SESAR Innovation Days
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The economic value of adding capacity at airports – a data-driven model

Gérald Gurtner, Andrew Cook, Anne Graham
Samuel Cristóbal, and Denis Huet

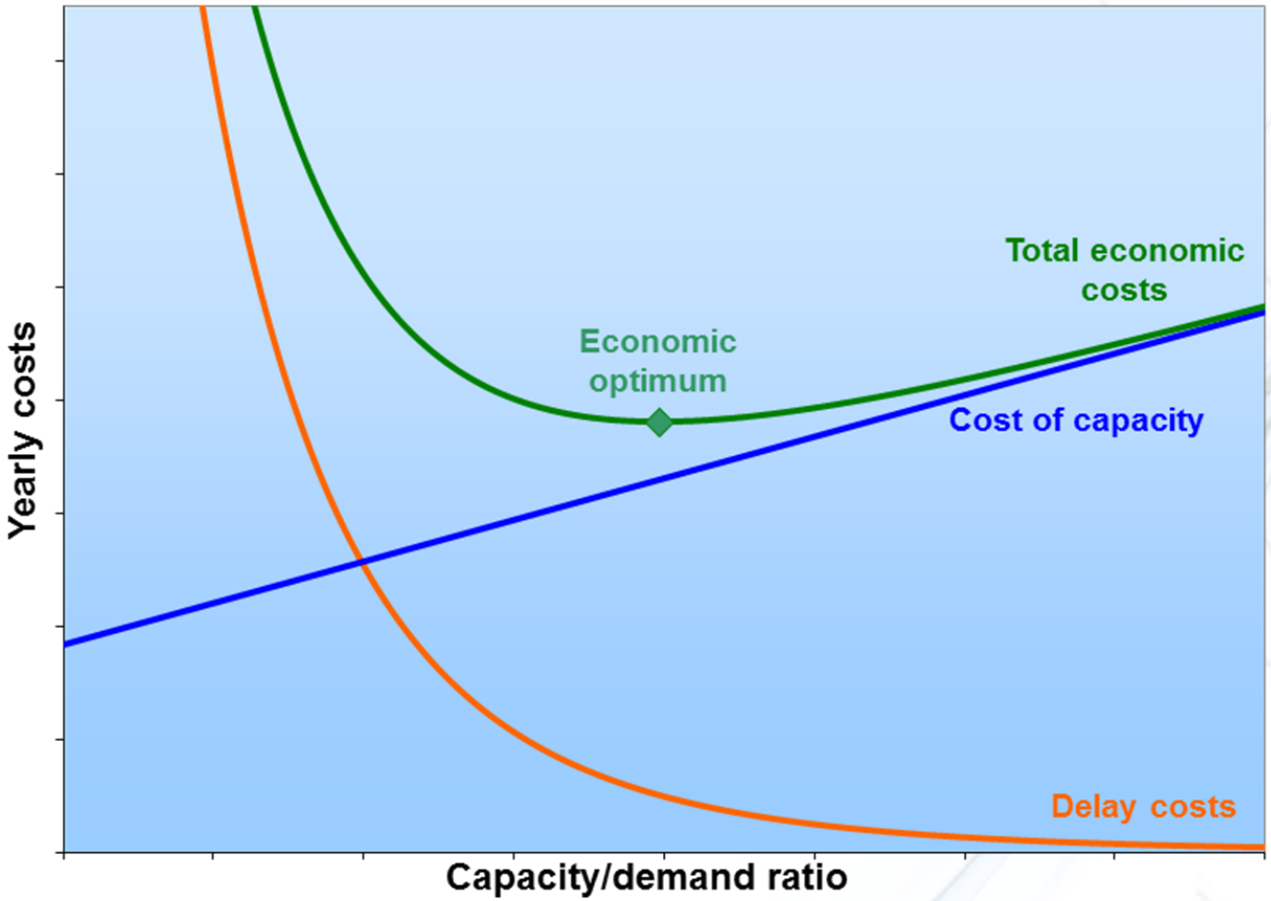
Introduction

Objectives

- Contribute to SESAR Operational Focus Area 05.01.01 (Airport Operations Management).
- Assess the economic value of extra capacity at an airport.
- Better understand interdependencies of various KPIs
- Assess existence and behaviour of an airport economic optimum, in a similar way to the early 2000s when estimating the economic en-route capacity optimum.
- Build a simple model but highly data-driven.

Introduction

Basic idea: capacity is costly, but brings higher revenues due to smaller delays



Data

Collection of very different types of data, including:

- Traffic data (delay, capacity, number of passengers etc.),
- financial data of airports,
- cost of delay for airlines,
- satisfaction data,
- airport infrastructure,
- etc...

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$\Rightarrow$ consolidated database of heterogeneous data (note: Data from 2014, except financial data).

$\Rightarrow$ Pre-data analysis aiming at guiding the modelling process.

Pre-data Analysis

- $\sim$20 parameters
- Structure of Correlation
- Principal Component Analysis: reduction
- Cluster analysis (modularity) + robustness
- $\Rightarrow$ Clusters roughly compatible with qualitative assessments of airports

Modelling guidelines

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- Passengers' choices determined by external factors (e.g. airport location, airline fare/service) $\Rightarrow$ not modelled here.
- Passengers have different experiences at different airports, based on the delay at the airport, the quality of service at the airport, etc. $\Rightarrow$ utility.

Relationships between variables

Delay-capacity

$$\delta t \sim \exp\left(T/C\right)$$

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$$c_{inf} = \alpha(\mathcal{C} - \mathcal{C}_{init}) + c_{init}$$

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Revenues of airport

$$r_a = (P + l_f w) N P_A$$

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Value of time for passengers

