INSTITUT NATIONAL DE LA STATISTIQUE ET DES ETUDES ECONOMIQUES
Série des Documents de Travail du CREST
(Centre de Recherche en Economie et Statistique)

n° 2004-08

Strategic Choice of Financing Systems in Regulated and Interconnected Industries*

A. BASSANINI[1]
J. POUYET[2]

---

* This paper originates from a joint research program between CERAS-ENPC and IDEI on the economics and the regulation of railroads. Financial and intellectual support from Réseau Ferré de France and the Direction des Transports Terestres (Ministry of Transportation, PREDIT Program) are gratefully acknowledged. We would also like to express our gratitude to Bernard Caillaud, Jean-Jacques Laffont, Jean Tirole and two anonymous referees whose detailed comments and suggestions have led to substantial improvements over the previous versions. We also thank Rodolphe Dos Santos Ferreira, Marie-Cécile Fagart, Saïd Souam and participants to various seminars and conferences for helpful remarks.

[1] University of Rome « La Sapienza » and University of Toulouse (IDEI).

[2] CREST-LEI, CORE-UCL, CERAS-ENPC and CEPR. *Corresponding author*: CREST-LEI : 28 rue des Saints-Pères, 75343 Paris cedex 07, France. Phone : +33 1 44 58 27 69. Fax : 33 1 44 58 27 72. Email : pouyet@ensae.fr

Strategic Choice of Financing Systems in Regulated and Interconnected Industries[*,†]

Anna Bassanini[‡] & Jerome Pouyet[§]

May 17, 2004

[*]This paper originates from a joint research program between CERAS-ENPC and IDEI on the economics and the regulation of railroads. Financial and intellectual support from Réseau Ferré de France and the Direction des Transports Terrestres (Ministry of Transportation, PREDIT Program) are gratefully acknowledged. We would also like to express our gratitude to Bernard Caillaud, Jean-Jacques Laffont, Jean Tirole and two anonymous referees whose detailed comments and suggestions have led to substantial improvements over the previous versions. We also thank Rodolphe Dos Santos Ferreira, Marie-Cécile Fagart, Saïd Souam and participants to various seminars and conferences for helpful remarks.

[†]Please, send correspondence to Jerome Pouyet, LEI-ENPC, 28 rue des Saint-Pères, 75343 Paris Cedex 07, France. Phone: +33 (0)144582769. Fax: +33 (0)144582772. E-mail address: `pouyet@ensae.fr`

[‡]University of Rome "La Sapienza" and University of Toulouse (IDEI).

[§]CREST-LEI, CORE-UCL, CERAS-ENPC and CEPR.

Résumé

L'importance croissante des échanges entre réseaux d'infrastructures influence les choix de régulation et la tarification de l'accès pour les services finals utilisant ces infrastructures. Nous analysons ce problème dans un cadre où deux gestionnaires d'infrastructures de pays frontaliers tarifent l'accès à leurs réseaux utilisés par des firmes pour fournir des services de transports internationaux. Les coûts des réseaux peuvent être financés par des fonds publics et des revenus d'accès. Les tarifs d'accès sont affectés par l'internalisation partielle du surplus total des consommateurs et du coût total des réseaux ; nous analysons l'impact de ces distorsions au niveau de la tarification de l'accès sur le montant de subventions publiques dédiées au financement des infrastructures.

Du fait de ces distorsions, dans un cadre non-coopératif, l'optimalité de second-rang impose que les gestionnaires d'infrastructures adoptent un système de financement sans subvention. Cependant, plusieurs équilibres peuvent émerger et le résultat optimal de second rang n'est jamais un équilibre stable. Nous étudions les propriétés des différents équilibres ainsi que l'impact d'une politique supra-nationale encourageant le développement des services internationaux.

Les problèmes de coordination peuvent parfois être résolus en séparant les décisions concernant le financement des infrastructures de celles portant sur la tarification de l'accès, permettant par là-même aux gestionnaires d'infrastructures de s'engager sur le mode de financement. Cependant, de nouveaux phénomènes de passager clandestin peuvent alors survenir et empêcher d'atteindre les décisions de subvention socialement désirables.

Classification *JEL* : L51.
Mots-Clés: Réseaux interconnectés,Financement des infrastructures, Tarification à la Ramsey.

Abstract

The growing importance of inter-network exchanges in infrastructure-based utilities influences regulatory choices and access pricing for downstream services using the networks. 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 for downstream transport firms that provide international services. Network costs can be financed either through public funds and user charges. Access prices are affected by the incomplete internalization of consumers' surplus and infrastructure costs; we analyze how this distortion at the access pricing level generates a distortion in the levels of public funds dedicated to infrastructure financing.

Because of these distortions, it turns out that in a non-cooperative setting the second-best outcome might consist in the simultaneous adoption of the no-subsidy system. However, multiple equilibria typically exist and the second-best outcome is never a stable equilibrium. Other properties of the different possible equilibria are studied, as well as the impact of supra-national policies aimed at encouraging the development of international services.

The coordination problems deriving from the existence of multiple equilibria can, sometimes, be solved by separating the choice of a regulatory mode from the access pricing stage, thereby allowing the infrastructure managers to commit to use a specific financing system before setting the access price. However, our analysis unveils that, since the choice a regulatory mode in a country strategically affects the pricing of access in the other country, non-cooperative infrastructure managers might have free-riding incentives when deciding the financing system for their own network.

JEL Classification: L51.
Keywords: Interconnected Networks, Infrastructure Financing, Ramsey Pricing.

1 Introduction

During the last two decades, network industries have undergone major changes in regulatory framework, market structure and demand features. In fact, regulatory oversight has been largely reduced in those segments which displayed 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, as such, 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 transport 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 conditions regulating network access differ significantly across countries. For example, consider the case of road traffic. Motorway tolls vary both in level and in nature: Highways are free in Germany, while in Switzerland or Austria a one-year sticker ('vignette') is required; in Italy and France, fees are usage-based. The different access pricing schemes also entail varying levels of infrastructure costs coverage by users. Consider for instance the case of railway networks: The 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 German access pricing system has been set with the aim of recovering all costs, excluding those related to new or enhanced infrastructure.[1] In general, 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. In view of these differences, particular attention should be devoted to infrastructure access pricing for inter-network services.[2]

The aim of this paper is to study the non-cooperative choice of a financing system by two national infrastructure managers who maximize welfare in their country while ensuring that network costs are covered. Final international services are provided by downstream firms, that require access to network facilities.

The question we ask is the following: Will the interaction between access pricing decisions due to international services affect the countries' choice of a financing system?

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 'subsidy financing system'. Alternatively, access charges imposed on downstream users could be meant to recover total infrastructure costs: We call this approach 'no-subsidy financing system'. The difference is that under the subsidy system the cost of the infrastructure deficit is evaluated at the shadow cost of public funds, whereas under a no-subsidy financing system it depends on the shadow cost of the strict budget constraint.

[1] See NERA (1998).

[2] In the railway case, a particular concern in this respect is expressed by EC Directive 14/2001, which upholds that coordination across countries is required in order to avoid the negative impact of the lacking harmonization of charging systems on service efficiency and market share.

If the two countries were perfectly cooperating, optimal access prices would obey standard Ramsey-Boiteux formulas. The optimal choice of a financing system would then depend on the relative magnitude of network fixed costs with respect to the revenue that can potentially be raised through access pricing. When infrastructure costs are small with respect to that revenue, the shadow cost of the budget constraint is smaller than the shadow cost of public funds and the infrastructure manager will adopt the no-subsidy system. Viceversa, when fixed costs are relatively high it will be preferable to use a subsidy since covering the network deficit exclusively through access revenues would imply excessive distortions.

Taking the cooperative case as a benchmark, we analyze the choice of a financing system by two independent countries. Under non-cooperation, access charges are distorted upwards. In fact, self-interested infrastructure managers only internalize a fraction of the total social surplus ('constituency effect') and half of the actual infrastructure cost ('double marginalization effect').

We first study the equilibria of a one-stage complete information game where non-cooperating infrastructure managers choose simultaneously a financing system and the access charges for their networks. We find that pricing decisions are tightly bound to the choice of a regulatory mode: In fact, a country's adoption of the no-subsidy system implies that its optimal charge is always positively related to the opponent's fee, while under the subsidy system the slope of the reaction function depends on the characteristics of the final demand.

In the simultaneous non-cooperative setting, both the financing system and the access price chosen in a given country will depend on the opponent's charge. The latter will often play the role of an additional cost; thus, an infrastructure manager will typically choose the no-subsidy system if he anticipates a low charge in the neighboring country, while he will subsidize his network in the opposite case. This intuitively paves the way for multiple equilibria: The final outcome of the game may differ according to each country's expectations. In (most) symmetric scenarios, two equilibria will emerge where both countries choose the same system.

In a broad variety of circumstances, the infrastructure managers will then face a coordination problem, which is even more dire since the different equilibria are not Pareto equivalent. In particular, we show that the second-best solution consists in the adoption of the no-subsidy system in both countries. Counter to intuition, this choice leads to lower access charges, since the infrastructure managers will jointly decrease prices in order to boost demand and increase consumer surplus. This alleviates pricing distortions, but final prices will typically remain higher than in the cooperative benchmark. Moreover, depending on the characteristics of final demand, there also exist cases where the unique equilibrium of the simultaneous game consists in the adoption of the subsidy system in both countries.

