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.**

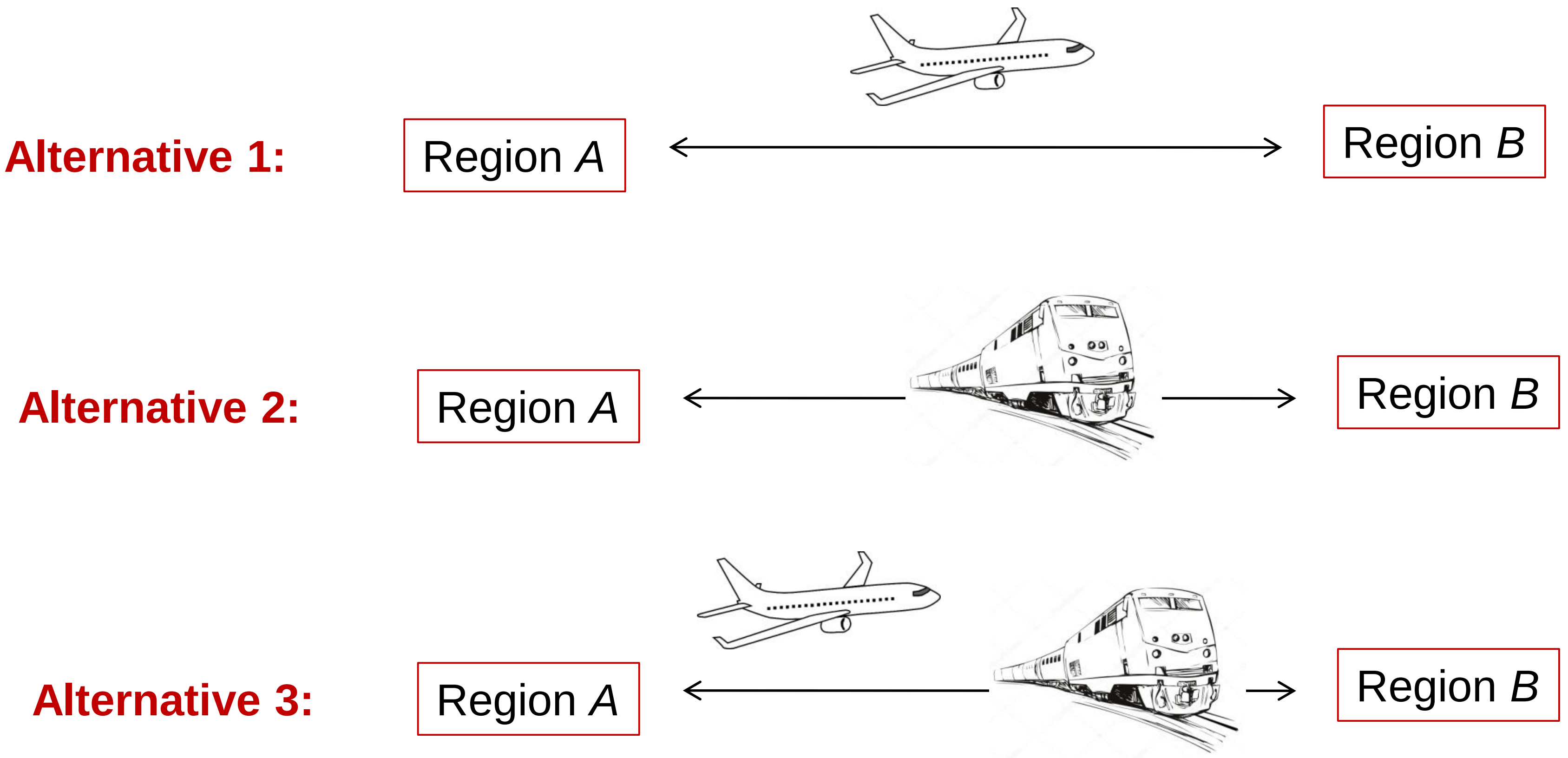
The model

- 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
Region B
Alternative 2:
Region A
Region B
Alternative 3:
Region A
Region B

The model

- In route AB, there exist ***N identical consumers*** with preferences on the transport sector and the *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 **no income effects on the transport sector** and we can perform **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:

μ_a: Access price for airports.
μ_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:

