An Agent-Based Auction Model for the Analysis of the Introduction of Competition in ATM

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Nommon Solutions & Technologies

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Content

An Agent-Based Auction Model for the Analysis of the Introduction of Competition in ATM:

Introduction

Introduction

- **COMPAIR project**: study how to introduce competitive incentives in ATM so as to best contribute to achieving the European policy objectives for aviation

- Analysis of tendering of the licenses to provide air traffic services within certain geographical areas employing ABM

Tendering of ATM licenses: Proposed institutional design

- Tendering of licenses to provide en-route air traffic services in each country
- Tenders are issued every X years
- Tenderers (ANSPs) offer a charge that will be the maximum applicable within the license period
- During the license period, ANSPs are allowed to reduce charges, but they cannot go above the charge bid
- Competition for the market + limited competition in the market

Tendering of ATM licenses: Research questions

- Explore potential effects of the auctioning process:
  - Resulting market structure
  - Consolidation of ANSPs?
  - Realisation of economies of scale (e.g., due to seasonality)?
- Compare different auction designs:
  - Maximum market share
  - Frequency of tenders
  - Auctioning order

Why ABM?

- Added value of ABM vs traditional approach (Game Theory):
  - Dynamic approach vs equilibrium seeking
  - Modelling learning processes and adaptive behaviors
  - Relax assumptions about perfect information

An Agent-Based Auction Model for the Analysis of the Introduction of Competition in ATM:

Model description

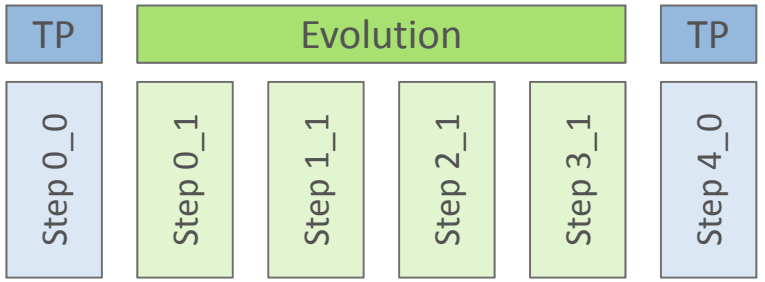
Overall description

Three main elements:

- Geographical context: countries and routes
- Agents: Regulator, ANSPs and Airlines
- Exogenous variables: Passenger OD demand, fuel cost, technology evolution

Two stages:

1. Tendering process: ANSPs compete for the licenses to control different areas
2. Evolution between auctions



Agents

Regulator

- Announce auction parameters, select winners, store data

ANSPs

- Objective: profit-maximisation
- Attributes:
    - Charging areas they control
    - Human resources
    - Financial capital
    - Bidding strategy: Algorithm to estimate the probability of winning an auction according to the past behaviour of competitors
    - Technology level: Driver of productivity

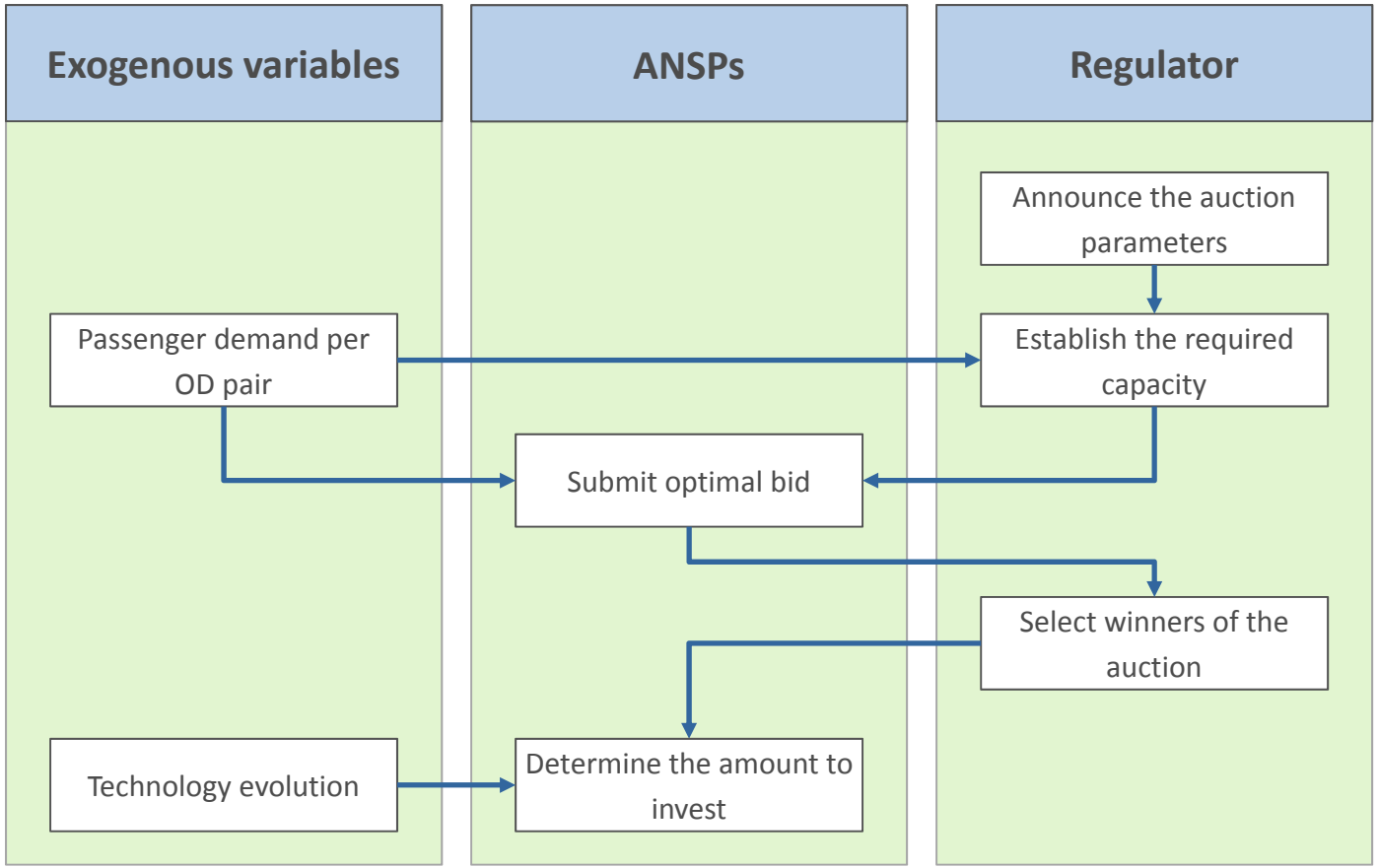
Airline

- Objective: meet the demand and minimise costs
- Attribute: Operating cost ASK (excluding fuel and charges)