We also show that no-subsidy access charges decrease with network costs. In a sense, fixed costs become a commitment to behave aggressively: Each country will keep prices low because it fears the opponent's reaction. This feature has important policy implications: In fact, it suggests that the mandatory adoption of the no-subsidy system in both countries could lead to distortions in the infrastructure managers' investment behavior. Moreover, a subsidy policy aimed at developing international exchanges through subsidies would affect national infrastructure costs and could therefore yield perverse effects on final prices. Thus, while our analysis suggests the potential importance of the role of a supra-national authority in coordinating the implementation of a usage-based access pricing scheme across countries, care should be exerted in translating our results into policy provisions. In fact, such measures should strictly depend on the regulatory mode adopted in each country and the characteristics of final demand.

While these caveats hold, we study whether different (and possibly more realistic) choice scenarios could favor coordination on our second-best solution. In this perspective, we separate the (first-stage) adoption of a regulatory mode from the (second-stage) determination of access prices, endowing the infrastructure managers with the possibility to commit to use a particular financing system before setting access prices.

In this environment, the choice of a regulatory mode will depend on the sign and relative magnitude of the *direct* and *indirect* effects. In fact, the adoption of a financing system in a given country affects its welfare both through a direct influence on the network charge and by indirectly modifying access revenue and consumers' surplus because of the change induced in the fee set by the opponent. For example, when access charges are strategic substitutes, the indirect effect provides an incentive to free-ride on the opponent, sticking to the no-subsidy system and triggering a price reduction in the neighboring country.

The magnitude of the indirect effect depends on the strength of the strategic interaction and influences the commitment power of the first-stage choice of a financing system. Therefore, the possibility to use strategically a regulatory mode will mainly deploy its effects when the interaction between access charges is strong.

For example, in the case of strong strategic complementarity the two-stage game has a completely different outcome: At the (unique) equilibrium both infrastructure managers will choose the no-subsidy system. Indeed, the possibility to choose a financing system prior to the access charge may provide an incentive to adopt the no-subsidy system in order to soften pricing distortions.

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; see for instance Laffont and Tirole (2000). Chang (1996) studies the problem of pricing access in a vertically separated industry but does not consider the issue of interconnection, which is central to our analysis. Armstrong (2001) analyzes two-way interconnection between telecommunications networks providing international calling services to captive consumers. Although similar in some respects, our work is more focussed on the choice of the mode of regulation.

Due to its emphasis on the issues concerning coordination 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 setting, 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 in the first place 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 one-stage non-cooperative game, in which infrastructure managers choose simultaneously their financing system and access price. After having characterized the network managers' best-responses, we derive the equilibria of this game and focus on some of their properties. Then, building on this analysis, we introduce the sequential game in Section 4: In each country, regulatory modes are now decided prior access prices. Section 5 offers some extensions and discussions of the initial setting. All proofs are contained in the Appendix.

2 The model

We consider two countries denoted by $i = 1, 2$. In country i an infrastructure manager IM_i chooses a financing system and sets an access charge, 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 services[3] and $S_*(q_*)$ the associated net total consumers' surplus, that is, the net consumers' surplus of *both* countries when a quantity $q_*(p_*)$ of international services is consumed at a price p_*, with $q'_* < 0$. We obtain $\frac{dS_*}{dp_*} = -q_*$. Let $\eta_* = \frac{-q'_* p_*}{q_*}$ be the price elasticity of the demand.

We assume that country i only internalizes a part $\theta_i \in (0, 1)$ of the international surplus. In other words, q_* is the total level of round-trip demand for transport (for example, from Paris to London 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 $\theta_i S_*(q_*)$.[4,5]

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

To simplify the exposition, we assume that international services travel in each country half of the total number of kilometers. Denoting by t_i the transfer given to the infrastructure by

[3]Demand is defined in terms of tons-km, the standard unit in freight transport industries.

[4]Other interpretations could easily be thought of. For example, let θ^i_{ij} be the fraction of consumers having a demand for transport from i to j that belongs to country i and q^i_{ij} the related demand. For $i, j = 1, 2$ and $i \neq j$, we have that $\theta^i_{ij} + \theta^j_{ij} = 1$, while $q_{ij} = q^i_{ij} + q^j_{ij}$ 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 $\theta^i_{ij} S_{ij}(q_{ij}) + \theta^i_{ji} S_{ji}(q_{ji}) = \theta_i S_*(q_*)$, where $\theta_i = \theta^i_{ij} + \theta^i_{ji}$ and $q_{ij} = q_{ji} = q_*$.

[5]Our results could be extended to cases in which a fraction of the net surplus accrues to a third country, the so-called 'absentee ownership' assumption in the tax competition literature; see Agrell and Pouyet (2003).

IM_i, the profit of the infrastructure in country i is

$$\pi_i^{\text{infra}} \equiv t_i + (a_{*i} - c_u)q_* - k_i,$$

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.

The use of public funds is costly and has distortionary effects on the whole economy. In our partial equilibrium approach, we denote by $\lambda_{pf} > 0$ the shadow cost of public funds which captures this effect[6], and we assume that λ_{pf} is the same in both countries.[7] Notice that for the moment, we impose no restriction on the transfers to the networks, which can be either positive (i.e., the case of a subsidy to the infrastructure) or negative (i.e., the case of a tax on the network).

We assume that downstream firms behave competitively.[8] Let c_d be the constant marginal cost of operation for downstream firms. Since we consider round-trip travel demand, the resulting price for international transport services is 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.

Therefore, the program of the infrastructure manager in country i writes as follows

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

3 Social optimum

As a preliminary to the forthcoming analysis, we consider the benchmark case where the infrastructure managers perfectly cooperate. The unique infrastructure manager maximizes total social welfare under the constraint that the whole infrastructure breaks even, or

$$\begin{aligned} &\max_{\{t, a_*\}} \{S_*(q_*) - (1+\lambda_{pf})t + t + (a_* - 2c_u)q_* - k\} \\ &\text{s.t. } (BB) : t + (a_* - 2c_u)q_* - k \geq 0, \end{aligned}$$

where a_* is the unique access charge imposed on the international service and $k \equiv k_1 + k_2$. In this standard Ramsey-Boiteux problem, the budget constraint binds at equilibrium due to the existence of network fixed costs, thereby determining the value of the optimal transfer to the infrastructure for a given access price a_*: $t^r = -(a_* - 2c_u)q_* + k$. Thus, the optimal access price

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

[7] Equal costs of public funds across countries indicate that fiscal systems have been harmonized, which might be an appropriate assumption in an integrated area such as the EU. This assumption simplifies the comparison between the cooperation and non-cooperation scenarios. Indeed, if this assumption were not satisfied, cooperative infrastructure managers would only tax the country with the smallest cost of public funds.

[8] While reasonable for motorway traffic, this assumption is only an approximation for the situation envisioned by the EU for the railway sector in the future.

a_*^r follows the by-now standard Ramsey-Boiteux formula[9]

$$\frac{a_*^r - 2c_u}{a_*^r + c_d} = \frac{p_*^r - c_*}{p_*^r} = \frac{\lambda_{pf}}{1+\lambda_{pf}} \frac{1}{\eta_*}, \tag{1}$$

where $c_* = 2c_u + c_d$ denotes the social marginal cost of the international services. The access charge must be distorted away from the total marginal cost of infrastructure. The magnitude of this distortion depends on demand elasticity: the larger the elasticity, the lower the access price since the more final consumers are sensitive to variation in the price of the transport services. Notice that the infrastructure fixed costs do not affect the value of the optimal access price.

Let us now focus on the transfer to the infrastructure. Depending on the comparison between the gross access revenue generated by the optimal access price (i.e., $a_*^r q_*(p_*(a_*^r))$) and the level on infrastructure costs (i.e., $2c_u q_*(p_*(a_*^r)) + k$), the transfer can be either positive or negative: Indeed, when the former is smaller than the latter, it is socially optimal to use public funds to subsidize the infrastructure; by contrast, when the gross access revenue exceeds the infrastructure costs, the unique infrastructure manager uses the revenues generated by the pricing of access to reduce the burden on taxpayers.

Finally, the second-order condition associated to the infrastructure manager's maximization problem can be rewritten as follows

$$\delta_* \equiv \frac{q_* q_*'' - {q_*'}^2}{{q_*'}^2} < \frac{1+\lambda_{pf}}{\lambda_{pf}}.$$

This condition is assumed to be satisfied in equilibrium; we also assume that the sign of δ_* is constant in the relevant range.[10] We add the following restriction, whose precise role will become clear later on.[11]

Assumption 1. *$\delta_* < \frac{1+\lambda_{pf}}{1+2\lambda_{pf}}$ in the relevant range of final price p_*.*

4 The non-cooperative interaction between regulatory choices

From now on, we return to the assumption of non-cooperative infrastructure managers. In this section we consider a one-stage game where each infrastructure manager chooses *simultaneously* and non-cooperatively a level of transfer and an access charge for his network, considering as given the network financing policy adopted by the neighboring country. The analysis of this scenario will highlight some of the characteristics of the interaction between the infrastructure managers' decisions.

[9] Superscript 'r' stands for 'Ramsey'. The demand elasticity depends on the access price.

[10] This assumption is satisfied for a linear, iso-elastic or exponential demand.

[11] In our working paper, Bassanini and Pouyet (2003), we do not impose this condition and treat the remaining cases. Basically, Assumption 1, together with some conditions on the infrastructure costs to be detailed later on, ensures that the game between non-cooperative infrastructure managers has one stable equilibrium.