$$v = v_l r_{lcc} + v_b (1 - r_{lcc}),$$

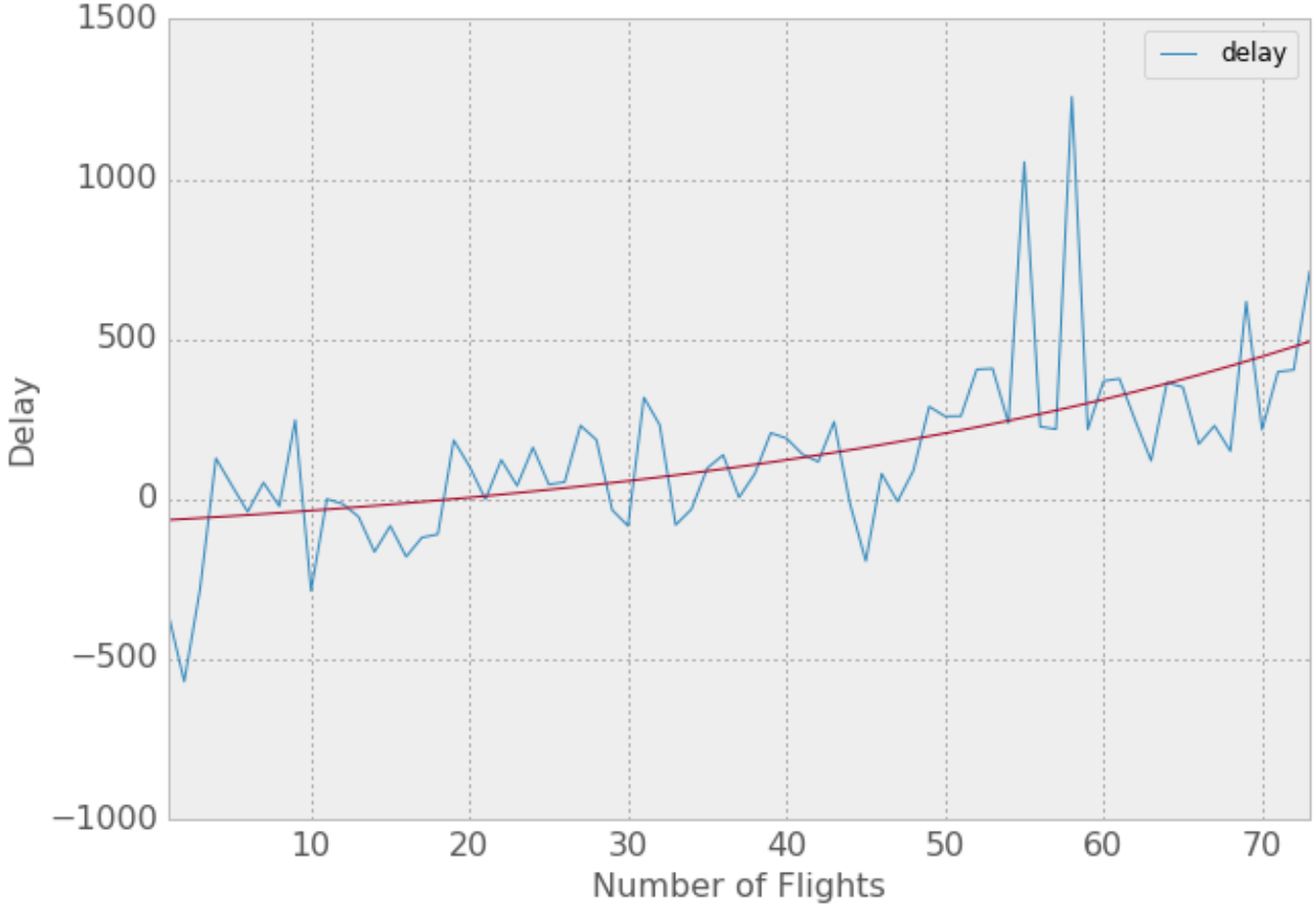
Calibration

Different steps of calibration

- Direct calibration: an input of the model is directly matched to some value extracted from the data. Ex: MTOW, typical traffic.
- Post-calibration: an output of the model is matched to some values from the data, sweeping input parameters. Ex: aeronautical revenues of airport
- Functional relationships: independent on the specific airport and fitted from data or taken from literature. Ex: delay as a function of capacity.

Delay vs Traffic

$$\delta t \sim \exp\left(T/C\right)$$



Cost of delay

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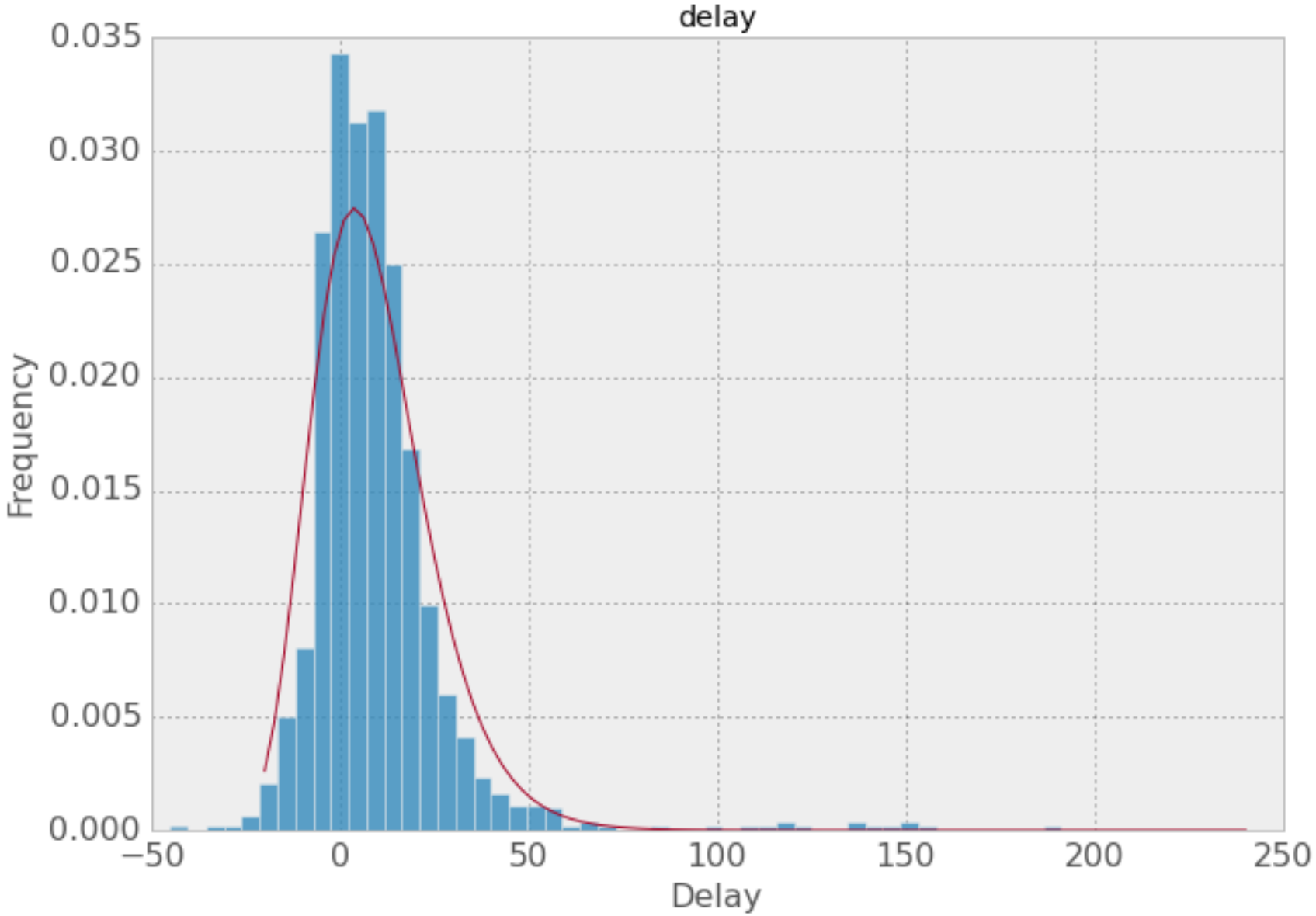
Problem