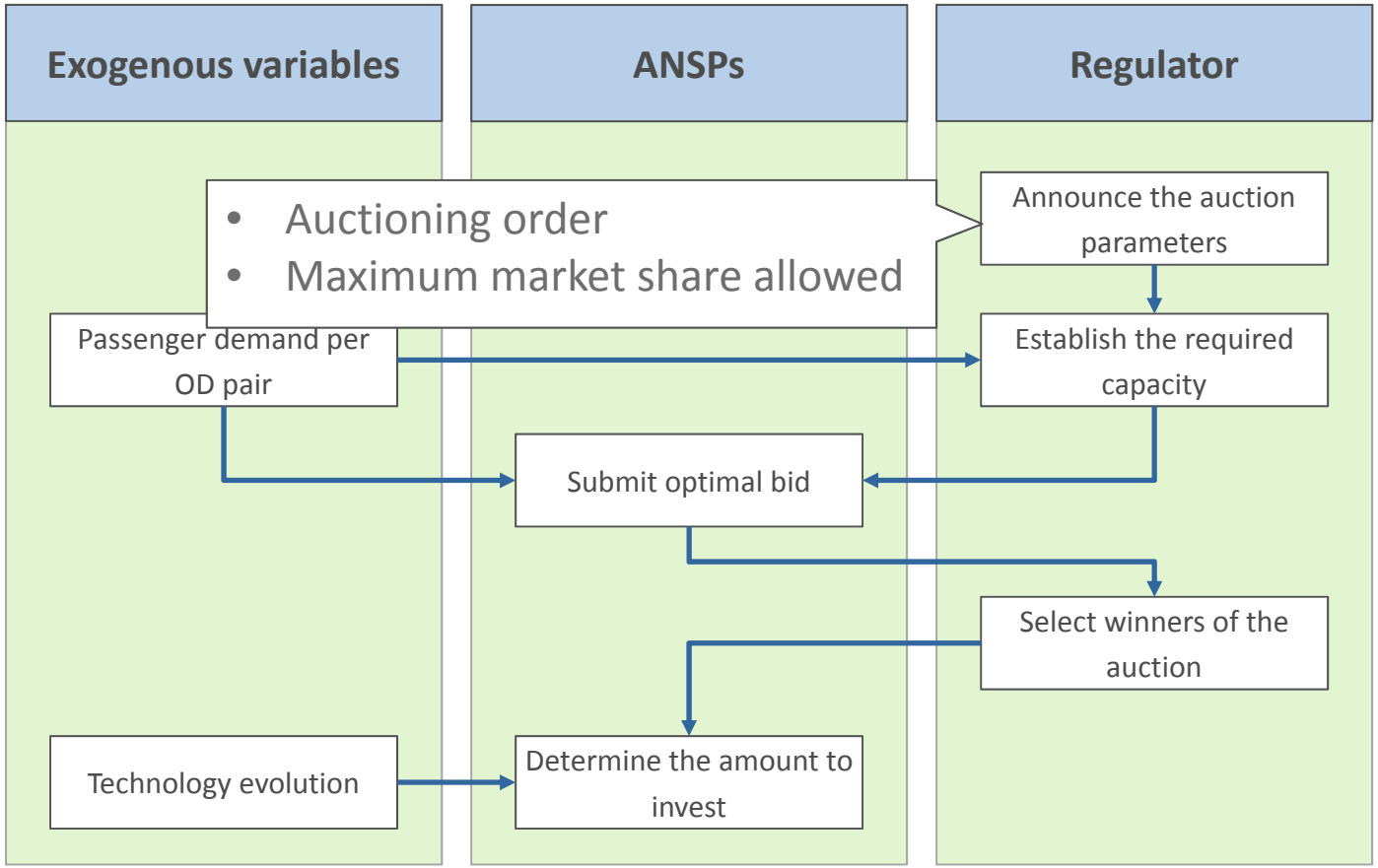
Assumptions and model constraints

- **ATCOs may monitor flights in any of the charging areas controlled by the ANSP** they are working at.
- **ATCOs working at a specific area** at the beginning of the simulation ("legacy ATCOs") **will work at the ANSP controlling their original area and will maintain their labour agreement** throughout the simulation (until retirement).
- **New ATCOs**, who are hired throughout the simulation, **have the same cost for all the ANSPs** and will be employed by the same ANSP during all the simulation, unless they are dismissed.
- When **hiring/dismissing ATCOs**, there is an initial extra cost due to **the training/dismissal costs**.
- Under same technology condition, ATCOs are assumed to be equally efficient regardless their experience. The **difference of productivity** between ANSPs is a **parameter of each ANSPs** (due to their level of technology adoption).
- **If the financial capital of an ANSP** during a certain period **becomes negative**, it goes into **bankruptcy** and disappears from the market in the subsequent tendering periods.
- The entrance of new players is not simulated.
- An **average plane size, occupancy rate and operational cost per kilometer** (excluding fuel and charges) are considered for all flights regardless of the origin-destination pair.

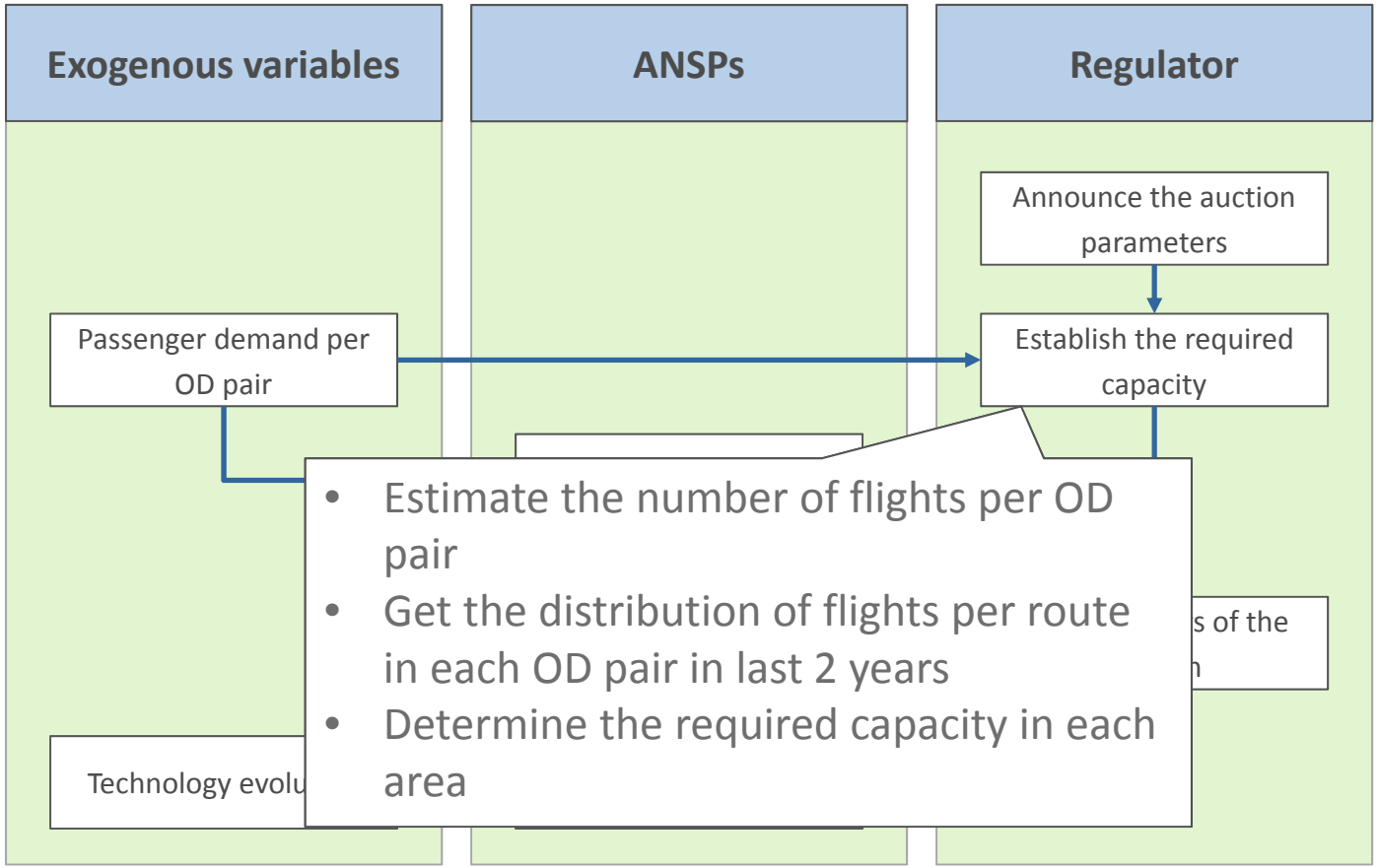
Agents' interaction rules
Tendering process



