

Strategic Choice of Financing Systems in Regulated and Interconnected Industries*

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Abstract

The growing importance of inter-network exchanges in infrastructure-based utilities influences regulatory choices and access pricing for downstream services using the infrastructures. We analyze this problem in a setting where the infrastructure managers of two bordering countries are in charge of pricing the access to their networks. The infrastructures are used by downstream firms to provide international services that link the two countries. Network costs can be financed either through a subsidy or solely through user charges.

We first characterize the strategic interaction between infrastructure managers and show that it is affected by the regulatory modes adopted in the two countries. Then, we determine the equilibrium non-cooperative choice of a financing system. As opposed to the perfect cooperation benchmark, in which subsidizing the infrastructures is socially desirable, the commitment to strict budget-balance in both countries becomes socially preferable since this alleviates the externalities generated by non-coordination between access pricing decisions.

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1 Introduction

During the last two decades, a major wave of deregulation has profoundly altered the organization of network industries. Regulatory oversight has been almost entirely removed from sectors with no significant returns to scale, while allowing competition and facilitating entry has become a major priority. However, infrastructure networks, characterized by non-negligible returns to scale and large fixed costs, are essential facilities and remain the subject of significant regulatory intervention.

Starting more recently, globalization is leading to an ever-growing number of international transactions. This is particularly true for telecommunications, and should also become the case for the electricity and railway industries in a near future. For the latter, this trend is reinforced by the strong political will to develop international freight transportation in order to reinforce the cohesion of the European Union. However, the implementation of liberalization reforms has followed different paths in the various countries, reflecting the networks' heterogeneous nature as well as significant differences in pre-existing market structures. In view of these differences, particular attention should be devoted to infrastructure access pricing for international services. EC Directive 14/2001 illustrates the issues at stake and upholds that dissimilar objectives of the infrastructure managers and consequently varying charging systems require coordination on the side of the infrastructure managers in order to avoid heavy impacts on service efficiency and market share.

The aim of this paper is to study the interaction between infrastructure managers in charge of pricing the access to their networks, which are exploited by downstream firms to provide services¹. Our stylized model considers two national railway networks which are linked by international services. Infrastructure managers maximize national welfare while financing their network costs.

The question we ask is the following: Does the interaction between infrastructure managers' access pricing decisions affect their choice of a regulatory mode?

We draw a basic distinction between regulatory modes according to the type of cost recovery principle adopted. In fact, the fraction of network costs which is not covered by access revenues could be funded through taxes levied on the economy as a whole: we name this kind of approach 'taxpayer-pay' financing system. Alternatively, access charges imposed on downstream users could be meant to recover total infrastructure costs: we call this approach 'user-pay' financing system. The difference is that under the taxpayer-pay financing system the cost of the infrastructure deficit is evaluated at the shadow cost of public funds, whereas under a user-pay financing system it is evaluated at the shadow cost of the budget constraint.

Note that access pricing schemes vary widely across European countries with respect to the level of infrastructure costs' coverage by users². For instance, the

¹Although our model refers directly to the railway industry, which is vertically separated, it could easily allow for vertical integration

²See NERA (1998).

French charging system has enabled RFF to cover about 25% of its total cost, while the percentage is 40% for SCHIG in Austria. On the other hand, the access pricing system implemented by NETZ in Germany has been set with the aim of recovering all costs, excluding those related to new or enhanced infrastructure. Therefore, the role played by network access pricing can be markedly dissimilar depending on the objective of the infrastructure manager or, more generally, on the choice of the mode of regulation.

If the infrastructure managers were perfectly cooperating, optimal access prices would obey standard Ramsey-Boiteux formulas. Moreover, the taxpayer-pay system would be socially preferred since it provides an additional regulation instrument (the subsidy).

However, in an open economy with non-cooperative countries, and in the tradition of the second-best literature, we show that the adoption of the user-pay system in both countries is socially desirable since it softens the distortions due to non-coordination between the two countries.

Taking the cooperative case as a benchmark, we analyze the choice of a financing system by two infrastructure managers acting independently. In particular, we study the equilibria of a two-stage non-cooperative complete information game where the infrastructure managers choose a financing system at the first stage, and then fix their respective access charges.

We start by discussing how access prices are set. Our results are driven by two basic effects. First, each infrastructure manager will only internalize the fraction of social surplus that accrues to his own consumers: this is the *constituency effect*. Second, the ‘perceived’ cost of the international service for each infrastructure manager differs from the total infrastructure cost because he is concerned with the financial viability of his network only: this is the *double marginalization effect*. Under the taxpayer-pay financing system, these two effects unambiguously lead to socially excessive access prices; under the user-pay system, care must be exerted to account for a third effect, namely the impact of non-cooperation on the endogenous shadow cost of infrastructure financing.

Proceeding back to the first stage, we analyze the strategic choice of a financing system. A country’s decision to adopt a particular system has two, sometimes countervailing, effects. First, the resulting access charge affects welfare in this country. The magnitude of this direct effect depends on the relative level of the shadow cost of public funds with respect to the endogenous Lagrange multiplier associated to the budget constraint under a user-pay system.

Second, the choice of a financing system in a country triggers a modification of the access charge set in the neighbouring one. This change, in turn, affects welfare in the first country through two channels: it changes the level of demand for international services and therefore the net consumers’ surplus; but it also modifies the access revenue and, consequently, the endogenous shadow cost of infrastructure financing under the user-pay system. This indirect effect strictly depends on the

type of strategic interaction between infrastructure managers.

When one country finances its infrastructure deficit with a subsidy, the access prices (from the perspective of the other country) can be either strategic complements or substitutes, depending on characteristics of the international demand; this comes naturally as regards the IO literature³. However, when one country chooses the user-pay system, we show that access prices become always strategic complements. Hence, the externalities created through the strict budget balance conditions imply that the commitment not to subsidize the infrastructure deficit in one country modifies substantially the nature of the strategic interaction.

The decision whether to implement a particular regulatory mode depends on how the direct and the strategic effects combine in equilibrium.

When country j has decided to subsidize its infrastructure, country i 's best response depends on the nature and intensity of the strategic interaction. Three cases have to be envisioned.

With strategic substitutability, the increase in the access charge due to the adoption of the user-pay system triggers a reduction in the access price set by country j . Thus, country i foresees the opportunity to free-ride on country j to reduce the amount of socially costly subsidy paid under the taxpayer-pay system. The final outcome depends on the relative magnitude of the conflicting direct and strategic effects.

Under strategic complementarity, the best response varies depending on the 'intensity' of complementarity itself. When access prices are strong complements, a deviation to the user-pay system is attractive and leads to *lower* access charges in both countries. Intuitively, a reduction of the access price in country i triggers a strong reduction of the access price in country j and offsets the loss of access revenue in the former country through the resulting demand increase. This is not the case when access prices are weak strategic complements: therefore, the adoption of the user-pay system is no longer profitable.

When country j has chosen the user-pay system, access prices are always strong strategic complements and country i will adopt the user-pay system.

Thus, it should not come as a surprise that total welfare is at its highest when both countries adopt the user-pay system: access prices become strong strategic complements and are consequently lower. Total, and individual, welfare is then unambiguously improved.

