Access pricing and regulation in international rail transport*

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Abstract

We study a model of non-cooperative interaction between two infrastructure managers (IMs) for international rail transport. We compare equilibrium access charges when the IMs are unregulated and regulated. We show that cooperation among IMs eliminates double-marginalization to the benefit of passengers and IMs. We also show that the delegation of access charge collection with adequate transfers allows the two IMs to reach efficiency, both in the unregulated and regulated régimes. We study the effect of differences in regulatory policies, and analyze the effect of monopoly power of train operators and competition among high speed and low speed train routes on access charges.

Keywords: International Rail Transport, Access Charges, International Regulation, Infrastructure Managers

JEL classification numbers: L92, L51, L43

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1 Introduction

The Fourth Railway Package of the European Union, adopted in 2016, specifically emphasized the importance of interoperability of railway systems to allow for smooth international rail travel inside the Union. As in other network industries, international rail transport requires the use of several infrastructures managed by independent entities. International trains operate on tracks belonging to different infrastructure managers who independently set access charges and are subject to different regulations as foreseen by the European legal framework.

In international rail transport, infrastructures are perfect complements in the production of the service. As it is well known, the use of separate, complementary inputs to produce a service generates double marginalization, and may lead to inefficiently high access charges. In order to reduce excessively high access charges international cooperation is required and one needs to come up with clear guidelines for access pricing of international rail transport. The objective of this paper is thus double. First, we analyze a *positive* model of access pricing among infrastructure managers in different regulatory environments. Second, we follow a *normative* approach to establish guidelines for cooperation in international rail transport. In particular, we study the role of terminal charges as a way to implement efficient access charges.

To illustrate the analysis, consider a train connecting two cities in different countries, Paris and Brussels. The train runs on tracks operated by infrastructure managers in the two countries, SNCF Réseaux in France and Infrabel in Belgium. The infrastructure managers in the two countries separately set access charges to the train operator. They are both regulated, and maximize a composite welfare function, taking into account both the profit of the infrastructure managers and the consumer surplus. In the benchmark model, we assume that the two infrastructure managers place the same weight on profit and consumer surplus. In an extension of the model, we allow for differences in the regulatory environment in the two countries which result in different objective functions for the two infrastructure managers.

We consider a model of international rail transport between two countries with three types of actors: passengers, a train operators (TO) and infrastructure managers (IMs) in the two countries. In the baseline scenario, train operators are competitive (either because they face competition or because their prices are regulated) and must buy access from the infrastructure managers. We model the interaction between the infrastructure managers as a noncooperative game and derive the equilibrium access charges of the two infrastructure managers in two different régimes: one where both infrastructure managers are unregulated and maximize profit, and one where both infrastructure managers are regulated by regulatory agencies with identical objectives. In the regulated régime, the regulator takes into account the costs of public funds which determines the weight placed on consumer surplus and IM profit in the social welfare objective. We obtain a simple ranking of equilibrium access charges. The charges are highest for unregulated IMs and lowest for regulated IMs. Consumer surplus and IM profits are highest under regulation.

We also obtain simple comparative statics results on the effect of parameters on the access charges in the two régimes. The access charges are increasing in the maintenance costs of the IMs but decreasing in the operating cost of the train operator. In the regulated régime, access charges are increasing in the cost of public funds. Prices are increasing in costs, and quantities are decreasing in costs. In equilibrium, consumers and IMs have aligned objectives, and are harmed by an increase in maintenance and operating costs, and the cost of public funds.

Turning to the optimal cooperative policies among the two countries, we compare the equilibrium access charges and welfare in the two régimes of non-cooperative interaction between IMs with the access charges and welfare when the two IMs cooperate and coordinate on the access charges. We find that welfare is highest when the two IMs cooperate and are regulated. When the IMs are unregulated, as in classical models of vertical integration, cooperation results in lower access charges, higher welfare and higher profits for the two IMs. Hence, not surprisingly, the optimal policy advocated in this paper is to foster cooperation between IMs and encourage a strict regulation to enhance social welfare. We also show that delegation of access charges to a single infrastructure manager (for example collecting access charges at origin) is a way to achieve efficiency. It eliminates double marginalization and does not require the two countries to adopt common regulatory policies. Coupled with a transfer to the other IM at marginal cost, terminal charges result in an efficient outcome.

Finally, we consider different variants of the model. We first study two countries with different regulatory regimes, resulting in different costs of public funds. Not surprisingly, we show that the country with the highest cost of public funds charges the highest access charge. We also note that the total access charge decreases with the dispersion of costs of public funds for a given average cost of public funds in the two countries, so that consumer welfare is highest when the two countries are more heterogeneous. We then study how market power of the train operators affects equilibrium access charges by considering a model with a monopolistic train operator. We observe that equilibrium access charges, both in the regulated and unregulated régimes, are equal to those chosen when prices are set at the competitive level. We finally analyze a model of competition between high-speed and low-speed train routes. We show that equilibrium access charges both in the unregulated and unregulated régimes treat the two markets as independent, and that access charges are lower under regulation.

While our model is cast in terms of international rail transport, it is applicable to any network service requiring the use of different, complementary infrastructures. However, we note that each network industry poses specific challenges and that the regulation of international services may differ across industries. The most extensively studied industry is telecommunications, where the issue of interconnection of networks has long been prevalent. In a national context, the seminal contributions of Laffont et al. (1996)), Laffont et al. (1998) and Armstrong (1998) analyze access pricing among two networks. Laffont et al. (1996) proposes an efficiency account of popular interconnection policies such as the efficient component pricing rule (ECPR). Laffont et al. (1998) study two interconnected networks which offer competing services and own different networks on which telecommunication must occur. Armstrong (1998) also analyzes competition between telecommunication operators, emphasizing the incumbency advantage of the historical operator who owns the network. These models assume a single regulator and abstract away from international services. The literature on international roaming on mobile phone networks is very scarce. Sutherland (2001) is the first to provide empirical evidence for excessive charges in international roaming. Infante and Vallejo (2012) discuss regulation in the European Union. Buehler (2015) proposes a theoretical model of access pricing by unregulated operators, focussing on the role of alliances to soften competition. None of the models studies non-cooperative interaction between regulators.