4.1 Best-response functions with unrestricted transfers

Before determining the equilibrium of the game under scrutiny, let us make the following points. First, infrastructure managers create on each other non-internalized externalities: indeed, the setting of access price in one country affects the final demand for international services, which in turn affects both the net surplus and the access revenue in the other country. Second, the amount of transfer provided to the infrastructure in, say, country j does not *directly* affect the optimization problem in country i. However, since the amount of transfer depends on the level of both access prices, any distortion on the access prices is likely to translate *indirectly* into a distortion in the levels of transfers to the networks.

Solving $(\mathcal{P}_{IM_i})$ immediately leads to the following first-order condition for the access charge in that country[12,13]

$$\frac{a_{*i}^{ut} - c_u}{p_*} = \frac{1 + \lambda_{pf} - \theta_i}{1 + \lambda_{pf}} \frac{1}{\eta_*}, \tag{2}$$

which depends on the access price set in country j. Similarly, the optimal access price in country j is given by

$$\frac{a_{*j}^{ut} - c_u}{p_*} = \frac{1 + \lambda_{pf} - \theta_j}{1 + \lambda_{pf}} \frac{1}{\eta_*}. \tag{3}$$

Define $a_{*i}^{ut,ut}$ and $a_{*j}^{ut,ut}$ the access charges that solve the system formed by Equations (2) and (3). Let $p_*^{ut,ut} = a_{*1}^{ut,ut} + a_{*2}^{ut,ut} + c_d$ and $t_i^{ut,ut}$ be the corresponding final price and transfer in country i respectively.

We are interested in understanding the interaction between the infrastructure managers' decisions. To this purpose, let $SW_i(a_{*i}^{ut}, a_{*j})$ be country i's welfare for a given access price a_{*j} in country j.[14] Using Equation (2), we obtain

$$\frac{da_{*i}^{ut}}{da_{*j}} = -\frac{\frac{\partial^2 SW_i(a_{*i}^{ut}, a_{*j})}{\partial a_{*i} \partial a_{*j}}}{\frac{\partial^2 SW_i(a_{*i}^{ut}, a_{*j})}{\partial a_{*i}^2}} \tag{4}$$

$$= \frac{(1 + \lambda_{pf} - \theta_i)\delta_*}{(1 + \lambda_{pf}) - (1 + \lambda_{pf} - \theta_i)\delta_*}. \tag{5}$$

The second-order condition in country i[15] implies that the denominator of the right-hand side of Equation (5) is positive. Therefore, the nature of the strategic interaction only depends on the sign of δ_*.[16]

Lemma 1. *With unrestricted transfers, access prices are strategic complements (respectively, strategic substitutes) iff $\delta_* \geq 0$ (respectively, $\delta_* \leq 0$).*

---

[12] Superscript 'ut' stands for 'unrestricted transfers'.

[13] We note that with unrestricted transfers, the budget constraint in each country binds at equilibrium.

[14] $SW_i(a_{*i}^{ut}, a_{*j})$ is the value function associated to $(\mathcal{P}_{IM_i})$.

[15] This condition amounts to $\delta_* < \frac{1+\lambda_{pf}}{1+\lambda_{pf}-\theta_i}$ and is satisfied under Assumption 1.

[16] Hendricks, Piccione and Tan (1997) find a similar condition to characterize the strategic interaction between two competing firms offering complementary products.

To complete the analysis, it remains to determine the level of transfer provided by IM_i to his infrastructure. To this purpose, we define $\underline{k}_i^{ut}$ as follows

$$t_i^{ut} = -\left(a_{*i}^{ut,ut} - c_u\right) q_*(p_*^{ut,ut}) + k_i \gtreqless 0 \Leftrightarrow k_i \gtreqless \underline{k}_i^{ut}.$$

As in the perfect cooperation benchmark, the equilibrium transfer to the network in country i is positive when, given the equilibrium access price set in country j, the gross access revenue is lower than the infrastructure costs in that country, and conversely; $\underline{k}_i^{ut}$ is the level of fixed cost in country i such that, at equilibrium, IM_i provides no transfer to his infrastructure. For future references, it is worth noting that whether IM_i subsidizes or taxes his network now also depends on the level of access price set in country j.

4.2 Properties of the equilibrium with unrestricted transfers

Not surprisingly, non-cooperation distorts access charges with respect to the cooperative benchmark. More precisely, the access charge in country i is distorted upwards because of two effects. First, IM_i does not fully internalize the impact of his decisions on total net consumers' surplus ($\theta_i < 1$). The access charge in country i will thus be excessive: This is the *constituency effect*. Moreover, even if each infrastructure manager were perfectly internalizing all surplus (i.e., $\theta_i = \theta_j = 1$), the equilibrium price would still be distorted, since the infrastructure (variable) cost of the international service perceived in each country is only a fraction of the actual cost: This is the *double marginalization effect*.

These upward distortions on the access price translate into too high a final price. Indeed, summing Equations (2) and (3) at equilibrium, we get

$$\frac{p_*^{ut,ut} - c_*}{p_*^{ut,ut}} = \frac{1 + 2\lambda_{pf}}{1 + \lambda_{pf}} \frac{1}{\eta_*}. \tag{6}$$

Comparing Equations (1) and (6), we observe that, indeed, the final price under non-cooperation is larger than the final price in the Ramsey-Boiteux benchmark.[17] Therefore, non-cooperation reduces welfare with respect to the perfect cooperation benchmark by distorting upwards the final price of international services.

We also observe that the equilibrium is stable if and only if[18]

$$\left|\frac{da_{*i}^{ut}}{da_{*j}}\right| < \left|\frac{da_{*j}^{ut}}{da_{*i}}\right|^{-1} \Leftrightarrow \delta_* < \frac{1 + \lambda_{pf}}{1 + 2\lambda_{pf}},$$

which holds under Assumption 1.

In order to go further in the analysis of the non-cooperative equilibrium, consider the following hypothetical situation: The management of the networks is delegated to a private entity,

[17] Notice that $\frac{p_* - c_*}{p_*}\eta_*$ is increasing with p_* under Assumption 1.

[18] See Dixit (1986).

which only seeks to generate as much access revenue as possible and does not receive any public funds[19]; the problem of such an entity simply writes as follows

$$\max_{a_*} (a_* - 2c_u)q_* - k.$$

Provided that infrastructure costs are not excessively large[20], the access price set by this entity would be such that[21]

$$\frac{a_*^m - 2c_u}{a_*^m + c_d} = \frac{p_*^m - c_*}{p_*^m} = \frac{1}{\eta_*}. \tag{7}$$

Comparing Equations (6) and (7), the final price that emerges under non-cooperation is even larger than the final price that would prevail would both networks be managed by a profit-maximizing infrastructure monopoly: $p_*^{ut,ut} > p_*^m$.

For illustrative purpose, consider a perfectly symmetric situation. In Figure 1, we draw the sum of the infrastructure profits as function of the total access price paid by the downstream sector. From the previous analysis, we know, first, that the total access price under non-cooperation exceeds the infrastructure monopoly access price, i.e., $a_{*i}^{ut,ut} + a_{*j}^{ut,ut} > a_*^m$, and, second, that the socially optimal access price is lower than the infrastructure monopoly access price, i.e., $a_*^r < a_*^m$.

Figure 1 allows us to highlight the impact of the distortions on the access prices on the choices of financing systems. Indeed, consider the Ramsey-Boiteux social optimum; when a_*^r is larger (respectively, smaller) than $\underline{a}_*$ then the infrastructure is taxed (respectively, subsidized). By contrast, under non-cooperation, whether networks are taxed or subsidized depends on the comparison between $a_{*i}^{ut,ut} + a_{*j}^{ut,ut}$ and $\overline{a}_*$. Consequently, with respect to the social optimum, the distortion on access prices generates a distortion in the choices of financing systems by the non-cooperative infrastructure managers. In particular, when the non-internalized externalities are strong enough, while the social optimum may require to tax the networks, the non-cooperative infrastructure managers end up subsidizing their networks.

Does privatization of the networks, in the admittedly simplistic way envisioned here, Pareto-dominate the situation in which infrastructure managers do not cooperate? In our model, this depends on the equilibrium choices of financing systems undertaken by the non-cooperative infrastructure managers. Indeed, when network managers subsidize their network, then delegation to a profit-maximizing infrastructure monopoly does unambiguously improve total welfare since it leads to a lower final price, and therefore a higher net consumers' surplus, while networks are financed without using costly subsidies. However, when infrastructure managers tax their networks at equilibrium, a trade-off appears: delegation of the management of the network to a private entity still reduces the burden on the international services; but, there is now also a loss of tax income. Depending on the magnitude of the distortion on the access prices, the latter effect may offset the former.

[19] Allowing the private infrastructure monopoly to use public funds would make no sense in our framework: the infrastructure monopoly would always have an incentive to ask for as much as possible public funds.

[20] Otherwise it is never possible to finance the infrastructure costs without public funds.

[21] Superscript 'm' stands for 'infrastructure monopoly'.

While highlighting the distortions deriving from non-cooperation, we also emphasize that other variables (such as investment incentives or X-inefficiencies), though absent from our setting, nonetheless play a significant role in determining the social desirability of infrastructure privatization.

We are therefore led to try to answer the following question: How can we improve on this situation? We shall show that, under certain circumstances, restricting the use of public funds by the infrastructure managers may lead to a Pareto-improvement.