The issue is then to determine whether non-cooperative infrastructure managers will succeed in reaching the socially optimal choice. The adoption of the user-pay system by both countries is always an equilibrium of the game; unfortunately, this equilibrium is not unique. Taxpayer-pay in both countries can also be an equilibrium: this is the case, for example, when access prices are strategic substitutes and the infrastructure deficit in both countries is large.

³See Tirole (1988) for instance.

Therefore, we stress the potential role for a supra-national authority in coordinating the implementation of a usage-based access pricing scheme across countries. It is noticeable that, over the variety of situations studied in the paper, this is the only coordination problem that emerges. The intervention of a supra-national authority, say the European Commission for instance, should simply consist in preventing any free-riding incentive in the simultaneous transition from a taxpayer-pay system to a user-pay system in both countries.

Indeed, we can compare our model with a framework without any interaction, i.e. where services are purely internal to each country. In this case, each country has an incentive to adopt the taxpayer-pay system and such choice is socially optimal. We also argue that one could take those two polar cases (purely international or purely domestic services) to understand the transition process as international services grow in importance with respect to the domestic ones.

Our paper borrows from distinct economic literatures. First, we use the work on regulation under a budget constraint, pioneered by Boiteux (1956) and Ramsey (1927) in a different context. We also refer to the literature on access pricing and interconnection, which has especially developed as regards the telecommunications sector. Chang (1996) studies the problem of pricing access in a vertically separated industry but does not consider the issue of interconnection. Armstrong (2001) analyzes two-way interconnection between telecommunications networks providing international calling services to captive consumers. Although similar in some respects, our work differs since our focus concerns more the choice of the mode of regulation.

Due to its emphasis on the coordination issues between infrastructure managers, our model also borrows from the insights obtained by the strategic trade literature, initiated by Brander and Spencer (1985). The impact of non-cooperation between policy-makers setting access prices can be viewed as a tax competition game (see e.g. Wilson (1999)); in our model, the fiscal revenue may be derived from two types of taxation and serves to finance a public infrastructure. The main feature that distinguishes our paper from these literatures consists first in the externalities between governments created by the interdependency between budget constraints and, second, in our focus on the choice of the financing system when governments compete.

The outline of the paper is as follows. In section 2 we describe the model and present the Ramsey-Boiteux benchmark. In section 3 we introduce the two-stage non cooperative game, analyzing first the setting of access charges and then the choice of a financing system; we also discuss some possible extensions. Section 4 concludes.

2 The model

We consider two countries denoted by $i = 1, 2$. In country i an infrastructure manager (IM_i) sets access charges, while downstream firms use the network to provide transport services to final consumers. Information is complete, both for the infrastructure manager and the downstream firms in a given country and across countries.

The final demand Let q_* be the international demand for transport services⁴ (with $q'_* \leq 0$) and $S_*(q_*)$ the associated net total consumers' surplus, that is, the net consumers' surplus of *both* countries when quantity $q_*(p_*)$ of international services is consumed at price p_* . We then have $\frac{dS_*}{dp_*} = -q_*$ and we assume that country i only internalizes a part $\theta_i \in (0, 1)$ of this surplus. In other words, q_* is the total level of round-trip demand for transport (for example, from Paris to Brussels and back to Paris), and θ_i is the fraction of consumers of country i that originates this demand. Then $\theta_1 + \theta_2 = 1$ and the surplus from international services accruing to country i amounts to $\theta_i S_*(q_*)$.⁵

The infrastructure managers and the modes of regulation Each infrastructure manager maximizes the welfare of his country, which is composed of three terms: the net consumers' surplus, the infrastructure deficit and the fraction of the downstream firms' profits that benefits this country (through, say, shares in these firms held by citizens of that country).

To simplify the exposition, we assume that international services travel in each country half of the total number of kilometers⁶. In the absence of subsidies, the profit of the infrastructure in country i is given by

$$\pi_i^{infra} \equiv (a_{*i} - c_u)q_* - k_i, \quad (1)$$

where a_{*i} is the access charge for a unit of international transport, while c_u is the (constant) marginal cost of the infrastructure in both countries and k_i is the fixed cost of the network.

⁴Demand is defined in terms of passengers-km, the standard unit in the railroad industry.

⁵Other interpretations could easily be thought of. For example, let θ_{ij}^i be the fraction of consumers having a demand for transport from i to j that belongs to country i and q_{ij}^i the related demand. For $i, j = 1, 2$ and $i \neq j$, we have that $\theta_{ij}^i + \theta_{ij}^j = 1$, while $q_{ij} = q_{ij}^i + q_{ij}^j$ is the total demand for international transport from country i to country j . Thus, we are able to define the (net) surplus $S_{ij}(q_{ij})$ related to the demand for international transport. Under the assumption of an isotropic travel pattern ($q_{ij} = q_{ji}$) and with equal prices, we have $S_{ij}(q_{ij}) = S_{ji}(q_{ji})$ and the surplus of consumers in country i related to international transport can be written as $\theta_{ij}^i S_{ij}(q_{ij}) + \theta_{ji}^i S_{ji}(q_{ji}) = \theta_i S_*(q_*)$, where $\theta_i = \theta_{ij}^i + \theta_{ji}^i$ and $q_{ij} = q_{ji} = q_*$.

⁶This entails no loss of generality with respect to the general case where the international traffic travels, say, in country 1 for a fraction α of the total kilometers and in country 2 for a fraction $1 - \alpha$.

We now discuss an important institutional feature, namely the possibility to use a subsidy to finance infrastructure costs. In what follows, we shall consider two possible financing systems:

- Under the ‘user-pay’ system, the infrastructure manager cannot directly subsidize the infrastructure, and access pricing alone must ensure the coverage of total (fixed and variable) costs. This case is labeled with a superscript ‘ u ’.
- In contrast, under the ‘taxpayer-pay’ system the infrastructure manager is allowed to finance the infrastructure through taxes levied on the rest of the economy. This case is labeled with a superscript ‘ t ’. Taxation is imperfect and has distortionary effects on the rest of the economy. In our partial equilibrium approach, we denote by λ_{pf} the shadow cost of public funds which captures this effect⁷, and we assume that λ_{pf} is the same in both countries.⁸

Throughout the paper, we will assume that downstream firms behave competitively. We will come back later on this assumption. Given the objective of the EU to promote competition in the railway industry, this assumption might be a first approximation of the competitive forces that should appear in a near future.

Let c_d be the constant marginal cost for downstream firms.⁹ Since we consider round-trip travel demand, the resulting price for international transport services will be given by $p_* = a_{*1} + a_{*2} + c_d$.

With downstream competitive behavior, transport firms raise no profit and the infrastructure budget constraint coincides with the industry budget constraint. The program of the infrastructure manager in country i will be

$$(\mathcal{P}_{IM_i}^u) : \max_{a_{*i}} \left\{ \theta_i S_*(q_*) + \pi_i^{infra} \right\} \text{ s.t. } \pi_i^{infra} \geq 0$$

under a user-pay system, and

$$(\mathcal{P}_{IM_i}^t) : \max_{\{t_i, a_{*i}\}} \left\{ \theta_i S_*(q_*) - (1 + \lambda_{pf})t_i + t_i + \pi_i^{infra} \right\} \text{ s.t. } t_i + \pi_i^{infra} \geq 0$$

under a taxpayer-pay system, where t_i is the subsidy provided to the infrastructure in country i .

