SESAR JOINT UNDERTAKING Modus

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Impacts of sustainability oriented regulatory measures on air-rail modal shifts: the case of a kerosene tax

Work in progress

Chantal Roucolle[1]

Tanja Bolic[2], Isabelle Laplace[1], Nathalie Lenoir[1], Annika Paul[3]

[1]Ecole Nationale de l'Aviation Civile, [2]University of Westminster, [3]Bauhaus Lufthart

EUROPEAN PARTNERSHIP

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Motivation

- Context
  - increasing environmental awareness, regulatory measures, capacity shortages across different modes, and the need for a more seamless passenger journey
  - optimization and alignment of multimodal transport in Europe to improve the overall performance of the (future) transport system
  - ➢ Modus Project (https://modus-project.eu/)

- Research questions
  - ➢ ***Assessing the substitution paths between air and rail on French markets***
  - ➢ ***Simulating regulatory measures enabling the steering of passengers' choices***

- Main results
  - ➢ A change in train price will have a higher impact on demand for air than a change in plane price will have on demand for train
  - ➢ With a tax on kerosene the modal shift from air to rail will depend on market supply structure

Literature review

- Inter-modal competition has been extensively studied in the literature
  - Most focus on air-rail competition only (Albalate et al., 2015), (Behrens & Pels, 2012), (Ortúzar & Simonetti, 2008), (Park & Ha, 2006) , (Ivaldi & Vibes 2008)
  - Others consider sets of other modal alternatives as bus, car-pooling and private cars (Bergantino & Madio, 2020)
- Some authors consider inter and intra-modal competition (Bergantino et al. 2015, Ivaldi & Vibes, 2008)
  - HSR network expansion captures air PAX: around 14% , in Spain 1999-2012 (Castillo-Manzano J. & al. (2015)), between 13% to 19% in Italy depending on the routes (Bergantino & Madio (2020))
  - If HSR dominates, cooperation with HSR is a workable option for airlines but there are less incentives for HSR to cooperate with airlines (Takebayashi (2014))
- Carbon taxation
  - Pagoni & al (2016): introducing a carbon tax in the US aviation is expected to cause moderate changes in prices and market shares
  - Fukui and Myoshi (2017): impact of a fuel tax on the emissions of the US aviation system and measure of the reduction in traffic; smaller airlines would be more impacted than larger ones; presence of rebound effect
  - Changmin (2021): considers air and rail, in the framework of a joint policy of air taxation to subsidize HSR and show in a theoretical framework that this integrated policy does not lead to a reduction of air traffic on all routes

Markets description

Air rail competition in France - oligopoly structure

Same approach as Ivaldi & Vibes 2008

- Market definition : Origin-Destination
  - Selection of geographic areas larger than the cities: NUTS3 level
    - ➢ *Several airports in departure and arrival areas*
  - Selection of OD where both air and rail are available – direct routes
    - ➢ *79 markets & 809 markets-month in 2016*

- Several transport alternatives available on each market
  - Train: HSR, Intercity, Night
  - Plane: Major/Legacy, Low-Cost Carriers

Number of alternatives	Alternatives per mode	Number of Route-Month	Percentage of Route-Month
2 alternatives	P1T1	418	51,67%
3 alternatives	P1T2	85	10,51%
	P2T1	218	26,95%
4 alternatives	P2T2	10	1,24%
	P3T1	14	1,73%
5 alternatives	P2T3	23	2,84%
	P3T2	40	4,94%
6 alternatives	P3T3	1	0,12%
		809	100,00%

Carrier Name		Freq.	Percent
SNCF		992	45.88
HOP!	Major	449	20.77
Air France	Major	390	18.04
Easyjet	LCC	139	6.43
Volotea	LCC	73	3.38
Jetairfly	LCC	54	2.50
Ryanair	LCC	47	2.17
Nouvelair	Major	10	0.46
Air Madagascar	Major	8	0.37
Total		2,162	100.00

		Freq.	Percent
	Train HSR	737	34.09
SNCF	Train ITC	111	5.13
	Train Night	144	6.66
Total		992	45.88

In 2016:

- None of the airlines belong to the same alliance
- Air France and its subsidiary HOP! do not operate on the same OD