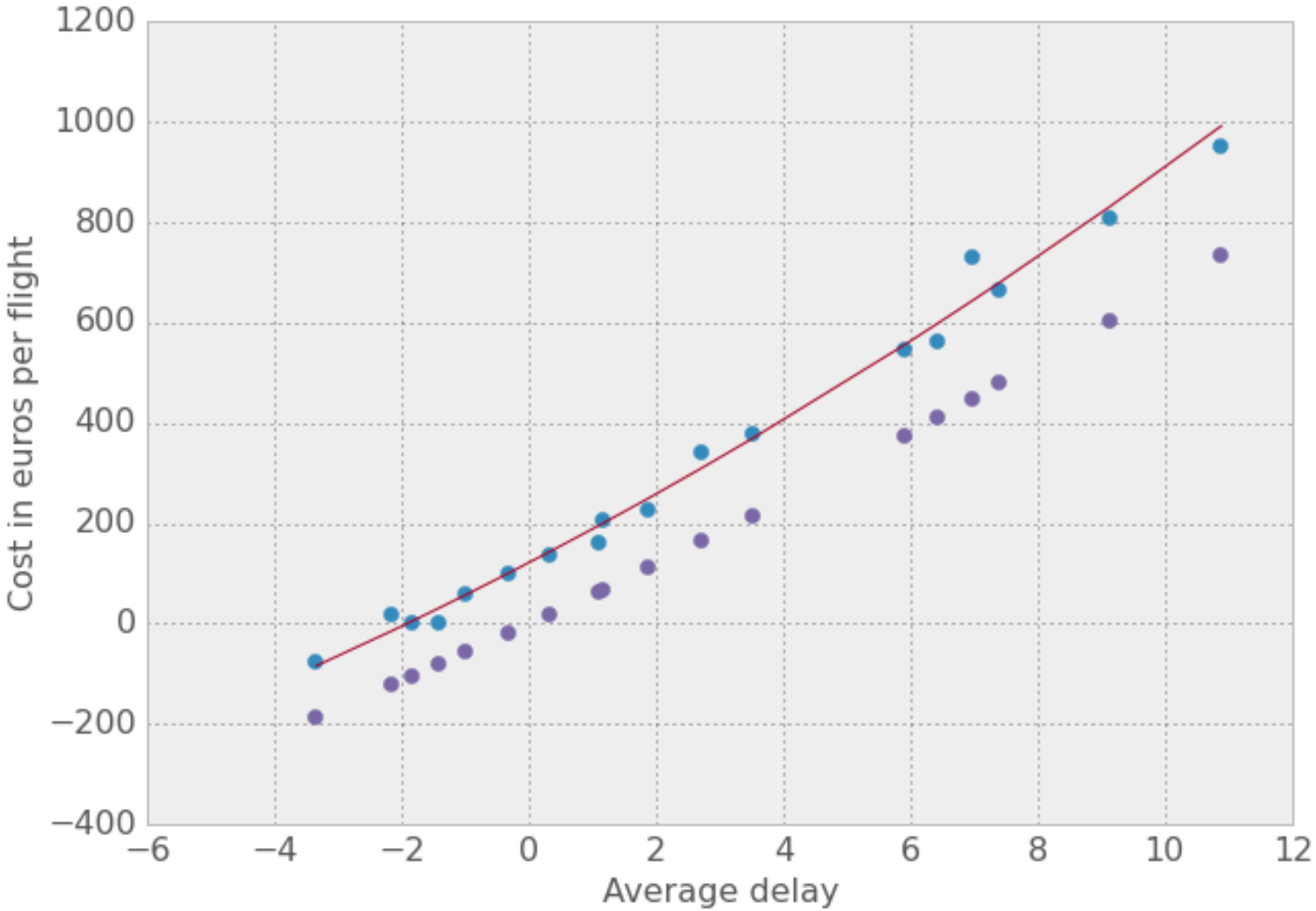
Cost of average delay **is not** *average cost of delay* because:

- Cost is not linear with delay,
- In particular air companies do not gain from negative delays (anticipated flights) in general.

Delay distribution – hourly pdf fit



Delay distribution – cost correction



Implicit equation of delay

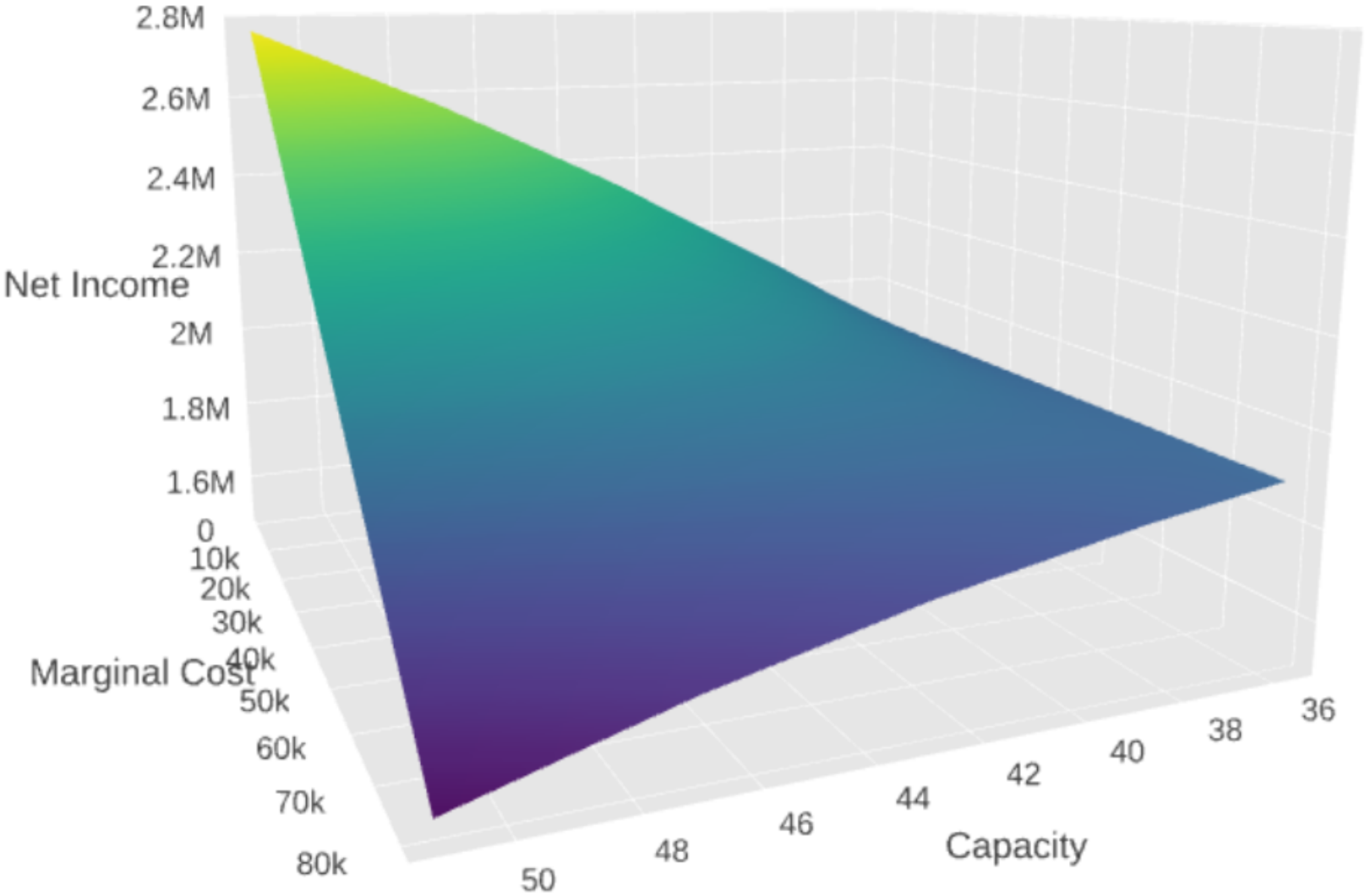
- **delay** depends on **traffic**
- **traffic** depends on **probability of operating** the flight
- **probability** depends on the **cost of delay**
- **cost of delay** depends on **delay**

⇒ Implicit equation which fortunately had always a solution
⇒ Post-calibration of a "traffic multiplicator", output traffic to be matched to data.