⁷Laffont and Tirole (1993) endogenize this shadow cost of public funds in a general equilibrium framework.

⁸That the costs of public funds are equal across countries means that fiscal systems have been harmonized, which might be an appropriate assumption in an integrated area such the EU. Also, this assumption simplifies the comparison between the cases of cooperative and non-cooperative infrastructure managers. Indeed, if this assumption were not satisfied, cooperative infrastructure managers would only tax the country with the smallest cost of public funds in order to minimize the distortionary effects of taxation.

⁹We implicitly assume that the cost of the downstream firms does not depend on travel length. Our setting could be extended to incorporate such considerations.

Social optimum As a preliminary to the forthcoming analysis, we consider the benchmark case where the infrastructure managers perfectly cooperate. We first assume that the unique infrastructure manager adopts a taxpayer-pay financing system. The optimal access charge must therefore solve the following program

$$\max_{\{t, a_*\}} \left\{ S_*(q_*) - (1 + \lambda_{pf})t + t + \pi_1^{infra} + \pi_2^{infra} \right\} \text{ s.t. } t + \pi_1^{infra} + \pi_2^{infra} \geq 0,$$

where a_* is the unique access charge imposed on the international service. The necessary first-order condition to be satisfied in an interior solution yields the standard Ramsey formula

$$\frac{p_* - c_*}{p_*} = \frac{\lambda_{pf}}{1 + \lambda_{pf}} \frac{1}{\eta_*}, \quad (2)$$

where $c_* = c_d + 2c_u$ is the social marginal cost of the international service and $\eta_* = -\frac{p_*}{q_*} q'_*$ denotes the price elasticity of the demand for international services.

The second-order condition can be rewritten as follows

$$\delta_* \equiv \frac{q_* q''_* - q'^2_*}{q'^2_*} < \frac{1 + \lambda_{pf}}{\lambda_{pf}} \quad (SOC)$$

and is assumed to be satisfied in equilibrium.¹⁰ Parameter δ_* will play an important role in the sequel, in particular in the determination of the infrastructure managers' incentive to adopt a particular financing system. From now on, we assume that δ_* is constant.¹¹

If the (unique) infrastructure manager adopts the user-pay financing system, then denoting by $\tilde{\lambda}$ the shadow cost of the budget constraint, the optimal access charge is given by (2) in which λ_{pf} is replaced by $\tilde{\lambda}$.

Before analyzing the incentives to choose a particular regulatory mode when infrastructure managers do not cooperate, let us start with the following proposition.

Proposition 0 *Consider the perfect cooperation situation. From the point of view of total welfare, the taxpayer-pay financing system is Pareto-superior to the user-pay financing system.*

Proposition 0 offers a clear benchmark: if the infrastructure managers were perfectly cooperating, then they would adopt the taxpayer-pay financing system. Indeed, in that case, from the point view of *total* welfare, the taxpayer-pay system always Pareto-dominates the user-pay system since it provides the unique regulatory institution with an additional instrument, the subsidy.

¹⁰Similar conditions have to be imposed when cooperative infrastructure managers adopt the user-pay system or when they do not cooperate and choose independently their financing system. For conciseness, we shall not repeat those conditions as we study the different cases.

¹¹For instance, $\delta_* = 0$ (respectively -1 , $1/\eta_*$) when the international demand is exponential (respectively linear, iso-elastic).

However, with non-cooperation, international services create externalities between the two countries. These externalities translate into distortions in access pricing decisions, which build up strategic incentives to choose one regulatory mode or the other. These strategic incentives may sometimes lead the infrastructure managers to a socially sub-optimal situation; but they may also change the socially preferred mode of regulation with respect to the perfect cooperation setting.

Let us finally mention that, as noted in Laffont and Tirole (2000) in more general environments, the taxpayer-pay financing system might come with its own inefficiencies: first, it does not prevent an infrastructure manager to undertake an undesirable activity (which is financed through taxes on the whole economy); second, it dilutes the incentives of consumers of the final services to act as ‘watchdogs’, that is, to monitor the infrastructure manager’s behavior. Since they are orthogonal to our primary focus, we do not consider such incentive issues from the side of the infrastructure managers.

3 Strategic choice of a financing system

Let us now consider the situation in which the infrastructure managers act independently. To focus on the infrastructure managers’ incentives to use strategically a financing system, we study the following two-stage game:¹²

1. The infrastructure managers independently choose a financing system (taxpayer-pay or user-pay).
2. The infrastructure managers non-cooperatively set the access charge in their countries.

Consequently, there are four possible outcomes for the first-stage game: taxpayer-pay in both countries (denoted by ‘*tt*’), user-pay in both countries (‘*uu*’), and taxpayer-pay in one country and user-pay in the other (‘*tu*’ or ‘*ut*’).

3.1 The access prices setting stage

Let us assume that country j has adopted the taxpayer-pay system. Solving $(\mathcal{P}_{IM_j}^t)$ yields¹³

$$\frac{a_{*j} - c_u}{p_*} = \frac{1 + \lambda_{pf} - \theta_j}{1 + \lambda_{pf}} \frac{1}{\eta_*}. \quad (3)$$

¹²Let us highlight that we could think of the following more general game: the political principal of IM_i chooses first the maximal level of subsidy T_i that could be used to finance the infrastructure deficit; then, the infrastructure manager decides the access price and the level of subsidy $t_i \leq T_i$. Our simplified game focusses on the polar cases $T_i = 0$ and $T_i = +\infty$. Considering the general game introduces additional difficulties and is left for future research.

¹³We will always assume that parameters are such that we obtain interior solutions.

Since $\theta_j < 1$, IM_j does not fully internalize the effect of his decision on total net consumers' surplus. The international access charge in country j will thus be excessive: this is the *constituency effect*.

Assume now that country i has also adopted the taxpayer-pay system. The optimal access price in this country is then given by changing indices in (3). Summing these conditions in both countries, we get

$$\frac{p_* - c_*}{p_*} = \frac{2(1 + \lambda_{pf}) - (\theta_i + \theta_j)}{1 + \lambda_{pf}} \frac{1}{\eta_*}.$$

Therefore, even in the (thoroughly hypothetical) case where each infrastructure manager perfectly internalizes the total surplus associated to the international service (i.e., $\theta_i = \theta_j = 1$), the equilibrium price will be excessive. This comes from the externality created by imposing the budget balance condition: the infrastructure (variable) cost of the international service perceived in country i is half of the social infrastructure cost of that service. This is the *double marginalization effect*.

Assume now that both countries decide to finance infrastructure costs solely through the revenue generated by access pricing. While under a taxpayer-pay system the fictitious cost of the budget constraint is the exogenous shadow cost of public funds, under a user-pay financing system this fictitious cost becomes endogenous. Thus, its value depends on the equilibrium configuration and is influenced by the distortions affecting the international service.

