Workshop on Financing, Regulation and Performance of the European Rail sector

Pricing and investment in transport infrastructures

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Introduction

• **Prices** affect demand and, thus, must be taken into account when evaluating transport infrastructure investments.

• Certain charging schemes **may favor certain transport modes** and influence the transport network configuration, leading to log-term equilibria that may not be optimal under other charging schemes.

• In this paper, we consider two charging schemes commonly used in real world: charging according to **short-run marginal cost or** charging to cover **long-run marginal costs**.

• Sometimes, different charging schemes are used in different transport modes, which affects intermodal competition and the comparison between different transport investment alternatives.

• In this paper we highlight **the importance of the charging scheme when deciding optimal transport infrastructures.**
The model

- Consider an economy composed of an **oligopolistic transport sector** and a competitive (*numeraire*) sector summarizing the rest of the economy.

- The transport sector contains two transport modes: **air transport** (two airlines producing $q_1$ and $q_2$) and **rail transport** (one rail operator producing $q_t$).

- The regulator must decide **the kind of transport infrastructure** to be constructed in order to connect two regions $A$ and $B$. 
The model

Alternative 1:  
Region A  $\xrightarrow{\text{}}$  Region B

Alternative 2:  
Region A  $\xrightarrow{\text{}}$  Region B

Alternative 3:  
Region A  $\xrightarrow{\text{}}$  Region B
The model

• In route AB, there exist \textit{N identical consumers} with preferences on the transport sector and the \textit{numeraire} good given by:

\[ V(q_1, q_2, q_t, m) = U(q_1, q_2, q_t) + m \]

Given these preferences there are \textbf{no income effects on the transport sector} and we can perform \textbf{partial equilibrium analysis}. 
The model

- In the transport sector, we assume that the representative consumer has the following preferences:

\[ U(q_1, q_2, q_t) = u_a q_1 + u_a q_2 + u_t q_t - \frac{1}{2} (q_1^2 + q_2^2 + q_t^2 + 2\gamma q_1 q_2 + 2\delta q_1 q_t + 2\delta q_2 q_t), \]

where:

- \( u_a \) and \( u_t \) measure consumer preferences for each transport mode,
- \( \gamma \in [0,1) \) represents the degree of product differentiation between airlines,
- \( \delta \in [0,1) \) represents the degree of product differentiation between air and rail transport.
The model

Let us denote by:

\( \mu_a \): Access price for airports.
\( \mu_t \): Access price for the rail infrastructure.

\( c_a \) and \( c_t \): Marginal operating costs for airlines and the rail operator.
\( C_a \) and \( C_t \): Marginal operating and maintenance cost of transport infrastructures.

\( r \): opportunity cost of public funds.
\( K_a \) and \( K_t \): construction cost of transport infrastructures.
The model

The timing of the game is:

1. The regulator decides **the charging scheme** for the use of transport infrastructures. Given the charging scheme, the regulator decides the kind of **transport infrastructure to be constructed** in order to connect regions A and B.
2. Given the charging scheme and the transport infrastructures that have been constructed, transport operators decide the **ticket price** to be charged to final consumers.
3. Given ticket prices, **consumers demand trips** in those transport modes for which transport infrastructures were constructed.

The game is solved by **backward induction**.
Stage 3: representative consumer demand

Given the charging scheme, the transport infrastructures that have been constructed and the ticket price, the representative consumer demands the number of trips that maximizes his utility:

$$\max_{q_1, q_2, q_t} U(q_1, q_2, q_t) - (p_1 + t_a)q_1 - (p_2 + t_a)q_2 - (p_t + t_t)q_t,$$

where $p_i$ is the ticket price; $t_a$ and $t_t$ denote all costs associated with the specific transport mode except the ticket price.

**SOLUTION:** Linear demand functions (for each possible alternative).
Stage 2: Optimal ticket prices

- Given the charging scheme and the transport infrastructures that have been constructed, and anticipating the representative consumer demand, \textbf{transport operators decide the ticket price} to be charged to final consumers in order to maximize their profits:

\[
Max \quad \pi_i = (p_i - c_a - \mu_a) q_i
\]

\[
Max \quad \pi_t = (p_t - c_t - \mu_t) q_t
\]

\textbf{SOLUTION: Optimal ticket prices} (for each possible alternative)
Stage 1: optimal transport infrastructures

Given the charging scheme, and anticipating operators’ and consumers’ behavior, the regulator must decide the kind of transport infrastructures to be constructed in order to connect regions A and B:

Alternative 0: To construct no transport infrastructure today and wait till the demand increases.