An important feature of our paper is that infrastructure managers run networks that are perfect complements. Cournot discussed in 1838 how a supplier of zinc and a supplier of copper would independently set prices for their respective products to brass producers (see Cournot (1995)). At equilibrium, the sum of the two prices exceeds the monopoly price that would be set by a single owner of both resources. Thus, each individual supplier chooses its price to maximize its own profit, not the common profit, and thus neglects the externality of the price of its product on the profitability of complementary products that a single supplier of both products would recognize, leading to double-marginalization. A merger of individual owners of essential production factors would benefit both producers, through higher total profits, and consumers, through a lower final product price (see also Waterson (1984), Perry (1989) and Tirole (1988)). In a similar fashion, Feinberg and Kamien (2001) consider a theoretical framework where two separate owners of consecutive segments of a route offer a transportation service to travelers. When sales on each of the two segments are sequential, a potential hold-up problem arises, where the owner of the first segment can impose such a high price that the consumer decides not to use the second segment. The hold-up problem (not double-marginalization) can be avoided by the simultaneity of sales. Brueckner (2001) considers in the airline industry that a realistic model of interline fare setting across multiple complementary segments is formulated within a framework in which each airline chooses a fare for its part of the journey, treating the other fare as given. In the presence of non-cooperative behavior, each carrier would disregard the negative impact on the profits of the other airline from raising its own price. However, when carriers are partners in the same alliance, they cooperatively set the overall fare, and internalize the negative externalities of both independent pricing decisions. In the market for electricity, Daxhelet and Smeers (2007) study a game played by regional regulators to set the rules for interconnection of electricity grids in Europe. They provide a numerical solution of the model, emphasizing that cost-allocation rules between generators and customers chosen in the first stage of the game affect the equilibrium access charges for interconnection. They also contrast the noncooperative outcome of the game with a cooperative outcome with a single regulator. In the postal sector, a model of international parcel service with terminal charges is proposed by Haller et al. (2013) who point out that reciprocal termination access charges are excessive with respect to the social optimum. Borsenberger et al. (2018) also study cross-border parcel fees in the context of the development of e-commerce.

In the particular case of rail transportation, several contributions discuss different potential organizations of the industry at the national level. Besanko and Cui (2019) studies the trade-off between regulated and negotiated access in a context where the infrastructure manager provides access to several train operators. It suggests that negotiation could result in downstream transport prices that are efficient, but too much bargaining power on the operators' side could lead to low access tariff, and could potentially have a negative impact on the quality of the infrastructure. A closer framework to ours is Besanko and Cui (2016) which compares the quality and welfare effects of vertical separation between infrastructure and transport operations, and horizontal separation of integrated transport activities. Horizontal separation allows to exploit the potential complementarity of distinct segments run by different integrated operators. The entire network, which is seen as the addition of all segments, is apprehended from a national perspective where a single regulator is active. In our setting, we focus on international routes. To the best of our knowledge, the only paper which also considers optimal access prices in international rail transport is an unpublished work by Friebel et al. (2011). They also consider a model with two infrastructure managers but assume that each country has a train operator running trains on the international route. The main focus on the analysis is on the effect of vertical integration of the track owner and train operator on the access prices, equilibrium prices and demand. Like us, they note that cooperation with a single infrastructure manager eliminates double-marginalization, thereby increasing both consumer welfare and the profits of the infrastructure managers. They do not analyze differences in regulation across the two countries, nor do they study in detail different modes of cooperation or different variants of the model.

The rest of the paper is organized as follows. We discuss the model in the next Section. Our main characterization of equilibrium access charges with two IMs are given in Section 3. We discuss optimal cooperation in Section 4. Section 5 contains our analysis of the different variants of the model and Section 6 concludes.

2 The Model

We consider a model of international rail transport, which is applicable to any other network service involving the use of different, complementary infrastructures. We suppose that there are two cities, labeled A and B in two countries denoted 1 and 2. In the baseline model, the two countries are taken to be symmetric. We assume that the distance between the two countries is normalized to 1 and that each city is located at the same distance from the border, so that the length of tracks is equal in the two countries. There are three types of actors in the model: passengers, train operators and infrastructure managers.

Passengers: In order to simplify the computations, we assume that a representative passenger has a linear-quadratic utility for international rail transport given by

$$U(q,p) \equiv \beta q - \frac{\gamma}{2}q^2 - pq,$$

where q is the quantity of transport demanded (that is taken to be a continuous variable and can be interpreted as the number of trips per period), p the unit price for travel and β and γ are positive parameters. The parameter β measures the absolute value of travel for the representative passenger and γ the decreasing returns experienced by the representative passenger when the number of trips increases. The consumer chooses its optimal quantity given the price p, which implies

$$\frac{\partial U(q,p)}{\partial q} = 0,$$

resulting in the demand:

$$q = \frac{\beta - p}{\gamma}. \tag{1}$$

We thus note that β captures the size of the demand of each consumer whereas γ measures the inverse of the sensitivity of demand to prices.

The passenger's linear-quadratic utility results in a linear demand function and allows for simple computations of the passenger surplus. The model is general enough to nest the alternative model of rail demand of Friebel et al. (2011)). Friebel et al. (2011) consider a model choice model where there is an alternative means of transport, road transport with a fixed price p_0 . Passengers are distributed uniformly along a Hotelling segment, representing their preferences for road or train transport. They assume furthermore that passengers incur a cost t per unit of distance between their ideal point and their chosen mode of transport. In that case, it is easy to see that the demand for rail transport is given by

$$q = \frac{1}{2} + \frac{p_0 - p}{2t},$$

which is equivalent to equation (1) with $\beta = t + p_0$ and $\gamma = 2t$. Notice however that as we consider a representative consumer whereas Friebel et al. (2011) consider heterogeneous consumers, computations of consumer surpluses are quite different.