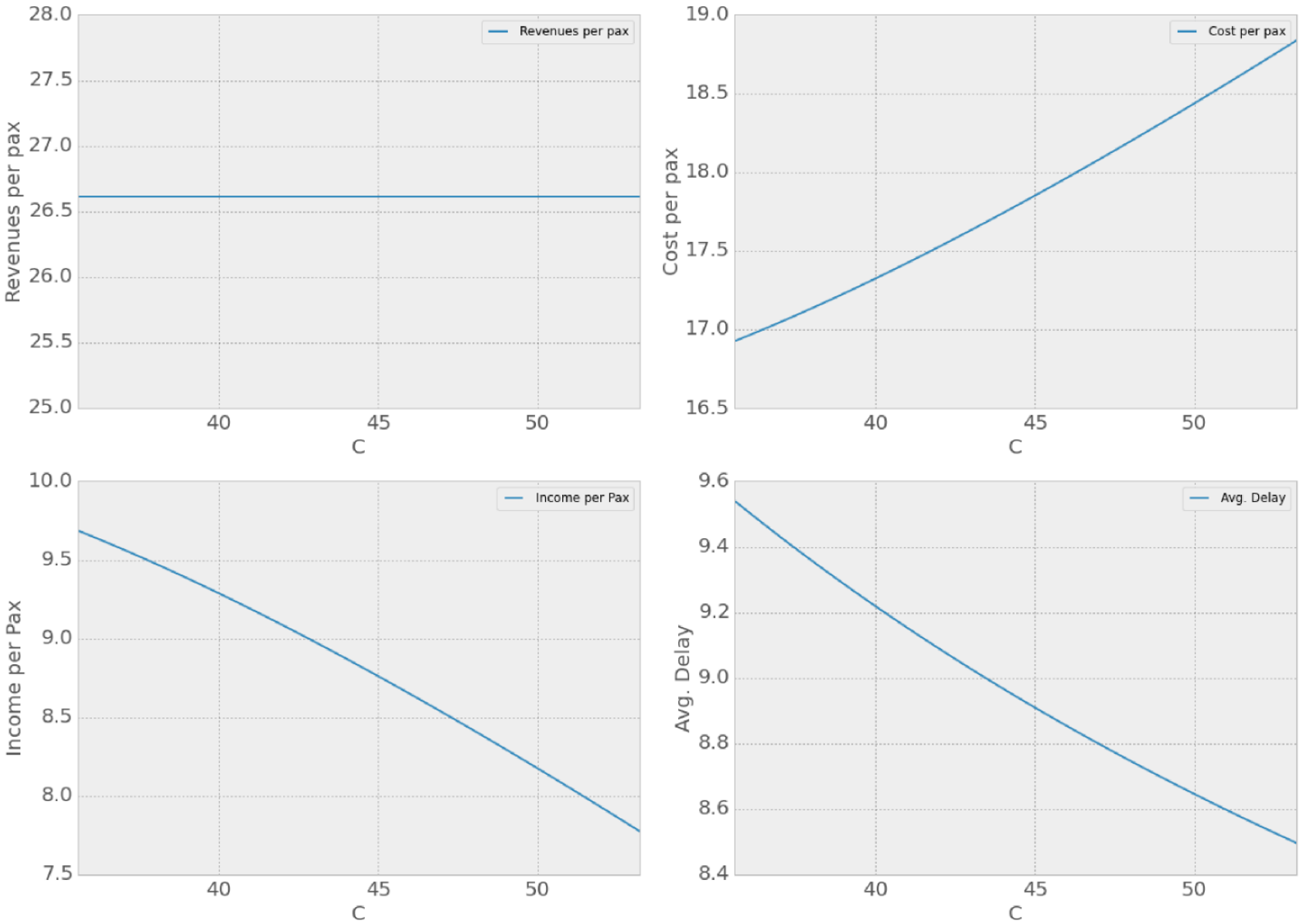
Calibration (on CDG)

Name of parameter	Short description	Type of parameter
$\sqrt{MTOW}$	Max. take-off weight	DC
l_f	Load factor	DC
P	Airport charges	DC
$\mathcal{C}_{init}$	(Departure) capacity	DC
cc	Delay at zero traffic	DC
v	Value of time	DC
T	Distribution of traffic	DC
w	Average revenue per passenger	DC
c_{init}	total initial cost	DC
β	Traffic multiplier (demand)	PC
α	Marginal cost of capacity	FP
s	Smoothness	FP

Results


2.8M
2.6M
2.4M
2.2M
Net Income
2M
1.8M
1.6M
0
10k
20k
30k
40k
Marginal Cost
50k
60k
70k
80k
50
48
46
44
42
40
38
36
Capacity