3.2 The direct and the strategic effects

When determining the financing system to be implemented in his country at the first stage, an infrastructure manager will have to deal with two, sometimes conflicting, forces.

Consider that IM_i deviates, say, from the taxpayer-pay financing system to the user-pay system. For a fixed access price in country j , the access price in country i will have to change in order to satisfy the strict budget constraint: this has a direct effect on welfare in this country. The magnitude of this effect depends on the comparison between the exogenous shadow cost of public funds and the endogenous Lagrange multiplier associated to the budget constraint under a user-pay system.

Since access prices are interdependent (through the international demand), the change in the access price in country i also triggers a change in the access price set by IM_j . Such a modification also affects welfare in country i : this is the strategic effect.

We now illustrate the following point: from the viewpoint of country i , the strategic interaction between the infrastructure managers depends on the mode of regulation chosen in the other country.

Consider that IM_j adopts the taxpayer-pay system and denote by $a_{*j}(a_{*i})$ the second-stage best-response of this country for a given access price a_{*i} in country i .

Let $SW_j(a_{*i}, a_{*j})$ be country j 's welfare¹⁴. Using the optimality conditions for access prices, we have

$$\frac{da_{*j}}{da_{*i}}(a_{*i}) = -\frac{\frac{\partial^2 SW_j}{\partial a_{*i} \partial a_{*j}}}{\frac{\partial^2 SW_j}{\partial a_{*j}^2}} = \frac{(1 + \lambda_{pf} - \theta_j)\delta_*}{(1 + \lambda_{pf}) - (1 + \lambda_{pf} - \theta_j)\delta_*}. \quad (4)$$

The second-order condition in country j (which is in this case $\delta_* < \frac{1+\lambda_{pf}}{1+\lambda_{pf}-\theta_j}$) implies that the denominator of (4) is positive. Therefore, the type of strategic interaction depends on the sign of δ_* .

Lemma 1 *Consider that country j adopts the taxpayer-pay system. Then, access prices are strategic complements (respectively substitutes) iff $\delta_* \geq 0$ (respectively $\delta_* \leq 0$).*

Assume now that IM_j adopts the user-pay system and denote by $\tilde{\lambda}_j$ the Lagrange multiplier associated to the budget constraint in that country. In this case, a change in the access price in country i modifies the shadow cost of the budget constraint in country j because it affects its access revenue. This effect must be accounted for when rebalancing the access price in country j . Indeed, simple manipulations show that

$$\frac{da_{*j}}{da_{*i}}(a_{*i}) = \frac{(1 + \tilde{\lambda}_j - \theta_j)\delta_*}{(1 + \tilde{\lambda}_j) - (1 + \tilde{\lambda}_j - \theta_j)\delta_*} + \frac{\frac{\theta_j}{1+\tilde{\lambda}_j} \frac{q_*}{-q'_*}}{(1 + \tilde{\lambda}_j) - (1 + \tilde{\lambda}_j - \theta_j)\delta_*} \frac{d\tilde{\lambda}_j}{da_{*i}}. \quad (5)$$

Ceteris paribus, when country i increases its access price, demand is reduced, making the budget-balance requirement in country j more demanding: the second term in (5) is positive. Therefore, when IM_j adopts the user-pay system, access prices tend to become more strategic complements because of the strict budget requirement.

Differentiating the optimality condition in country j and rearranging terms yields

$$\frac{da_{*j}}{da_{*i}}(a_{*i}) = \frac{\theta_j}{(1 + \tilde{\lambda}_j)^2} \frac{q_*}{-q'_*} \frac{d\tilde{\lambda}_j}{da_{*i}} + \frac{1 + \tilde{\lambda}_j - \theta_j}{1 + \tilde{\lambda}_j} \left\{ 1 + \frac{da_{*j}}{da_{*i}}(a_{*i}) \right\} \delta_*. \quad (6)$$

Equation (6) allows us to rewrite (5) as follows

$$\frac{da_{*j}}{da_{*i}}(a_{*i}) = \frac{1 + \tilde{\lambda}_j - \theta_j}{\theta_j}, \quad (7)$$

which is always positive. Therefore, we obtain the following lemma.

Lemma 2 *Consider that country j adopts the user-pay system. Then, access prices are strategic complements.*

¹⁴Throughout the paper, SW_i will denote the value of the objective associated to country i 's maximization problem.

Therefore, the requirement imposed by the strict budget constraint in country j forces access prices to be strategic complements, whatever the value of δ_* .

This feature distinguishes the strategic interaction that arises in our model from the standard one in IO literature. Here, the constraint imposed by the (political principal of an) infrastructure manager on the financing of the infrastructure deficit affects not only the level of access prices in this country, but also the nature of the strategic interaction.

For future reference, we now introduce some further notation. When country i adopts the user-pay system and country j chooses the taxpayer-pay one, the Lagrange multiplier associated to the budget constraint in country i is denoted by $\tilde{\lambda}_i^{ut}$; access prices are denoted by $(a_{*i}^{ut}, a_{*j}^{ut})$ and are given by (3) for country j and by replacing λ_{pf} by $\tilde{\lambda}_i^{ut}$ in (3) for country i ; finally, welfare in country j is $SW_j^{ut} = \theta_j S_*(q_*(a_{*i}^{ut}, a_{*j}^{ut})) + (1 + \lambda_{pf})[(a_{*j}^{ut} - c_u)q_*(a_{*i}^{ut}, a_{*j}^{ut}) - k_j]$

and welfare in country i is $SW_i^{ut} = \theta_i S_*(q_*(a_{*i}^{ut}, a_{*j}^{ut}))$. Similar notations carry over to the other cases.

3.3 The choice of regulatory modes game

It remains now to determine the incentive of an infrastructure manager to adopt a particular financing system. This requires an analysis regarding how the direct and the strategic effects combine.

Choice of a regulatory mode in country i when country j adopts the taxpayer-pay system As we have shown, when country j adopts the taxpayer-pay system, the type of strategic interaction between the two infrastructure managers is determined by δ_* . As a consequence, our results depend on the sign, but also the magnitude, of δ_* itself. We start with the following proposition.

Proposition 1 *Consider that δ_* is positive and large (i.e., $\delta_* > \bar{\delta}_{*i}$). Then, when country j adopts the taxpayer-pay system, country i adopts the user-pay system.*

Proof See Appendix A.1. ■

With Lemma 1, a large value of δ_* characterizes strong strategic complementarity between access prices. This implies, for instance, that if country i reduces its access price, country j will react by strongly decreasing its own access price. Therefore, a deviation from the taxpayer- to the user-pay system by IM_i may become appealing since it might force IM_j to reduce his international access charge, thereby raising net surplus and infrastructure revenue in country i .