Train operators: In the baseline model, we suppose that there is a competitive market for train operators between A and B. This assumption either reflects the presence of multiple potential train operators, who compete in prices, or the presence of a single regulated train operator who must choose a price equal to its marginal cost. Notice that Friebel et al. (2011) consider a different model of competition between two horizontally differentiated train operators, and thus obtain a different pricing rule. We suppose that the train operator faces a constant marginal cost c, (normalized by passenger) representing the cost of staff and the depreciation of the railway rolling stock. In addition, the train operator pays access charges a_1 and a_2 to the two infrastructure managers of countries 1 and 2. The train operator chooses the price p for passenger rail travel. As the market is assumed to be competitive, the price is chosen to equate the marginal cost:

$$p = a_1 + a_2 + c. \tag{2}$$

Given this rule of price formation, demand of rail transport is given by

$$q = \frac{\beta - (a_1 + a_2 + c)}{\gamma}.$$

Infrastructure managers: Each country $i = 1, 2$ has a single infrastructure manager who sets the access charge a_i. The infrastructure manager of each country faces a constant marginal cost, given by d, and a fixed cost K. The constant marginal cost d represents the costs which can be attributed to each train, covering maintenance costs of the tracks and electricity provision. These costs are measured by passenger. The constant cost K measures the maintenance costs which are unrelated to train circulation, and the financial charges on past and present infrastructure investments.

We suppose that the operating and maintenance costs are small enough so that service is profitable, namely

$$\beta > c + 2d.$$

We consider two types of infrastructure managers. An **unregulated** infrastructure manager of country i chooses the access price a_i in order to maximize its profit:

$$\Pi_i = (a_i - d)q - K. \tag{3}$$

A **regulated** infrastructure manager selects an access charge a_i to maximize total welfare. The state subsidizes the infrastructure manager to cover its losses. We assume that there is a positive cost of public fund $\lambda \geq 0$ that the state incurs to raise money and pay the subsidy. Total welfare is given by the sum of consumer surplus, of profit of the train operators in country i (assumed to be zero because the market is competitive), of the profit of the infrastructure manager of country i and of the cost of the subsidy. We thus have

$$W_i = U(q, p) + \Pi_i - \lambda(K - (a_i - d)q).$$

Replacing, we obtain:

$$W_i = \beta q - \frac{\gamma}{2}q^2 - [a_1 + a_2 + c]q + (1 + \lambda)[(a_i - d)q - K]. \tag{4}$$

3 Non-cooperative interaction between infrastructure managers

In this Section, we analyze the non-cooperative game played by two infrastructure managers who select the access prices a_1 and a_2. We consider two different régimes: (i) one with two unregulated IMs and (ii) one with two regulated IMs.

3.1 Two unregulated infrastructure managers

Suppose first that the two infrastructure managers are unregulated. Infrastructure manager $i = 1, 2$ selects the access charge a_i to maximize

$$\Pi_i = (a_i - d)\frac{(\beta - (a_1 + a_2 + c))}{\gamma} - K,$$

Taking first order conditions, we obtain the best response function:

$$a_i = \frac{d + \beta - a_j - c}{2},$$

The two access charges are *strategic substitutes*: an increase in the access charge a_j results in a decrease in the access charge a_i. The intuition for this observation stems from the fact that the two infrastructures are perfect complements: the train operator must use both infrastructures simultaneously. Hence an increase in the access charge a_j results in a higher price of the train operator, and a lower passenger demand so that the optimal access price of the other infrastructure manager, a_i, decreases. In other words, if the IM of the other country increases its access charge, the IM needs to reduce her access charge to compensate and maintain passenger demand. This result is of course related to the well-known observation that, in a Bertrand game, prices are strategic complements when the goods are substitutes, but strategic substitutes when the goods are complements (Bulow et al. (1985))

Figure 1 illustrates the best response functions in the non-cooperative game between two unregulated IMs. The Nash equilibrium of the game is obtained at the intersection of the two best-response functions.

The best response function suggests that the optimal decision of each IM is a direct function of the decision of the other IM. This stems from our assumption that infrastructure managers have perfect knowledge of the access charges of the other infrastructure managers.

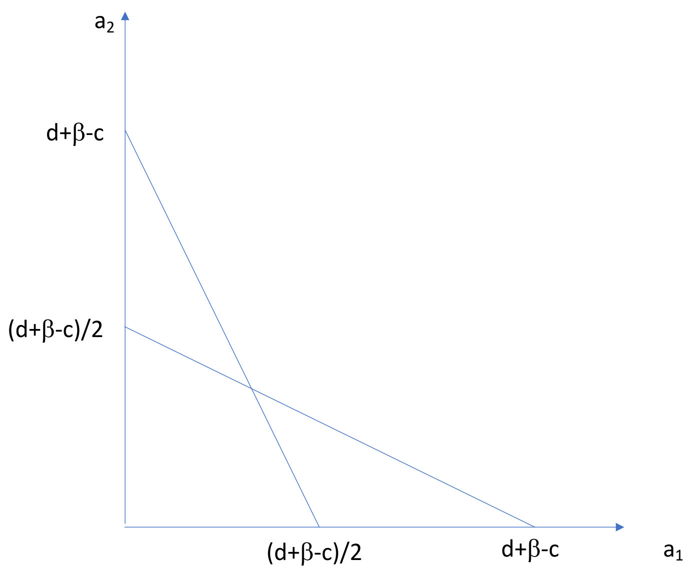

Figure 1: Non-cooperative interaction between unregulated IMs

Proposition 1. *When the two infrastructure managers are unregulated, the equilibrium access charges are given by*

$$a = \frac{\beta + d - c}{3},$$

The equilibrium prices and quantities are given by

$$p = \frac{2\beta + 2d + c}{3}, q = \frac{\beta - c - 2d}{3\gamma}.$$

We note that the consumer surplus is given by

$$CS = \frac{\gamma q^2}{2} = \frac{(\beta - c - 2d)^2}{18\gamma},$$

and the profit of every IM is given by

$$\Pi = \gamma q^2 - K = \frac{(\beta - c - 2d)^2}{9\gamma} - K.$$

The following table shows the comparative statics effects of changes in the parameters on the equilibrium outcomes.

	c	d	β	γ
a	$-$	$+$	$+$	$=$
p	$+$	$+$	$+$	$=$
q	$-$	$-$	$+$	$-$
CS	$-$	$-$	$+$	$-$
Π	$-$	$-$	$+$	$-$

Table 1: Comparative statics effects - non-cooperative game between unregulated IMs

When the two IMs are unregulated, the equilibrium access charge of the two IMs of country i is increasing in the maintenance cost of the track, but decreasing in the operating cost of the train operator. Prices are increasing in the operating and maintenance costs whereas demand is decreasing in operating and maintenance costs. The consumer surpluses in the two countries are equal to the squares of the demands and hence experience the same comparative statics effects as the demand: an increase in costs lowers the consumer surpluses. The gross profits of the IMs are also proportional to the square of demands, and are hence decreasing in maintenance and operating costs.