Agents' interaction rules
Tendering process



Agents' interaction rules
Tendering process



Agents' interaction rules
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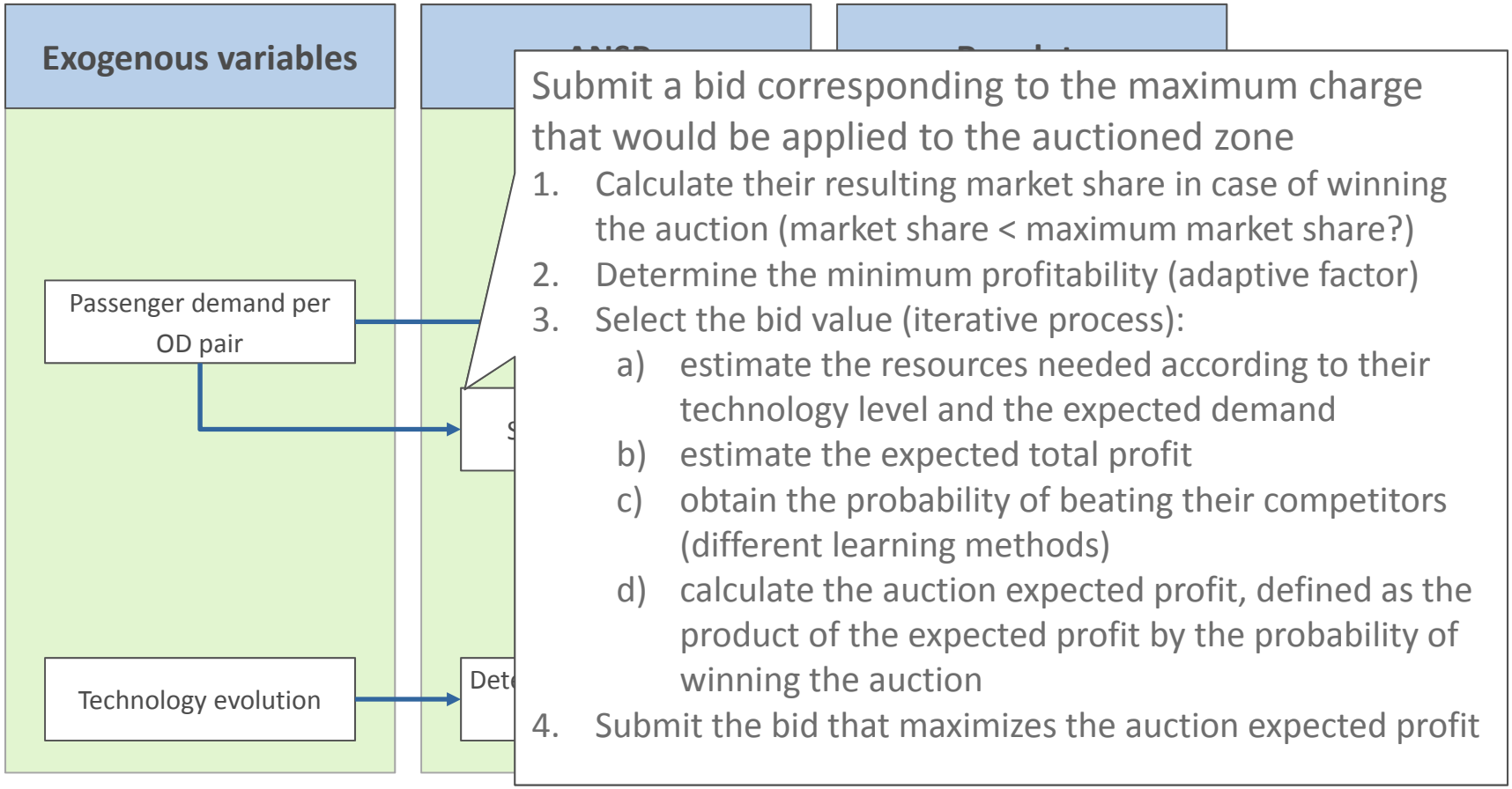

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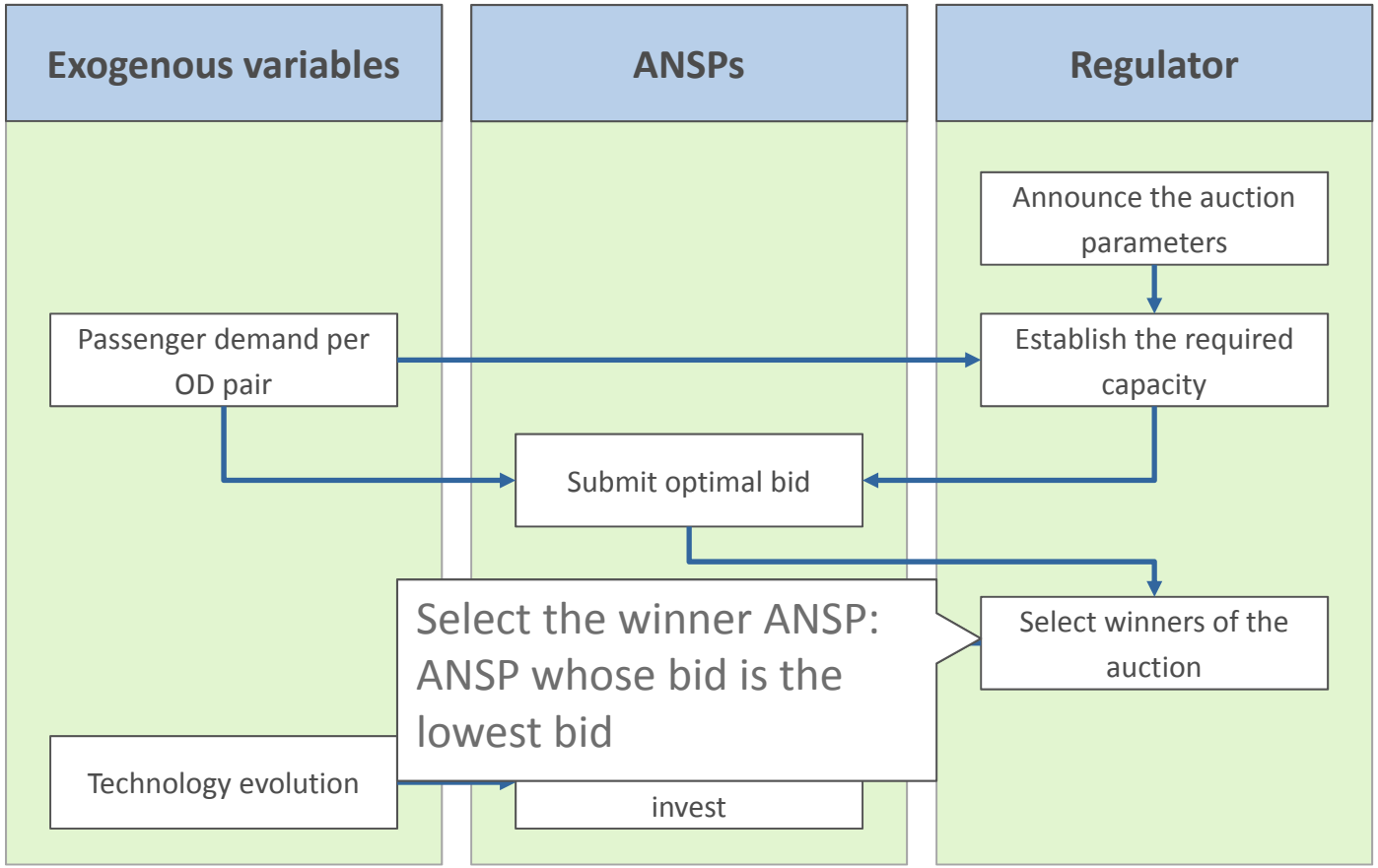
Tendering process