Indeed, consider that there exists a parameter configuration such that, when IM_i adopts the taxpayer-pay system, the infrastructure subsidy is null; this is the case when the revenue generated by access charges $(a_{*i}^{tt}, a_{*j}^{tt})$ exactly covers infrastructure

costs. For those values of the parameters, the shadow cost of the budget constraint under a user-pay system coincides with the shadow cost of public funds and the taxpayer- and user-pay systems yield the same welfare level. To keep things as simple as possible, we define $\underline{k}_i^t$ as the level of fixed cost such that $\tilde{\lambda}_i^{ut}(\underline{k}_i^t) = \lambda_{pf}$.¹⁵

We shall only consider the case $k_i \geq \underline{k}_i^t$. Otherwise, when IM_i adopts the taxpayer-pay system, the subsidy provided to the infrastructure turns out to be negative in equilibrium. This would not be consistent with our focus on the railway industry: indeed, in that case we should expect a railway infrastructure manager to finance (part of) the State expenses since raising funds from a distortion in the provision of railway services would have a lower social cost than distortionary taxation on the rest of the economy; this appears unrealistic.

We show in the Appendix that $\delta_* > \bar{\delta}_{*i}$ implies that the access price in country i decreases with the infrastructure deficit in that country (i.e., $\frac{da_i^{ut}}{dk_i} \leq 0$ for all $\tilde{\lambda}_i^{ut}$). Hence, with strong strategic complementarity between access prices, forcing the infrastructure manager to satisfy a strict budget-balance condition is indeed attractive since this will lead to lower access prices in both countries.

This result is somewhat surprising. At a first sight, one would be tempted to say that an infrastructure manager would raise the access price following the decision not to use any subsidy. However, reducing the level of the access price turns out to be the preferred option when it is anticipated that this will force the other infrastructure manager to strongly reduce his own access price.

As we state in the following Proposition, this is no longer the case when access prices are weakly strategic complements under the taxpayer-pay system.

Proposition 2 *Consider that δ_* is positive and small (i.e., $\delta_* \in [0, \underline{\delta}_{*i})$). Then, when country j adopts the taxpayer-pay system, country i adopts the taxpayer-pay system.*

Proof See Appendix A.2. ■

Let us now compare this proposition with the previous one. For a fixed access price in country j , or equivalently when $\delta_* = 0$, IM_i tends to increase his access price when he chooses the user-pay system. Hence, when the strategic reaction anticipated in the other country is weak, IM_i will indeed increase the access price to ensure that the infrastructure is financed without a subsidy, even though by doing so he triggers a (limited) demand reduction.

This result can first be demonstrated locally, then extended globally thanks to the convexity of the welfare difference¹⁶ in the case of weak strategic complemen-

¹⁵We emphasize that the level of the fixed cost of infrastructure only plays a role with respect to the level of access revenue. Using the fixed cost is the simplest way to parametrize the infrastructure deficit.

¹⁶That is, the difference between the welfare in country i under the taxpayer-pay system and under the user-pay one, given that IM_j chooses the taxpayer-pay system.

tarity. This characteristic has an intuitive explanation: the larger the infrastructure deficit, the stronger the (negative) direct and strategic effects since the larger the (upward) distortion imposed on the access price to satisfy the strict budget balance requirement. Therefore, in the case of weak strategic complementarity, the loss related to the adoption of the user-pay system increases with the infrastructure deficit.

However, we show that with strategic substitutes the welfare difference is still convex, but the direct and the strategic effects are now conflicting: when IM_i deviates from the taxpayer- to the user-pay system, the access price in his country increases but this now triggers a decrease of the access price set in the other country. Obviously, for a given level of infrastructure deficit in country i , the stronger the strategic effect relative to the direct one (i.e., the larger δ_*), the larger the incentive to adopt the user-pay system. However, the larger the infrastructure deficit, the larger the distortion on the access price needed to ensure budget balance, and the weaker the incentive for the infrastructure manager not to use any subsidy. We summarize the case of strategic substitutes under the taxpayer-pay system in the following proposition.

Proposition 3 *Consider that δ_* is negative. Then, when country j adopts the taxpayer-pay system, there exists $\tilde{k}_i^t$ such that:*

- *for low infrastructure deficits (i.e., $k_i \leq \tilde{k}_i^t$), country i adopts the user-pay system;*
- *for high infrastructure deficits (i.e., $k_i \geq \tilde{k}_i^t$), country i adopts the taxpayer-pay system.*

Proof See Appendix A.2. ■

Taken together, Propositions 1, 2 and 3 give a characterization of the choice of a financing system in one country, given that the other country has adopted the taxpayer-pay system¹⁷.

Choice of regulatory mode in country i when country j implements the user-pay system In the case where country j chooses the user-pay system, strategic complementarity between the access pricing decisions of the two infrastructure managers prevails. Thus, we obtain the following result.

Proposition 4 *When country j adopts the user-pay financing system, country i adopts the user-pay system.*

Proof See Appendix A.3. ■

¹⁷For $\delta_* \in (\underline{\delta}_{*i}, \bar{\delta}_{*i})$ (provided that this interval is non-empty), we cannot characterize in a simple way the choice of a financing system in country i . This is left for future research.

Strategic complementarity always favors the adoption of the user-pay system. In a sense, when IM_j adopts the user-pay system, he commits to react in the same ‘direction’ as country i . When country i adopts the user-pay system, the strict budget balance condition in this country, together with strategic complementarity, implies that access prices will decrease in both countries. Notice finally that this case is similar to the one stated in Proposition 1.

Equilibria of the two-stage game To draw a comparison with the situation of perfect cooperation, we have to determine the choice of the regulatory mode in each country that yields the largest total welfare.

Proposition 5 *Consider the non-cooperation situation. From the viewpoint of total welfare, the user-pay system in both countries is the preferred choice of regulatory mode.*

Proof See Appendix A.3. ■

Indeed, as we explained in the previous section, the adoption of the user-pay system by *both* infrastructure managers softens the pricing distortions. Thus, as opposed to the perfect cooperation case studied in Proposition 0, it turns out that welfare is unambiguously larger when each country fulfills the budget-balance requirement without any subsidy. When infrastructure managers do not coordinate, this result should not come as a surprise in view of the second-best literature: with Lemma 2, a commitment to strict budget-balance generates the strategic complementarity property; in that case, the user-pay regulatory mode is socially preferred since this softens the burden imposed on the international services.

Since we have determined the best-reply of each infrastructure managers for the first stage of the game, it simply remains to determine the equilibrium of the overall game. We obtain the following propositions¹⁸.

Proposition 6 *Consider that δ_* is positive and large (i.e., $\delta_* > \max\{\bar{\delta}_{*i}, \bar{\delta}_{*j}\}$). Then, both infrastructure managers adopt the user-pay system.*

Proof See Appendix A.4. ■

The intuition behind Proposition 6 can be explained as follows. In the first place, from the viewpoint of a given country, strong strategic complementarity favours a reduction of access charges in both countries, whatever the choice of regulatory mode in the other country. This boosts international demand (thereby allowing the fulfilment of the budget balance requirement) and, at the same time, increases consumers’ surplus in both countries. Therefore, in that case, each infrastructure manager has an incentive to finance the infrastructure deficit without any subsidy.

¹⁸We focus on pure strategy equilibria.

When access prices are *always* strong strategic complements, then the individual incentives of the infrastructure managers are compatible with the maximization of social welfare: when pursuing its own interest, a country has an individual incentive to commit to strict budget balance since this fosters the international demand;¹⁹ such incentives from the side of the infrastructure managers maximize social welfare.

