Managing Change in Air Traffic Control: a Regional Forerunner Approach

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Motivation

- present ATC system in EU is composed of 37 national providers
  - compared to FAA, EU system is 34% more costly (2011)
- barriers to cost efficiency:
  - ownership form: governmental organizations
  - fragmentation: missing economies of scale
  - protectionism: power of Labor Unions & member states
  - weak regulation: failure to implement FABs or strict price-caps
- barriers to increasing capacity:
  - SESAR estimated cost: 30 billion euro
  - relatively low congestion currently
  - opposition to change / fear of technology
how could cost efficiency and technology adoption be encouraged simultaneously?

• changes in ownership form
  • horizontal integration
  • vertical integration
  • privatization

• changes in pricing regulation
  • strict individual price-caps
  • peak / off peak charges
  • hybrid price-caps

• changes in capacity
  • Pilot Common Project
  • SESAR Step 1
Outline of talk

- Literature search
- Methodology to analyse ATM market: 2-stage game
  - 1st stage: ANSPs
  - 2nd stage: airline response
- Case study
  - Western Europe covering 6 ANSP areas
  - Data collected
- Scenarios analysed
  - Base case
  - Pricing
  - Technology adoption: PCP and SESAR Step 1
  - Horizontal mergers: FABs
  - Vertical mergers: Regional forerunner
- Conclusions & Future Research
Literature Search

- **Air Traffic Control**
  - **On the US system:**
    - Morrison & Winston (2008)
    - Nextor (2010)
  - **On the European system:**
    - Grushka-Cockayne, De Reyck and Degraeve (2008)
    - Castelli, Labbe and Violin (2013)
    - Jovanovic, Totic, Canganovic, Stanojevic (2014)
    - Button and Neiva (2014)

- **Network congestion games**
  - Rosenthal (1973)
  - Monderer & Shapley (1996)
  - **Application:**
    - Computer networks: Roughgarden (2009)
2 Stage Game

- **Stage 1:**
  - ANSPs set peak/off-peak charges according to regulatory rules
  - ATC terminal set charges and limit flights in peak (slot allocation)
    - Cost recovery
    - Profit maximization
    - Peak/Off peak price-caps

- **Stage 2 - Airlines choose flight paths given schedules**
  - 3 cost components: operational, congestion & ATC en-route charges
  - + Revenue loss: flying off-peak lowers airfares
  - Option to ‘not fly’ necessary for demand elasticity

- **Note:** Congestion is non-linear
  - Closer to capacity: the higher the delays
2 Stage Game

• Stage 1:
  • ANSPs set peak/off-peak charges according to regulatory rules
  • ATC terminal set charges and limit flights in peak (slot allocation)
    • Cost recovery
    • Profit maximization
    • Peak/Off peak price-caps
• Stage 2 - Airlines choose flight paths given schedules
  • 3 cost components: operational, congestion & ATC en-route charges
  • + Revenue loss: flying off-peak lowers airfares
  • Option to ‘not fly’ necessary for demand elasticity

• **User optimal**: Airlines set flight paths to minimize own costs
  • Minimize only self-inflicted delays
• **System optimal**: central planner set flight paths to minimize sum of airline costs
  • Bird’s eye view: Minimize total sum of all delay
Case Study of Western Europe
Case Study of Western Europe
Players

- **6 Air navigation service providers:** (~50% of EU traffic)
  - NATS (U.K.)
  - LVNL (Netherlands)
  - DFS (Germany)
  - AENA (Spain)
  - Belgocontrol (Belgium)
  - DSNA (France)

- **5 Airlines:**
  - 3 alliances:
    - Star (Lufthansa)
    - Oneworld (BA)
    - SkyTeam (AF-KLM)
  - Low cost carrier (EasyJet)
  - Unaligned carrier (Emirates)

- **9 ATC terminal providers:**
  - Large airports (slot constrained):
    - AMS
    - BRU
    - CDG
    - FRA
    - LHR
    - MAD
  - Small airports (no slots):
    - BER
    - MAN
    - PMI
### Key Data


