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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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 ANSP (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

Exogenous variables
- Passenger demand per OD pair
- Technology evolution

ANSPs
- Submit optimal bid

Regulator
- Announce the auction parameters
- Establish the required capacity
- Select winners of the auction
- Determine the amount to invest

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Agents’ interaction rules
Tendering process

### Exogenous variables
- Passenger demand per OD pair
- Technology evolution

### ANSPs
- Auctioning order
- Maximum market share allowed
- Submit optimal bid
- Determine the amount to invest

### Regulator
- Announce the auction parameters
- Establish the required capacity
- Select winners of the auction

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**Introduction**

**Model description**

**Case study**

**Analysis of results**

**Conclusions**

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Agents’ interaction rules

Tendering process

Exogenous variables
- Passenger demand per OD pair
- Technology evolution

ANSPs
- Announce the auction parameters
- Establish the required capacity

Regulator
- Establish the required capacity

- Estimate the number of flights per OD pair
- Get the distribution of flights per route in each OD pair in last 2 years
- Determine the required capacity in each area

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Agents’ interaction rules
Tendering process

### Exogenous variables
- Passenger demand per OD pair
- Technology evolution

### Agents’ interaction rules
Submit a bid corresponding to the maximum charge that would be applied to the auctioned zone

1. Calculate their resulting market share in case of winning the auction (market share < maximum market share?)
2. Determine the minimum profitability (adaptive factor)
3. Select the bid value (iterative process):
   a) estimate the resources needed according to their technology level and the expected demand
   b) estimate the expected total profit
   c) obtain the probability of beating their competitors (different learning methods)
   d) calculate the auction expected profit, defined as the product of the expected profit by the probability of winning the auction
4. Submit the bid that maximizes the auction expected profit
Agents’ interaction rules
Tendering process

Exogenous variables
- Passenger demand per OD pair
- Technology evolution

ANSPs
- Submit optimal bid

Regulator
- Announce the auction parameters
- Establish the required capacity
- Select winners of the auction

Select the winner ANSP: ANSP whose bid is the lowest bid

Invest

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Agents’ interaction rules
Tendering process

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<td>Technology evolution</td>
<td>Determine the amount to invest</td>
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<td>Select winners of the auction</td>
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<td>• Update controlled areas</td>
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<td>• Determine the amount of capital to invest during the license</td>
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Agents’ interaction rules
Evolutive process

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<td>Set flights and select routes for each flight</td>
<td>Announce charges and capacity of each Area</td>
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Agents’ interaction rules
Evolutive process

### Exogenous variables
- Passenger demand per OD pair
- Fuel price

### ANSPs
- Select charges and adjust staff

Set the charge in each charging area:
1. Examine different combination of charges within the areas they control:
   a) estimate the resources needed according to the demand forecast and the charge of their competitors in the previous period
   b) calculate the expected profit of the combination for the following time step
2. Select the charges that maximize the expected profit
3. Adjust the staff according to the resources needed

### Analysis of Results
- Calculate economic results of the period
Agents’ interaction rules
Evolutive process

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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.

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Agents’ interaction rules
Evolutive process

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1. Update the technological level according to the investment set in the auctioning process.
2. Calculate the actual profit
3. Update the financial capital
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
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Analysis of results
Simulation scenarios
Maximum market share allowed

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<td>MS 40%</td>
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<tr>
<td>MS 60%</td>
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**Market share**

- **MS 30%**
- **MS 40%**
- **MS 60%**

**Technology**

- **Average charge**
- **Number of ATCOs**

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**Chart Descriptions**

- Market share
- Technology
- Average charge
- Number of ATCOs

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**Table Descriptions**

- **Average network change**
- **Total 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

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Simulation scenarios
Licenses duration

10 years

Market share
Charges
Technology

5 years

Market share
Charges
Technology

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Analysis of results
Interactive tool
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!