TAKING INTO ACCOUNT THE DYNAMICS OF DEPARTURE TIME CHOICES

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ITF: ROUNDTABLE ON SOCIAL IMPACTS OF TIME AND SPACE-BASED ROAD PRICING
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Winning or Losing from Dynamic Congestion Pricing?

• Standard textbook model of congestion
  – Road pricing raises welfare
  – But (most) users lose substantially
  – The rich gain, the poor lose

• Congestion varies over the day
  – People care when they travel & have heterogeneous preferences
  – Road pricing raises welfare much more
  – Distributional effects are very different
    • Most users gain directly (without using the toll revenues)
    • It is not users with the lowest values of time that lose most
Static flow congestion

Number of users

No road pricing

Social Optimum

Welfare gain

Consumer surplus loss

MSC

€

D

c

MSC

Consumer surplus loss
Distributional effects under static flow congestion

- 3 types of users that differ in their values of time

<table>
<thead>
<tr>
<th>VOT in NZ$/h</th>
<th>8</th>
<th>16</th>
<th>32</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel time</td>
<td>1h</td>
<td>1h</td>
<td>1h</td>
</tr>
<tr>
<td>Toll</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full price</td>
<td>8</td>
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<th>VOT in NZ$/h</th>
<th>8</th>
<th>16</th>
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<tbody>
<tr>
<td>Travel time</td>
<td>½h</td>
<td>½h</td>
<td>½h</td>
</tr>
<tr>
<td>Toll</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Full price</td>
<td>16</td>
<td>20</td>
<td>28</td>
</tr>
<tr>
<td>Change in price</td>
<td>+8</td>
<td>+4</td>
<td>-4</td>
</tr>
</tbody>
</table>

The rich gain, the poor loose
But congestion varies over the day

For the Netherlands: travel times over the day

Health pollutants, global warming & accident externalities also vary

Fig. 2.1., pp. 14
The charge should also vary over time.

Singapore: Bugis-Marina Centre (Nicoll Highway)

Figure by Robin Lindsey; data accessed on 1 May 2010, from www.onemotoring.com.sg/publish/onemotoring/en/on_the_roads/ERP_Rates.html

1S$ = 1.08NZ$
1S$ ≈ 0.62€
Bottleneck model of congestion

- Travel time delay due to queuing before a bottleneck
- People choose when to travel
- Preferences
  - Preferred time of arrival: $t^*$
  - Monetary value of a hour of travel time: $\alpha$
  - Schedule delay
    - Monetary value per hour earlier arrival than preferred: $\beta$
    - Monetary value per hour later arrival than preferred: $\gamma$

- Full price: $p = \text{travel time cost} + \text{schedule delay cost} + \text{congestion charge} + \text{fuel cost}$
Road pricing in the bottleneck model

- For now, everyone has the same preferences
- The road charge should vary continuously over time to eliminates the queuing
- Welfare gain is much larger
  - Pricing removes all queuing and this was pure waste
  - People can also choose when to travel
- Optimal road pricing does not affect the full price
  - Queuing time costs are turned into charge payments of equal value
Less time variation in the toll

• Uniform charge
  – 1 charge for the entire day
    • Blunt instrument and queuing remains
  – Full price is doubled

• Single-step charge is in between the first-best & uniform
  – Much higher welfare gain
  – Full price increases by about 50%

v.d. Berg (2012, fig 3)
Preferences vary over the population

- Heterogeneity in 2 dimensions
  - Proportional heterogeneity may stem from income differences
    - It equally scales all values of time and schedule delay
  - ‘Ratio heterogeneity’ in $\mu_i = \alpha_i / \beta_i$
    - Between value of time, $\alpha_i$, & values of schedule delay, $\beta_i$
    - Differences in how people trade off travel time & schedule delay
    - Heterogeneity in flexibility
Distribution of preferences
Overall effects

<table>
<thead>
<tr>
<th>Spread of $\mu_i = \alpha_i/\beta_i$</th>
<th>Homogeneity</th>
<th>Base case</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>–</td>
<td>2</td>
</tr>
</tbody>
</table>

| Spread of $\beta_i$                 | –           | 6         |

<table>
<thead>
<tr>
<th>No charging equilibrium</th>
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</thead>
<tbody>
<tr>
<td>Number of users</td>
<td>9000</td>
<td>9000</td>
</tr>
<tr>
<td>Welfare = Consumer surplus</td>
<td>239 332</td>
<td>239 332</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Social Optimum (first-best)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of users</td>
<td>9000</td>
<td>9054.6</td>
</tr>
<tr>
<td>Consumer surplus</td>
<td>239 332</td>
<td>242 571</td>
</tr>
<tr>
<td>Welfare</td>
<td>284 102</td>
<td>281 708</td>
</tr>
<tr>
<td>%Δ Welfare from no charging</td>
<td>18.7%</td>
<td>17.7%</td>
</tr>
<tr>
<td>% users with decrease in full price</td>
<td>p unchanged</td>
<td>55%</td>
</tr>
</tbody>
</table>

v.d. Berg & Verhoef (2011, Table 1)
ΔP: Full price change due to road pricing

**ΔP**: Full price change due to road pricing

**β**: Value of schedule delay

**α**: Value of time

v.d. Berg & Verhoef (2011, Fig. 7)
Other dynamic equilibrium models

• Chu (1994, 1999)
  – Congestion works as in the static model
  – But people do choose when to travel

• Hydro-dynamic (Mun, 1999, 2003)
  – Flow congestion and queuing

• Optimal charge
  – Should vary over time and equal the MEC[t]
  – Attains a higher welfare gain than in the static model
  – Hurts users, but less than in the static model

• Uniform toll is higher on average, hurts users more and has a lower welfare gain
Concluding

• Standard textbook model of congestion
• Congestion varies over the day
• A dynamic model of congestion
  – People care when the travel and have heterogeneous values for travel time and arrival moment
  – Road pricing is much more beneficial
  – It is vital that the toll also varies over time
  – Distributional effects differ from with static congestion
    • Most users gain directly, even before the revenue is used
    • It is not the users with the lowest values of time and schedule delay that lose most
Thanks

- Questions and discussion