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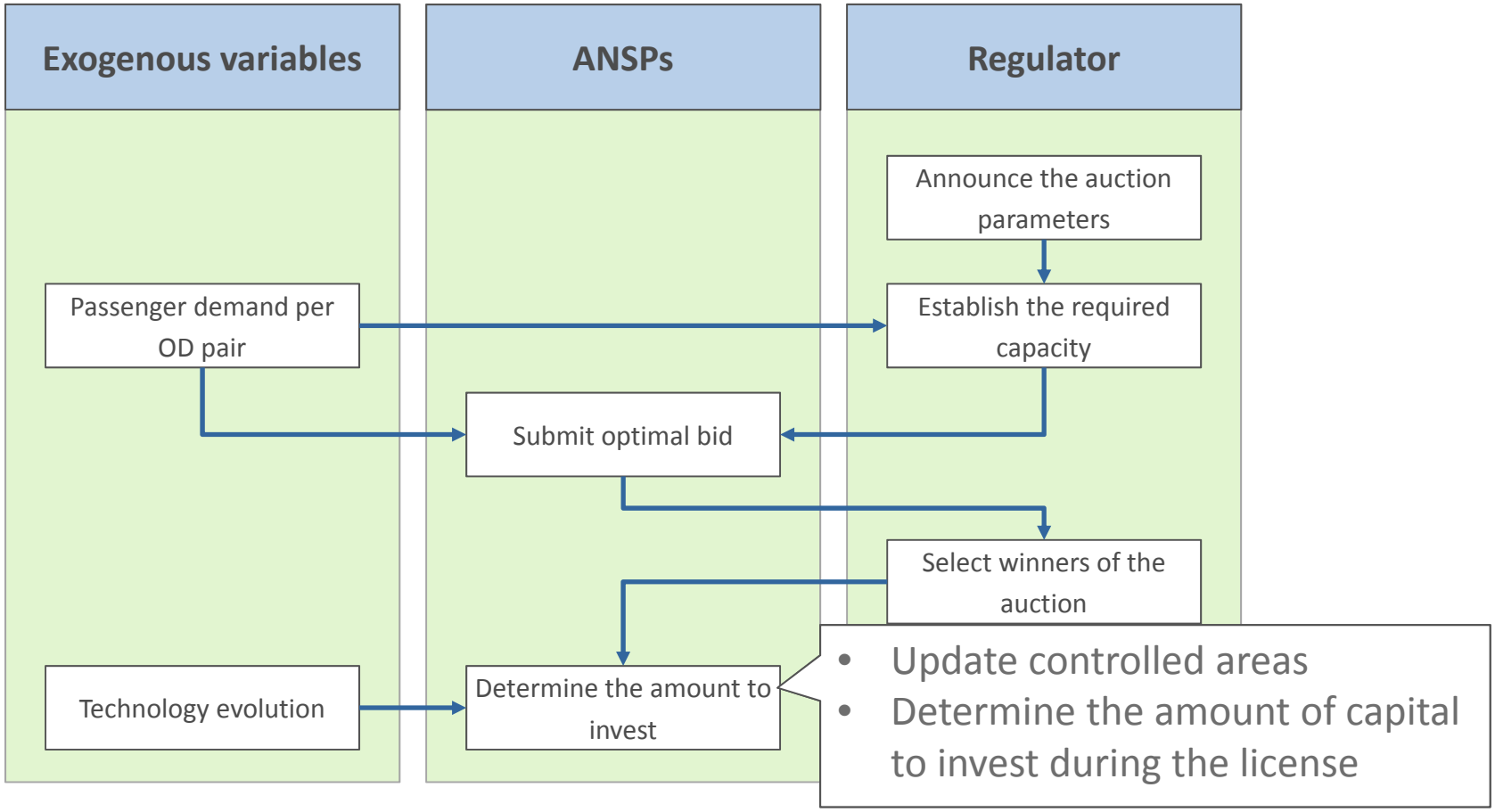
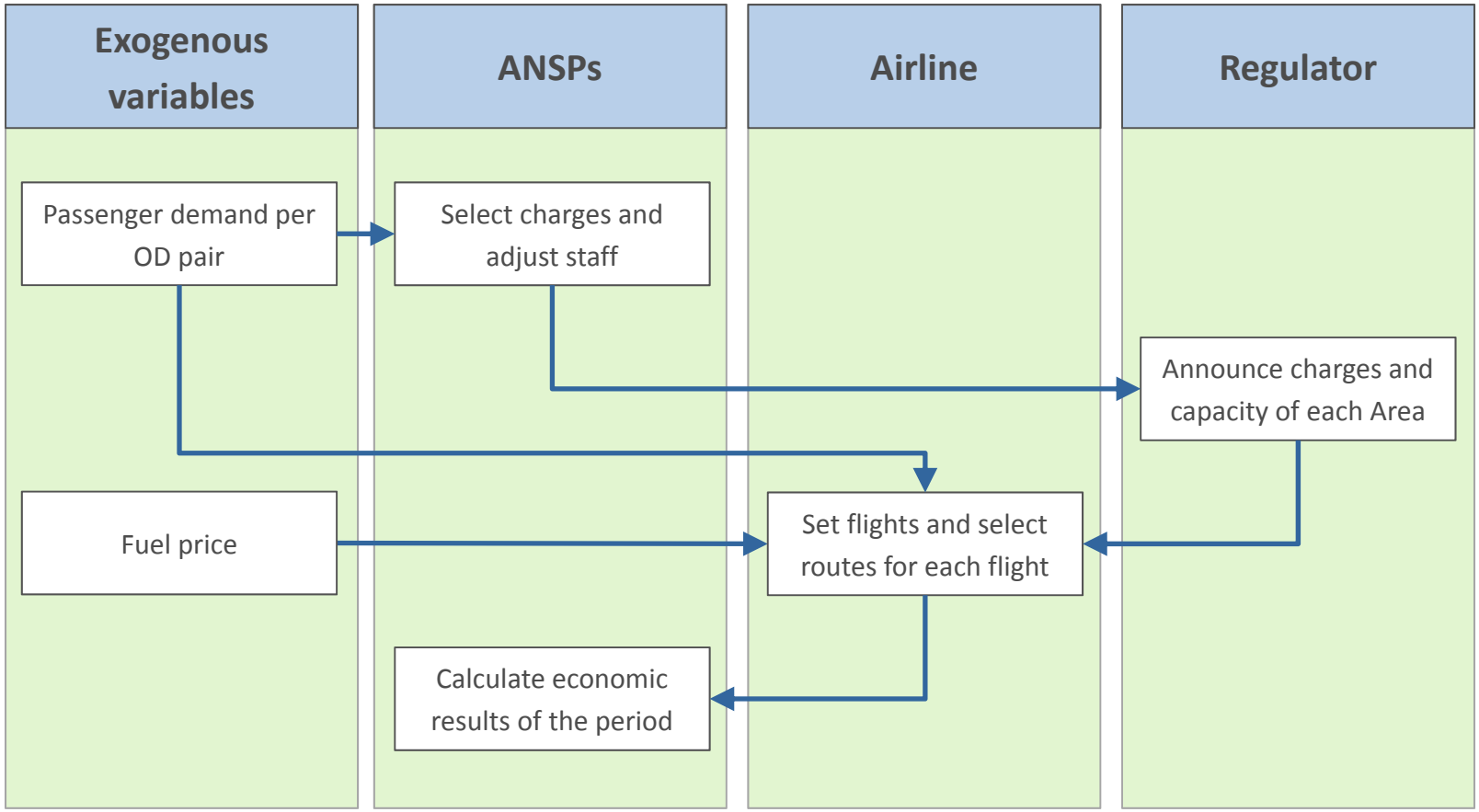
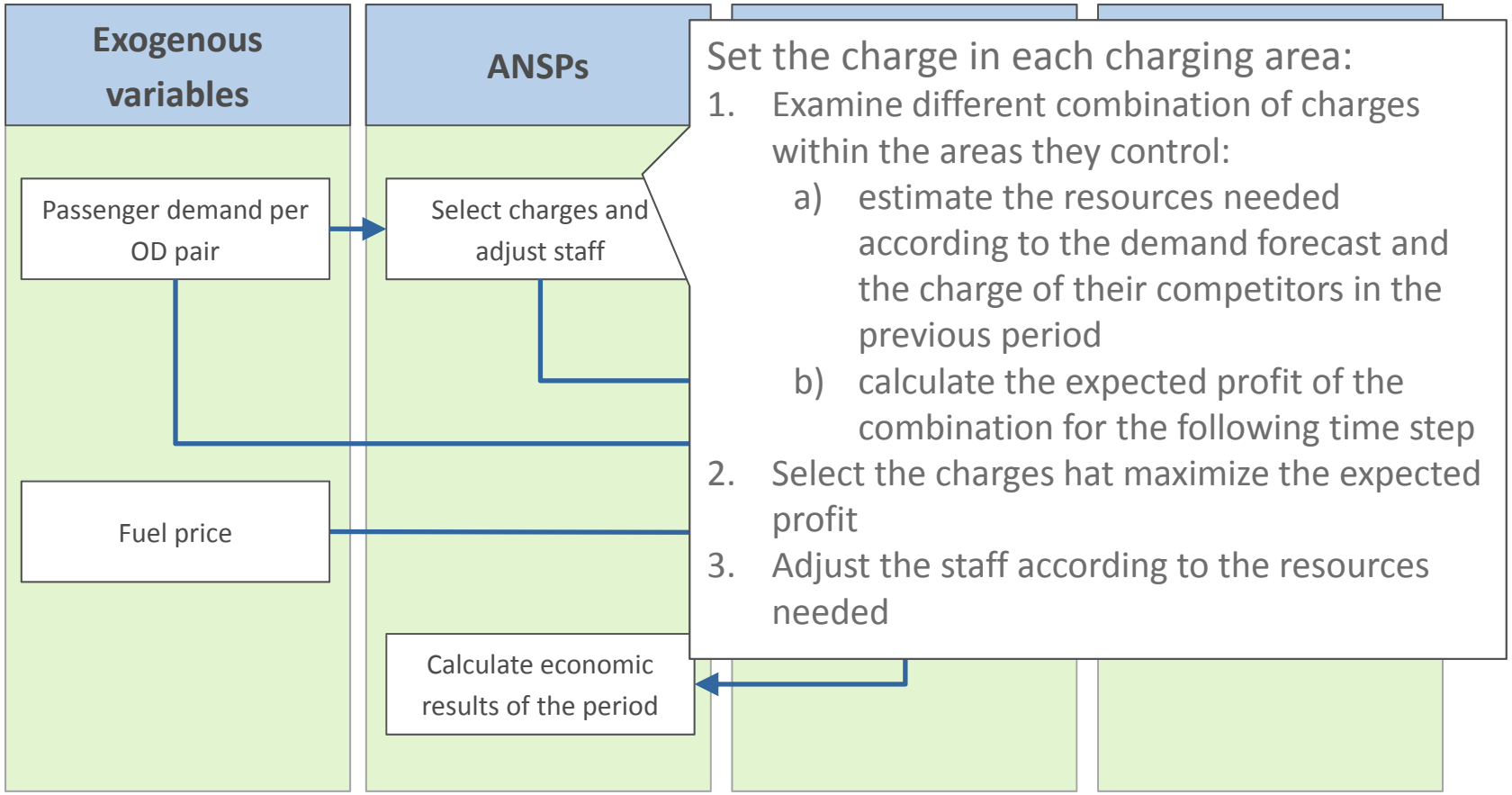