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

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, **transport operators decide the ticket price** to be charged to final consumers in order to maximize their profits:

$$\underset{p_i}{Max}\ \pi_{\mathrm{i}} = (p_i - c_a - \mu_a)q_i$$

$$\underset{p_t}{Max}\ \pi_{\mathrm{t}} = (p_t - c_t - \mu_t)q_t$$

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

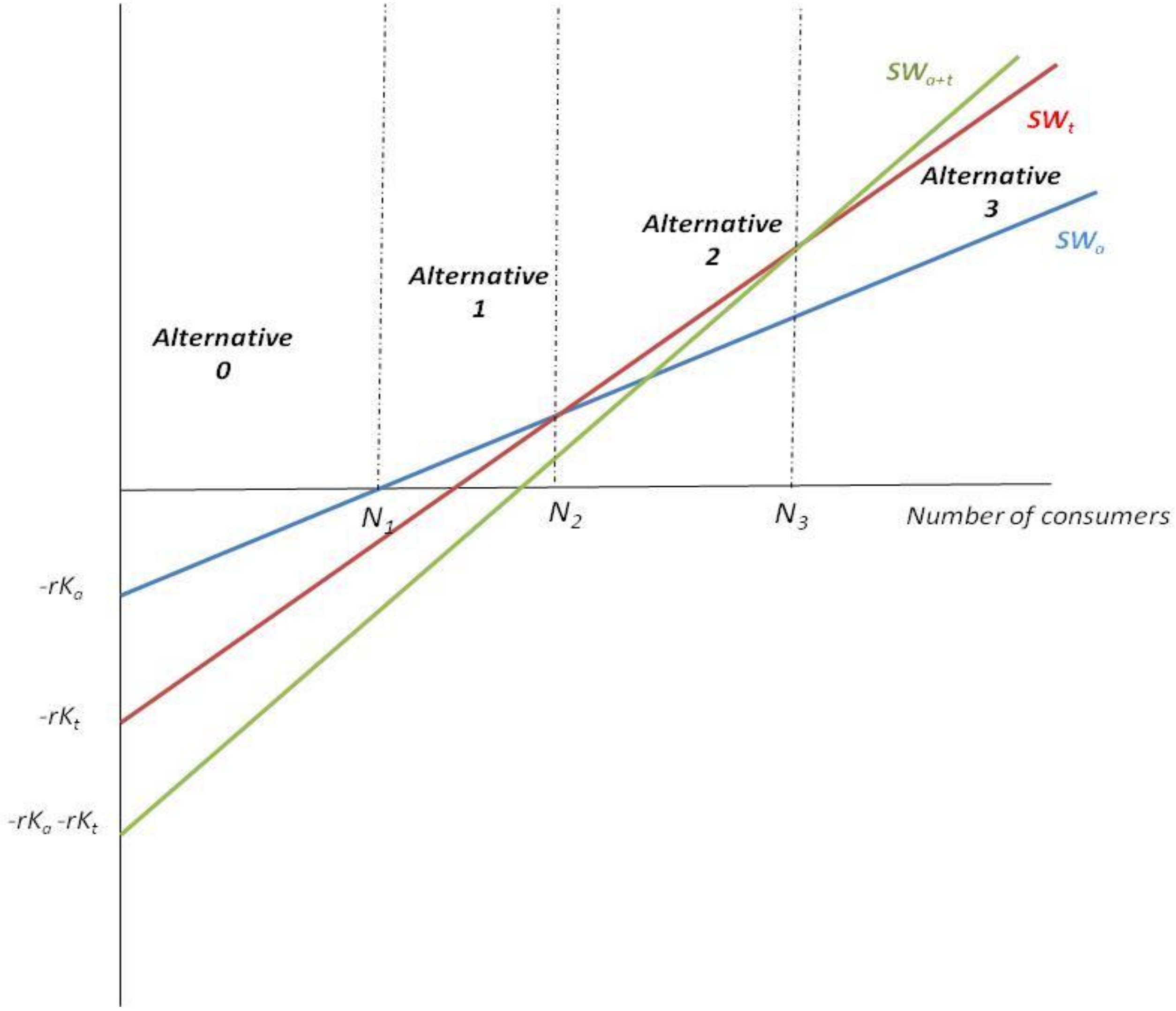
In order to decide the optimal transport infrastructures, the regulator should **compare the social welfare associated with each alternative**.