#### ANSP

<table>
<thead>
<tr>
<th>ANSP</th>
<th>Revenues (000 €)</th>
<th>Variable Costs (000 €)</th>
<th>Fixed Costs (000 €)</th>
<th>Total Distance in Charging Area (Km)</th>
<th>Avg. Charge per km</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSNA</td>
<td>1,167,138</td>
<td>804,653</td>
<td>113,876</td>
<td>1,463,618,011</td>
<td>0.80</td>
</tr>
<tr>
<td>DFS</td>
<td>739,112</td>
<td>631,983</td>
<td>129,285</td>
<td>1,007,485,777</td>
<td>0.73</td>
</tr>
<tr>
<td>Aena</td>
<td>794,710</td>
<td>498,756</td>
<td>135,599</td>
<td>859,175,623</td>
<td>0.93</td>
</tr>
<tr>
<td>NATS</td>
<td>651,366</td>
<td>368,015</td>
<td>153,001</td>
<td>707,474,135</td>
<td>0.92</td>
</tr>
<tr>
<td>LVNL</td>
<td>169,365</td>
<td>102,058</td>
<td>11,378</td>
<td>191,563,198</td>
<td>0.88</td>
</tr>
<tr>
<td>Belgocontrol</td>
<td>155,805</td>
<td>82,605</td>
<td>13,884</td>
<td>166,751,138</td>
<td>0.93</td>
</tr>
</tbody>
</table>

#### ATC Terminal by country

<table>
<thead>
<tr>
<th>Country</th>
<th>IFR airport movements controlled by ANSP</th>
<th>Fixed Cost (€)</th>
<th>Variable Cost per Movement (€)</th>
<th>Income From Charges per Movement (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>2,059,372</td>
<td>41,208,000</td>
<td>86</td>
<td>101</td>
</tr>
<tr>
<td>France</td>
<td>1,892,868</td>
<td>31,704,000</td>
<td>127</td>
<td>122</td>
</tr>
<tr>
<td>Spain</td>
<td>1,854,896</td>
<td>49,253,000</td>
<td>117</td>
<td>116</td>
</tr>
<tr>
<td>UK</td>
<td>1,746,362</td>
<td>9,863,000</td>
<td>87</td>
<td>115</td>
</tr>
<tr>
<td>Netherlands</td>
<td>485,525</td>
<td>5,313,000</td>
<td>99</td>
<td>113</td>
</tr>
<tr>
<td>Belgium</td>
<td>380,572</td>
<td>9,208,000</td>
<td>130</td>
<td>69</td>
</tr>
</tbody>
</table>
Cases

• **Base case**: reproduce 2011
• **Pricing**: peak/off-peak price, price regulation vs. no regulation
• **Technology**: pilot common project & SESAR step 1
• **Horizontal Integration**: FABs
  • Belgocontrol & DSNA
  • LVNL & DFS
  • DSNA & DFS
  • Belgocontrol, LVNL & DFS (MUAC lower airspace)
• **Vertical Integration**: Regional Forerunner
  • Germany: DFS, FRA, BER and Lufthansa
  • France: DSNA, CDG & Air France
  • Spain: AENA, MAD, PMI & British Airways/Iberia
Base case: reproducing current equilibria 2011

- User optimal (cost recovery)

**AIRLINE COSTS IN €**

<table>
<thead>
<tr>
<th>Airline</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emirates</td>
<td>7,799,266,681</td>
</tr>
<tr>
<td>Low Cost Carrier</td>
<td>11,371,448,750</td>
</tr>
<tr>
<td>BA/IB</td>
<td>6,891,443,879</td>
</tr>
<tr>
<td>LH</td>
<td>7,615,174,955</td>
</tr>
<tr>
<td>AF/KLM</td>
<td>4,288,508,980</td>
</tr>
</tbody>
</table>

**ANSP Profits in €**

<table>
<thead>
<tr>
<th>Location</th>
<th>Profits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heathrow</td>
<td></td>
</tr>
<tr>
<td>AMS</td>
<td></td>
</tr>
<tr>
<td>FRA</td>
<td></td>
</tr>
<tr>
<td>BRU</td>
<td></td>
</tr>
<tr>
<td>CDG</td>
<td></td>
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<tr>
<td>MAD</td>
<td></td>
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<tr>
<td>MAN</td>
<td></td>
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<tr>
<td>BER</td>
<td></td>
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<tr>
<td>PMI</td>
<td></td>
</tr>
</tbody>
</table>

**ATC Terminal Profits in €**

<table>
<thead>
<tr>
<th>Location</th>
<th>Profits</th>
</tr>
</thead>
<tbody>
<tr>
<td>LHR</td>
<td></td>
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<tr>
<td>AMS</td>
<td></td>
</tr>
<tr>
<td>FRA</td>
<td></td>
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<tr>
<td>BRU</td>
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<tr>
<td>BER</td>
<td></td>
</tr>
<tr>
<td>PMI</td>
<td></td>
</tr>
</tbody>
</table>
System Optimal