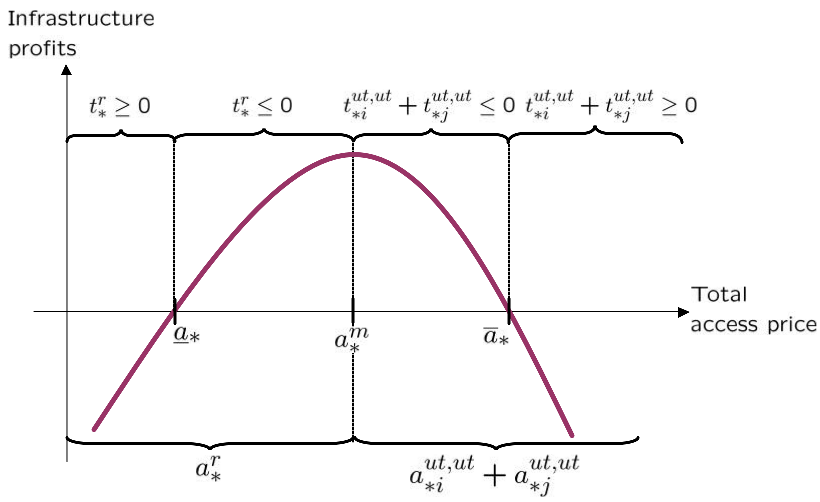

Figure 1: Access prices and financing systems under cooperation and non-cooperation (the symmetric case).

4.3 Equilibria with positive transfers only

In this section, we consider that infrastructure managers cannot tax the infrastructure: In terms of our notations, we impose that $t_i \geq 0$, $i = 1, 2$. We first determine the impact of such a restriction on the infrastructure managers' best-responses in access prices. Then, we determine the equilibria of the game in which infrastructure managers behave non-cooperatively and cannot tax the infrastructure.

In the sequel, we shall make a distinction according to whether the subsidy in country i is null or strictly positive: in the former (respectively, the latter) case, we say that IM_i adopts the no-subsidy financing system (respectively, the subsidy financing system). The choice of one or the other regulatory mode impacts the strategic interaction between access prices as we emphasize now.

Best-response functions with positive transfers only. Consider that IM_i adopts the no-subsidy system (i.e., $t_i = 0$). In that case, the optimal access price in country i is given by[22]

$$\frac{a_{*i}^{nt} - c_u}{p_*} = \frac{1 + \tilde{\lambda}_i - \theta_i}{1 + \tilde{\lambda}_i} \frac{1}{\eta_*}, \tag{8}$$

where $\tilde{\lambda}_i$ is the endogenous shadow cost of infrastructure financing (i.e., the Lagrange multiplier associated to the strict budget-balance constraint in that country): a change in country j's access price modifies the shadow cost of the budget constraint in country i because it affects its access revenue.[23] Denote by $SW_i(a_{*i}^{nt}, a_{*j})$ the corresponding welfare in country i. Using the formula stated in Equation (4), simple manipulations lead to

$$\frac{da_{*i}^{nt}}{da_{*j}} = \frac{(1 + \tilde{\lambda}_i - \theta_i)\delta_*}{(1 + \tilde{\lambda}_i) - (1 + \tilde{\lambda}_i - \theta_i)\delta_*} + \frac{\frac{\theta_i}{1+\tilde{\lambda}_i} \frac{q_*}{-q'_*}}{(1 + \tilde{\lambda}_i) - (1 + \tilde{\lambda}_i - \theta_i)\delta_*} \frac{d\tilde{\lambda}_i}{da_{*j}}. \tag{9}$$

With respect to Equation (5), the second-term in the right-hand side of Equation (9) highlights the impact of an increase in the access price set by IM_j on the (endogenous) cost of satisfying the budget balance of the infrastructure in country i without the help of public funds. We prove in Appendix A.1 that, in line with intuition, this term is positive and, therefore, tends to make access prices 'more strategic complements'.

In order to fully characterize the strategic interaction, differentiate the optimality condition for the access price in country i given by Equation (8) to obtain

$$\frac{da_{*i}^{nt}}{da_{*j}} = \frac{\theta_i}{(1 + \tilde{\lambda}_i)^2} \frac{q_*}{-q'_*} \frac{d\tilde{\lambda}_i}{da_{*j}} + \frac{1 + \tilde{\lambda}_i - \theta_i}{1 + \tilde{\lambda}_i} \left[1 + \frac{da_{*i}^{nt}}{da_{*j}} \right] \delta_*. \tag{10}$$

Then, Equation (10) allows us to rewrite Equation (9) as follows[24]

$$\frac{da_{*i}^{nt}}{da_{*j}} = \frac{1 + \tilde{\lambda}_i - \theta_i}{\theta_i},$$

which is always strictly positive.

Lemma 2. *If country i adopts the no-subsidy system, then access prices are strategic comple-*

[22] Superscript 'nt' stands for 'no transfer'.

[23] When $t_i = 0$, since only a fraction of the net surplus and of the infrastructure costs associated to the international services is internalized by IM_i, it might be possible that the budget constraint is not binding in that country, i.e., $\tilde{\lambda}_i = 0$; this depends both on the different parameters of the model (e.g., the infrastructure costs) and on the anticipated access price in country j. In order to focus on the most interesting situations, we shall assume that the infrastructure costs in each country are, loosely speaking, 'sufficiently large' to ensure that the budget constraint is indeed binding for any value of the access price set in the other country in the relevant range. Agrell and Pouyet (2003) provide an analysis of this possibility in a slightly different framework.

[24] Under the no-subsidy system, since there is only one final service, the access price is completely determined by the binding budget constraint. The strategic interaction could therefore be obtained directly by differentiating this condition. That would show that the strategic interaction under the no-subsidy system does not depend directly on θ_i. While reminding that the Lagrangean is endogenous, we keep our formulation in terms of the former, mainly for consistency reason but also because this approach will enable us to characterize in a simple way the best-response functions.

ments.

When country i chooses the no-subsidy system, it will react to a change in a_{*j} by modifying its own price in the same direction, whatever the characteristics of final demand. The use of the no-subsidy system forces access prices to be strategic complements, whatever the characteristics of the final demand.

In order to fully characterize the best-responses in access prices, it remains to determine the choice of a financing system in each country. In this simultaneous setting, since each infrastructure manager considers the access price set in the neighboring country as fixed, the choice of a mode of regulation simply depends on the comparison between the exogenous shadow cost of public funds λ_{pf} and the endogenous shadow cost of infrastructure financing under the no-subsidy system $\tilde{\lambda}_i(a_{*j})$: Given a_{*j}, if $\tilde{\lambda}_i(a_{*j}) \leq \lambda_{pf}$ (respectively, $\tilde{\lambda}_i(a_{*j}) \geq \lambda_{pf}$), then the infrastructure manager in country i chooses the no-subsidy system (respectively, the subsidy system). Moreover, as already noticed, the shadow cost of infrastructure financing under the no-subsidy system in country i is an increasing function of the access price set in country j (i.e., $\tilde{\lambda}_i'(a_{*j}) > 0$ for all a_{*j})[25]. Define $\tilde{a}_{*j}$ the access price in country j such that the shadow cost of infrastructure financing under the no-subsidy system in country i is equal to the shadow cost of public funds: $\tilde{\lambda}_i(\tilde{a}_{*j}) = \lambda_{pf}$.[26] The best-response in access price in country i when positive transfers only can be used is thus defined as follows[27]

$$a_{*i}^{pt}(a_{*j}) = \begin{cases} a_{*i}^{nt}(a_{*j}) & \text{if } a_{*j} \leq \tilde{a}_{*j} \quad (\Leftrightarrow \tilde{\lambda}_i(a_{*j}) \leq \lambda_{pf}), \\ a_{*i}^{ut}(a_{*j}) & \text{if } a_{*j} \geq \tilde{a}_{*j} \quad (\Leftrightarrow \tilde{\lambda}_i(a_{*j}) \geq \lambda_{pf}). \end{cases}$$

The intuition is rather clear: In the simultaneous game IM_i takes as given the access price set in country j, which plays the role of an 'additional infrastructure cost'. If that additional cost is large, the demand for international services is depreciated, leading IM_i to subsidize his network. By contrast, when a_{*j} is low, IM_i would like to tax his infrastructure since access revenues exceed infrastructure costs in that country; in that case, since transfers must be positive, IM_i chooses the no-subsidy financing system.

For future reference, we introduce the following notation: When country i adopts the no-subsidy system and country j strictly subsidizes its network, the Lagrange multiplier associated to the budget constraint in country i is denoted by $\tilde{\lambda}_i^{nt,ut}$; access prices[28] are denoted by $a_{*i}^{nt,ut}$ and $a_{*j}^{nt,ut}$; the final price is denoted by $p_*^{nt,ut}$. Finally, welfare in country j is $SW_j^{nt,ut} = \theta_j S_*(q_*(p_*^{nt,ut})) + (1+\lambda_{pf})[(a_{*j}^{nt,ut} - c_u)q_*(p_*^{nt,ut}) - k_j]$ and welfare in country i is $SW_i^{nt,ut} = \theta_i S_*(q_*(p_*^{nt,ut}))$. A similar notation carries over to the other cases.

We can now determine the equilibria of our game. We mainly deal with symmetric settings

[25] See Appendix A.1.

[26] We assume that $\tilde{a}_{*j} \geq 0$ always exists; otherwise, this would imply that IM_i would never use the no-subsidy financing system and the analysis would be immediate.

[27] Superscript '*pt*' stands for 'positive transfers only'.

[28] They solve the system formed by Equation (3) for country j and Equation (8) for country i.

in order to illustrate our results by means of simple graphical representations. In a first step, we consider that the infrastructure fixed cost in country i is such that $k_i > \underline{k}_i^{ut}$, for $i = 1, 2$.