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

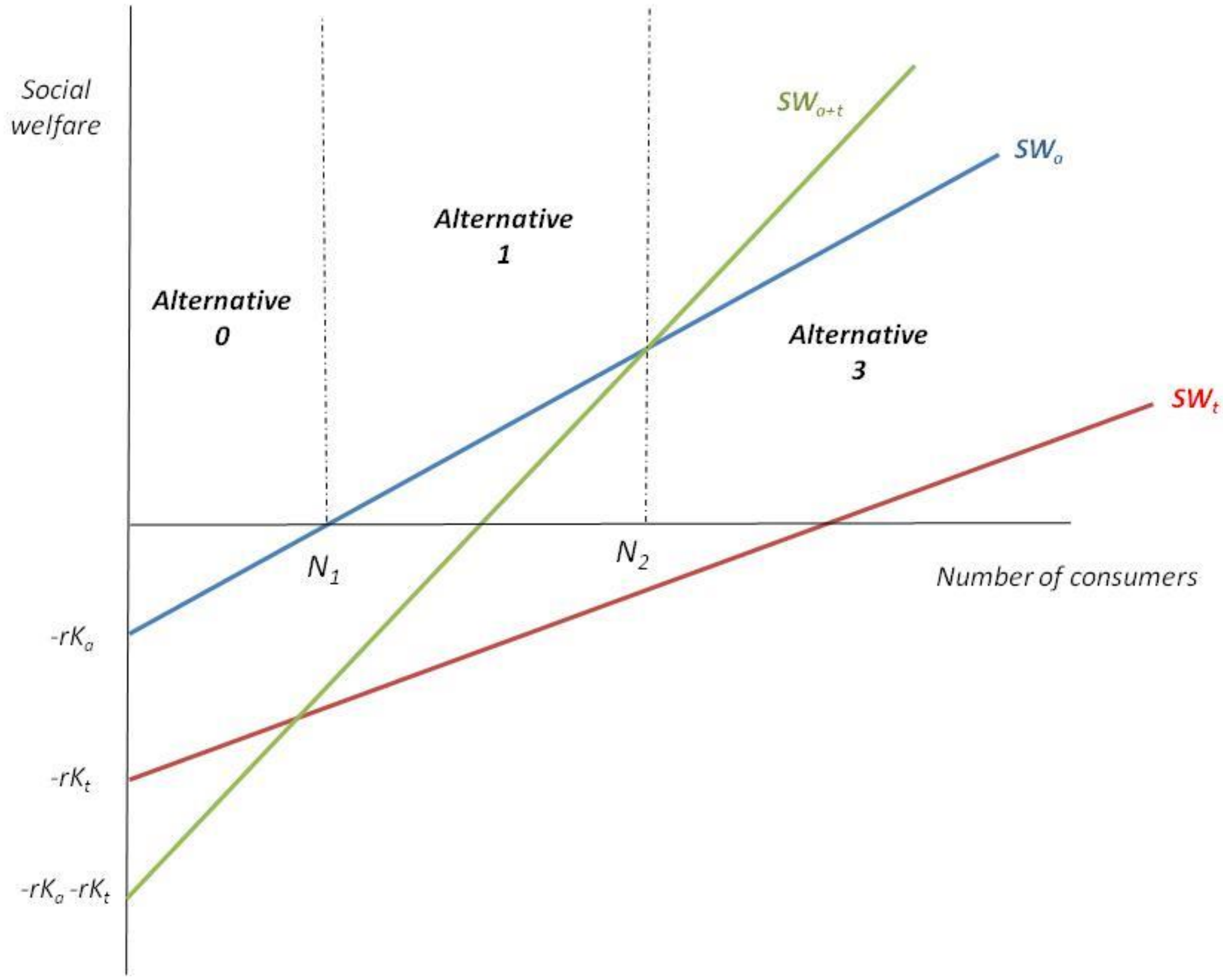
$$SW_{t+a} = N[U(q_1, q_2, q_t) - (p_1 + t_a)q_1 - (p_2 + t_a)q_2 - (p_t + t_t)q_t + \pi_1 + \pi_2 + \pi_t$$
$$+ (\mu_a - C_a)(q_1 + q_2) + (\mu_t - C_t)q_t] - rK_a - rK_t.$$

When comparing alternatives **we do not consider the environmental impact**.

Optimal transport infrastructures



Optimal transport infrastructures



Optimal transport infrastructures

The choice of the optimal transport infrastructure depends on:

-The **number of consumers,** *N*.