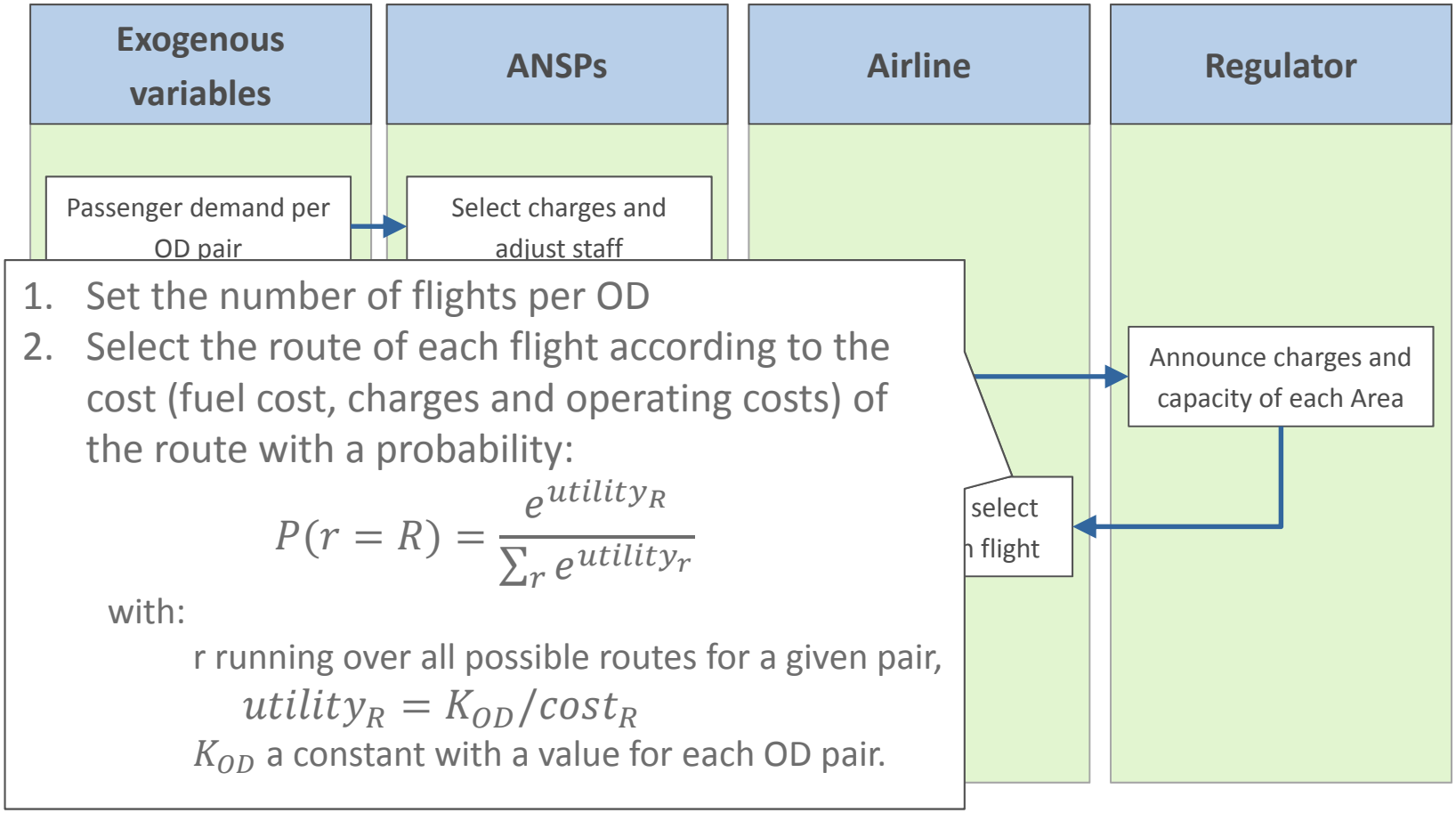
Agents' interaction rules
Evolutive process