The remaining cases are gathered in the next proposition.

Proposition 7

- Consider that δ_* is positive and small (i.e., $0 \leq \delta_* < \min\{\underline{\delta}_{*i}, \underline{\delta}_{*j}\}$). Then, two equilibria can arise: either both infrastructure managers choose the taxpayer-pay system, or they both choose the user-pay system.
- Consider that δ_* is negative. Then, the equilibrium choice depends on the level of the infrastructure deficits in the two countries:
 1. If the infrastructure deficit is small in both countries, i.e. $k_i \leq \tilde{k}_i^t$ for $i = 1, 2$, then both infrastructure managers choose the user-pay system.
 2. If the infrastructure deficit is small in country i and large in country j , i.e. $k_i \leq \tilde{k}_i^t$ and $k_j \geq \tilde{k}_j^t$, then both infrastructure managers adopt the user-pay system.
 3. If the infrastructure deficit is large in both countries, i.e. $k_i \geq \tilde{k}_i^t$ for $i = 1, 2$, then two equilibria can emerge: either both infrastructure managers choose the user-pay system, or they both choose the taxpayer-pay system.

Proof See Appendix A.4. ■

In the first case (weak strategic complementarity under a taxpayer-pay system), a multiplicity of equilibria arises. We end up with both countries adopting the same regulatory mode. Let us consider the reasons that may prevent the infrastructure managers from choosing the user-pay financing system. When IM_i contemplates a deviation from the taxpayer-pay to the user-pay system, he anticipates that the other country will not change much its access price following the modification of the tariff set in country i . Therefore, a commitment to finance the infrastructure deficit without a subsidy would lead to a higher access price in country i and, through (weak) strategic complementarity, also in country j . Taking the behavior of IM_j as fixed, country i fears to trigger an increase in access prices and a decrease in demand if it decides not to subsidize its infrastructure. That fear stems from the non-cooperative behavior of the infrastructure managers and may prevent countries from reaching a better outcome. The same logic carries over the case of large infrastructure deficits in both countries with δ_* negative.

¹⁹When $\delta_* > \bar{\delta}_{*i}$, choosing the user-pay financing system is a dominant strategy.

This stresses the potential role for a supra-national authority (the EC for instance) in coordinating a simultaneous move from a situation in which national infrastructure managers subsidize their infrastructures to a situation in which access pricing systems are usage-based. Indeed, the infrastructure managers face a coordination problem: one equilibrium is individually preferred to the other by both countries, but their non-coordination may lead to a dominated outcome.

We focus now on the case where δ_* is negative. In this situation, access prices are strategic substitutes under the taxpayer-pay system and become strategic complements under the user-pay system. Let us analyze the case where the infrastructure deficit is small in both countries. As previously, let us assume that both infrastructure managers subsidize their networks. Then, IM_i has an incentive to deviate: even though he expects that such a deviation will force him to increase his access price, the negative direct effect is more than compensated by the strategic reaction *anticipated* from the other country. However, a similar reasoning occurs in country j , leading IM_j to deviate from the taxpayer-pay system. In the end, the taxpayer-pay system, which is no longer the socially optimal regulatory mode in our context, cannot be supported in equilibrium since each country tries to free-ride to save on the subsidy bestowed on its infrastructure.

That free-riding incentive is generated by non-coordination between countries and finally leads to the socially preferable regulatory mode since when one country adopts the user-pay system, the other country is willing to commit to strict budget balance to alleviate the burden on the international services. Here, non-coordination is, in a sense, beneficial since it creates an incentive to adopt the user-pay system in order to free-ride on the neighbouring country. This incentive is generated by strategic substitutability under the taxpayer-pay system. Given that no country has an incentive to finance its infrastructure through a subsidy, access charges will become strategic complements and each infrastructure manager will have the correct incentive to adopt the user-pay system.

3.4 Extensions

3.4.1 Downstream market power

Our assumption that downstream firms behave competitively is certainly not totally consistent with most of the existing market structures in the railways industry, given that competition still remains at an infant stage in this industry. Many previous state monopolies are the main (even only) operator in many member States in the European Union. However, the results presented in our model can be easily extended to allow for downstream market power if the infrastructure managers can use two-part access tariffs. In this case, the variable part of the tariff is set so as to reduce the incentive of the downstream firms to exert their market power and

underproduce²⁰; the fixed part is then determined to capture all the profits earned by these firms. We simply notice that, as concerns the international service, another coordination problem might appear since both infrastructure managers would seek to capture these rents. Such a coordination problem is reminiscent of the multi-principal nature of our model.²¹

3.4.2 Domestic and international services

Let us briefly consider the case in which services are purely internal in both countries. Then, the problem faced by an infrastructure manager does not depend on the access prices set in the other country and the setting is analogous to the perfect cooperation situation. With purely domestic services, each infrastructure manager would always prefer to adopt the taxpayer-pay system since this provides an additional instrument. Moreover, that choice obviously maximizes social welfare.

To summarize, when downstream services are purely domestic, the taxpayer-pay system is the socially optimal mode of regulation and each infrastructure manager has indeed an incentive to subsidize his network deficit; when downstream services are purely international, it becomes socially optimal to prevent countries from subsidizing their infrastructure deficit since this softens the negative externalities on the access prices for international services.

In our working paper (Bassanini and Pouyet, 2001)²², we consider domestic services in country i only. We assume that the domestic demand is independent from the international one and that the access charge for domestic services may differ from that imposed to international services.²³

When country i adopts the user-pay system, domestic and international services are, in a sense, tied together in that they jointly contribute to the fulfillment of the budget balance requirement. This affects the strategic interaction under the user-pay system for country j . Also, when a country adopts the user-pay system, the distortions affecting the international access price influence the shadow cost of the budget constraint which, in turn, affects domestic access prices.

²⁰The access price is now a subsidy.

²¹See Martimort (1992) for the analysis of a common agency under complete (and incomplete) information.

²²In this paper, we assumed that the level of the infrastructure deficit is relatively small in both countries. We emphasize that this assumption does not restrict the possible level of network fixed costs, but rather means that demand levels are sufficiently high with respect to these costs.

²³This discriminatory access pricing scheme allows us to isolate more effectively the forces at work: nondiscriminatory pricing would entail a complex pattern of cross-subsidies between international and domestic services, depending on relative demand levels and price elasticities. Moreover, consider that differentiation of access charges according to service characteristics or congestion is widely accepted and implemented and can yield *de facto* discrimination between different types of service. Similarly, imposing a single tariff on each line would mean to discriminate between domestic and international services if they traveled on different routes.

The choice of a financing system depends on the strategic interaction between access prices and, not surprisingly, on the relative level of the domestic demand with respect to the international one. A country may still have an incentive to commit to strict budget balance if the gain (when there is a gain) from reducing the excessive international prices, or from free-riding on the costly subsidy bestowed on the infrastructure is larger than the loss (when there is a loss) due to the distortion imposed to the domestic services through the modification of the endogenous shadow cost of infrastructure financing. For these intermediate cases, the welfare analysis becomes ambiguous since the distortions also depend on the level of the infrastructure deficits in both countries. For instance, even in the case where the domestic demand in country i is much larger than the international one, it could be socially optimal that countries adopt the user-pay system if the loss caused by the distortion on the domestic services is small enough with respect to gain generated by a decrease of the international access price; this tends to be the case if infrastructure deficits are small.

