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► **To cite this version:**

Nicolas Gruyer, Nathalie Lenoir. Air and rail: cooperating and competing?. ATRS 2004, Air Transport Research Society World Conference, Jul 2004, Istanbul, Turkey. pp xxxx. hal-01022243

HAL Id: hal-01022243

<https://hal-enac.archives-ouvertes.fr/hal-01022243>

Submitted on 17 Jul 2014

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Air and Rail : Cooperating and Competing*?

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Abstract: The objective of this paper is to explore how the development of air-rail intermodality, encouraged by the European commission, can have an impact on competitive and collusive behavior on the part of the railway operators and airlines. Since they both are network industries, partnership on certain links will obviously have impacts on other links of the networks. By modeling in a simple setting the interactions that take place, we examine the consequences of intermodality on the outputs and prices on final markets. We then try to draw implications in terms of financing and transport policy : is it possible to encourage intermodality without distorting competition on final consumer markets ?

Keywords: airlines, airports, rail, competition, intermodality

Introduction

In its 2001 white paper on transport [2], the European Commission mentions in its main proposals, the development of intermodality, for goods as well as for people. It is part of a plan for "shifting the balance between modes of transport", towards "rail and other environmentally friendly modes" The main concerns of the European commission is the growing share of road transport in both goods and passengers transport (respectively 44% and 79% of the market) with some adverse effects on the environment and public health, and with the resulting increase of congestion on main routes, cities, airports(which might eventually impede growth

*This paper does not necessarily reflect the views of the French Civil Aviation Directorate, but only its authors views

inside the Union). The commission puts the blame on distortions of competition between modes due to "the lack of fiscal and social harmonisation". According to them, some modes, notably road transport, have not been paying the full external costs and respecting social and safety regulations.

In this white paper, intermodality is seen in a very strong sense, not only as a cooperation between transport modes, but as a way of shifting passengers and goods from one mode to another. It aims at replacing competition between modes by cooperation.

In a broader sense intermodal transport can be viewed as the transport of goods or passengers by the use of several coordinated modes. For example, in the case of passengers, the coordination of modes can be a coordination of schedules, a single ticket for the whole trip, a single check in of baggage. The aim is to exploit the advantages of each mode while making the trip seamless for the passengers.

So far, experiments in air-rail intermodality for passengers have been quite limited, but this can be justified by the fact that convenient (high speed) train links are still limited, especially when considering access to airports. For instance, in the United States, only ten cities are linked directly to their main airport by a direct rail access¹. In Europe, since the rail infrastructure is much more developed than in the United states, rail links to airports are more frequent, and most major airports are linked to the city, but it is not frequently a direct "high speed" convenient link.

This raises several questions, which we shall try to answer in the following sections. Considering an airport conveniently connected to the rail infrastructure, what incentives do the airlines and rail operators have to set up intermodal transport? When is it in their best interest to sign agreements, and what would be the consequences of such agreements on competition and on the welfare of the passengers and of society? This obviously depends on the structure of competition in the air and rail markets, and on the effects on intermodal agreements on competition.

This will enable us to see if and how certain conditions will or will not give incentives to airlines, airports and railway operators to reach agreements for co-financing infrastructures in order to link the networks together². The financing of rail infrastructure, and particularly rail links to airports is indeed a major concern. The funding of an infrastructure project is obviously linked to the expected benefits of its use (social or private). If private funding is expected, then the operators will be willing to finance in relation to the benefits they derive from the use of the infrastructure. This is in turn clearly linked to the market structure,

¹Washington DC Reagan, Hartsfield Atlanta, Midway Chicago, Boston Logan, O'Hare Chicago, Baltimore Washington, Cleveland Hopkins, Philadelphia, St Louis and quite recently San Francisco International Airport

²Or even give incentives to one of these players to finance these infrastructures on its own.

and therefore, not independent from the intermodal agreements between firms.

Finally, we will see how the Public Authorities can intervene in order to compensate certain inefficient aspects (in certain cases, as a result of the fact that no interconnection agreement has been reached or, in other cases, due to a limitation of the competition concerning the interconnection).

1 Intermodality and competition on feeder markets to airport A

The objective of this section is to analyse the consequences of the building of a railway station in the airport of city A, on the competition between air and rail on feeder markets to airport A. Therefore, we are exclusively concerned here with the market of travelers who intend to go to A for the sole purpose of continuing their journey on a long or medium haul flight to a city Z (or, in an equivalent manner, who intend to go to a town which is close to a rail-linked town or city after a long or medium haul flight arriving at A).

1.1 Setting and Conventions

To illustrate our subject, we shall assume that two cities A and L, each of which has an airport, are connected by a railway line which also passes through towns b, c, d, e, f, g, h, i, j and k. We will assume that a dominant hub airline is located on airport A (and we will assume that this airline is the only one to provide connections between A and L, and is organized to route passengers to medium and long haul flights to several Z cities. Airport L is a local airport. Unless otherwise specified, we shall assume that so far, only one railway operator can run trains on the line between A and L.