- Conclusions:
  - Possible to reorganize flight paths to reduce congestion
  - Some airlines worse off thus unlikely to agree to central planner approach
Pricing scenarios

- ANSP profit maximization

  ANSP Charge per Km

- Consequences compared to base-run:
  - ANSP prices ↑ by average magnitude of 10
  - Airline CASKs doubled
  - LH stops flying off-peak and cuts down operations during peak by half
  - Airlines cut down operation during peak, only REST business as usual
  - Different peak, off-peak prices
  - Insufficient competition to remove price regulation in current market

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Peak versus off-peak pricing

<table>
<thead>
<tr>
<th>ANSP</th>
<th>Base price</th>
<th>Peak-price (120%)</th>
<th>Off-peak price (80%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NATS UK</td>
<td>0.921</td>
<td>1.1052</td>
<td>0.7368</td>
</tr>
<tr>
<td>LVNL Netherlands</td>
<td>0.884</td>
<td>1.0608</td>
<td>0.7072</td>
</tr>
<tr>
<td>DFS Germany</td>
<td>0.734</td>
<td>0.8808</td>
<td>0.5872</td>
</tr>
<tr>
<td>Belgocontrol</td>
<td>0.934</td>
<td>1.1208</td>
<td>0.7472</td>
</tr>
<tr>
<td>DSNA France</td>
<td>0.797</td>
<td>0.9564</td>
<td>0.6376</td>
</tr>
<tr>
<td>AENA Spain</td>
<td>0.925</td>
<td>1.11</td>
<td>0.74</td>
</tr>
</tbody>
</table>

- **Single price-cap**: ANSPs charge maximum
- **2 price-caps**: ANSP revenues equivalent or increase
- **Off-peak price**: low (negative) to induce airline changes
- **Revenue loss**:
  - greater than ANSP charges hence no impact on airlines
  - half revenue loss parameter not impact results

% Change in Airline Costs

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Technology: Pilot Common Project

- **PCP cost = € 2.5 billion**

- **Airlines (~16% of cost):**
  - congestion: reduction of 8.7% en-route, 12.51% at airport
  - operational costs: reduction 0.63% (technology less fuel)

- **ANSP (~65% of cost)**
  - variable cost: reduction of 8.4%
  - fixed cost: increase of 22%
  - constant price

- **ATC Terminal (~5% of cost):**
  - airport capacity: increase of 4%
  - variable cost: reduction of 8.4%
  - fixed cost: increase of 104%
  - constant price
Results:

- Airlines: 1.913% change
- ANSPs: 31.379% change
- ATC terminal: 17.290% change

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Technology: SESAR Step 1

- **Step 1 cost** = € 30 billion
- **Airlines** (~50% of cost):
  - congestion: reduction of 27% en-route, 14% at airport
  - variable costs: increase of 0.1%
- **ANSP** (~16% of cost):
  - variable cost: reduction of 8.4%
  - fixed cost: increase of 64%
  - price: reduction of 6.1%
- **ATC Terminal** (~13% of cost):
  - airport capacity: increase of 14%
  - variable cost: reduction of 8.4%
  - fixed cost: increase of 600%
  - price: reduction of 6.1%
Technology: SESAR Step 1, 2030

- **Results:**
  - Airlines 😊
  - ANSPs 😞
  - ATC 😞

- **Conclusions:**
  - based on expected demand growth of 38.7%
  - ANSP & ATC prices insufficient

**ANSP Profits: Base Case vs. SESAR Step 1**

**% Change in Airline Costs**

- BA: -8.91%
- LH: -1.77%
- AF: -2.46%
- LC: -2.58%
- Rest: -1.92%

**ANSP Profits:**

- NATS UK: $300,000,000
green
- LVNL: $200,000,000
red
- DFS Germany: $100,000,000
green
- Belgocontrol: $200,000,000
red
- DSNA France: $300,000,000
red
- AENA Spain: $400,000,000
red

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**Technology: SESAR Step 1 2030 + Price Cap**

- **ATC terminal**: worthwhile
- **Conclusions:**
  - **20% increase** in peak for both ANSP and ATC terminal **sufficient**
  - **Airlines**: wipes out all savings