Model assumptions

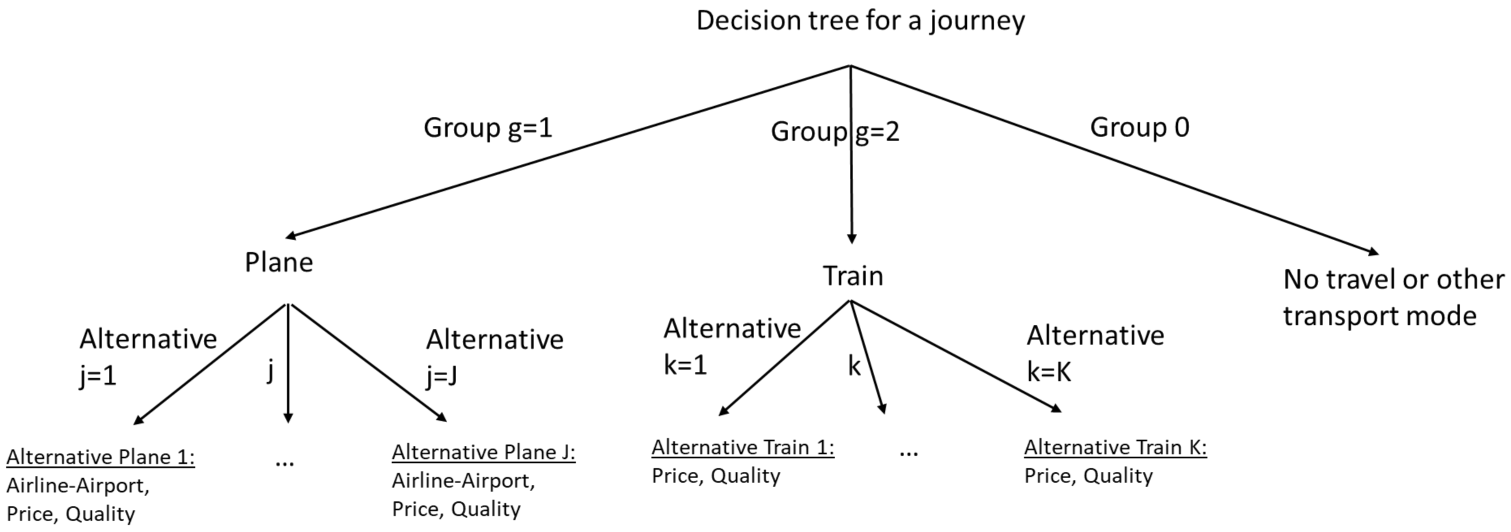
- Competition in price and quality of service – these two attributes drive customers' choice

  - Quality in transport supply: associated with the transport mode and the type of carrier for air, the type of train for rail
    - ➢ *Major supply: HSR, Legacy carriers*
    - ➢ *Low-Cost supply: Intercity, Night, Low-Cost Carriers*
  - Other attributes for quality:
    - frequency (number of departure per month)
    - speed
    - hour of departure (<10 am; 10am-3pm; 3pm-8pm; >8pm)
  - Market attributes: distance ; departure and arrival average income ; number of inhabitants

- Assumptions:
  - ➢ Quality is determined ex-ante: Restriction to price competition
  - ➢ Products are differentiated, and that each operator produce one unique good
    - ➢ questionable assumption for SNCF : 14 OD (17,72%) with several train services; for Air France on few routes with several airports

Model assumptions

Demand for transport: A two-stages decision model



- *Alternative attributes*: combinaison of a mode, quality of service & corresponding price ; observable
- Individual preferences for quality ; not observed
- *Selection of the best alternative considering all the possibilities on the OD: utility split between deterministic and random part:*

$$U_j = V_j + \epsilon_j$$

- *The deterministic part (mean utility level) is expressed as:* $V_j = \psi_j - h\, p_j$ *h: part of the marginal utility of income*
- *The random part is expressed as:* $\epsilon_j = \gamma_g + (1 - \sigma)\gamma_j$

σ: measures the degree of intra-group correlation, γ_g *and* γ_j *assumed to be distributed as the standard extreme value*