Strategic complements: $0 \leq \delta_* < \frac{1+\lambda_{pf}}{1+2\lambda_{pf}}$. The best-response functions can be drawn as shown in Figure 2.[29] We obtain multiple equilibria; the underlying intuition can be explained

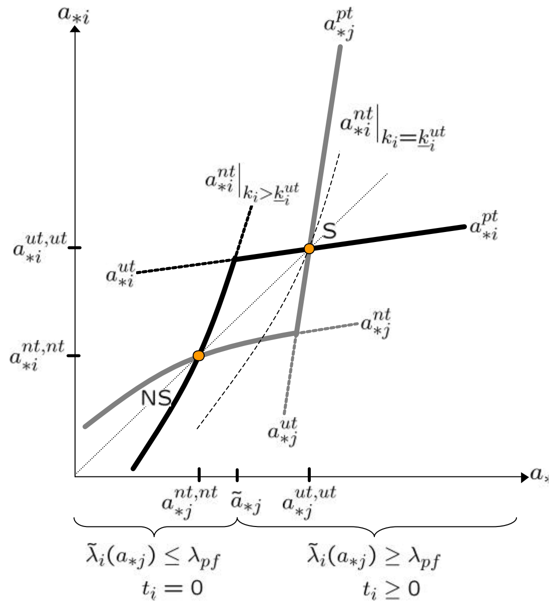

Figure 2: Equilibria in the symmetric case with positive transfers only and $0 \leq \delta_* < \frac{1+\lambda_{pf}}{1+2\lambda_{pf}}$.

as follows. In order to choose a financing system, IM_i must anticipate the level of the access charge set in country j. If this charge were low, IM_i would face a (relatively) large residual demand and could thus afford adopting the no-subsidy system. In a symmetric setting, there exists an equilibrium in which both infrastructure managers do not subsidize their networks. This equilibrium is labeled by NS in Figure 2.

By contrast, if IM_i anticipates that IM_j will set a high access price, then the distortion needed to finance the infrastructure under strict budget balance becomes large, and IM_i will adopt the subsidy system. This equilibrium is labeled by S in Figure 2.

Strategic substitutes: $\delta_* \leq 0$. When δ_* is negative, we obtain again multiple equilibria, as shown in Figure 3. The underlying intuition is similar to the one in the strategic complements case.

Discussion. Let us first highlight the role of the assumptions we made on the infrastructure fixed costs. In Figure 2, the dashed curve corresponds to the access price set in country i under

[29] In Appendix A.1, we provide additional results on the shape of the best-response functions.

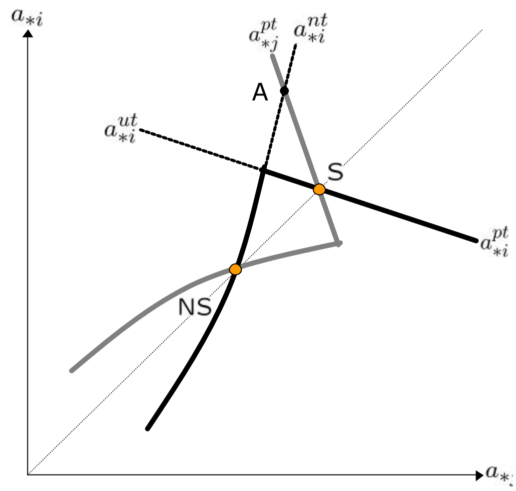

Figure 3: Equilibria in the symmetric case with positive transfers only and $\delta_* \leq 0$.

the no-subsidy system when $k_i = \underline{k}_i^{ut}$: given $a_{*j}^{ut,ut}$, IM_i is exactly indifferent between the two modes of regulation. Remind that, for a fixed a_{*j}, the higher k_i, the larger a_{*i}^{nt}: a_{*i}^{nt} moves toward the north-west when k_i increases. Therefore, assuming that $k_i > \underline{k}_i^{ut}$, $i = 1, 2$, ensures that there exists a stable equilibrium in which infrastructure managers subsidize the networks. Similarly, when k_i is sufficiently large, then only the S-equilibrium emerges. By contrast, for values of k_i sufficiently smaller than $\underline{k}_i^{ut}$ no equilibrium exists.[30] Finally, consider a setting where k_j is larger than $\underline{k}_j^{ut}$ but k_i is slightly smaller than $\underline{k}_i^{ut}$. In that configuration, multiple equilibria can emerge; interestingly, there exists an asymmetric equilibrium where the 'high cost' country j subsidizes its network while the 'low cost' country i chooses the no-subsidy system.[31]

Does a mandatory requirement of the strict budget balance financing system improve welfare? To answer this interrogation, we must compare welfare in the NS- and S-equilibrium when

[30]Interestingly, that the S-equilibrium is unique only requires that the infrastructure fixed cost in one country be sufficiently large. In the same vein, that the game between non-cooperative infrastructure managers has no equilibrium only requires that the infrastructure fixed cost in one country be sufficiently small.

[31]It is instructive, although less realistic, to briefly consider the situation in which infrastructure managers are prevented from subsidizing their network: in terms of our notations, the constraint imposed on the transfers becomes now $t_i \leq 0$, $i = 1, 2$. We can adapt the previous analysis to determine the best-response function in access price in country i in that configuration, which is now characterized as follows

$$a_{*i}(a_{*j}) = \begin{cases} a_{*i}^{nt}(a_{*j}) & \text{if } a_{*j} \geq \tilde{a}_{*j}, \\ a_{*i}^{ut}(a_{*j}) & \text{if } a_{*j} \leq \tilde{a}_{*j}. \end{cases}$$

In a sense, this case mirrors the situation in which infrastructure managers can only use positive transfers: simple manipulations show that to ensure the existence of an equilibrium, infrastructure costs have to be sufficiently low; typically, two equilibria exist, one in which each country taxes its infrastructure, one in which each country adopts the no-subsidy financing system; the equilibrium with taxes, which arises when both infrastructure managers anticipate a low access price in the other country, Pareto-dominates the equilibrium with no-subsidy. This highlights that preventing countries from using public funds might not be socially desirable when countries tax their networks.

they co-exist. To this purpose, we first devote some time studying some properties of the NS-equilibrium, which will also be useful later on; then, we analyze the welfare implications of the different equilibria.

4.4 Properties of the No-Subsidy equilibrium with positive transfers only

Strategic role of network (fixed) costs. Starting from the NS-equilibrium, let us analyze the consequences of an increase in country i's fixed cost. For a given a_{*j}, the increase in k_i tightens the strict budget constraint to be satisfied by IM_i: Graphically, the a_{*i}^{nt}-curve moves north-west. This implies that equilibrium access prices will be *smaller* in both countries.

Lemma 3. *In the NS-equilibrium the access price in country i is decreasing with the infrastructure fixed costs of both countries: $\frac{d}{dk_i}a_{*i}^{nt,nt} < 0$ and $\frac{d}{dk_j}a_{*i}^{nt,nt} < 0$.*

Proof. See Appendix A.2. □

This result highlights the role of network costs as a commitment device that can be used to deter the rival from raising his access charge.[32] From Lemma 3, it can be immediately noticed that at the no-subsidy equilibrium there is a scope for the use of infrastructure investment as a strategic device.[33] Moreover, the infrastructure managers' cost reducing behavior could be adversely affected. Since these two dimensions are absent from our analysis, one should be careful in translating our results directly into policy guidelines.

The NS-equilibrium is unstable. Indeed, simple manipulations yields

$$\left|\frac{da_{*i}^{nt}}{da_{*j}}\right| > \left|\frac{da_{*j}^{nt}}{da_{*i}}\right|^{-1}.$$

The impact of supra-national subsidy policies. Suppose that a supra-national authority, say the European Commission, decides to implement a policy aimed at developing international exchanges. In order to promote the international traffic, this policy should try to minimize the distortions on access pricing due to non cooperation between national infrastructure managers. Thus, each country should be provided with the correct incentives to internalize the externalities it creates. Since access prices are excessively high, at a first glance this goal could be achieved by subsidizing the infrastructures in both countries. However, the impact of such a policy would strongly depend both on the type of equilibrium that emerges in the simultaneous game and on the characteristics of the final demand. To see this, one can refer to our representation of the different scenarios in the above figures, considering that a per-unit subsidy to national networks translates into lower infrastructure marginal costs, while a lump-sum subsidy would yield lower fixed costs.

Consider first the no-subsidy equilibrium. If national networks are subsidized, then for a given access price in country j, the strict budget balance constraint in country i is relaxed: a_{*i}^{nt}

[32] We remind that the existence of the NS-equilibrium requires assuming an upper bound on infrastructure fixed costs.

[33] Agrell and Pouyet (2003) also argue that the precise way such an investment is financed matters.

will move downwards, leading, at equilibrium, to higher access prices! Thus, when the no-subsidy system is adopted in both countries, both lump-sum and per-unit supra-national subsidies would have adverse effects on final prices.

By contrast, consider now the subsidy equilibrium. It is immediate to check that a subsidy in both countries leads to lower access prices.

Therefore, policies aimed at developing international services through subsidies assigned to national networks might turn out to have a negative impact on welfare depending both on the financing system chosen by the two countries and the characteristics of final demand. Then, such policies should be strictly contingent on the modes of regulation implemented by national infrastructure managers.

4.5 Welfare analysis

When positive transfers only can be used, the total access price $a_{*i} + a_{*j} + c_d$ is the lowest when both countries adopt the no-subsidy system. This is immediate from the previous graphical representations and is formally shown in Appendix A.3. Intuitively, the no-subsidy system entails strategic complementarity and thus creates the conditions for access charges to remain low at equilibrium. This softens the upward distortions due to the constituency and double marginalization effects.