Results – fixed marginal cost



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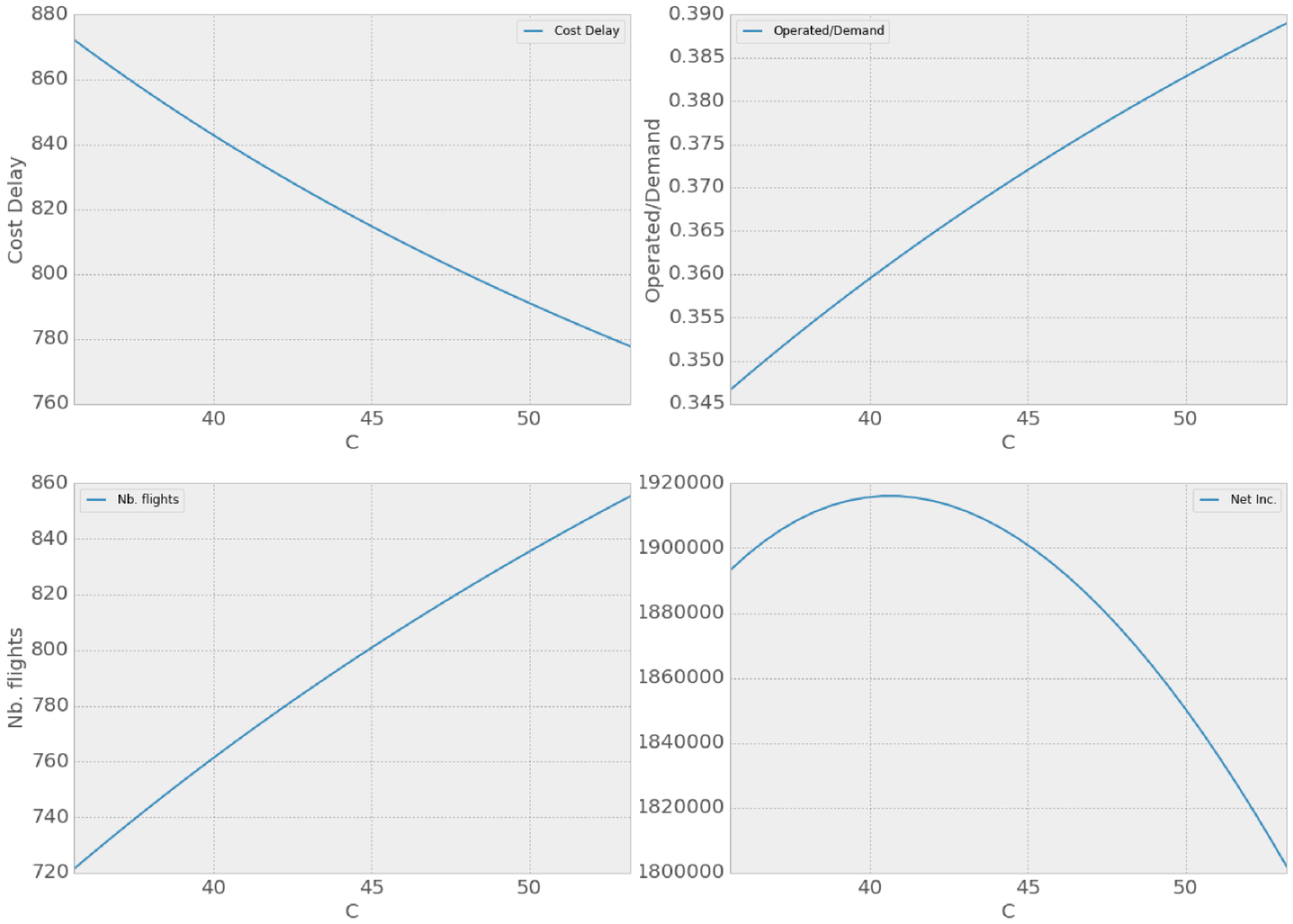
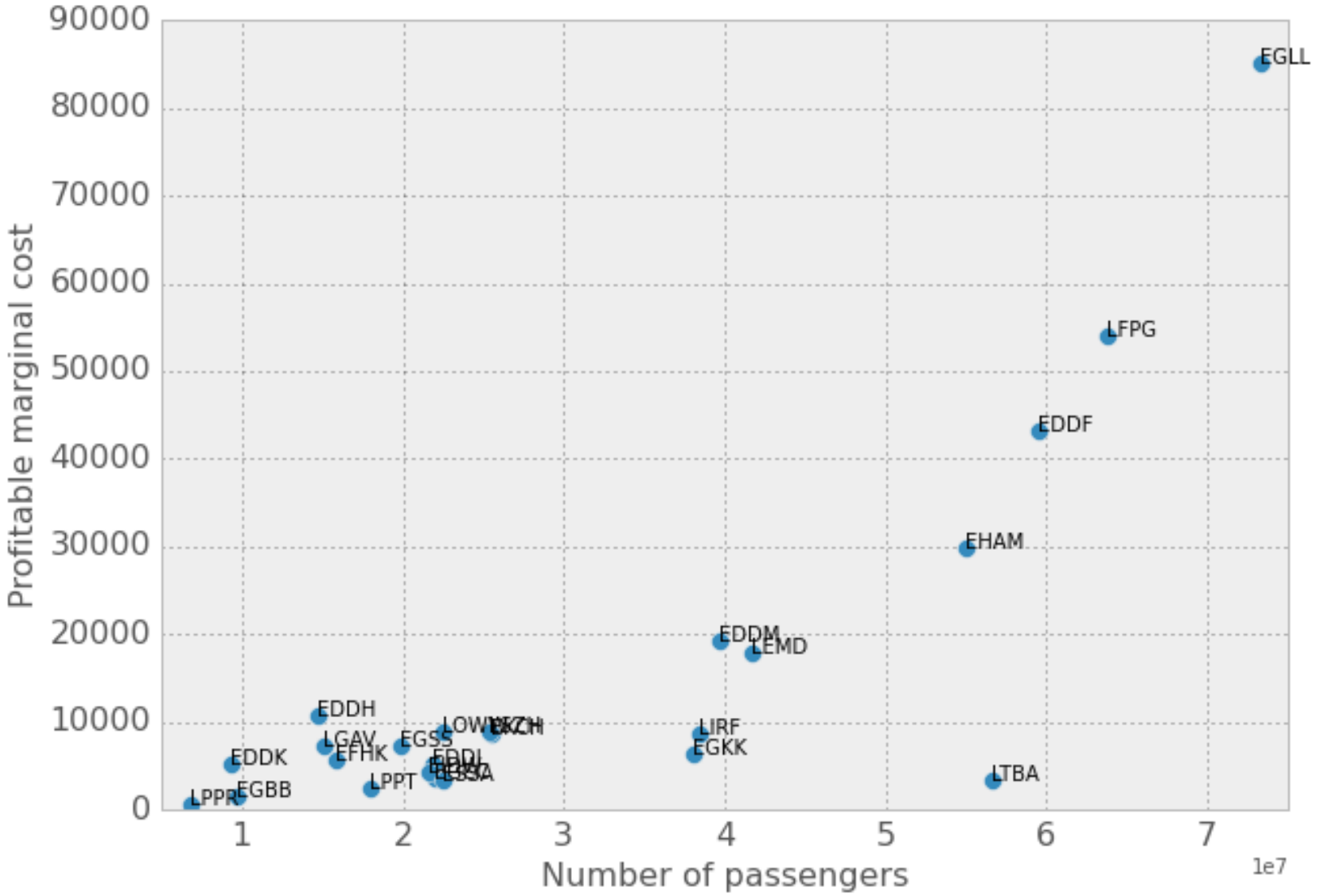


