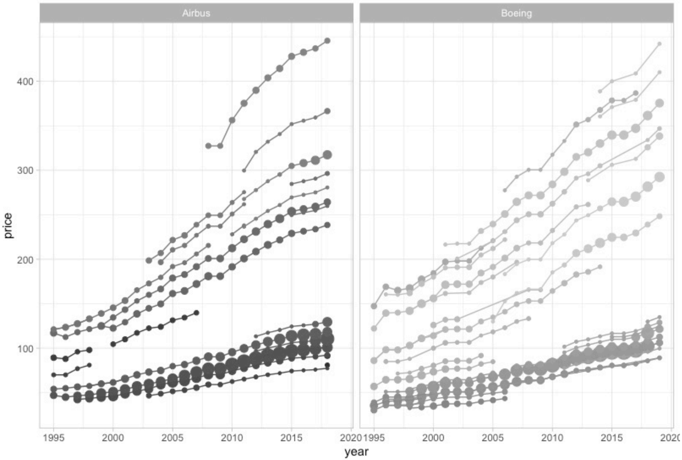


Figure 1: Evolution list prices by model and manufacturer (1995-2018)

Table 1: Growth rate of prices

	Single Aisle	Widebody	Very Large Aisle
Airbus	3.0	3.2	2.9
Boeing	3.8	4.4	3.5

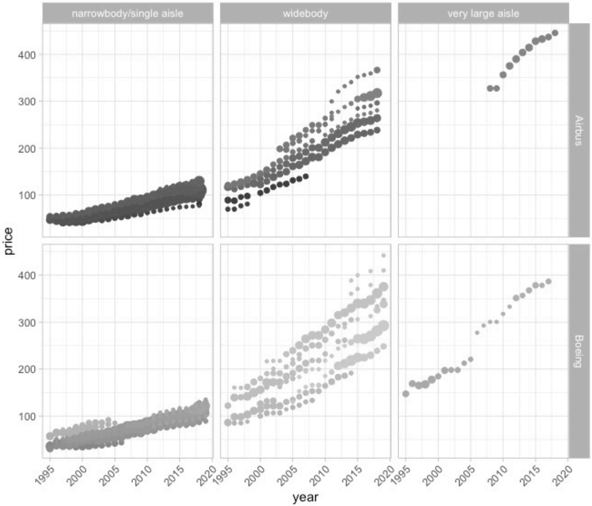


Figure 2: Prices for Airbus and Boeing in the single aisle, widebody and very large aisle segment (1995-2018)

Table 2: Technical characteristics average (1995-2018).

	Single Aisle		Wide body		Very Large Aisle	
	Airbus	Boeing	Airbus	Boeing	Airbus	Boeing
Economy Seats	137	140	256	252	439	307
Range (10^3 km)	3	3	6.7	6.8	8.1	7.6
Max.Takeoff Weight (in tones)	79	79	265	266	569	416
Fuel cost (thousand of USD, per trip)	2.2	2.3	29	41	97.8	83

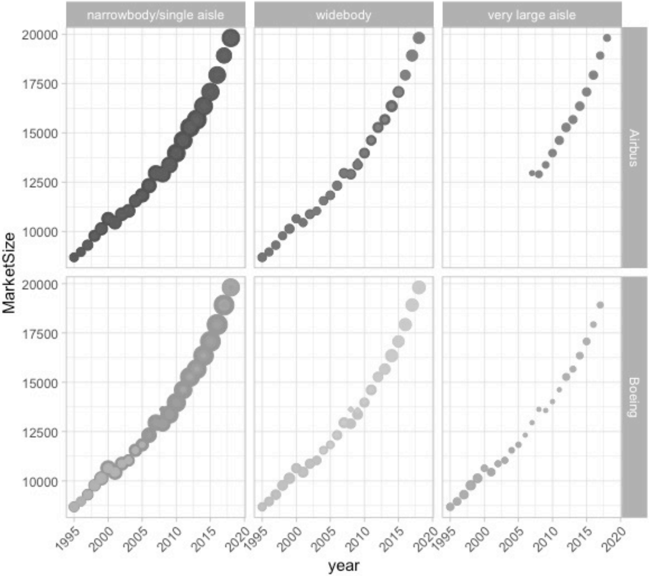


Figure 3: The size market (aircraft in operation) grows over time (1995-2018)