We also prove in Appendix A.3 that when both S- and NS-equilibria exist access prices are always excessively distorted since the final price in the NS-equilibrium is still larger than the infrastructure monopoly price. We summarize these results in the following proposition.

Proposition 1. *Consider that infrastructure costs are large (i.e., $k_i > \underline{k}_i^{ut}$, $i = 1, 2$). The (unstable) NS-equilibrium Pareto-dominates the (stable) S-equilibrium.*

Proof. See Appendix A.3. □

In the simultaneous game, infrastructure managers would unambiguously profit from choosing the no-subsidy system; however, since the NS-equilibrium is unstable, small deviations from the corresponding access prices would provide an incentive to subsidize, leading to a Pareto-dominated outcome: therefore, there exists a strong tension between those two situations. In the next section, we shall determine whether the possibility to commit to the choice of financing system before the determination of access price allows the network managers to overcome this tension.

5 Strategic choice of a financing system

The timing we have considered so far, in which each infrastructure manager chooses simultaneously a financing system and an access price in his country, provides a good insight on the main features of the interaction between national regulatory decisions. However, this timing might not adequately reflect the real decision-making process since the choice to finance the network typically emanates from the political principal of the infrastructure manager; moreover, the adoption of a regulatory mode commits in the long term the decisions undertaken by the infrastructure manager (e.g., the level of access prices). Then, it becomes interesting to analyze a setting where subsidies are decided prior the access prices. In this section, we shall focus on the strategic use of the financing system.[34] The game we consider is the following:[35]

1. The infrastructure managers independently choose a financing system.
2. The infrastructure managers non-cooperatively set an access charge in their countries.

The question we ask can therefore be stated as follows: Will the infrastructure managers succeed in coordinating on the socially preferable outcome? To restrict the scope of the analysis, we shall focus only on the case where $k_i > \underline{k}_i^{ut}$, $i = 1, 2$. Moreover, we also assume that δ_* is constant.

We study the countries' best-responses proceeding by backward induction. For given financing systems, the access price subgame can be immediately inferred from the analysis undertaken in Section 4 and will not be repeated. Then, it remains to examine the infrastructure managers' incentives to adopt the no-subsidy or the subsidy financing system. This decision now implies two, sometimes countervailing effects.

First, country i's choice of a financing system has a direct influence on its access charge a_{*i}. Second, this choice also induces a change in the access charge set by IM_j, and this (indirectly) affects country i's consumers' surplus and access revenue. The sign and magnitude of the latter effect are determined by the type of strategic interaction, which in turn depends on the regulatory mode.

When choosing a financing system, country i considers as given the *financing system* adopted in country j, but knows that the access charge in that country will depend on its own first-stage decision. Differently from the simultaneous game, the choice of a financing system cannot directly derive from the comparison between the endogenous Lagrange multiplier and the exogenous shadow cost of public funds, since the former will eventually result from country j's first-period choice.[36]

5.1 Choice of a financing system in country i when country j adopts the no-subsidy system

From the viewpoint of country i, if IM_j chooses the no-subsidy system, he is in fact committing to react to a change in a_{*i} by modifying his own price in the same direction, whatever the characteristics of the final demand. In our previous analysis, moreover, we observed that the

[34] Since this is somewhat orthogonal to our focus, we assume no conflict between the objectives of the infrastructure manager and those of his political principal.

[35] 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 $T_i = +\infty$.

[36] In other words, given the financing mode chosen by its opponent, country i could prefer to adopt the no-subsidy rather than the subsidy system even though $\tilde{\lambda}_i > \lambda_{pf}$, for example because it anticipates that in the former case the access charge in country j will be lower and this reduction will increase its own net consumers' surplus.

simultaneous adoption of strict budget balance by both countries implies that both access prices will decrease. Therefore, choosing the no-subsidy system is appealing for IM_i since this will raise net surplus and infrastructure revenue.

Proposition 2. *When country j adopts the no-subsidy financing system, country i adopts the no-subsidy system.*

Proof. See Appendix A.4. □

A simple illustration of this proposition can be obtained by looking at Figure 3. When country i commits in the first stage to a strict budget balance system, its second-stage best-response curve is given by a_{*i}^{nt}. If country j adopts the no-subsidy system instead of the subsidy one, access prices will change from A to NS and will be lower in both countries.

A consequence of Proposition 2 is that no-subsidy in both countries is always an equilibrium of the sequential game. Whether this is the unique equilibrium depends on country i's incentive to choose the no-subsidy system when country j subsidizes its own network.

5.2 Choice of a financing system in country i when country j adopts the subsidy system

As we have shown, when country j adopts the subsidy system, the slope of its reaction function is determined by the characteristics of final demand. As a consequence, our results depend on the sign and magnitude of δ_*.

When access prices are strategic complements, we obtain the following proposition.[37]

Proposition 3. *Assume that δ_* is positive and small (i.e., $\delta_* \in [0, \underline{\delta}_{*i}^{+})$). Then, when country j adopts the subsidy system, country i adopts the subsidy system.*

Proof. See Appendix A.5. □

In that case, country j's reaction following IM_i's deviation from the subsidy to the no-subsidy financing system does not favor the adoption of the no-subsidy system. Graphically, consider Figure 2. Starting from S, if IM_i deviates to the no-subsidy system access prices will increase in both countries. The direct and indirect effects both lead to the adoption of the subsidy system.

In the case of strategic substitutes, instead, the direct and the strategic effects are conflicting: When IM_i deviates from the subsidy to the no-subsidy system, a_{*i} increases but this triggers a decrease in a_{*j}. For a given level of the infrastructure deficit in country i, the stronger the strategic effect (i.e., the smaller δ_*), the larger the incentive to choose the no-subsidy system. However, as the infrastructure deficit grows, the magnitude of the direct effect increases, leading to the adoption of the subsidy system.

Proposition 4. *Assume that δ_* is strictly negative.*

[37] In the following propositions we refer to threshold values of δ_* that are fully specified in the Appendix.

- *If δ_* is sufficiently small (i.e., $\delta_* < \underline{\delta}^-_{*i}$), then when country j adopts the subsidy system country i always chooses the no-subsidy system.*
- *If δ_* is sufficiently large (i.e., $\delta_* > \underline{\delta}^-_{*i}$), then when country j adopts the subsidy system, there exists $\tilde{k}_i$ such that:*
  - *For low infrastructure costs (i.e., $k_i < \tilde{k}_i$), country i adopts the no-subsidy system;*
  - *For high infrastructure costs (i.e., $k_i \geq \tilde{k}_i$), country i adopts the subsidy system.*

Proof. See Appendix A.5. □

Again, an intuition can be obtained from Figure 3. When IM_j chooses the subsidy system and IM_i moves from the subsidy to the no-subsidy system, then access prices move from S to A. In this case, IM_i adopts a priori (i.e., for a given access price set in country j) a sub-optimal mode of regulation, increasing the shadow cost of infrastructure financing and his access price;[38] however, IM_j is led to reduce his own access charge. The incentive of IM_i to choose the no-subsidy system is built on two conflicting forces whose relative magnitude depends on the level of infrastructure cost in country i (which, roughly speaking, represents how much IM_i loses by increasing his access price) and on the strength of the strategic interaction between access prices (which determines the gain for IM_i from free-riding on the decrease in a_{*j}).

While non-internalized externalities between infrastructure managers were the source of a coordination problem in the simultaneous game, they may now create potentially socially harmful free-riding incentives when network managers can commit to the regulatory mode before setting their access prices.

5.3 Equilibria of the sequential game

Since we have determined the best-reply functions at the first stage of the sequential game, it simply remains to determine the equilibria of the overall game. We obtain the following Propositions.[39]

Proposition 5. *Assume that δ_* is negative and sufficiently small (i.e., $\delta_* < \min\{\underline{\delta}^-_{*i}, \underline{\delta}^-_{*j}\}$). Then, both infrastructure managers adopt the no-subsidy system.*

Proof. See Appendix A.6. □

In order to compare the results of the sequential game with those of the simultaneous one, let us focus on symmetric settings. Under (strong) strategic substitutability, due to the strength of the indirect effect, the two countries succeed in coordinating on the NS equilibrium: Each infrastructure manager has a strong incentive to adopt the no-subsidy system in order to free-ride on the access price set in the other country. However, this free-riding incentive, which is potentially harmful for total social welfare, leads to the second-best outcome.

[38] In A, the Lagrange multiplier associated to the strict-budget constraint in country i is strictly greater than the shadow cost of public funds.

[39] We focus on pure strategy equilibria.

The remaining cases are gathered in the next proposition.

Proposition 6.