Results – different airports comparison



More exploratory model

Variable indirect revenues per passenger

$$w(\delta t) = w_{init} + w_{shop}(\delta t) + w_{sat}(\delta t).$$

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More shopping time

$$w_{shop}(\delta t) = t_e \frac{\delta t - \delta t_{init}}{120} w_{init},$$

More exploratory model

Variable indirect revenues per passenger

$$w(\delta t) = w_{init} + w_{shop}(\delta t) + w_{sat}(\delta t).$$

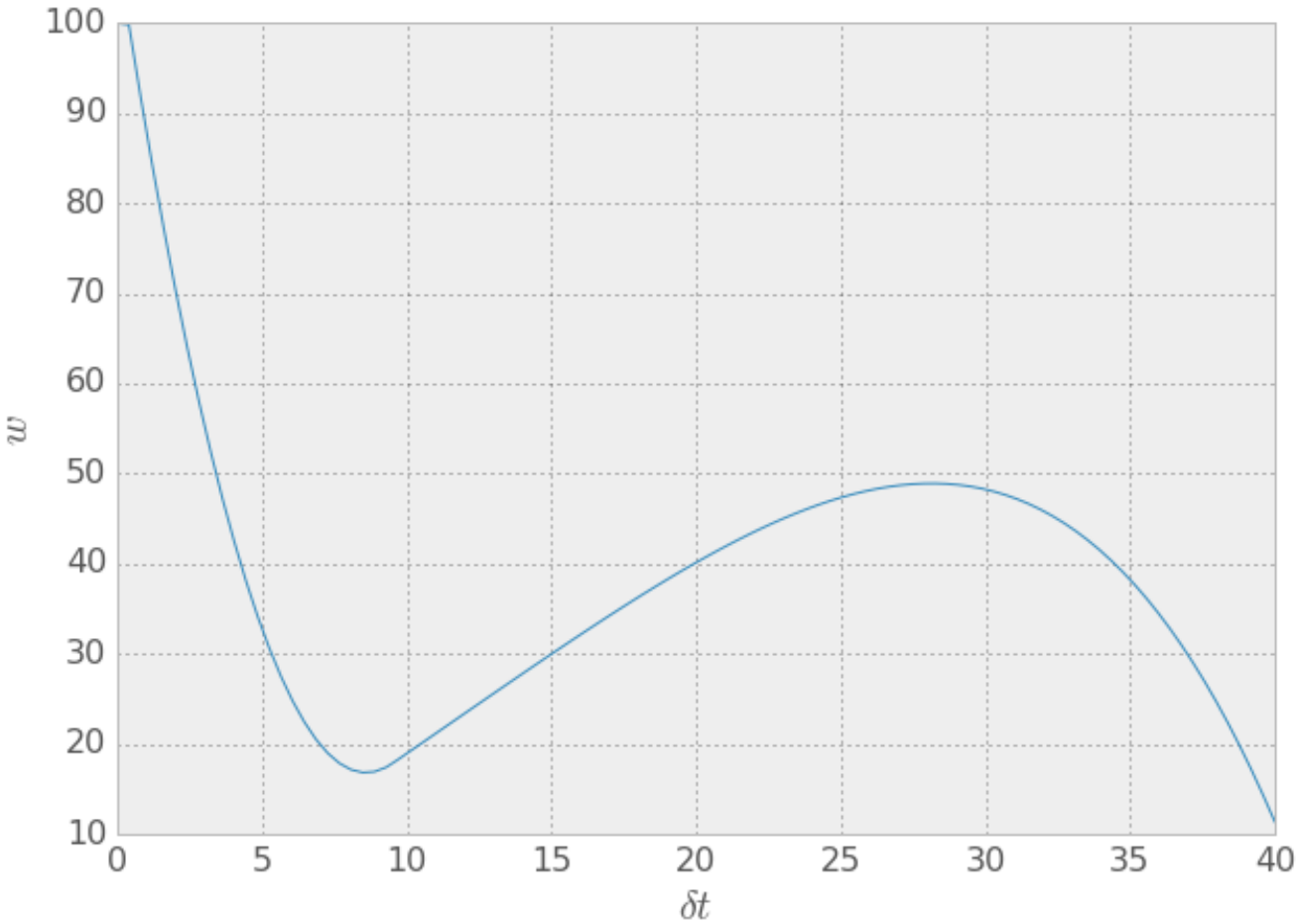
More shopping time

$$w_{shop}(\delta t) = t_e \frac{\delta t - \delta t_{init}}{120} w_{init},$$

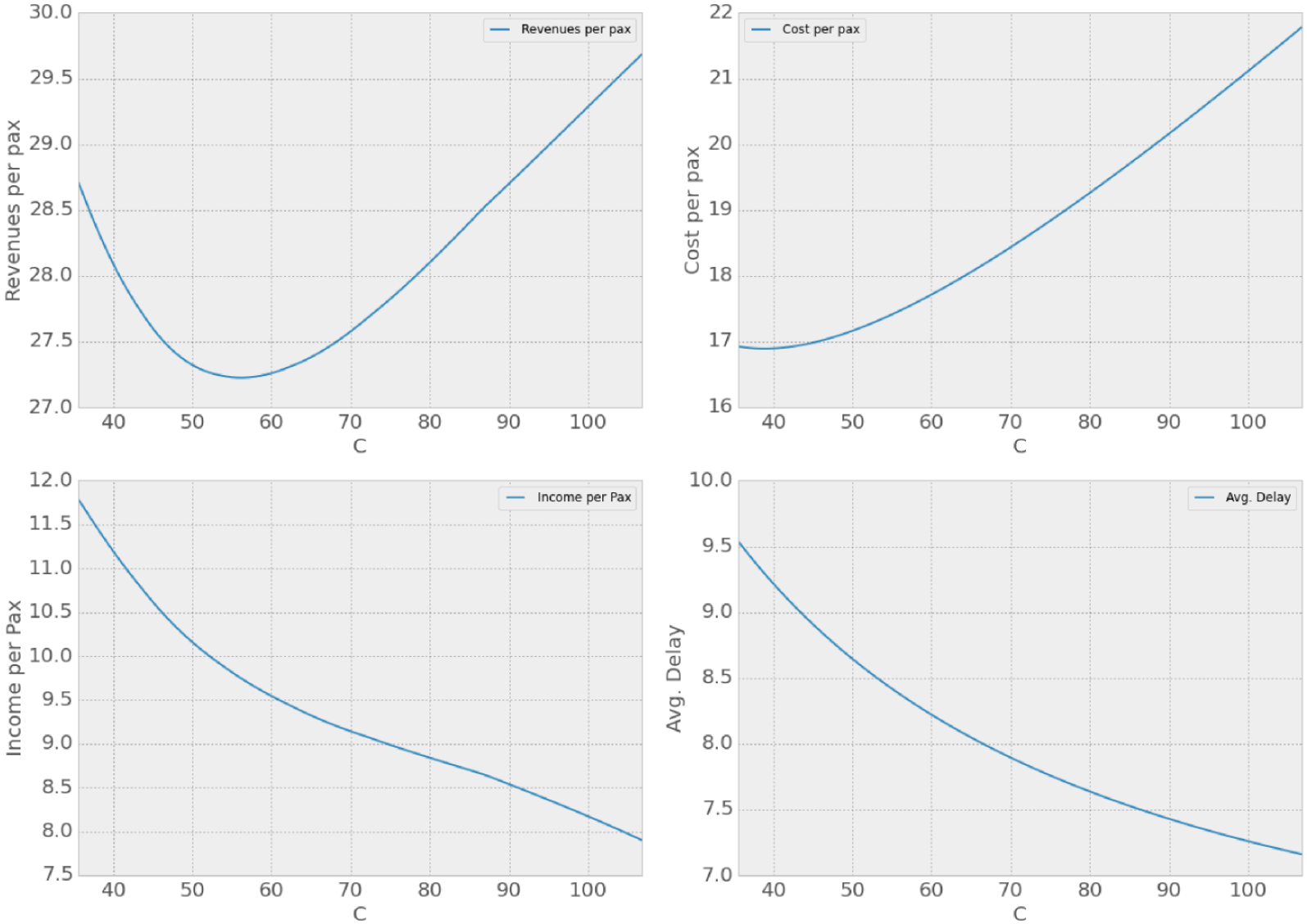
Worse shopping time

$$w_{sat}(\delta t) = \begin{cases} s_e \left(\frac{\delta t - \delta t_{init}}{120}\right)^2 w_{init} & \text{if} \quad \delta t < \delta t_{init} \\ -s_e \left(\frac{\delta t - \delta t_{init}}{120}\right)^2 w_{init} & \text{else.} \end{cases}$$