3.2 Two regulated infrastructure managers

Next we suppose that the two infrastructure managers are regulated. Infrastructure manager i selects the access charge a_i to maximize

$$W_i = \frac{[\beta - (a_1 + a_2 + c)]^2}{2\gamma} + (1+\lambda)[\frac{(a_i - d)(\beta - (a_1 + a_2 + c))}{\gamma} - K].$$

Taking first order conditions, we obtain the best response functions

$$a_i = \frac{\lambda(\beta - a_j - c) + (1+\lambda)d}{1+2\lambda}.$$

We observe again that the two access charges are again strategic substitutes: if the access charge to the network of country j is higher, the optimal access charge of country i will be smaller.

Figure 2 illustrates the best response functions in the non-cooperative game between two regulated IMs. Solving simultaneously for the two best-response function, we obtain the equilibrium access charge as stated in the following Proposition.

Proposition 2. *When the two infrastructure managers are regulated, the access charges are given by*

$$a = \frac{\lambda(\beta - c) + (1+\lambda)d}{1+3\lambda}$$

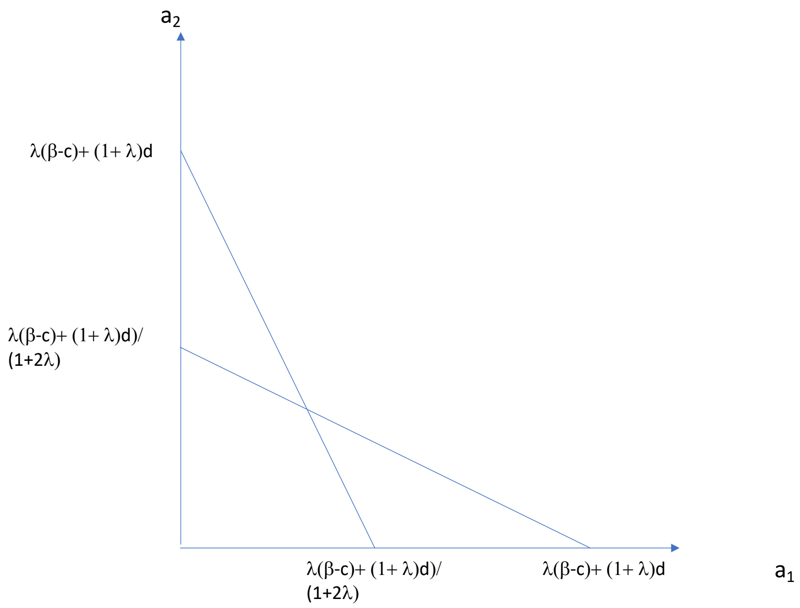

Figure 2: non-cooperative game between regulated IMs

The equilibrium prices and quantities are given by

$$p = \frac{(2d + c)(1 + \lambda) + 2\lambda\beta}{1 + 3\lambda}, q = \frac{(\beta - c - 2d)(1 + \lambda)}{(1 + 3\lambda)\gamma}.$$

As in the régime of unregulated IMs, the consumer surplus is given by

$$CS = \frac{\gamma q^2}{2}$$

The profits of the IMs are now given by

$$\Pi = (a - d)q - K = \frac{(\beta - c - 2d)^2\lambda(1 + \lambda)}{\gamma(1 + 3\lambda)^2} - K.$$

The comparative statics effects of parameters on equilibrium outcomes are summarized in the following Table.

	c	d	β	γ	λ
a	$-$	$+$	$+$	$=$	$+$
p	$+$	$+$	$+$	$=$	$+$
q	$-$	$-$	$+$	$-$	$-$
CS	$-$	$-$	$+$	$-$	$-$
Π	$-$	$-$	$+$	$-$	$-$

Table 2: Comparative statics effects - non-cooperative game between regulated IMs

Increases in costs have the same comparative statics effects as in the case of two unregulated IMs. An increase in operating costs of the train operators reduces access charges, increases travel prices, and reduces quantities, consumer surplus and the profit of the IMs. An increase in maintenance costs increases access charges and prices, reduces quantities, consumer surplus and the profits of the IMs. An increase in the cost of public funds shifts the objective function of the regulator away from consumer surplus and towards the profit of the IMs. It results in higher access charges, higher prices and lower quantities. It also reduces consumer surplus, and, by increasing competition among the IMs, ends up leading to lower profits for the IMs.

3.3 A comparison between the two régimes

We finally compare the equilibrium access charges, prices and quantities under the two régimes. Letting a^U and a^R denote the equilibrium access charges in the unregulated and regulated régimes, we observe that

$$a^U = \frac{\beta - c + d}{3} > \frac{\lambda(\beta - c) + (1+\lambda)d}{3\lambda + 1} = a^R,$$

as $\beta - c - 2d > 0$. Hence, not surprisingly, the equilibrium access price is higher in the unregulated than in the regulated régime. However, as λ increases, a^R increases and in the limit, as λ goes to infinity, the two access charges are equal, as the regulator has the same objective function as an unregulated IM maximizing profit.

As the access charge is lower under regulation, the equilibrium price is lower under regulation and the equilibrium quantity higher under regulation. As the consumer surplus is proportional to the square of the equilibrium quantity, we also conclude that consumers are better off in the regulated régime.