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Horizontal Integration: Functional Airspace Blocks
**Horizontal Integration:** FABs = 30% fixed cost savings

### Belgocontrol & DSNA France: Profit

<table>
<thead>
<tr>
<th>FAB</th>
<th>Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>separately</td>
</tr>
<tr>
<td>FAB</td>
<td></td>
</tr>
</tbody>
</table>

### LVNL Netherlands & DFS Germany: Profit

<table>
<thead>
<tr>
<th>FAB</th>
<th>Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>separately</td>
</tr>
<tr>
<td></td>
<td>FAB</td>
</tr>
</tbody>
</table>

### DSNA France & DFS Germany: Profit

<table>
<thead>
<tr>
<th>FAB</th>
<th>Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>separately</td>
</tr>
<tr>
<td>FAB</td>
<td></td>
</tr>
</tbody>
</table>

### % Change in Airline Costs

<table>
<thead>
<tr>
<th>BA</th>
<th>LH</th>
<th>AF</th>
<th>LC</th>
<th>Rest</th>
<th>Change in Airline Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.02%</td>
<td>-0.12%</td>
<td>0.03%</td>
<td>0.05%</td>
<td>-0.27%</td>
<td>-0.30%</td>
</tr>
<tr>
<td>0.011%</td>
<td>0.042%</td>
<td>0.049%</td>
<td>0.046%</td>
<td>-0.045%</td>
<td>0.060%</td>
</tr>
<tr>
<td>0.00%</td>
<td>0.20%</td>
<td>0.40%</td>
<td>0.60%</td>
<td>0.57%</td>
<td>0.80%</td>
</tr>
</tbody>
</table>

- 0.02% 0.03% 0.05% 0.049% 0.046% -0.045% 0.060% 0.00% 0.20% 0.40% 0.60% 0.57% 0.80%
Horizontal Integration: FABs

- **MUAC lower airspace FAB:**

  DFS Germany, Belgocontrol & LVNL Netherlands:

  ![MUAC lower airspace FAB diagram](image1)

- **With lowest price (Germany) – MUAC lower airspace FAB**

  ![With lowest price (Germany) – MUAC lower airspace FAB diagram](image2)
Vertical Integration: Regional Forerunner

- ANSP cost recovery & PCP implementation
- German Coalition:

<table>
<thead>
<tr>
<th>Member</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lufthansa (Cost)</td>
<td>7,615,174,955</td>
<td>7,529,739,840 ✓</td>
</tr>
<tr>
<td>DFS</td>
<td>19,871,750</td>
<td>23,998,701 ✓</td>
</tr>
<tr>
<td>BER</td>
<td>492,550</td>
<td>-1,985,179 x</td>
</tr>
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</table>

- French Coalition:

<table>
<thead>
<tr>
<th>Member</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>AF/KLM (Cost)</td>
<td>4,288,508,980</td>
<td>4,216,128,108 ✓</td>
</tr>
<tr>
<td>DSNA</td>
<td>265,366,417</td>
<td>311,248,918 ✓</td>
</tr>
<tr>
<td>CDG</td>
<td>-19,397,050</td>
<td>-17,132,471 ✓</td>
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</tbody>
</table>

- Spanish Coalition:

<table>
<thead>
<tr>
<th>Member</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA/Iberia (Cost)</td>
<td>6,891,443,879</td>
<td>6,841,060,627 ✓</td>
</tr>
<tr>
<td>AENA</td>
<td>19,932,172</td>
<td>12,165,925 x</td>
</tr>
<tr>
<td>MAD</td>
<td>-12,088,200</td>
<td>-17,202,306 x</td>
</tr>
<tr>
<td>PMI</td>
<td>-5,043,880</td>
<td>-7,465,139 x</td>
</tr>
</tbody>
</table>

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Conclusions

- Modeling air traffic control via network congestion game enables cost-benefit analysis
- **Ownership form**
  - regional forerunner approach preferable to functional airspace blocks
    - but dependent on partnership
  - commercialization appears to be necessary to change behavior
    - e.g. through time dependent tenders
- **Pricing approach**
  - insufficient competition to ensure ANSPs charge reasonable prices
  - peak & off-peak price caps necessary to separate charges
- **New technology (capacity)**
  - pilot common project is positive for airlines but unlikely to succeed without permitting ANSPs to charge higher prices
  - SESAR step 1 even more unlikely to occur without re-balancing of charges &/or subsidies
  - hybrid price-caps necessary to balance cost & benefits of SESAR technologies

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