Variable indirect revenues per passenger



More exploratory results



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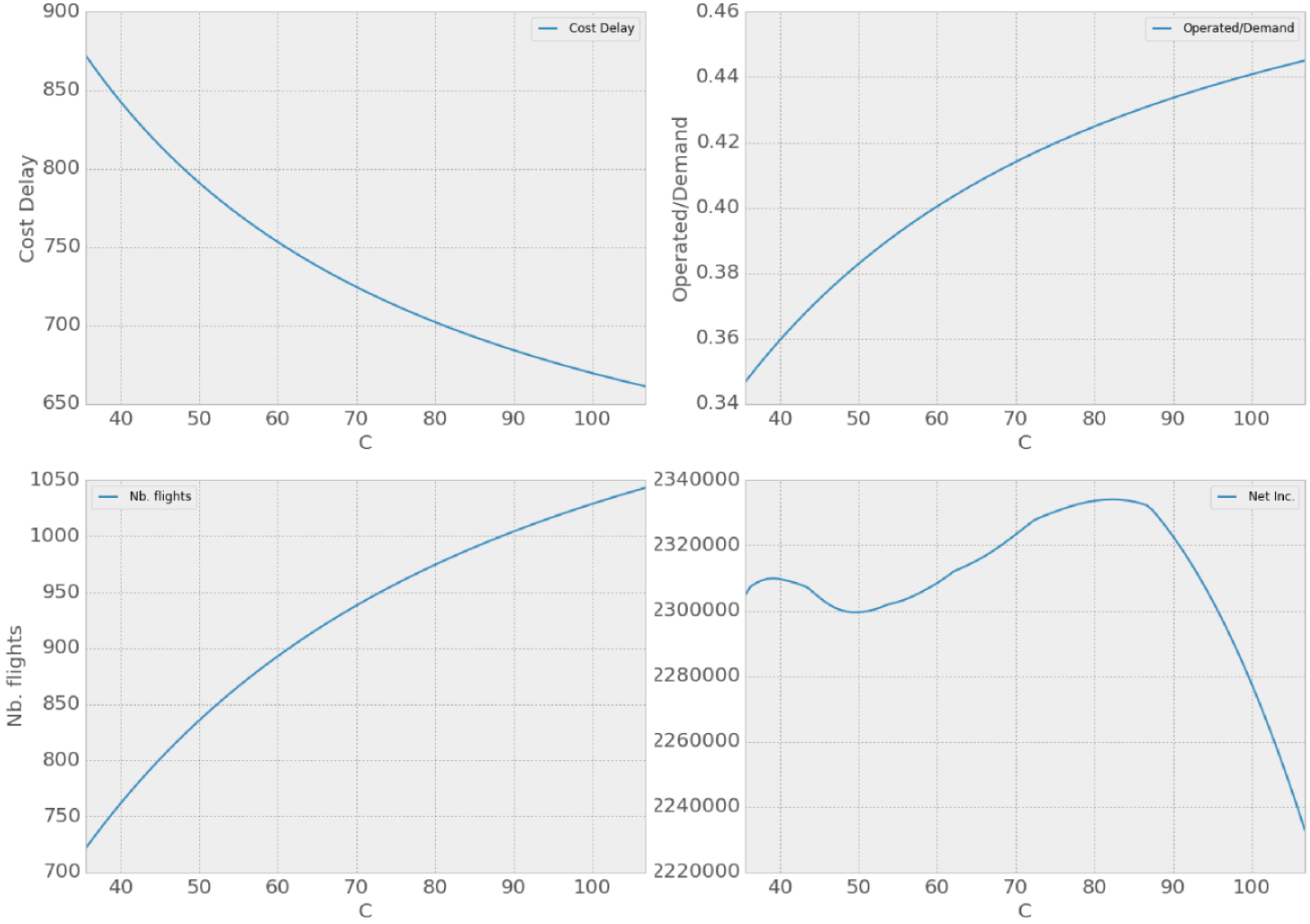
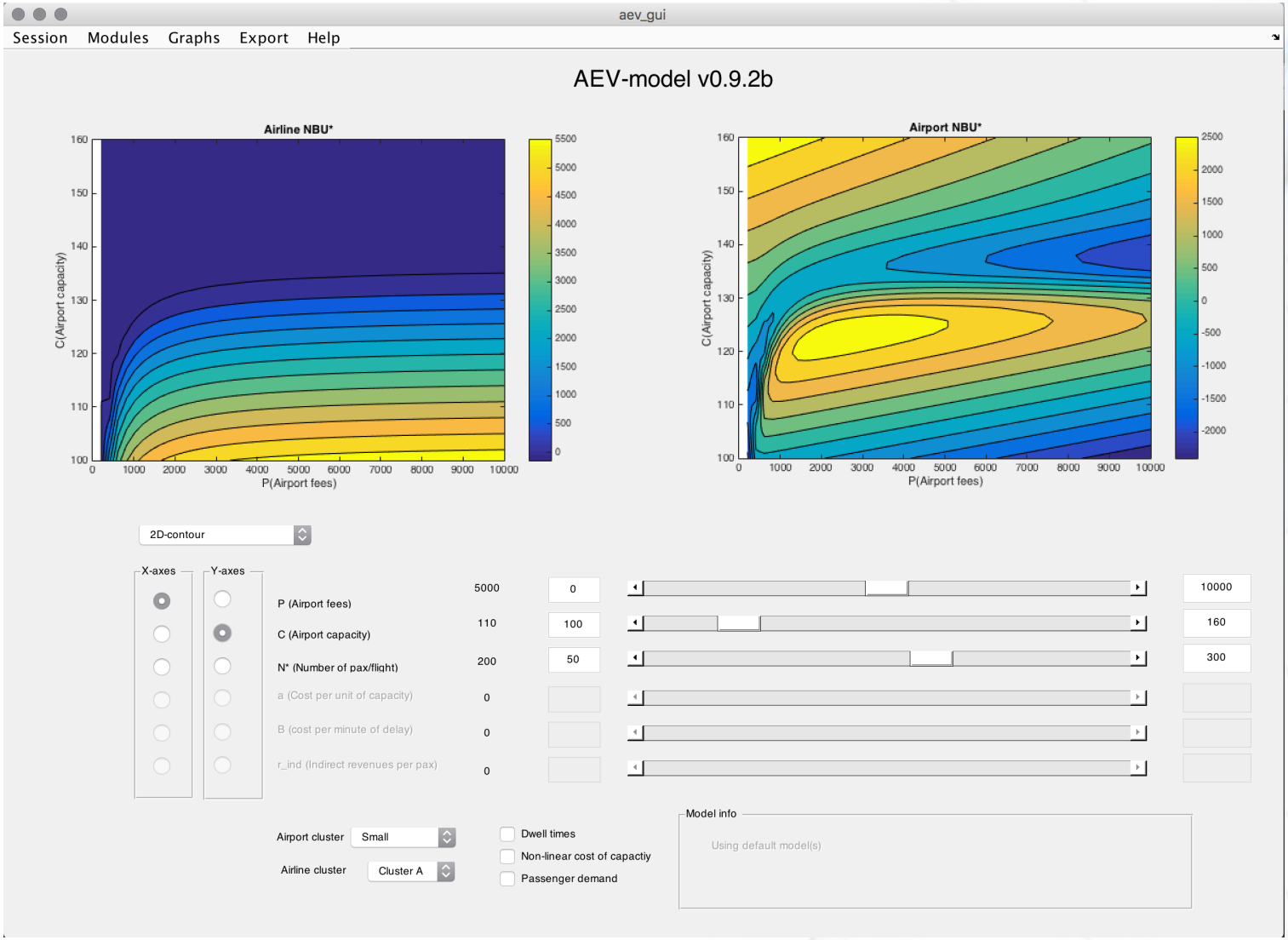