The gross profit of infrastructure managers is equal to $\frac{(\beta-c-2d)^2}{9\gamma}$ in the unregulated régime and $\frac{(\beta-c-2d)^2\lambda(1+\lambda)}{\gamma(1+3\lambda)^2}$ in the regulated régime. As long as $\lambda \geq \frac{1}{3}$, the profit of the IM is higher in the regulated régime than in the unregulated régime. Again, as λ goes to infinity, the profits under regulation and in the unregulated régimes converge to the same value, as the objective function of the regulator converges to the objective function of an unregulated IM maximizing profit.

4 Cooperation between infrastructure managers

A non-cooperative interaction between infrastructure managers results in inefficiently high access charges. Double marginalization occurs, as train operation requires the use of the two infrastructures. In order to decrease access charges, infrastructure managers need to cooperate. In this Section, we consider three ways in which international cooperation can occur: (i) coordination to set access charges to maximize the sum of profits of the two IMs, (ii) coordination to set access charges to maximize total welfare of the two countries and (iii) delegation to one of the two IM to collect access charges (either through "origin" or "destination" charges).

4.1 Cooperation among unregulated IMs

We first consider cooperation among two unregulated IMs selecting an access charge a to maximize their sum of profits

$$\Pi = (a - 2d)q - 2K.$$

Replacing, we obtain

$$\Pi = (a - 2d)[\beta - (a + c)] - 2K.$$

resulting in the following optimal access charge.

Proposition 3. *Cooperating unregulated IMs select an optimal access charge*

$$a = \frac{\beta - c + 2d}{2}.$$

The equilibrium prices and quantities are given by:

$$p = \frac{\beta + c + 2d}{2}, q = \frac{\beta - c - 2d}{2\gamma}.$$

Cooperation among IMs eliminates double-marginalization, resulting in lower prices and higher quantities than in the case of two independent unregulated IMs. As consumer surplus and infrastructure manager profits are indexed on the passenger demand, *both consumers and infrastructure managers benefit from cooperation among IMs.*

4.2 Cooperation among regulated IMs

Next, we suppose that the access charge is chosen cooperatively by the two regulators. The welfare function under cooperation takes into account consumer surpluses in the two countries and is thus given by

$$\begin{aligned} W &= \beta q - \frac{\gamma}{2}q^2 - [a+c]q \\ &+ (1+\lambda)[(a-2d)q - 2K]. \end{aligned}$$

Replacing, we obtain

$$W = \frac{1}{2\gamma}[\beta - (a+c)]^2 + \frac{1+\lambda}{\gamma}[(a-2d)(\beta - (a+c))] - 2K.$$

Proposition 4. *Cooperating regulated IMs choose an optimal access charge*

$$a = \frac{\lambda(\beta - c) + (2+2\lambda)d}{1+2\lambda}.$$

The equilibrium prices and quantities are given by:

$$p = \frac{\lambda\beta + (1+\lambda)(c+2d)}{1+2\lambda}, q = \frac{(1+\lambda)(\beta - c - 2d)}{\gamma(1+2\lambda)}.$$

When there is cooperation among regulators, the access charge is equal to marginal cost when the cost of public funds is equal to zero. As the cost of public fund increases, the access charge rises above marginal cost in order to cover the infrastructure managers' fixed cost. When the cots of public funds goes to infinity, the access charge converges to the access charge of the unregulated cooperative régime. The optimal access charge, equilibrium prices and quantities, differ from the uneregulated values because of the distortion induced by the cost of public fund. However, it is easy to see that the access charges set by two cooperating regulated IMs are lower than those set by two cooperating unregulated IMs, and that prices are lower and quantities higher in the regulated régime.

Compared to the non-cooperative game between two regulated IMs, cooperation results in lower access charges, lower prices and higher quantities. Hence consumer surplus is highest under regulation and cooperation. For the profits of the IM, we compare the sum of the profits obtained in the non-cooperative game with two regulators, denoted Π^N with the sum of profits obtained by two cooperating IMs, Π^C.

$$\Pi^N = \frac{2(1+\lambda)\lambda(\beta - c - 2d)^2}{(1+3\lambda)^2}, \Pi^C = \frac{(1+\lambda)\lambda(\beta - c - 2d)^2}{(1+2\lambda)^2}.$$

As long as $\lambda^2 + \lambda \geq 1$, $\Pi^N < \Pi^C$, so that cooperation also results in an increase in the profits of the IMs. Hence, when the cost of public funds is sufficiently large, the régime of cooperation with regulation is the best régime, both from the point of view of consumers and of infrastructure managers.

4.3 Delegation and terminal charges

In order to achieve the highest possible welfare level for consumers and IMs, we consider here a situation where the setting and collection of access charges on the rail upstream market (path allocation) is delegated to only one of the two IMs, as this is commonly the case in other network industries when more than one network is used to supply goods or services.

We first consider a situation where a single IM collects charges, without any transfer to the other IM. In an unregulated environment, the IM chooses the access charge to maximize

$$\Pi = (a - d)[\beta - (a + c)] - K,$$

resulting in an access charge $a = \frac{\beta - c + d}{2}$, which would be in any case insufficient to cover the maintenance cost of the other IM. Similarly, if the IMs are regulated, the origin IM will choose an access charge to maximize

$$W = \frac{1}{2\gamma}[\beta - (a + c)]^2 + \frac{1 + \lambda}{\gamma}[(a - d)(\beta - (a + c))] - K,$$

yielding an access charge $a = \frac{(\beta - c)(2+\lambda)\lambda + d(1+\lambda)}{2+3\lambda}$. Again, the access charge is too low, as the IM does not take into account the maintenance cost of the other IM.

To implement a delegated regime, operators need to charge each other on the upstream market for the usage of their respective networks in order to serve clients on the downstream market. This is, for instance, the case in the telecoms sector in cases where a fixed or mobile call is made up of an originating call handled by the calling party operator (operator A) and a call termination handled by the called party operator (operator B). A charging scheme between the operators involves the payment of call terminations in which operator A (operator of the calling party) pays a conveyance cost, known as the call termination, to operator B (operator of the called party). A rather similar process takes place for international shipments in the postal sector as the postal operator of a country A is often unable to deliver postal items in another given country B. In that case, the postal operator of the originating country normally receives the fee of the shipment from the sender for the full service but only performs a duty in its own country (collection, outward sorting and transport) and outsources the operation in the destination country to a foreign postal operator (inward sorting, transport and delivery).