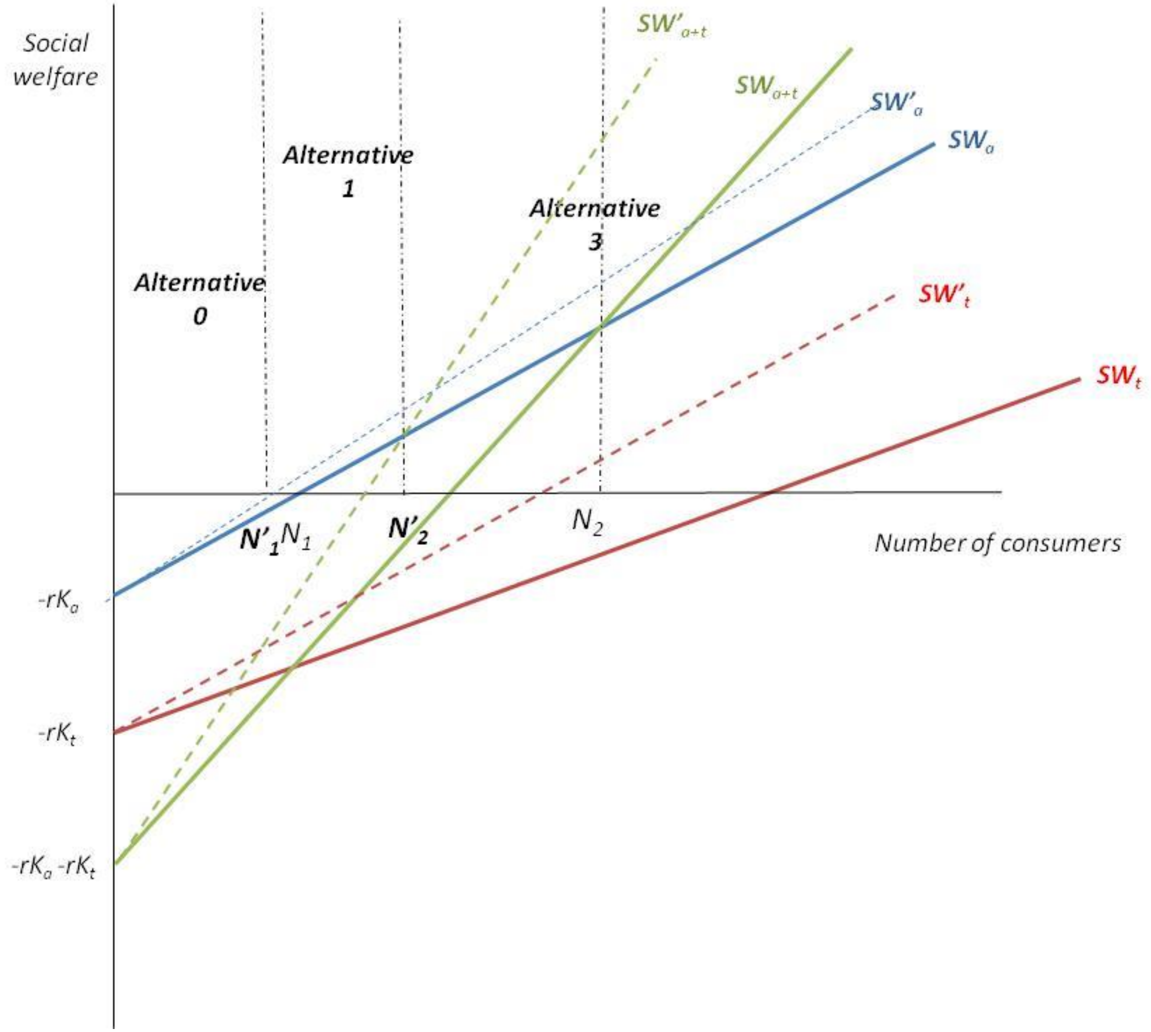
- **Construction costs and opportunity cost of public funds**.

- 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

	Alternative 1: Only air	Alternative 2: Only HSR	Alternative 3: air + HSR
Charging according to SHORT-RUN marginal costs	**Minimum number of trips:** **Air: 1,558,407**	-	**Minimum number of trips:** Air: 16,964,926 HSR: 14,949,419 **Total: 31,914,345**
Charging scheme to cover LONG-RUN marginal costs	**Minimum number of trips:** **Air: 1,538,500**	-	**Minimum number of trips:** Air: 34,854,9149 HSR: 12,182,311 **Total: 47,036,460**

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.