- *Assume that* δ_* *is positive and small (i.e.,* $0 < \delta_* < \min\{\underline{\delta}^+_{*i}, \underline{\delta}^+_{*j}\}$*). Then, two equilibria can arise: Either both infrastructure managers choose the subsidy system, or they both choose the no-subsidy system.*

- *Assume that* δ_* *is negative and large (i.e.,* $0 > \delta_* > \max\{\underline{\delta}^-_{*i}, \underline{\delta}^-_{*j}\}$*). Then, the equilibrium choices of financing system depend on the level of the infrastructure deficit in the two countries:*

    1. *If the infrastructure deficit is small in both countries (i.e.* $k_i < \tilde{k}_i$ *for* $i = 1, 2$*), then both infrastructure managers choose the no-subsidy system.*
    2. *If the infrastructure deficit is small in country* i *and large in country* j *(i.e.* $k_i < \tilde{k}_i$ *and* $k_j > \tilde{k}_j$*), then both infrastructure managers adopt the no-subsidy system.*
    3. *If the infrastructure deficit is large in both countries (i.e.* $k_i > \tilde{k}_i$ *for* $i = 1, 2$*), then two equilibria can emerge: Either both infrastructure managers choose the no-subsidy system, or they both choose the subsidy system.*

Proof. See Appendix A.6. □

Under strategic complementarity, two equilibria emerge where both countries choose the same system. With reference to Figure 2, we note that the outcome of the sequential game is unchanged with respect to the simultaneous one: The opportunity to commit to a financing system offers no significant advantages, since the reaction expected from the neighboring country is not strong enough to lead the two infrastructure managers to a single equilibrium.

Under weak strategic substitutability, the equilibrium outcomes depend on the relative magnitude of the direct and indirect effects. A low infrastructure deficit reduces the impact of the direct effect and favors the adoption of the no-subsidy system. Thus, when the deficit in (at least) one country is low, the NS-equilibrium emerges. However, when the infrastructure deficit is large in both countries the balance between the direct and indirect effects becomes uncertain and we obtain multiple equilibria where both countries adopt the same regulatory mode.

6 Conclusions

As a conclusion, let us briefly consider the case in which services are purely internal to each country. Then, the decision problem facing by an infrastructure manager does not depend on the access price set in the other country and the setting is analogous to the perfect cooperation situation. With purely domestic services, each infrastructure manager perfectly internalizes all the effects associated to the choice of the mode of regulation and access price. Therefore, social welfare does not suffer from non-coordination between countries.

By contrast, as shown by our analysis, when downstream services are purely international it may become preferable to prevent countries from subsidizing since this enables to soften the negative externalities on the access prices for international services.

We are then tempted to draw the following scenario. With the development of international services and the decrease of infrastructure deficits, countries should evolve towards a system where access pricing and the infrastructure financing system are mainly 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 subsidize the networks; when the international demand is sufficiently stronger than the domestic one, it could become preferable to encourage the adoption of a usage-based pricing system. Simultaneously, a thorough study of the countries' incentives to choose one system or the other is needed, keeping into account the previously mentioned issues concerning investment choices. In order to reach reliable policy conclusions, 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.

Our analysis highlights the importance of the role of a supra-national authority ensuring coordination between both the access pricing decisions and the regulatory choices in different countries, in order to minimize distortions on downstream services. However, we also emphasize that the welfare effects of policy measures aimed at favoring international services strictly depend on the financing system adopted in each country as well as the features of final demand.

We have also 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, in the case of railroads it has been argued that the development of international traffic also suffers from a poor quality of interconnection. This interoperability problem appears to be critical for the development of intra-European networks.

Similarly, we have just alluded to the strategic role of investment in this non-cooperative setting. For instance, the decisions to create or to close railway lines should be incorporated in our framework: The fixed cost of maintaining an only-freight line is low due to less restrictive safety standards. This choice should not be neutral with respect to the interaction between infrastructure managers.

A Appendix

A.1 Properties of the best-response functions

Lemma 4. *The following properties hold:*

- $$Sign\left[\frac{d^2 a_{*i}^{nt}}{da_{*j}^2}\right] = Sign\left[\frac{d\tilde{\lambda}_i}{da_{*j}}\right] = Sign\left[1-\delta_*\right], \qquad (\mathcal{C}_1)$$
- $$\frac{da_{*i}^{ut}}{da_{*j}} < \left.\frac{da_{*i}^{nt}}{da_{*j}}\right|_{\tilde{\lambda}_i=\lambda_{pf}} \Leftrightarrow \delta_* < 1. \qquad (\mathcal{C}_2)$$

Proof. $(\mathcal{C}_2)$ is immediate.

Totally differentiating Equation (3) with respect to a_{*i}^{nt} and a_{*j}, we obtain

$$da_{*i}^{nt} = \frac{\theta_i}{(1+\tilde{\lambda}_i)^2}\frac{q_*}{-q'_*}d\tilde{\lambda}_i + \frac{1+\tilde{\lambda}_i-\theta_i}{1+\tilde{\lambda}_i}\delta_*\left(1+\frac{da_{*i}^{nt}}{da_{*j}}\right)da_{*j},$$

which can be rearranged as follows

$$\frac{1+\tilde{\lambda}_i-\theta_i}{\theta_i}(1-\delta_*) = \frac{\theta_i}{(1+\tilde{\lambda}_i)^2}\frac{q_*}{-q'_*}\frac{d\tilde{\lambda}_i}{da_{*j}}$$

This concludes the proof of $(\mathcal{C}_1)$ and implies that $\tilde{\lambda}_i$ is strictly increasing in a_{*j} under Assumption 1. $\square$

A.2 Proof of Lemma 3

Let us focus on access pricing in country i under the no-subsidy system. Differentiating the budget constraint in country j, we get

$$\frac{da_{*j}^{nt,nt}}{dk_i} = \frac{1+\tilde{\lambda}_j^{nt,nt}-\theta_j}{\theta_j}\frac{da_{*i}^{nt,nt}}{dk_i}. \tag{A.1}$$

Then, differentiating the budget-balance condition in country i, we obtain

$$da_{*i}^{nt,nt}\left[q_* + (a_{*i}^{nt,nt}-c_u)q'_*\right] + da_{*j}^{nt,nt}(a_{*i}^{nt,nt}-c_u)q'_* = dk_i,$$

which can be rearranged as follows (using the optimality condition in country i)

$$\frac{da_{*i}^{nt,nt}}{dk_i} = \frac{1}{q_*}\frac{(1+\tilde{\lambda}_i^{nt,nt})\theta_j}{\theta_i\theta_j - (1+\tilde{\lambda}_j^{nt,nt}-\theta_j)(1+\tilde{\lambda}_i^{nt,nt}-\theta_i)} < 0 \quad \forall\tilde{\lambda}_i^{nt,nt}, \tilde{\lambda}_j^{nt,nt} > 0.$$

Then, using Equation $(A.1)$ we obtain that $\frac{da_{*i}^{nt,nt}}{dk_j} < 0 \ \forall\tilde{\lambda}_i^{nt,nt}, \tilde{\lambda}_j^{nt,nt} > 0$.

A.3 Proof of Proposition 1

Consider first the function $\mathcal{A}(p_*) \equiv \frac{p_*-c_*}{p_*}\eta_*$. We have $\mathcal{A}'(p_*) \propto 1 - \frac{p_*-c_*}{p_*}\eta_*\delta_* > 0$ under Assumption 1.

Given Lemma 4 and the assumptions on the infrastructure fixed costs, we have $\tilde{\lambda}_i^{nt,nt} \leq \lambda_{pf}$, $i = 1, 2$. Now, since $\frac{1+\tilde{\lambda}_i^{nt,nt}-\theta_i}{1+\tilde{\lambda}_i^{nt,nt}} + \frac{1+\tilde{\lambda}_j^{nt,nt}-\theta_j}{1+\tilde{\lambda}_j^{nt,nt}} \leq \frac{1+2\lambda_{pf}}{1+\lambda_{pf}}$, we obtain $p_*^{nt,nt} \leq p_*^{ut,ut}$.

Notice now that $\frac{1+\tilde{\lambda}_i^{nt,nt}-\theta_i}{1+\tilde{\lambda}_i^{nt,nt}} + \frac{1+\tilde{\lambda}_j^{nt,nt}-\theta_j}{1+\tilde{\lambda}_j^{nt,nt}} > 1$, for all $\tilde{\lambda}_1, \tilde{\lambda}_2 > 0$. This implies that the final price when both infrastructure managers choose the no-subsidy system is larger than the infrastructure monopoly final price p_*^m defined in Section 4.

A.4 Proof of Proposition 2

First, we define $\underline{k}_i^{nt}$ as the value of country i's infrastructure fixed cost such that when country i adopts the subsidy system and country j the no-subsidy one, the subsidy in the former country is equal to 0. $\underline{k}_i^{nt}$ depends on the endogenous shadow cost of the budget constraint in country j, $\tilde{\lambda}_j^{ut,nt}$.

We define $\Delta SW_i^{nt} \equiv SW_i^{ut,nt} - SW_i^{nt,nt}$ the welfare difference in country i between the subsidy and the no-subsidy system when IM_j has chosen the no-subsidy system. We have $\Delta SW_i^{nt}|_{k_i=\underline{k}_i^{nt}} = 0$. We have $\frac{dSW_i^{ut,nt}}{dk_i} = -(1+\lambda_{pf})$ and $\frac{dSW_i^{nt,nt}}{dk_i} = -\theta_i q_*(1+\frac{da_{*j}^{nt,nt}}{da_{*i}^{nt,nt}})\frac{da_{*i}^{nt,nt}}{dk_i}$. Since $1+\frac{da_{*j}^{nt,nt}}{da_{*i}^{nt,nt}} > 0$ and $\frac{da_{*i}^{nt,nt}}{dk_i} < 0$ (from Lemma 3), we immediately obtain that $\frac{d\Delta SW_i^{nt}}{dk_i}$ is *always* negative. This concludes the proof of Proposition 2.

A.5 Proof of Propositions 3 and 4

Let us denote by $\Delta SW_i^{ut} \equiv SW_i^{ut,ut} - SW_i^{nt,ut}$ the gain for country i related to the deviation from the subsidy to the no-subsidy system, given that IM_j chooses the subsidy system. Then, $\Delta SW_i^{ut}|_{k_i=\underline{k}_i^{ut}} = 0$.