The implementation of such a system in the rail sector would lead to the payment of "terminal train paths". The final customer on the market of paths would then be the rail operators and the entities which should provide a one stop shop would be the infrastructure managers. If, as this is the case in the telecoms or postal sector, the "one stop shop" is the originating part of the journey and that rail services go from country A to country B, the rail operator would pay infrastructure tolls to the IM in country A only. The IM in country B would then have to charge the IM in country A for "terminal paths" at marginal cost. This would not change the structure of the downstream market between passengers and railway operators. In order to abstract from the possible difficulty of potential imbalance between inbound and outbound traffic, and in line with our running example of international railroad passenger transport, we assume that inbound and outbound flows are balanced. This hypothesis appear robust as trains usually go back and forth the same locations.

We now suppose that the origin IM reimburses the other IM at marginal cost, and hence pays a transfer dq to the other IM. In an unregulated environment, the IM charges an access charge to maximize

$$\Pi = (a - 2d)[\beta - (a + c)] - K,$$

resulting in *the optimal access charge* $a = \frac{\beta - c + 2d}{2}$.

In a regulated environment, the IM chooses an access charge to maximize

$$W = \frac{1}{2\gamma}[\beta - (a + c)]^2 + \frac{1 + \lambda}{\gamma}[(a - 2d)(\beta - (a + c))] - K,$$

yielding the access charge

$$a = \frac{\lambda(\beta - c) + (2 + 2\lambda)d}{1 + 2\lambda}.$$

which is the same as the optimal access charge in the cooperative, regulated régime. We summarize in the following Proposition.

Proposition 5. *Suppose that access charges are only collected by the infrastructure manager at origin. If the origin IM compensates the destination IM at marginal cost, the optimal access charges are identical to those chosen under cooperation, both in the unregulated and regulated régimes.*

Implementing a single tariff signal by only one IM would lead more easily to the optimal regime than the addition of non-coordinated tolls from separate IM which do not have the proper incentives to cooperate efficiently. The fact that only one IM would be allowed to collect mark-ups for cross-border services would prevent opportunist behavior from IMs leading to socially sub-optimal market configurations. Moreover, monitoring the relevance of price signals from à single IM through a one-stop-shop would be more straightforward as regulators would, in a simpler way than today, regulate only one price for an end-to-end service.

Given that rail traffic is generally symmetrical between countries (a train departing for a foreign country generally returns to its country of origin, and passengers departing for a foreign country generally end up returning to their country of origin), the two IMs can alternatively raise tariff mark- ups to cover their fixed costs. For traffic departing from their own country, and taking into account the terminal dues they have to pay to the IM of the destination country, they can determine the level of fare surcharges they consider appropriate, taking into account the amount of fixed costs to be covered, net of public subsidy, and the characteristics of demand.

5 Extensions

In this Section, we discuss three extensions of the model: one where the two regulators have different costs of public funds, one where the train operator has market power, and one with competition between high-speed and low-speed train lines.

5.1 Different regulators

We first extend the model to allow for differences in the cost of public funds of the regulators in the two countries. This difference can stem from different sources. First, the two countries may differ in the efficiency of the tax collection system. Second, the two countries may differ in their budgetary situations, resulting in differences in the opportunity cost of public funds. Third, the governments of the two countries may have different ideological perspectives on the role of government, and the opportunity cost of subsidies. These differences in the opportunity cost of public funds are reflected in differences in the relative importance that each country will assign to subsidies and access charges. A country with higher cost of public funds will place a higher weight on access charges and a lower weight on subsidies.

To study the effect of differences in the costs of public funds, we let λ_1 and λ_2 denote the costs of public funds in the two countries, with $\lambda_1 \geq \lambda_2$. When the two regulated IMs choose their access charges non-cooperatively, the reaction functions are given by

$$\begin{aligned}
a_1 &= \frac{\lambda_1(\beta - a_2 - c) + (1+\lambda_1)d}{1+2\lambda_1}, \\
a_2 &= \frac{\lambda_2(\beta - a_1 - c) + (1+\lambda_2)d}{1+2\lambda_2}.
\end{aligned}$$

Solving this system of equations, we obtain

Proposition 6. *The equilibrium access charges of two regulated IMs with different costs of public funds are given by*

$$\begin{aligned}
a_1 &= \frac{(1+\lambda_2)\lambda_1(\beta - c) + d(1+2\lambda_2+\lambda_1\lambda_2)}{1+2\lambda_1+2\lambda_2+3\lambda_1\lambda_2}, \\
a_2 &= \frac{(1+\lambda_1)\lambda_2(\beta - c) + d(1+2\lambda_1+\lambda_1\lambda_2)}{1+2\lambda_1+2\lambda_2+3\lambda_1\lambda_2}.
\end{aligned}$$

The equilibrium prices and quantities are given by:

$$p = \frac{(1+\lambda_1)(1+\lambda_2)(c+2d) + \beta(\lambda_1+\lambda_2+\lambda_1\lambda_2)}{1+2\lambda_1+2\lambda_2+3\lambda_1\lambda_2}, q = \frac{(1+\lambda_1)(1+\lambda_2)(\beta - c - 2d)}{1+2\lambda_1+2\lambda_2+3\lambda_1\lambda_2}.$$

We observe that, as in the case of identical countries, access charges are increasing in the maintenance cost and decreasing in the operating costs of the train operator. Transport prices are increasing in costs, and demand is decreasing in costs. The difference in access charges is given by

$$a_1 - a_2 = \frac{(b-c-2d)(\lambda_1 - \lambda_2)}{1+2\lambda_1+2\lambda_2+3\lambda_1\lambda_2},$$

so that, not surprisingly, the country with the highest cost of public funds sets the highest access charge. Differentiating the access charges with respect to the two variables λ_1 and λ_2, we observe that the access charge of the regulated IM in country $i = 1, 2$ is increasing in the cost of public fund in country i, but decreasing in the cost of public fund in country j. A higher cost of public fund in country i leads the regulator to put more weight on the profit of the IM, thereby yielding a higher access charge. On the other hand, a higher cost of public fund in country j results in a higher access charge in country j, and as the two access charges are strategic substitutes, a lower access charge in country i.