GUI


aev_gui
Session
Modules
Graphs
Export
Help
AEV-model v0.9.2b
Airline NBU*
C(Airport capacity)
P(Airport fees)
Airport NBU*
C(Airport capacity)
P(Airport fees)
2D-contour
X-axes
Y-axes
P (Airport fees)
C (Airport capacity)
N* (Number of pax/flight)
a (Cost per unit of capacity)
B (cost per minute of delay)
r_ind (Indirect revenues per pax)
5000
0
10000
110
100
160
200
50
300
0
0
0
Airport cluster
Small
Airline cluster
Cluster A
Dwell times
Non-linear cost of capactiy
Passenger demand
Model info
Using default model(s)

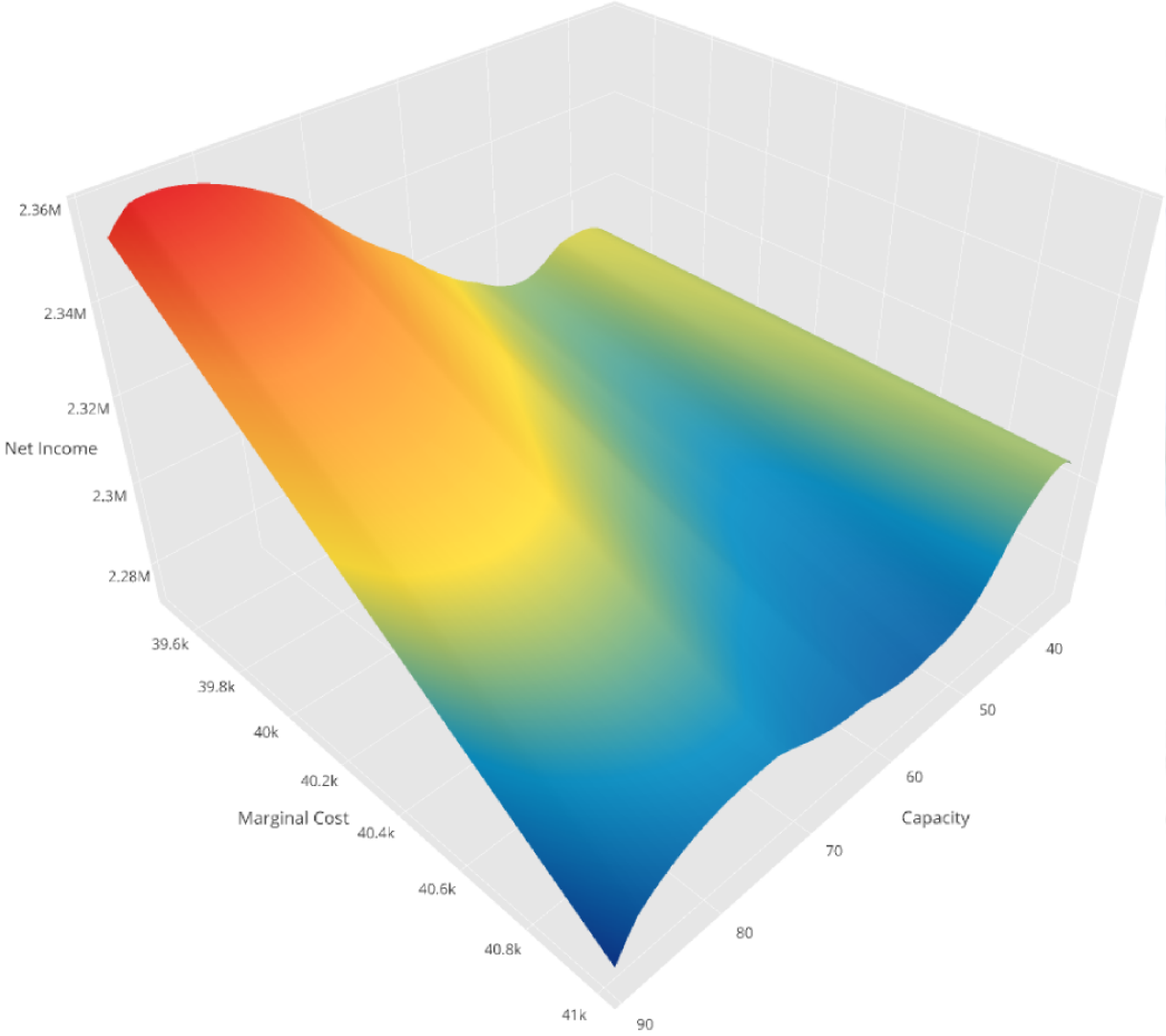
Conclusions

- Simple but highly data-driven model.
- Data come from different sources, hard to consolidate.
- Data analysis shows main differences in airports is size, then business models.
- Calibrated model: presence of an optimum in capacity, depending on the marginal cost of capacity: not always reachable.
- Profitability threshold is different among airports.
- More complex indirect passengers revenues: presence on local minima, complexification of the cost analysis.

Future Work

- More Data!
- Further liaisons with ACI on joint modelling initiatives.
- Further liaisons with Heathrow in particular on PAX satisfaction.
- The work on AirPort Operation Concept will continue s part of its Project 04: additional variables, closer interaction with interested airports.

Thank you for your attention



Cluster analysis

Categorisation of the airports, likely to have different functional relationships for different types (hubs, etc.).

- Used Modularity-based method, coming from network science. Louvain algorithm maximises the modularity.
- Network-based method: construction of a system where airports are nodes and links are weighted with Euclidean distance
- Distance is based on the four components from PCA + weighting of variance share:

$$d_{ij}^2 = v_0^2(c_0^i - c_0^j)^2 + v_1^2(c_1^i - c_1^j)^2 + ...$$

- Scaling sweep with Modularity to discover the different clusters level in the data.

Cluster Id	ICAO Code	Airport Name
2	EBBR	Brussels
	EDDL	Dusseldorf
	EGCC	Manchester
	EIDW	Dublin
	EKCH	Copenhagen Kastrup
	ENGM	Oslo Gardermoen
	ESSA	Stockholm Arlanda
	LOWW	Vienna
	LPPT	Lisbon
1	EDDF	Frankfurt
	EDDM	Munich
	EGKK	London Gatwick
	EGLL	London Heathrow
	EHAM	Amsterdam Schiphol
	LEBL	Barcelona-El Prat
	LEMD	Madrid Barajas
	LFPG	Paris Charles de Gaulle
	LIRF	Rome Fiumicino
	LSZH	Zurich
	LTBA	Istanbul Ataturk
0	EDDH	Hamburg
	EDDK	Cologne Bonn
	EFHK	Helsinki
	EGBB	Birmingham
	EGSS	London Stansted
	ELLX	Luxembourg
	EPWA	Warsaw Chopin
	LFMN	Nice Cote d'Azur
	LGAV	Athens
	LHBP	Budapest
	LKPR	Prague
	LPPR	Porto

	0	1	2
AO_tot	L	M	M
CUI	L	M	M
NBU	H	M	H
cap	L	H	M
cht	M	L	M
delay_per_flight	L	M	M
delay_tot	L	M	L
exp_tot	L	M	L
flight_EU	H	M	M
flight_per_rnwy	L	M	M
flight_per_term	L	M	L
flight_tot	L	H	M
fsc	M	H	M
gate_tot	L	M	L
pax_per_flight	M	H	M
pax_tot	L	M	L
rev_aero	L	L	L
rev_non_aero	L	M	L
rnwy_tot	L	M	L
route_tot	L	M	M
sat	*	*	*
term_tot	L	L	L