We are then tempted to draw the following scenario. With the development of international services and the decrease of infrastructure deficits, countries should evolve from a system in which they subsidize their infrastructures to a system where access pricing must be usage-based. During this transition, different types of equilibria can emerge; therefore, such a move requires some coordination. If domestic services remain relatively important, it may be efficient to prevent countries from imposing a strict budget balance requirement; when the international demand is sufficiently stronger than the domestic one, it becomes efficient to impose that each country adopt a usage-based access pricing system. Simultaneously, a thorough study of the countries' incentives to choose one system or the other is needed. To determine the transition point, such a work should be complemented with an empirical analysis as the one performed by Ivaldi and Gagnepain (1999) for local transport services in France.

4 Conclusion

In this paper, we have analyzed the effect of the strategic interaction between two infrastructure managers, created by inter-network services provided by downstream firms to final users. Access charges for these services are affected by distortions due to the incomplete internalization of the related surplus and infrastructure costs. The interaction between the infrastructure managers' decisions at the downstream level leads indirectly to a subtle interaction between their choices of regulatory mode. This interaction sometimes provides the infrastructure managers with an incentive to finance their infrastructure deficit without a subsidy. With non-cooperative infrastructure managers, such choices lessen the distortion on the international services and improve welfare.

Our results highlight the need for increasing coordination on the side of infrastructure managers, in order to favor upstream access pricing choices that minimize distortions on downstream services. Therefore, future work should study the design of supra-national institutions or rules that enable to implement a certain level of cooperation.

Throughout our analysis, we have referred to the railway industry. In this respect, however, we have remained silent on a number of questions.

For instance, our model implicitly assumes that networks are interconnected: transport services can always go from one country to the other. However, it has been argued that the development of the international traffic also suffers from a poor quality of interconnection. This is the so-called interoperability problem, which appears to be critical for the development of intra-European networks.

Another question concerns the investment decisions undertaken by the infrastructure managers. More specifically, the decisions to create or to close lines should be incorporated in our framework. For instance, the fixed cost of maintaining the line is much lower for an only-freight line because of lower safety standards. This choice should not be neutral with respect to the strategic interaction between infrastructure managers or the possibility to choose a particular financing system.

A Appendix

A.1 Proof of Proposition 1

Let us denote by $\Delta SW_i^t \equiv SW_i^{tt} - SW_i^{ut}$ the gain for country i related to the deviation from the taxpayer- to the user-pay system, given that IM_j chooses the taxpayer-pay system. Then, $\Delta SW_i^t|_{k_i=k_i^t} = 0$.

We have $\frac{dSW_i^{tt}}{dk_i} = -(1 + \lambda_{pf})$ since, under the taxpayer-pay system, the access price depends only on demand elasticity and the exogenous cost of public funds, and the infrastructure manager covers the remaining infrastructure deficit through a subsidy.

We also have $\frac{dSW_i^{ut}}{dk_i} = -\theta_i q_*(a_{*i}^{ut}, a_{*j}^{ut}) \left(1 + \frac{da_{*j}^{ut}}{da_{*i}^{ut}}\right) \frac{da_{*i}^{ut}}{dk_i}$, where the strategic interaction between access prices is given by (4). When IM_i adopts the user-pay system, an increase in the infrastructure deficit forces country i to modify its access price in a way that can be obtained by considering that the budget constraint holds as an equality in equilibrium:

$$(a_{*i}^{ut} - c_u) q_*(a_{*i}^{ut}, a_{*j}^{ut}) = k_i. \quad (BB_i^{ut})$$

Totally differentiating (BB_i^{ut}) yields

$$\frac{da_{*i}^{ut}}{dk_i} = \frac{1}{q_* \left\{ 1 + (a_{*i}^{ut} - c_u) \frac{q'_*}{q_*} \left(1 + \frac{da_{*j}^{ut}}{da_{*i}^{ut}} \right) \right\}} = \frac{1}{q_* \left\{ 1 - \frac{1 + \bar{\lambda}_i^{ut} - \theta_i}{1 + \bar{\lambda}_i^{ut}} \left(1 + \frac{da_{*j}^{ut}}{da_{*i}^{ut}} \right) \right\}}. \quad (8)$$

Then, simple manipulations lead to

$$\frac{d\Delta SW_i^t}{dk_i} = -(1 + \lambda_{pf}) + \frac{\theta_i(1 + \lambda_{pf})(1 + \tilde{\lambda}_i^{ut})}{\theta_i(1 + \lambda_{pf}) - (1 + \tilde{\lambda}_i^{ut})(1 + \lambda_{pf} - \theta_j)\delta_*}. \quad (9)$$

Now, consider that $\theta_i(1 + \lambda_{pf}) - (1 + \tilde{\lambda}_i^{ut})(1 + \lambda_{pf} - \theta_j)\delta_* < 0 \quad \forall \tilde{\lambda}_i^{ut} \geq 0$, which is equivalent to $\delta_* > \bar{\delta}_{*i} \equiv \frac{\theta_i(1 + \lambda_{pf})}{\theta_i + \lambda_{pf}} > 0$. In this case, both terms of the right-hand side of (9) are negative for all parameter configurations. This gives us Proposition 1.

It is immediate to check that $\delta_* > \bar{\delta}_{*i} \Leftrightarrow \frac{da_{*i}}{dk_i} \leq 0 \quad \forall \tilde{\lambda}_i^{ut} \geq 0$.

A.2 Proof of Propositions 2 and 3

With (9), we obtain

$$\lim_{k_i \rightarrow \underline{k}_i^t} \frac{d\Delta SW_i^t}{dk_i^t} = \frac{(1 + \lambda_{pf})(1 + \lambda_{pf} - \theta_j)\delta_*}{\theta_i - (1 + \lambda_{pf} - \theta_j)\delta_*}. \quad (10)$$

For δ_* positive but not too large, the right-hand side of (10) is positive.

Simple computations show that

$$\frac{d^2\Delta SW_i^t}{dk_i^2} = \left\{ \frac{(1 + \lambda_{pf})\theta_i}{(1 + \lambda_{pf})\theta_i - (1 + \tilde{\lambda}_i^{ut})(1 + \lambda_{pf} - \theta_j)\delta_*} \right\}^2 \frac{d\tilde{\lambda}_i^{ut}}{dk_i}.$$

But, since $\frac{da_{*i}^{ut}}{dk_i} = \frac{da_{*i}^{ut}}{d\tilde{\lambda}_i^{ut}} \frac{d\tilde{\lambda}_i^{ut}}{dk_i}$, we can deduce that

$$\text{Sign} \left[\frac{d\tilde{\lambda}_i^{ut}}{dk_i} \right] = \text{Sign} \left[\frac{da_{*i}^{ut}}{d\tilde{\lambda}_i^{ut}} \right] \times \text{Sign} \left[\frac{d\tilde{\lambda}_i^{ut}}{dk_i} \right] = \text{Sign} [1 - \omega_*^t \delta_*] \times \text{Sign} [1 - \omega_*^t], \quad (11)$$

where $\omega_*^t = \frac{1 + \tilde{\lambda}_i^{ut} - \theta_i}{1 + \tilde{\lambda}_i^{ut}} \frac{1 + \lambda_{pf}}{(1 + \lambda_{pf}) - (1 + \lambda_{pf} - \theta_j)\delta_*}$. Consequently, for δ_* positive and small, ΔSW_i^t is convex in k_i . Defining $\underline{\delta}_{*i}$ as the smallest positive value of δ_* such that $1 - \omega_*^t$, $1 - \omega_*^t \delta_*$ and $\theta_i - (1 + \lambda_{pf} - \theta_j)\delta_*$ are simultaneously positive, we obtain Proposition 2.