The consumer surplus is proportional to the square of the equilibrium quantity q. This quantity is *decreasing* in λ_1 and λ_2: the higher the cost of public funds, the higher the total access charge $a_1 + a_2$, which translates into a higher price and a lower quantity. Interestingly, we note that the quantity q is a *convex function of* λ_1 *and* λ_2. This observation implies that, for a fixed sum $\lambda_1 + \lambda_2$, the quantity and consumer surplus are higher when the two values λ_1 and λ_2 are more unequal. Consumers benefit from the dispersion in the cost of public funds and prefer countries with heterogeneous regulators.

We now consider cooperation among the two IMs, assuming that they use, as the cost of public fund used in their computation of the objective of the IM, the average cost of public fund $\frac{\lambda_1+\lambda_2}{2}$. From the analysis of the cooperation between regulated IMs, the optimal access charge is given by

$$a = \frac{(\lambda_1 + \lambda_2)(\beta - c) + (2 + 2(\lambda_1 + \lambda_2))d}{2 + 2(\lambda_1 + \lambda_2)}.$$

The total access charge is lower than $a_1 + a_2$, but it is not necessarily the case that both access charges a_1 and a_2 are lower than $\frac{a}{2}$. The regulated IM with the lowest cost of public fund may choose a lower value a_i than the value chosen by cooperating IMs. We also note that, when the two regulated IMs are heterogeneous, it may be that one of the IM experiences a drop in profit in the régime of cooperation. Hence, in order to induce both IMs to cooperate, it may be necessary to engineer a transfer. This transfer will naturally need to be computed if one sets up a system of delegation with terminal charges among two heterogeneous infrastructure managers.

5.2 Market power in train operations

We now modify the model to allow the transport operator to charge prices above marginal cost. We suppose that there is a monopolistic transport operator, owned by the two countries with shares equal to the country sizes, which sets the price for transport services. With a monopolistic train operator, the price of transport is chosen to maximize

$$T_i = \frac{(\beta - p)}{\gamma}(p - (a_1 + a_2 + c)),$$

resulting in an optimal price

$$p = \frac{\beta + a_1 + a_2 + c}{2}, \tag{5}$$

Compared to the situation of a competitive train operator, the price has increased and demand has been exactly halved. Replacing in the infrastructure manager's profit, we obtain

$$\Pi_i = \frac{(a_i - d)(\beta - (a_1 - a_2 - c))}{2\gamma} - K.$$

And the consumer surplus is given by

$$CS = \frac{(\beta - (a_1 - a_2 - c))^2}{8\gamma},$$

We observe that, compared to the competitive train operator, the demand of both infrastructure managers has been exactly halved. This implies that, when two unregulated infrastructure managers do not cooperate, the equilibrium access charges are *identical to the equilibrium access charges when the train operator is competitive*

Proposition 7. *When the two infrastructure managers are unregulated and the train operator is a monopoly, the access charges are identical to the access charges in the competitive train operator case and are given by*

$$a_i = \frac{\beta + d - c}{3},$$

The equilibrium prices and quantities are given by

$$p = \frac{5\beta + c + 2d}{6}, q = \frac{\beta - c - 2d}{6\gamma}.$$

We now turn to a regulated infrastructure manager. Compared to the competitive train operator situation, the consumer surplus has been divided by four rather than two, so that the weight of consumer surplus in the welfare function has gone down. However, the welfare function now also includes the share of the train operator's profit which can be assigned to country i. We assume that the profits of the train operator are divided equally among the two symmetric countries. The profit of the train operator in country i is thus given by

$$T_i = \frac{(\beta - (a_1 - a_2 - c))^2}{8\gamma}.$$

With these assumptions, the new welfare function is given by

$$\begin{aligned} W &= \frac{(\beta - (a_1 - a_2 - c))^2}{8\gamma} + \frac{(\beta - (a_1 - a_2 - c))^2}{8\gamma} \\ &+ (1+\lambda)\frac{(a_i - d)(\beta - (a_1 - a_2 - c))}{2\gamma} - K \\ &= \frac{(\beta - (a_1 - a_2 - c))^2}{4\gamma} + (1+\lambda)(\frac{(a_i - d)(\beta - (a_1 - a_2 - c))}{2\gamma} - K). \end{aligned}$$

Gross of the fixed cost, the welfare is thus exactly equal to half of the welfare in the competitive train operator situation, and the optima access charge is the same.

Proposition 8. *When the two infrastructure managers are regulated and the train operator is a monopoly, the access charges are identical to the access charges in the competitive train operator case and are given by*

$$a = \frac{\lambda(\beta - c) + (1+\lambda)d}{1+3\lambda}$$

The equilibrium prices and quantities are given by

$$p = \frac{\beta(1+5\lambda) + (c+2d)(1+\lambda)}{2(1+3\lambda)}, q = \frac{(\beta - c - 2d)(1+\lambda)}{2(1+3\lambda)\gamma}.$$

The equilibrium transport price is higher and the equilibrium quantities lower than in the case of a competitive train operator. Compared to the competitive train operator, the consumer surplus has gone down. The equilibrium profit of the two infrastructure managers have also gone down with respect to the case of a competitive train operator. Hence the only entity which benefits from the market power of the train operator is the train operator itself.

Finally, we consider cooperation among IMs when the train operator has market power. If two unregulated IMs cooperate, they will choose an access charge a to maximize

$$\Pi = (a - 2d)(\beta - a - c),$$

so that, as in the case of a competitive train operator, the optimal access charge is:

$$a = \frac{\beta + 2d - c}{2}.$$

If two regulated IMs cooperate, they will choose the access charge a to maximize the sum of welfare in the two countries

$$W = [\frac{3}{8\gamma}(\beta - (a-c))^2 + (1+\lambda)\frac{1}{2\gamma}(a-2d)(\beta - (a-c))] - 2K,$$

resulting in an optimal access charge

$$a = \frac{(\beta - c)(\lambda - \frac{1}{2}) + 2(1+\lambda)d}{2\lambda + \frac{1}{2}}.$$

We check that the equilibrium access charge is lower than when the train operator is competitive, and that the equilibrium price is higher and the quantity lower.

