Implications of interdependencies between charging strategies of local authorities for the protection of sensitive areas in the Trans-Pennine Corridor

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Research Focus

“Competition” between agglomerations and areas of high natural significance

- Protection of sensitive areas
- Non-cooperative duopoly
- Welfare maximising cordon charges

Content of Presentation:
- Case Study Description
- Problem Definition & Modelling Approach
- Results & Policy Implications
- Conclusions
Characteristics of the Trans-Pennine Corridor

- Agglomeration area (total of 13 Mio. Inhabitants)
- High quality natural capital
- Unique cultural heritage (e.g. UNESCO heritage sites)
- Recreational areas (e.g. National Parks)
- Extensive transport infrastructure including TEN-T corridors
- Area of economic regeneration

Mapbase: Google Maps
Charging Cordons around Transport Sensitive Areas

Peak District National Park
- Protection from Trough Traffic
- High natural + recreational value
- Infrastructure, Noise sensitive

Sheffield AQMA
- Through and area wide traffic
- Densely populated
- Air quality problems
- Air pollution, noise sensitive
Pricing Strategies (Policy Scenarios)

Cordon is Fixed (one around Peak District) and (one around Sheffield)

→ Determine the cordon / area charge for all user classes to pay
→ Difference is the objective function

<table>
<thead>
<tr>
<th>Regulation Scenario</th>
<th>Scope of User Benefits</th>
<th>Scope of Savings from Pollution Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scenario 1: Global</strong></td>
<td>for all travellers in the network.</td>
<td>Reduction in pollution over entire road network.</td>
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<tr>
<td>regulator</td>
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<tr>
<td><strong>Scenario 2: Myopic</strong></td>
<td>for all residents of and Peak District</td>
<td>Reduction in pollution on road network within and Peak District only.</td>
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<td>One regulator covering and the Peak District sensitive areas.</td>
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<tr>
<td><strong>Scenario 3: Nash Game</strong></td>
<td>for residents in own local area only</td>
<td>Reduction in pollution in own local area only.</td>
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<td>Separate Local Regulators for and the Peak District</td>
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Modelling Approach

- Welfare function includes
  - User benefits (generalised costs)
  - Revenues
  - Pollution costs (NMVOC, NO\textsubscript{x}, PM\textsubscript{10})

- Models
  - SWYMBUS transport data
  - Base case 2005 and BAU scenario
  - SATURN traffic assignment software
  - Specific environmental models

- Valuation
  - Pollution: HEATCO (Impact pathway approach)
  - User benefits: COBA
Optimisation Approach Scenarios 1 + 2

- Mathematical program with equilibrium constraints
- Incremental increase of tolls in steps of £0.5 from £0 to £5 (Peak) / £8 (Sheffield)
- Traffic assignment: Road users choose routes minimising costs (Wardrop’s equilibrium)
- Optimal tolls determined by 2-dimensional grid search to maximise welfare

Surface has many optima when we consider global benefits pollution is transferred from one locale to another!
Optimisation Approach Nash Game

- Equilibrium problem with equilibrium constraints (EPEC)
- Simple search method as iterative process, repeated until convergence:
  1. determine optimal toll area 1
  2. with this determine optimal toll area 2
  3. using this repeat from 1.
## Results

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Area</th>
<th>Toll £</th>
<th>Welfare £ per hour</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Cordon Charge</td>
<td>Area Charge</td>
</tr>
<tr>
<td>Scenario 1: Global Peak</td>
<td>Peak</td>
<td>0</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td>Sheffield</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Global (Regulator)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 2: Myopic Peak</td>
<td>Peak</td>
<td>1.50</td>
<td>2.50</td>
</tr>
<tr>
<td></td>
<td>Sheffield</td>
<td>2</td>
<td>5.50</td>
</tr>
<tr>
<td></td>
<td>Regulator (Peak + Sheffield)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Global</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 3: Nash Game between authorities</td>
<td>Peak</td>
<td>4.00</td>
<td>4.00</td>
</tr>
<tr>
<td></td>
<td>Sheffield</td>
<td>5.50</td>
<td>5.50</td>
</tr>
<tr>
<td></td>
<td>Global</td>
<td></td>
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</tbody>
</table>

*Cordon charge*: per crossing

*Area charge*: per entry and circulation in area, 80% discount for residents
Observations

• Global welfare and for Sheffield highest under global regulator and lowest in Nash Game

• Welfare for Peak District highest under Nash game

• No cordon charge for Peak District under global regulator

• Area charging generates higher benefits (smaller losses) though charges partly higher (discounts to residents)

• Only inclusion of pollution leads to overall welfare benefits
Environmental Benefits

- Considerable benefits in tolled areas but overall reduction small
- Area charges slightly more effective (despite discounts to residents)
Rerouting Impacts

- Relocation of environmental burden due to **long distance rerouting**, in particular under Nash game.
Conclusions

• **Necessity for some global regulation** of charging in ‘competitive’ situation in order to
  • Avoid revenue extraction by regulators from non-local traffic
  • Avoid relocation of impacts
  • Myopic scenario could be *compromise*

• **Bias of results towards impacts on human health**
  • Valuation approaches for tranquillity + impacts on biodiversity required (concern expressed by Peak District National Park)
  • Difference between Nash (as optimum for Peak) and global could be seen as ‘opportunity cost’ / ‘mark-up’

• Cordon / area charges rather blunt instruments, but successful approach to determine ‘optimal tolls’
Outlook

• Towards first-best pricing: **Differentiated charges**, e.g. HGV
  
  “The high proportion of HGV traffic, coupled with the geography of the area often leads to long convoys of slow moving vehicles, and their associated noise and air quality impacts.”

• Policy integration: Inclusion of **other modes**

• Accuracy of calculations:
  • Improvement of **environmental models**
  • More sophisticated **assignment**

• **More players** involved to reduce relocation effects: e.g. other urban areas or highways agency
Protected Areas in Trans-Pennine Case Study Region