Demand function

Nested logit model

Demand is expressed in terms of market shares

$$ln(s_j) - \ln(s_0) = \psi_j - hp_j + \sigma ln(s_{j/g})$$

- s_j : market share of alternative *j*
- s_0 : market share of the outside good – geometric mean of departure and arrival population (Berry, Carnall Spiller, 2006)
- p_j : price of alternative *j*
- $s_{j/g}$: conditional market share of alternative *j* given the choice of mode *g*
- ψ_j : vector of characteristics for the alternative *j*
    - Route characteristics:

    average income at departure and arrival, distance, route fixed effects, month fixed effects
    - Alternative characteristics:

    type of service provided, frequency, speed (& cross effects between the type of service or mode), hour of departure, percentage of business seats

Mark-up equation

- Under price competition, firms maximize their profit
  - Bertrand-Nash equilibrium characterized by the mark-up equation

$$p_j = c_j + \frac{1-\sigma}{h\left(1-\sigma\sum_{k\in g} s_{k/g} - (1-\sigma)\sum_{k\in g} s_k\right)}$$

c_j : marginal cost of production, linear function of factors that are assumed to impact its level

Price of energy – kerosene & electricity in their lagged value; cross effect with mode

Number of employees per seat

Number of seats per movement

Distance & cross effect with type of service

Data collection

Data sources

For air: OAG Schedule Analyzer, FRACS (France Aviation Civile Services) databases, airline annual reports, IATA paxIS
For rail: MERITS (UIC database), SNCF
Socio-economic data: Eurostat

A unique air and rail monthly aggregated database in 2016 - An observation is an alternative per route and month

Price (€)		France
		Mean *(Sd)*
Plane	Major	129.704 *(19.014)*
	Low-Cost	100.058 *(62.485)*
Train	HSR	121.667 *(28.053)*
	ITC	61.147 *(17.917)*
	Night train	106.644 *(12.874)*

	Count	*Mean* s_j	*Mean* $s_{j/g}$	*Mean* s_g	Mean s0
Plane Major	857	.0105 *(.0149)*	.8112 *(.2713)*	.0130 *(.0198)*	0.9258 *(.0679)*
Plane LCC	313	.0049 (.0067)	.364 (.2528)		
Train HSR	737	.0615 *(.0651)*	.9586 *(.1235)*	.0612 *(.0626)*	
Train ITC	111	.0328 *(.0244)*	.7737 *(.3167)*		
Train Night	144	.0035 *(.0022)*	.1156 *(.1545)*		

PlaneLCC	1,89873418
PlaneMajor	51,1603376
TrainHSR	60,9704641
TrainITC	7,27848101
TrainNight	0,3164557

Percentage of OD-month with a unique alternative per mode

Estimated Models

Model 1: Demand function described by the nested logit model with instrumental variables

Instruments: lag energy cost, number of employees, BLP type instruments

Model 2: Simultaneous equation model described by a multinomial logit model; demand with corrected errors

Model 3: Simultaneous equation model described by the nested logit model; demand with corrected errors

- Method for error correction: Blundel & Robin (1999)

Decomposition of the error term in the demand function: $u_j = \rho \ \vartheta_j + \mu_j$

Where ϑ_j are the estimated residuals of the regressions of $\ln(s_{j/g})$ on previous instrumental variables

Estimated models

- ✓ Model 1: Instruments pass the tests (under identification, weak identification, over identification test of all instruments, endogeneity test of endogenous regressors
- ✓ LR tests: Model 3 is preferred to Model 2

	Model 1	Model 2	Model 3
h	0.00993***	0.0183***	0.0201***
	(0.000916)	(0.000600)	(0.000533)
sigma	0.419***		0.463***
	(0.0283)		(0.0356)
Demand function			
Average departure and arrival NUTS3 income	-0.000308***		
	(1.06e-05)		
Distance > 750 km	-0.378***	-0.372***	-0.523***
	(0.0648)	(0.0702)	(0.0605)
Frequency (monthly number of departure)	0.00661***	0.00341***	0.00299***
	(0.000546)	(0.000149)	(0.000132)
Cross effect frequency & type of service	YES	NO	NO
Percentage business seats	2.258***	3.504***	3.337***
	(0.205)	(0.228)	(0.216)
Speed	0.367***	0.0836	0.0911
	(0.0308)	(0.0858)	(0.0799)
Cross effect speed & plane		-0.123*	-0.129*
		(0.0594)	(0.0549)
Cross effect speed & train	0.333***		
	(0.0515)		
Hour of departure			
Before 10 a.m	reference	reference	reference
between 10:00 am and 3:00 pm	-0.332***	-0.568***	-0.501***
	(0.0844)	(0.108)	(0.100)
betwenn 3:00 pm and 8 pm	0.408***	-0.389**	-0.154
	(0.102)	(0.123)	(0.114)
after 8 pm	0.514***	-0.303	-0.0829
	(0.140)	(0.164)	(0.150)
Estimated residuals of $\ln(s_{j/g})$		0.612***	0.218***
		(0.0294)	(0.0352)
Month Fixed effects	YES	YES	YES
Route Fixed effects	YES	YES	YES
Type of service fixed effect	YES	NO	NO