Demand

- Nested logit: substitution patterns depend on the nests (σ: single aisle, widebody, very large aisle)

$$\ln\left(s_{jt}\right) - \ln\left(s_{0t}\right) = x_{jt}\beta - \left(\alpha_{0t} + \alpha_1 t\right) p_{jt} + \sigma \ln\left(s_{jt/st}\right) + \xi_{jt}$$

- **Buyer**: world demand for a given model by a representative airline
- **Products** (j): aircraft model (14-24 unique ones per year approx)
- **Market size** (M): new and used aircraft in operation (with $\geq$ 100 seat)
- **Outside good** ($j = 0$): not new aircraft in operation

Supply

- **Duopoly**
- **Cost trajectory** *(modeled statically, 5 year horizon):* learning-by-doing
- **Price Competition**
- **Fixed aircraft specifications**
  - choice of characteristics is given
  - no investment
- First Order Condition:

$$p_t + M_t^{-1} s_t = \underbrace{c_t + F_t}_{c_t^{dym}}$$

Cost Function

- Cumulative quantity reflects accumulated experience: firms anticipate that they will reduce their costs in the future by increasing their production of aircraft over time.
  - Learning by doing, (θ is the learning parameter)

$$c_{jt} = z_{jt}\gamma \left(\sum_{s=1}^{t-1} q_{js} \right)^{\theta} + \omega_{jt}$$

$$F_{jt} = E_t \left[\sum_{n=1}^{\infty} \beta^n q_{jt+n} \theta \left(\sum_{s=1}^{t+n-1} q_{js} \right)^{\theta-1} \right]$$

Estimation

- Joint estimation of demand and supply through 2 step linear IV-GMM
- Identification:
  - Instruments for price (p) and group market share ($\bar{s}_{j/g}$):

    a) BLP instruments (computed by segment)

    b) *Differentiation IVs* (Gandhi and Houde, 2023)
- Product characteristics of rivals
  - Note: variation from changes in the number of products in the market (as characteristics are fixed for a given product)

Results

- Price sensitivity: increasing marginal utility of price (more price inelastic)
  - $\alpha_0 + \alpha_1 t = -(0.047 - 0.001) \times t$
- Group correlation: high within segment correlation
  - $\sigma = 0.67$

Extensions / Next Steps

- possibility extend to Random Coefficients Nested Logit (Verboven and Grigolon 2014)
  - more flexible substitution patterns between products with similar characteristics.

    e.g. cash operating costs COC (related to fuel expenditure)

Thank you for your attention!

Work in progress, any feedback is very welcome.

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Aviation demand

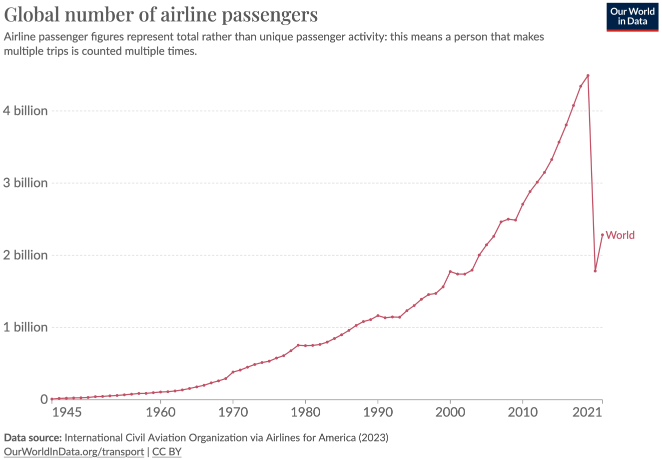

Figure 4: Increase in airline passengers