Agents' interaction rules
Evolutive process



Agents' interaction rules
Evolutive process



1. Set the number of flights per OD
2. Select the route of each flight according to the cost (fuel cost, charges and operating costs) of the route with a probability:

$$P(r = R) = \frac{e^{utility_R}}{\sum_r e^{utility_r}}$$

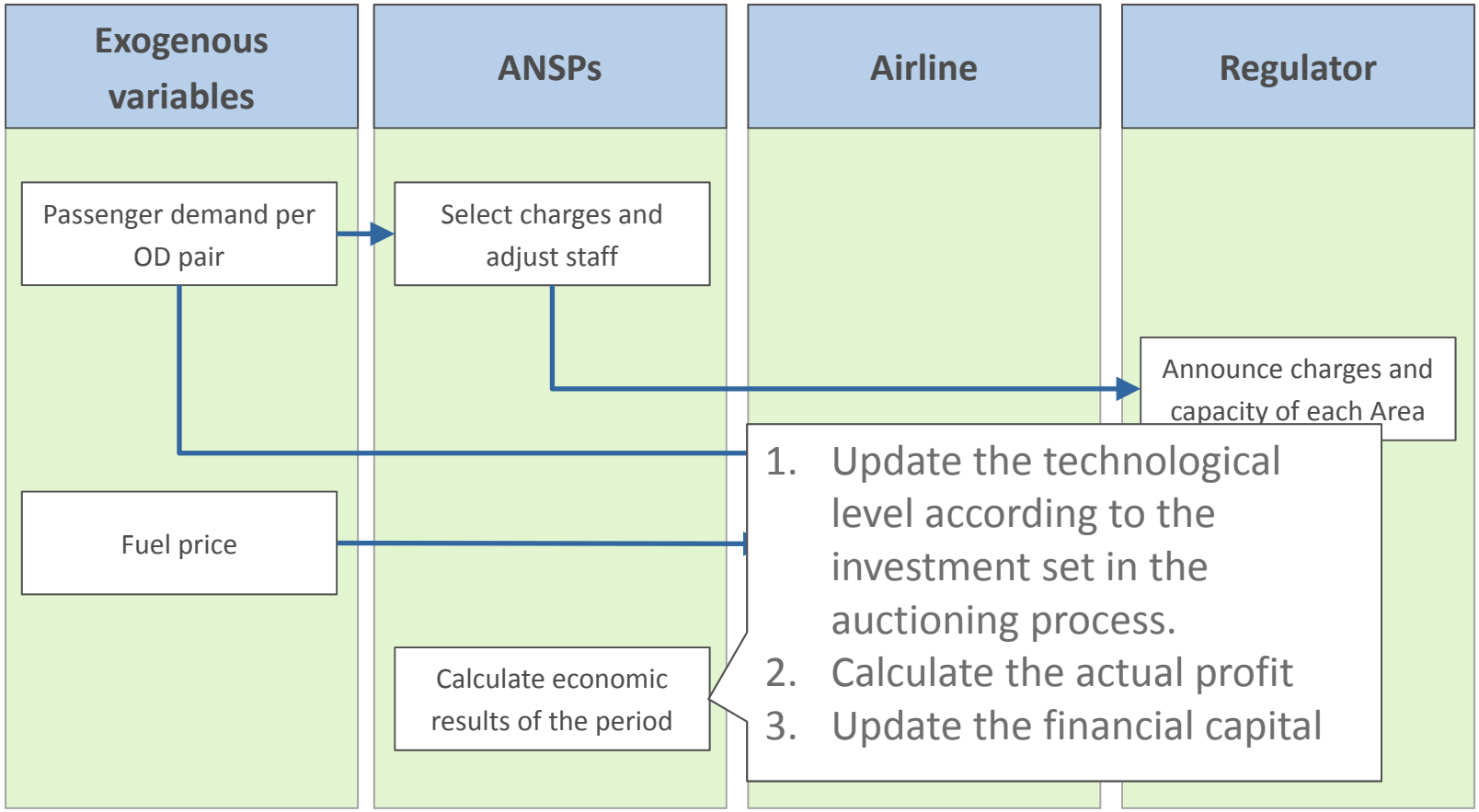
with:

r running over all possible routes for a given pair,

$utility_R = K_{OD}/cost_R$

K_{OD} a constant with a value for each OD pair.

Agents' interaction rules
Evolutive process



An Agent-Based Auction Model for the Analysis of the Introduction of Competition in ATM:

Case study

Case study

Geographical context:

- 11 countries → ~100 OD pairs
- Set of routes for each OD pair

ANSP:

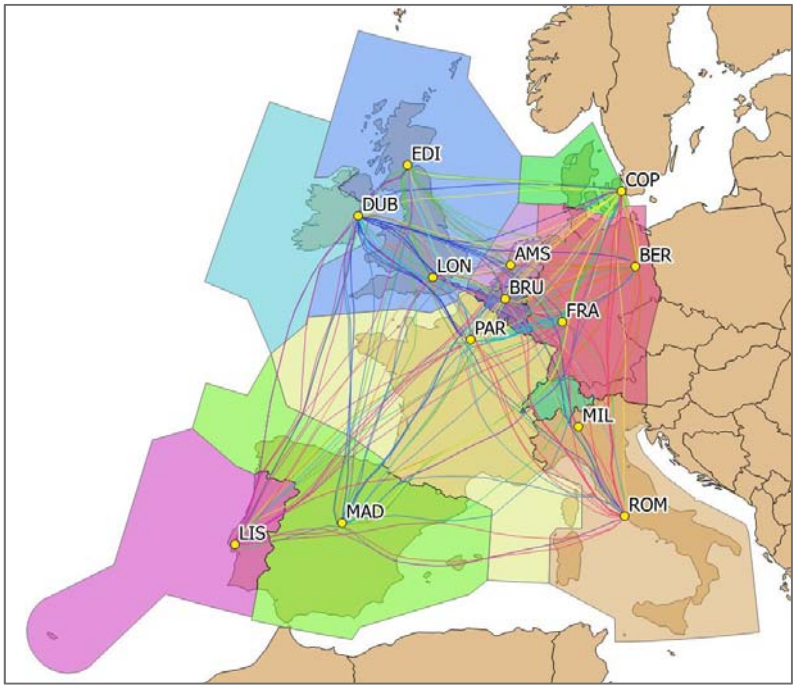
- 11 ANSPs (1 per country)
- ACE Benchmarking Report from 2014

Airline:

- CASK data (EJ, AF, LH, BA)

Temporal scope:

- 2015 - 2050



Demand forecast:

- Challenges of growth 2013 Task 7, “Regulated growth”

Simulation scenarios

Analyse the outcome of different auction parameters

- **Maximum market share allowed:** 30%, 40%, 60%
- **Auctioning order:**
    - Ascending: From smallest area to biggest area
    - Descending: From biggest area to smallest area
    - Mixed order
- **Licenses duration:** 5, 10 years

An Agent-Based Auction Model for the Analysis of the Introduction of Competition in ATM:

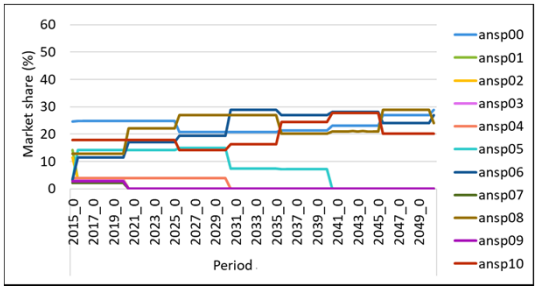
Analysis of results

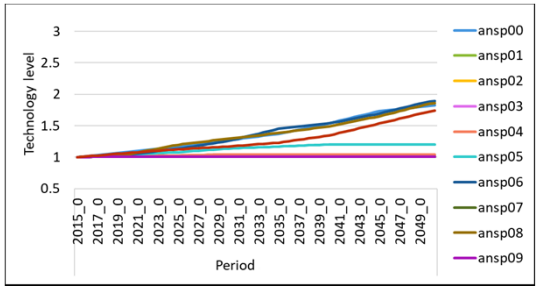
Simulation scenarios
Maximum market share allowed

Market share

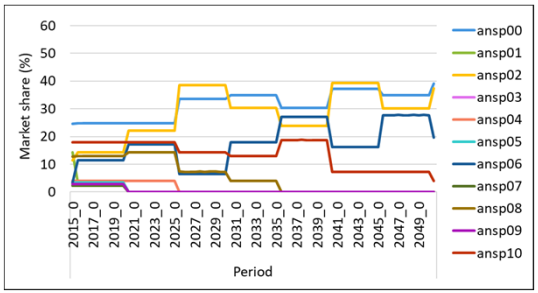
Technology

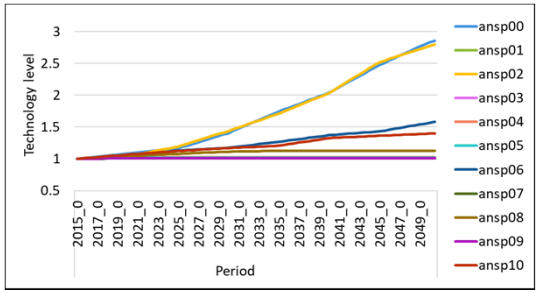
MS 30%



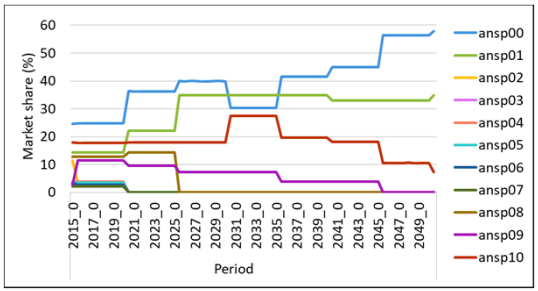


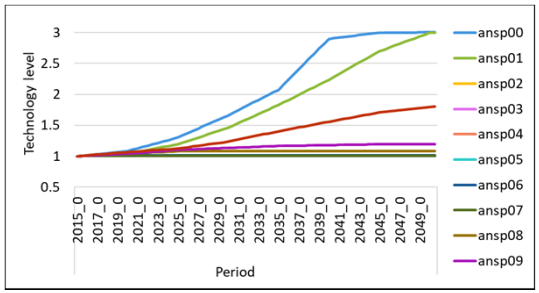
MS 40%



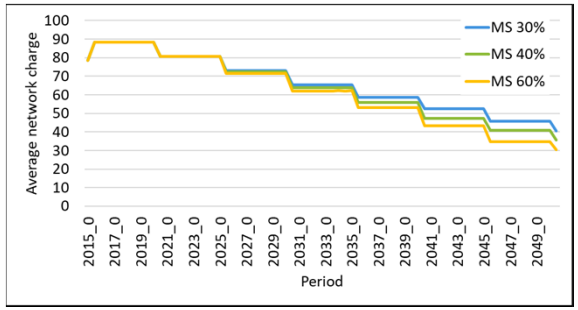


MS 60%

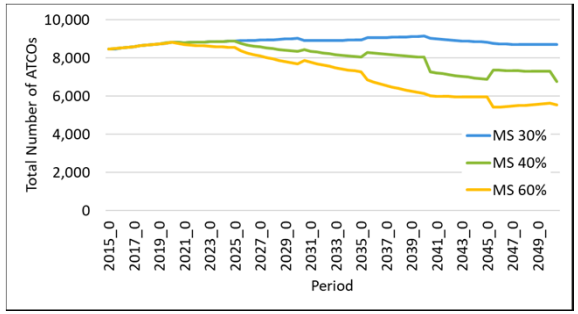




Average charge



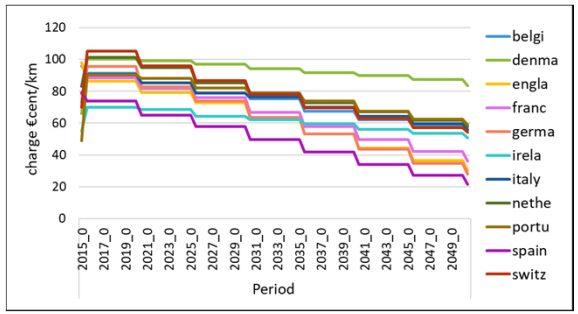
Number of ATCOs



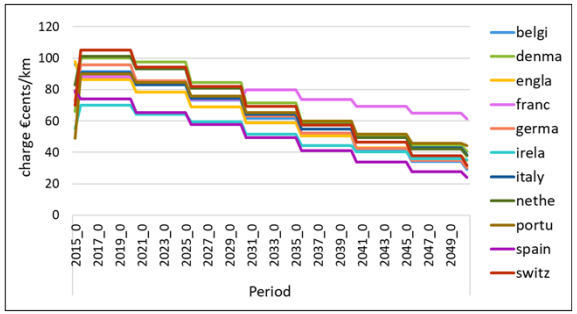
Simulation scenarios
Auctioning order

The auctioning order influences locally the charging prices resulting from the tendering but has a minor impact on the global outcome