Estimation NLSUR method

Main results on demand side

- *h* : correct negative impact on demand
- *σ* : belongs to [0,1] and low
  - Low intra-mode competition: intermodal competition (competition between air and rail) is higher than intramodal competition
  - Structure of the French market

	Model 1	Model 2	Model 3
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Estimation NLSUR method

Main results on demand side

- *Positive impact of frequency*

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Route Fixed effects	YES	YES	YES
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Estimation NLSUR method

	Model 1	Model 2	Model 3
Marginal cost function			
Cross effect Lagged kerosene price (monthly 2015) / Plane		6.385	6.776
		(3.851)	(3.836)
Lagged electricity price (monthly 2015)		0.770^{***}	0.744^{***}
		(0.0848)	(0.0835)
Employees per seat in 2016		0.218^{***}	0.190^{***}
		(0.0476)	(0.0436)
Seat per movement		0.0167	0.0389
		(0.0228)	(0.0223)
Cross effect seat per movement & train		-0.142^{***}	-0.152^{***}
		(0.0261)	(0.0261)
Cross effect distance and type of service			
Plane LCC		-0.0419^{***}	-0.0158
		(0.00848)	(0.00962)
Plane Major		-0.00162	0.0165
		(0.00758)	(0.00876)
Train HSR		0.109^{***}	0.111^{***}
		(0.00418)	(0.00415)
Train ITC		0.0192^{***}	0.0248^{***}
		(0.00475)	(0.00451)
Train Night		0.0252^{***}	0.0306^{***}
		(0.00472)	(0.00473)
Uncentered R-sq			
Demand function		0.9796	0.9810
Price function		0.9442	0.9434
AIC		24916.4	24610.9
BIC		25535.4	25235.6

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Main results on supply side

- ***Positive impact of lagged kerosene tax for airlines***

(Significant at 10% level)

- ***Positive impact of lagged electricity price***

Estimation – results

Marginal cost per mode

Marginal cost	Train	Plane
Mean *(Std. Dev.)*	59.406 *(28.649)*	79.455 *(8.089)*
Obs.	992	1170

Marginal cost per type of service

Marginal Cost	Train			Plane	
	HSR	ITC	Night	Major	LCC
Mean *(Std. Dev.)*	67.699 *(25.684)*	10.740 *(7.4184)*	54.473 *(5.739)*	83.867 *(3.617)*	67.373 *(3.053)*
Obs.	737	111	144	857	313

- Marginal cost is on average higher for plane
- Marginal cost is on average higher for major type of service

Measures of demand sensitivity

Own price elasticity of demand: $\eta_{jj} = \frac{\partial s_j}{\partial p_j} \times \frac{p_j}{s_j} = hp_j \left(s_j - \frac{1}{1-\sigma} + \frac{\sigma}{1-\sigma} s_{j/g} \right)$

	Own price elasticity	
	Plane	Train
Mean *(Std. Dev.)*	-3.031 (1.274)	-2.480 (0.881)
Obs.	1170	992

	Own price elasticity				
	Plane		Train		
	Major	LCC	HSR	ITC	Night train
Mean *(Std. Dev.)*	-3.016 (0.816)	-3.072 (2.063)	-2.379 (0.635)	-1.469 (0.719)	-3.776 (0.606)
Obs	857	313	737	111	144

- Air passengers are on average more price sensitive
- Night train pax are on average the most sensitive to price