We have $\frac{dSW_i^{ut,ut}}{dk_i} = -(1+\lambda_{pf})$ and $\frac{dSW_i^{nt,ut}}{dk_i} = -\theta_i q_*(a_{*i}^{nt,ut}, a_{*j}^{nt,ut})\left(1+\frac{da_{*j}^{nt,ut}}{da_{*i}^{nt,ut}}\right)\frac{da_{*i}^{nt,ut}}{dk_i}$, where the strategic interaction between access prices is now given by Equation (5). The strict budget balance constraint in country i when country j adopts the subsidy-system is

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

Totally differentiating $(BB_i^{nt,ut})$ yields

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

Then, simple manipulations lead to

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

From Equation $(A.2)$, we obtain

$$\lim_{k_i \to \underline{k}_i^{ut}} \frac{d\Delta SW_i^{ut}}{dk_i^{ut}} = \frac{(1+\lambda_{pf})(1+\lambda_{pf}-\theta_j)\delta_*}{\theta_i - (1+\lambda_{pf}-\theta_j)\delta_*}. \qquad (A.3)$$

For $0 < \delta_* < \frac{\theta_i}{1+\lambda_{pf}-\theta_j}$, the right-hand side of Equation $(A.3)$ is positive. Simple computations show that

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

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

$$\text{Sign}\left[\frac{d\tilde{\lambda}_i^{nt,ut}}{dk_i}\right] = \text{Sign}\left[\frac{da_{*i}^{nt,ut}}{d\tilde{\lambda}_i^{nt,ut}}\right] \times \text{Sign}\left[\frac{da_{*i}^{nt,ut}}{dk_i}\right] = \text{Sign}\left[1 - \omega_*^s \delta_*\right] \times \text{Sign}\left[1 - \omega_*^s\right], \qquad (A.4)$$

where $\omega_*^s = \frac{1+\tilde{\lambda}_i^{nt,ut} - \theta_i}{1+\tilde{\lambda}_i^{nt,ut}} \frac{1+\lambda_{pf}}{(1+\lambda_{pf}) - (1+\lambda_{pf} - \theta_j)\delta_*}$.

Define $\underline{\delta}_{*i}^{+}$ as the highest positive value of δ_* such that $1-\omega_*^s$, $1-\omega_*^s\delta_*$ and $\theta_i - (1+\lambda_{pf} - \theta_j)\delta_*$ are simultaneously positive.[40] Then, for $0 < \delta_* < \underline{\delta}_{*i}^{+}$, ΔSW_i^{ut} is strictly convex in k_i and we obtain Proposition 3.[41]

If $\delta_* < 0$, the first and second term in the right-hand side of Equation $(A.4)$ are strictly positive. But we now obtain $\lim_{k_i \to \underline{k}_i^{ut}} \frac{d\Delta SW_i^{ut}}{dk_i} < 0$. Given that the welfare difference ΔSW_i^{ut} is still strictly convex, two cases have to be distinguished depending on whether the sign of its derivative eventually becomes positive or not; this is equivalent to study the sign of

$$\lim_{k_i \to +\infty} \frac{d\Delta SW_i^{ut}}{dk_i^{ut}} = (1+\lambda_{pf}) \frac{\theta_i + (1+\lambda_{pf} - \theta_j)\delta_*}{-\delta_*(1+\lambda_{pf} - \theta_j)}.$$

Define $\underline{\delta}_{*i}^{-} \equiv \frac{-\theta_i}{1+\lambda_{pf} - \theta_j}$. Then, when $\delta_* < \underline{\delta}_{*i}^{-}$ the welfare difference will always be negative and country i will always choose the no-subsidy system. On the other hand, if $0 > \delta_* > \underline{\delta}_{*i}^{-}$ the derivative of the welfare difference will eventually become positive and there will exist a threshold value of the fixed cost such that the welfare difference above that cost will be positive (i.e., country i will adopt the subsidy system). This concludes the proof of Proposition 4.

A.6 Proof of Propositions 5 and 6

When $\delta_* < \min\{\underline{\delta}_{*i}^{-}, \underline{\delta}_{*j}^{-}\}$, each infrastructure manager has a dominant strategy and we do not need to compare $\underline{k}_i^{ut}$ and $\underline{k}_i^{nt}$.

Similarly, when $0 < \delta_* < \min\{\underline{\delta}_{*i}^{+}, \underline{\delta}_{*j}^{+}\}$, 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 $\underline{k}_i^{ut}$ and $\underline{k}_i^{nt}$.

When $\max\{\underline{\delta}_{*i}^{-}, \underline{\delta}_{*j}^{-}\} < \delta_* < 0$, using Equation $(A.4)$, we have $\frac{d\tilde{\lambda}_j^{ut,nt}}{dk_j} > 0$. Therefore, $\tilde{\lambda}_j^{ut,nt} \geq \lambda_{pf}$ and $a_{*i}^{nt,ut} \geq a_{*i}^{ut,ut}$ for all $k_j \geq \underline{k}_j^{ut}$. This implies that $\underline{k}_i^{nt} \leq \underline{k}_i^{ut}$. Since we focus only on cases where, under a subsidy system, the transfer t_i is positive, we restrict attention to cases where $k_i \geq \underline{k}_i^{ut}$. Then, it suffices to use Propositions 1 and 5 to determine the equilibrium.

[40] $\theta_i - (1+\lambda_{pf} - \theta_j)\delta_* \geq 0 \Leftrightarrow \delta_* \leq \frac{\theta_i}{1+\lambda_{pf} - \theta_j}$. Notice that $\frac{\theta_i}{1+\lambda_{pf}-\theta_j} < 1$; therefore, $\underline{\delta}_{*i}^{+} < 1$; since we consider values of δ_* such that $\delta_* < \underline{\delta}_{*i}^{+}$, $1-\omega_*^s \geq 0$ implies $1-\omega_*^s\delta_* \geq 0$. Then $\underline{\delta}_{*i}^{+} \equiv \min\{\frac{\theta_i(1+\lambda_{pf})}{(1+\tilde{\lambda}_i^{nt,ut})(1+\lambda_{pf}-\theta_j)}, \frac{\theta_i}{1+\lambda_{pf}-\theta_j}\}$. When $\delta_* < \underline{\delta}_{*i}^{+}$, we have $\frac{d\tilde{\lambda}_i^{nt,ut}}{dk_i} > 0$ and therefore $\tilde{\lambda}_i^{nt,ut} \geq \lambda_{pf}$ for $k_i \geq \underline{k}_i^{ut}$. Consequently, $\underline{\delta}_{*i}^{+} = \frac{\theta_i(1+\lambda_{pf})}{(1+\tilde{\lambda}_i^{nt,ut})(1+\lambda_{pf}-\theta_j)} > 0 \; \forall \tilde{\lambda}_i^{nt,ut} \geq 0$.

[41] For $\delta_* \in (\underline{\delta}_{*i}^{+}, \overline{\delta}_{*i}^{+})$ (provided that this interval is non-empty), the choice of a financing system in country i cannot be characterized in a simple way.

B References

Agrell, P. J. and J. Pouyet, 2003, "Regulatory Competition through Network Interaction", *mimeo.*

Armstrong, M., 2001, "The Theory of Access Pricing and Interconnection", forthcoming in M. Cave, S. Majumdar, I. Vogelsang (eds), *Handbook of Telecommunications Economics*,North-Holland.

Bassanini, A. and J. Pouyet, 2003, "Strategic Choice of Financing Systems in Regulated and Interconnected Industries", *Working Paper* CERAS-ENPC (available at `http://www.enpc.fr/ceras/pouyet`).

Boiteux, M., 1956, "Sur la Gestion des Monopoles Publics Astreints à l'Equilibre Budgétaire", *Econometrica*, 24: 22-40. Published in English as "On the Management of Public Monopolies Subject to Budgetary Constraints", *Journal of Economic Theory*, 1971, 3: 219-40.

Brander, J.A. and B.J. Spencer, 1985, "Export Subsidies and International Market Share Rivalry", *Journal of International Economics*, 18, 83-100.

Chang, M.C., 1996, "Ramsey Pricing in a Hierarchical Structure with an Application to Network-Access Pricing", *Journal of Economics*, 64: 281-314.

Dixit, A., 1986, "Comparative Statics for Oligopoly", *Rand Journal of Economics*, vol. 27(1): 107-122.

Directive 2001/14/EC of the European Parliament and of the Council of 26 February 2001 on the allocation of railway infrastructure capacity and the levying of charges for the use of railway infrastructure and safety certification.

Hendricks, K., M. Piccione and G. Tan, 1997, "Entry and Exit in Hub-spoke Networks", *Rand Journal of Economics*, 28(2): 291-303.

Ivaldi, M. and P. Gagnepain, 1999, "Incentive Regulatory Policies: The Case of Public Transit Systems in France", *Working Paper* IDEI.

Laffont, J.-J. and J. Tirole, 1993, *A theory of incentives in procurement and regulation*, The MIT Press, Cambridge, Massachusetts.

Laffont, J.-J. and J. Tirole, 2000, *Competition in telecommunications*, The MIT Press, Cambridge, Massachusetts.

NERA, 1998, "An Examination of Rail Infrastructure Charges", Final Report for the European Commission, London.

Ramsey, F., 1927, "A Contribution to the Theory of Taxation", *Economic Journal*, 47.

Wilson, J., 1999, "Theories of Tax Competition", *National Tax Journal*, 52: 269-304.