If $\delta_* < 0$, the first and second term in the right-hand side of (11) are still positive. But we now obtain $\lim_{k_i \rightarrow \underline{k}_i^t} \frac{d\Delta SW_i^t}{dk_i} < 0$. This, together with the convexity of ΔSW_i^t , completes the proof of Proposition 3.

A.3 Proof of Propositions 4 and 5

First, we define as $\underline{k}_i^u$ the value of country i 's infrastructure fixed cost such that when country i adopts the taxpayer-pay system and country j the user-pay one, the

subsidy in the former country is equal to 0. $\underline{k}_i^u$ depends on the endogenous shadow cost of the budget constraint in country j , $\tilde{\lambda}_j^{tu}$. A priori, $\underline{k}_i^u$ is different from $\underline{k}_i^t$ since the access prices in both countries are set at different levels.

We define $\Delta SW_i^u \equiv SW_i^{tu} - SW_i^{uu}$ the welfare difference in country i between the taxpayer- and the user-pay system when IM_j has chosen the user-pay system. We have $\Delta SW_i^u|_{k_i=\underline{k}_i^u} = 0$.

We have $\frac{dSW_i^{tu}}{dk_i} = -(1 + \lambda_{pf})$ and $\frac{dSW_i^{uu}}{dk_i} = -\theta_i q_*(1 + \frac{da_{*j}^{uu}}{da_{*i}^{uu}}) \frac{da_{*i}^{uu}}{dk_i}$. Using (7), we get

$$\frac{dSW_i^{uu}}{dk_i} = \frac{\theta_i(1 + \tilde{\lambda}_j^{uu})(1 + \tilde{\lambda}_i^{uu})}{(1 + \tilde{\lambda}_j^{uu})(1 + \tilde{\lambda}_i^{uu} - \theta_i) - \theta_j(1 + \tilde{\lambda}_i^{uu})} > 0 \quad \forall (\tilde{\lambda}_j^{uu}, \tilde{\lambda}_i^{uu}).$$

This implies that $\frac{d\Delta SW_i^u}{dk_i}$ is *always* negative. This enables us to state Proposition 4.

Let us also focus on the setting of the access price in country i under the user-pay system. Using the optimality conditions for access charges in both countries and differentiating the budget constraint in country j , we get

$$\frac{da_{*i}^{uu}}{d\tilde{\lambda}_i^{uu}} = \frac{\partial a_{*i}^{uu}}{\partial \tilde{\lambda}_i^{uu}} + \frac{\partial a_{*i}^{uu}}{\partial \tilde{\lambda}_j^{uu}} \frac{d\tilde{\lambda}_j^{uu}}{d\tilde{\lambda}_i^{uu}} = - \frac{\frac{q_*}{-q_*} \theta_i (1 - \theta_i)}{(1 + \tilde{\lambda}_i^{uu}) \left[\delta_*(1 + \tilde{\lambda}_j^{uu})(1 + \tilde{\lambda}_i^{uu} - \theta_1) - (1 - \theta_1)(1 + \tilde{\lambda}_i^{uu}) \right]}.$$

Then, differentiating the budget constraint in country i , we obtain

$$\frac{d\tilde{\lambda}_i^{uu}}{dk_i} = \frac{(1 + \tilde{\lambda}_i^{uu})^2 \left[\delta_*(1 + \tilde{\lambda}_j^{uu})(1 + \tilde{\lambda}_i^{uu} - \theta_1) - (1 - \theta_1)(1 + \tilde{\lambda}_i^{uu}) \right]}{\frac{q_*^2}{-q_*} \theta_i (\tilde{\lambda}_j^{uu} + \tilde{\lambda}_i^{uu} \tilde{\lambda}_j^{uu} + \tilde{\lambda}_i^{uu} \theta_i - \tilde{\lambda}_j^{uu} \theta_i)}.$$

Therefore, the adoption of the user-pay system by both infrastructure managers unambiguously leads to a reduction of infrastructure charges: $\frac{da_{*i}^{uu}}{dk_i} \leq 0 \quad \forall \tilde{\lambda}_i^{ut} \geq 0$.

The lower infrastructure charges that obtain in the ‘ uu ’ case entail a higher social surplus with respect to ‘ ut ’ situation. Moreover, the second component of social welfare under the taxpayer-pay system (i.e. the infrastructure deficit) is negative due to our previous assumption that $k_i \geq \underline{k}_i^t$. Therefore, since access prices are smaller in the ‘ uu ’ case than in the ‘ tu ’ case, welfare in each country in the former situation is higher than in the latter one. A similar reasoning can be made to compare the ‘ tt ’ situation with the ‘ uu ’ one: when $k_i = \underline{k}_i^u$ for $i = 1, 2$, $\tilde{\lambda}_i^{uu} = \lambda_{pf}$, $i = 1, 2$; since access prices are strategic complements in the ‘ uu ’ case and $\frac{da_{*i}^{uu}}{dk_i} \leq 0$ for $i = 1, 2$, welfare in each country is larger in the ‘ uu ’ case than in the ‘ tt ’ case. This completes the proof of Proposition 5.

A.4 Proof of Propositions 6 and 7

When $\delta_* > \max\{\bar{\delta}_{*i}, \bar{\delta}_{*j}\}$, each infrastructure manager has a dominant strategy and we do not need to compare $\underline{k}_i^t$ and $\underline{k}_i^u$.

Similarly, when $0 \leq \delta_* < \min\{\underline{\delta}_{*i}, \underline{\delta}_{*j}\}$, the first-stage best-responses of the infrastructure managers do not depend on the levels of infrastructure deficit and we do not need to compare $\underline{k}_i^t$ and $\underline{k}_i^u$.

When $\delta_* \leq 0$, using (11), we have $\frac{d\tilde{\lambda}_j^{tu}}{dk_j} \geq 0$. Therefore, $\tilde{\lambda}_j^{tu} \geq \lambda_{pf}$ and $a_{*i}^{ut} \geq a_{*i}^{tt}$ for all $k_j \geq \underline{k}_j^t$. This implies that $\underline{k}_i^u \leq \underline{k}_i^t$. Since we focus only on cases where, under a taxpayer-pay system, the subsidy given to the infrastructure is positive, we restrict attention to cases where $k_i \geq \underline{k}_i^t$.

Then, it suffices to use Propositions 1 – 4 to determine the equilibrium.

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