Measures of demand sensitivity

Cross price elasticity of demand

- intramodal elasticities are lower than intermodal elasticities – consistent with low value of σ
- Inter-modal price elasticity: $\eta_{jk} = \frac{\partial s_j}{\partial p_k} \times \frac{p_k}{s_j} = h\, p_k s_k \qquad j \neq k, \qquad k \notin g\,, \qquad j \in g$

η_{jk}	Intermodal price elasticity per mode	
j/k	Train/Plane	Plane/Train
Mean	0.0228	0.1076
(Std. Dev.)	(.0395)	(0.130894)
Obs.	1170	992

η_{jk}	Intermodal price elasticity				
	Plane		Train		
j/k	Train / LCC	Train / Major	Plane / HSR	Plane / ITC	Plane / Night
Mean	0.0062	0.0288	0.137	0.0421	0.008
(Std. Dev.)	(0.007)	(0.044)	(0.139)	(0.036)	(0.005)
Obs	313	857	737	111	144

- An increase in the price of train will lead to higher switch to plane than vice versa: air travelers seem more captive to this mode of transport than train travelers. Consistent with Wartman et al. (2018)
- PAX stick to their cheap alternative. Consistent with Bergantino (2020)
- Particularly users of night trains

Kerosene tax - Simulation

Percentage change in market shares for different tax scenarii

Total number of rail and air alternatives on the OD	Transport mode	Percentage change in market share			
		Scenario +0,15[ii]	Scenario +0,33[ii]	Scenario +0,65[ii]	Scenario +1[ii]
P1T1	*% increase in price*	*0.75 (0.13)*	*1.68 (0.15)*	*3.33 (0.18)*	*5.13 (0.22)*
	Plane	-6.84	-9.09	-12.96	-17.00
	Train	11.69	11.73	11.80	11.87
	Outside good	-0.12	-0.11	-0.10	-0.09
P1T2	*% increase in price*	*0.70 (0.09)*	*1.60 (0.13)*	*3.21 (0.18)*	*4.97 (0.25)*
	Plane	-14.69	-16.73	-20.22	-23.88
	Train	2.53	2.54	2.56	2.58
	Outside good	-0.04	-0.02	0.01	0.03
P2T1	*% increase in price*	*0.94 (2.70)*	*2.02 (2.80)*	*3.93 (2.98)*	*6.03 (3.19)*
	Plane	19.66	16.78	11.82	6.64
	Train	11.90	11.91	11.93	11.96
	Outside good	0.07	0.08	0.11	0.14
P2T2	*% increase in price*	*0.54 (3.05)*	*1.62 (3.19)*	*3.53 (3.44)*	*5.62 (3.72)*
	Plane	-33.00	-34.47	-37.01	-39.68
	Train	15.05	15.22	15.52	15.84
	Outside good	3.41	3.58	3.87	4.17
P3T1	*% increase in price*	*1.00 (2.20)*	*2.13 (2.29)*	*4.12 (2.47)*	*6.30 (2.66)*
	Plane	-36.18	-37.71	-40.34	-43.09
	Train	19.31	19.33	19.38	19.42
	Outside good	0.03	0.05	0.09	0.12

[i] Median variation

[ii] € per litre in addition to already existing carbon tax; Scenarii based on literature and/or authorities' recommendations.

Evidence of modal shift – depends on the structure of the supply

- Decrease in plane market share is higher with higher price increase and higher with the increase of competitors on the route
- The modal shift from plane to train exists whatever the kerosene tax level:
- It increases with increasing plane price
- It increases with the number of air competitors

Conclusion

Contribution

Large set of routes

Intra and intermodal competition - alternatives proposed to travelers: combination of type of service, quality of supply, price

Marginal cost estimation – Dependence with kerosene price

Main results

- Model with nest is validated
- Strong sensitivity of demand to changes in fares
- Inter-modal competition is higher than intra-modal competition

Policy implications & Next steps

- In terms of modal shift: responses in train price changes are higher than responses in plane price changes
  - ➢ Could the regulators also incentivize a decrease in train fares?
- Following a kerosene tax, the modal shift from plane to train depends on the structure of the supply
- Investigate more on the supply characteristics (frequency…) that regulators should consider to influence the PAX choice towards choices that could be more valued from a societal point of view

THANK YOU FOR YOUR ATTENTION

chantal.latge-roucolle@enac.fr

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