5.3 Competition between high-speed and low-speed train lines

Finally, we suppose that there are two alternative routes to link cities A and B. One routes is a high-speed rail route, with an operating cost c and maintenance costs d in the two countries. The other route is a classical train route, with an operating cost $c' < c$ and maintenance costs $d' < d$. We let $\Delta = d - d' > 0$ denote the difference in maintenance costs between the high-speed and classical train lines. The fixed costs of the two infrastructure managers on the two routes are denoted K and K'.

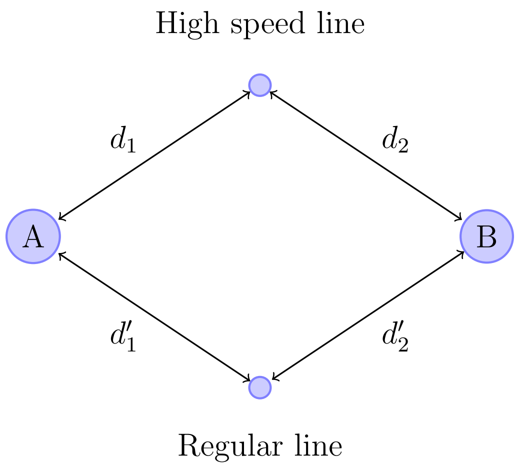

Figure 5: A network with two competing routes

The two routes are vertically differentiated. High speed travel is associated to a quality level s and regular travel with a quality level s'. We let Δs denote the difference in quality. Consumers have a utility function

$$U = \theta s - p,$$

where p is the price of the service, s the quality, and θ a taste parameter uniformly distributed over $[0, 1]$. Under this assumption, the market is segmented into a group of passengers who do not use the train (taste parameter between 0 and θ'), a group of passengers which use the regular train service (taste parameter between θ' and θ) and a group of passengers who use the high speed train service (taste parameter between θ and 1) where

$$\begin{aligned} \theta' &= \frac{p'}{s'}, \\ \theta &= \frac{p - p'}{\Delta s} \end{aligned}$$

Given that taste parameters are uniformly distributed, demands are thus given by

$$q' = \theta - \theta', q = 1 - \theta.$$

We assume again that prices are set at the competitive level, so that $p = c + a_1 + a_2$ and $p' = c' + a_1' + a_2'$ and let $\Delta = c - c'$ denote the difference in operating costs between a high speed train and a regular train. The profit of infrastructure manager i is thus given by

$$\Pi_i = \left\{ (a_i' - d')[\frac{\Delta c + a_1 + a_2 - a_1' - a_2'}{\Delta s} - \frac{c' + a_1' + a_2'}{s'}] + (a_i - d)\frac{\Delta s - \Delta c + a_1' + a_2' - a_1 - a_2}{\Delta s} \right\}$$
$$- K - K'.$$

We compute consumer surplus as

$$\begin{aligned} CS &= [\int_{\theta'}^{\theta} ts'dt + \int_{\theta}^{1} tsdt - q'p' - qp], \\ &= \frac{1}{2}s'[[\frac{\Delta c + a_1 + a_2 - a_1' - a_2'}{\Delta s}]^2 - [\frac{c' + a_1' + a_2'}{s'}]^2] + s[1 - [\frac{\Delta c + a_1 + a_2 - a_1' - a_2'}{\Delta s}]^2] \\ &- (c' + a_1' + a_2')[\frac{\Delta c + a_1 + a_2 - a_1' - a_2'}{\Delta s} - \frac{c' + a_1' + a_2'}{s'}] \\ &- \frac{1}{\Delta s}(c + a_1 + a_2)[\Delta s - \Delta c + a_1' + a_2' - a_1 - a_2], \end{aligned}$$

and the welfare of the regulator in country i as

$$W_i = CS + (1 + \lambda)\Pi_i.$$

Proposition 9. *In the model with two competing routes, when the infrastructure managers are unregulated the equilibrium access charges are given by*

$$\begin{aligned} a &= \frac{s + d - c}{3}, \\ a' &= \frac{s' + d' - c'}{3} \end{aligned}$$

When the infrastructure managers are regulated the equilibrium access charges are given by

$$\begin{aligned} a &= \frac{2(d(1 + \lambda) + \lambda s - c\lambda)}{1 + 3\lambda} \\ a' &= \frac{2(d'(1 + \lambda) + \lambda s' - c'\lambda)}{1 + 3\lambda} \end{aligned}$$

Notice that in the computation of access charges, the two markets are independent. The access charges on each route only depend on the demand and costs on each route: they are increasing in the value of the service (measured by s), increasing in maintenance costs d but decreasing in the operating costs c. As expected, the equilibrium access charges are lower in the regulated environment, and converge to the marginal cost ($a = 2d$ and $a = 2d'$) when the cost of public funds goes to zero.

6 Conclusion

In this paper, we study a model of strategic interaction between two infrastructure managers (IMs) for international rail transport. We compare equilibrium access charges when the IMs are unregulated and regulated . We show that cooperation among IMs eliminates double-marginalization to the benefit of passengers and IMs. We analyze the effect of differences in regulation and discuss the effect of monopoly power of train operators on access charges.

We believe that our analysis gives strong support for cooperation among IMs to set access charges for international trains. This would allow a decrease in total access charges, thereby increasing demand for international rail services and allowing for a shift from air transport to train transport for medium-haul destinations across Europe. The implementation of a coordinated access charge may however be difficult, as it involves possible transfers across IMs. The delegation of access charge collection to one of the two countries (for example terminal charges collected by the origin country) is a good option as it eliminates double marginalization without requiring that the two countries harmonize their regulatory and tariff policies.

While our analysis has focussed on access charges, we understand that IMs should also cooperate on other dimensions to enhance international train services. Upgrading of tracks, inter-operability of tracks and navigation systems are still very imperfect in Europe. The setting of common standards and a better coordination on schedules and quality of service are necessary conditions for the improvement of international train services in Europe. We hope to tackle these issues in future research by studying investment in quality and incentives for the construction of new lines in international rail transport.

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