Alternative 1: To construct just the air transport infrastructure.

Alternative 2: To construct just the rail infrastructure.

Alternative 3: To construct both the air and rail infrastructures.
Charging schemes

We suppose two charging schemes commonly used in real world:

Charging according to short-run marginal cost:

\[ \mu_a = C_a \]
\[ \mu_t = C_t. \]

Charging to cover long-run marginal costs:

\[ \mu_a = C_a + A \]
\[ \mu_t = C_t + T. \]
Optimal transport infrastructures

In order to decide the optimal transport infrastructures, the regulator should compare the social welfare associated with each alternative.

Social Welfare is defined as: consumers surplus + transport operators profits + transport infrastructure owner profits − opportunity cost of public funds.

\[
SW_{t+a} = N[U(q_1, q_2, q_t) - (p_1 + t_a)q_1 - (p_2 + t_a)q_2 - (p_t + t_t)q_t + \pi_1 + \pi_2 + \pi_t + (\mu_a - C_a)(q_1 + q_2) + (\mu_t - C_t)q_t] - rK_a - rK_t. 
\]

When comparing alternatives we do not consider the environmental impact.
Optimal transport infrastructures

![Diagram of transport infrastructures with alternatives labeled 0, 1, 2, and 3, and SW0, SW1, SWo lines.](image-url)
Optimal transport infrastructures
Optimal transport infrastructures

The choice of the optimal transport infrastructure depends on:

- The number of consumers, $N$.

- Construction costs and opportunity cost of public funds.

- The slope of the social welfare function associated with each alternative, which depends on:
  - consumers preferences, marginal operating and maintenance costs, and the charging scheme.

The charging scheme is the only one under the regulator’s control.
Optimal transport infrastructures
Empirical illustration: the Spanish case

• Application to a 600 km. length route (for example, Madrid-Barcelona route).

• Two transport modes: air transport and high speed rail.

• Real value to the parameters according to real data.

• This example does not substitute cost-benefit analysis. It just illustrates how the model provides intuitions about optimal transport infrastructure investment.
Empirical illustration: The Spanish case

Table 1. Minimum number of trips depending on the charging scheme

<table>
<thead>
<tr>
<th>Charging according to SHORT-RUN marginal costs</th>
<th>Alternative 1: Only air</th>
<th>Alternative 2: Only HSR</th>
<th>Alternative 3: air + HSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum number of trips:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air: 1,558,407</td>
<td></td>
<td></td>
<td>Minimum number of trips:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Air: 16,964,926</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HSR: 14,949,419</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total: 31,914,345</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Charging scheme to cover LONG-RUN marginal costs</th>
<th>Alternative 1: Only air</th>
<th>Alternative 2: Only HSR</th>
<th>Alternative 3: air + HSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum number of trips:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air: 1,538,500</td>
<td></td>
<td></td>
<td>Minimum number of trips:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Air: 34,854,9149</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>HSR: 12,182,311</td>
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<td></td>
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<td>Total: 47,036,460</td>
</tr>
</tbody>
</table>
Conclusions

• **Pricing and investment** decisions are not independent.

• **Before deciding whether or not to construct** a transport infrastructure we need to know the charging scheme.

• This is not what some countries do (Spain).

• In **Spain**, according to the level of demand, to construct **just the air transport infrastructure** would have been the optimal decision (**even with a short-run marginal cost charging scheme!!!**).

• **Once the infrastructure has been constructed, it should be used** (if at least variable costs are covered) but we should not continue constructing new routes. We should wait till the demand is sufficiently high.
Conclusions

• **Other issues** to be taken into account:

- Once you have connected two regions with airports you only need one more airport to connect a third region (half of the previous investment). By rail, the cost of connecting the third region is almost the same...

- The cost of constructing airports varies with demand but the cost of constructing the rail infrastructure is less flexible.

- Airports are multiproduct: domestic and international flights...

All these issues should be taken into account when deciding **the optimal transport infrastructures to be constructed** in order to connect two regions.