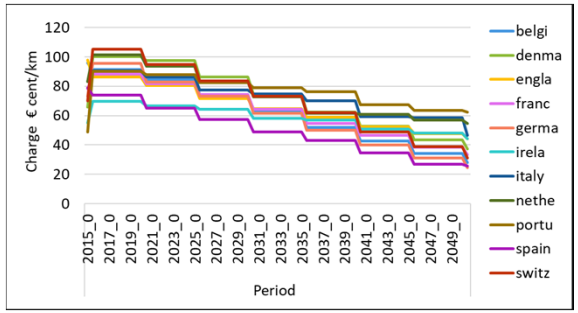
Descending order



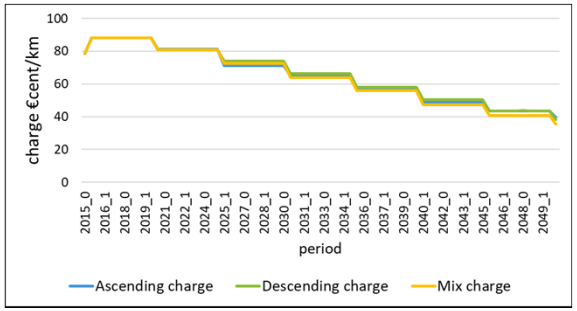
Ascending order



Mixed order



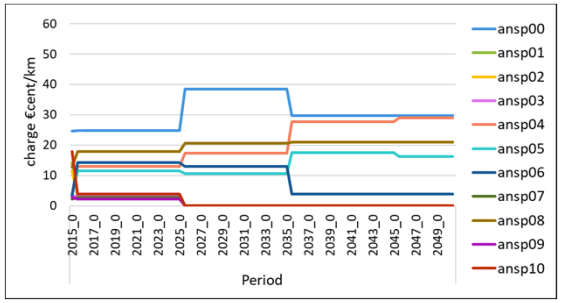
Comparison



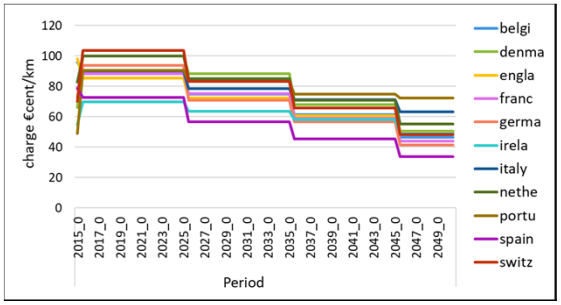
Simulation scenarios
Licenses duration

10 years

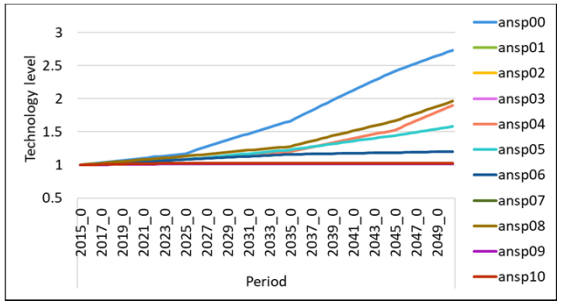
Market share



Charges

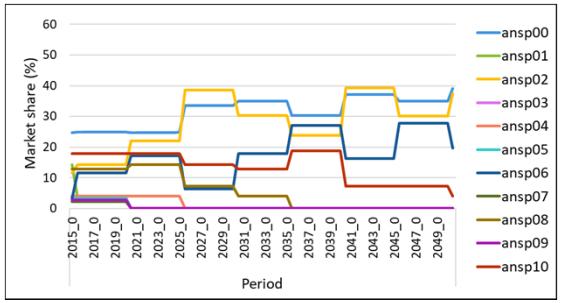


Technology



5 years

Market share



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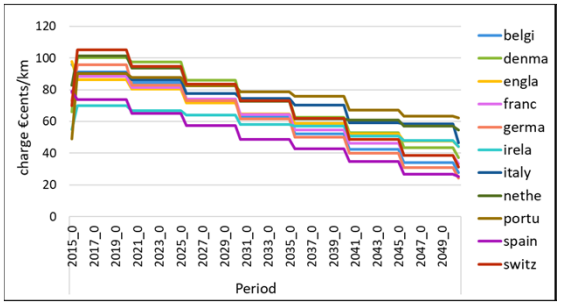
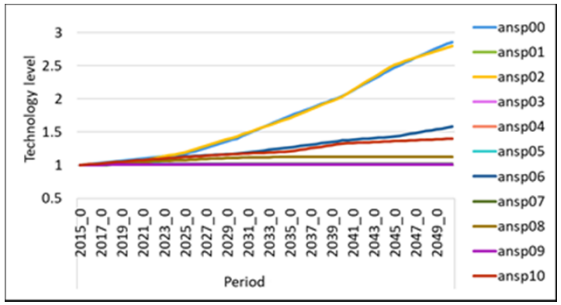
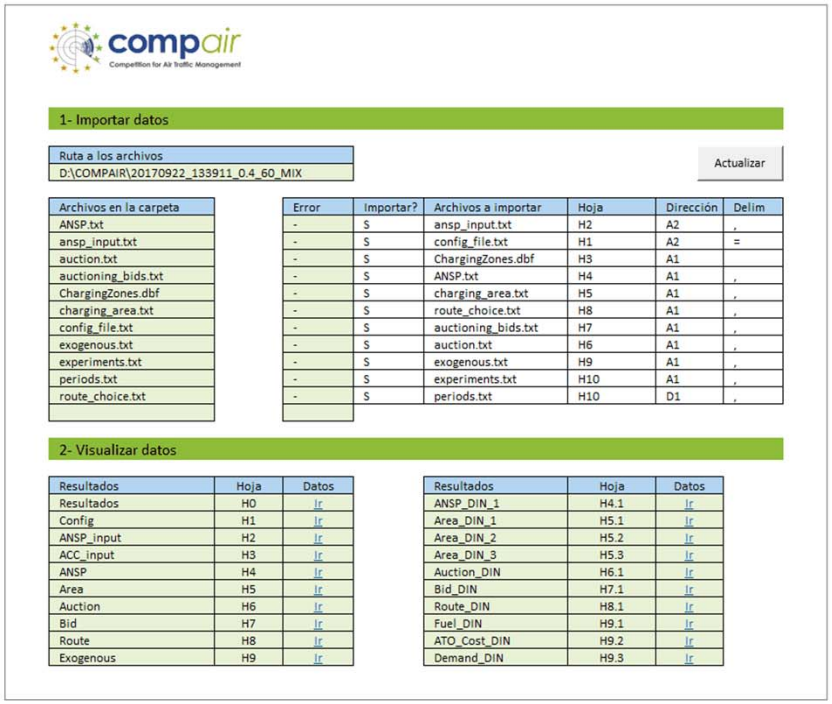


Technology



Analysis of results
Interactive tool



compair
Competition for Air Traffic Management

1- Importar datos

Ruta a los archivos
D:\COMPAIR\20170922_133911_0.4_60_MIX

Actualizar

Archivos en la carpeta
ANSP.txt
ansp_input.txt
auction.txt
auctioning_bids.txt
ChargingZones.dbf
charging_area.txt
config_file.txt
exogenous.txt
experiments.txt
periods.txt
route_choice.txt

Error	Importar?	Archivos a importar	Hoja	Dirección	Delim
-	S	ansp_input.txt	H2	A2	,
-	S	config_file.txt	H1	A2	=
-	S	ChargingZones.dbf	H3	A1	
-	S	ANSP.txt	H4	A1	,
-	S	charging_area.txt	H5	A1	,
-	S	route_choice.txt	H8	A1	,
-	S	auctioning_bids.txt	H7	A1	,
-	S	auction.txt	H6	A1	,
-	S	exogenous.txt	H9	A1	,
-	S	experiments.txt	H10	A1	,
-	S	periods.txt	H10	D1	,

2- Visualizar datos

Resultados	Hoja	Datos
Resultados	H0	Ir
Config	H1	Ir
ANSP_input	H2	Ir
ACC_input	H3	Ir
ANSP	H4	Ir
Area	H5	Ir
Auction	H6	Ir
Bid	H7	Ir
Route	H8	Ir
Exogenous	H9	Ir

Resultados	Hoja	Datos
ANSP_DIN_1	H4.1	Ir
Area_DIN_1	H5.1	Ir
Area_DIN_2	H5.2	Ir
Area_DIN_3	H5.3	Ir
Auction_DIN	H6.1	Ir
Bid_DIN	H7.1	Ir
Route_DIN	H8.1	Ir
Fuel_DIN	H9.1	Ir
ATO_Cost_DIN	H9.2	Ir
Demand_DIN	H9.3	Ir

An Agent-Based Auction Model for the Analysis of the Introduction of Competition in ATM:

Conclusions & future research

Conclusions

- Competition leads to lower charges and smaller number of players.
- The ANSPs which control the biggest charging zones at the beginning of the simulation perform better in the long term thanks to economies of scale.
- When there is a dominant ANSP both the total number of ATCOs and the average charge are lower than in the case where the market is controlled by more ANSPs, but it could lead to an oligopoly in the long-term.
- The auctioning order has an important local effect on the tendering results, obtaining better bids for the countries that are auctioned first.

Future research

Additional simulations

- Simulate scenarios with different degrees of uncertainty in the exogenous variables and different bidding strategies
- Compare different auction designs: Sequential auctioning of different areas (learning process) vs Simultaneous auctioning of all areas in Europe

Additional model developments

- Model the possibility of new entrants
- Model different ANSPs and airlines strategies regarding investment in new technologies
- More realistic representation of airline behavior (e.g., route planning)

Questions?

An ABM for the Analysis of the Introduction of Competition in ATM

Thank you very much for your attention!

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