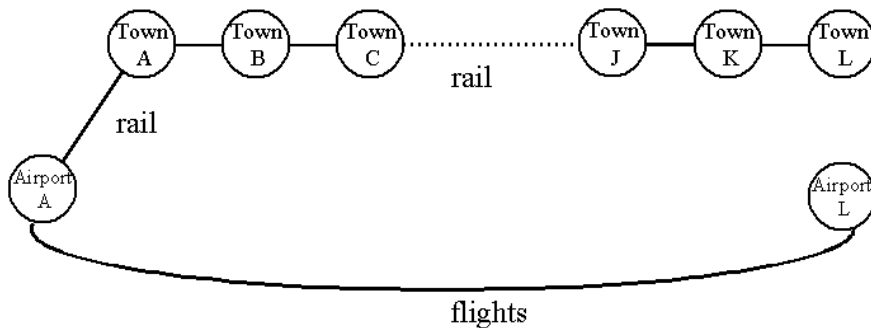


Figure 1: L to A travel

There are apparently several simple reasons for an airline, which runs medium and long haul flights from airport A, to be in favor of an airport rail connection (we will discuss in part III the different types of connections that can be envisioned).

First of all, it makes it easier to bring in passengers located in towns which are far away from the airport but which are served by the rail network. In certain cases, it even becomes possible to attract customers who formerly chose other hubs (diversion traffic).

Furthermore, if the dominant airline on airport A succeeds in establishing agreements with the railway operator, it might consider reducing or suspending its flights between airports A and L, which would enable it to recover take-off and landing slots, which are a rare commodity on many airports, while continuing to supply its Hub with passengers travelling from (or to) city L.

As for the railway operator, it can hope to benefit from the increased traffic due either to the fact that the airlines no longer operate the A-L link, or to the diversion and the carriage of a greater number of passengers than before (plus the traffic between airport A and city A).

However, we need to be wary of this type of first-order consideration: The reason is that an event which initially appears advantageous for certain economic players can, when considering the changes in behaviour it induces for the economic players concerned, turn out to be disadvantageous. It is for this reason that this paper will discuss if and how the interconnection between an airport used as a hub and a railway line can modify the competition between rail and air.

In what follows, we will distinguish between two main types of market in which airlines and railway operators are potentially in competition.

In the first section, we will discuss the markets for routing passengers to airport A for the purpose of connecting with medium and long haul flights.

In the second section, we will analyze if and how the interconnection of the networks poses or does not pose a problem for the airlines and railway operators in the point-to-point market between city A and other towns and cities located along the railway line.

1.2 The double marginalisation problem

If the airlines and the railway operator do not establish a pricing agreement, we will observe a double marginalisation phenomenon. This is because the railway operator will not take the profits made by the airlines on long or medium haul flights into account in his pricing system.

To illustrate this problem, let us consider the following example which, although simplistic, provides a better understanding of the problem: To simplify the situation, we assume that only the dominant airline proposes flights to a city

Z, and that both the airline and the railway operator have zero marginal costs³. We assume that the market demand for travel between a town or city located on the railway line and a faraway city Z is $Q = \alpha - \beta p$.

If the airline and railway operator could coordinate their prices, they would choose to charge $\frac{\alpha}{2\beta}$ for the entire journey V-A-Z.

If the railway operator and the airline simultaneously set their own prices without consulting each other (assuming that all passengers who go to airport A are bound for Z as a final destination), the airline and railway operator will both charge⁴ $\frac{\alpha}{3\beta}$ making a total price of $\frac{2\alpha}{3\beta}$.

Without coordination, the price of the journey is therefore higher and the profits of the "airline and railway operator considered together" are lower (neither of the two takes into consideration the positive externality induced by a decrease in its charges on the other, and the prices established are therefore "too" high).

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This problem continues to be present, and is even accentuated, when we consider the fact that the airline offers several destinations departing from airport A.

To illustrate this problem, let us extend the previous example: We assume that only the dominant airline offers flights to a city Z'. The airlines still have zero marginal costs. The market demand for travel between a town or city V located on the railway line and a remote city Z is $Q = \alpha - \beta p$, while that for travel between V and city Z' is $Q' = \alpha' - \beta' p'$.

If the firms could coordinate their prices, they would choose to charge $\frac{\alpha}{2\beta}$ for the entire V-A-Z journey and $\frac{\alpha'}{2\beta'}$ for the entire V-A-Z' journey⁶.

If the railway operator and the airline simultaneously choose their prices without consulting each other, the railway operator will charge $p_2 = \frac{\alpha + \alpha'}{3(\beta + \beta')}$ and the airline will charge $p_1 = \frac{\alpha}{2\beta} - \frac{\alpha + \alpha'}{6(\beta + \beta')}$ for A-Z flights from V and $p'_1 = \frac{\alpha'}{2\beta'} - \frac{\alpha + \alpha'}{6(\beta + \beta')}$ for A-Z' flights from V.

Here again, without coordination, the price of the journey is therefore higher than in the case of coordination ($p_1 + p_2 = \frac{\alpha}{2\beta} + \frac{\alpha + \alpha'}{6(\beta + \beta')}$, $p'_1 + p_2 = \frac{\alpha'}{2\beta'} + \frac{\alpha + \alpha'}{6(\beta + \beta')}$), and the profits of the "airline and railway operator considered together" are

³Which has no effect on the qualitative results.

⁴This is a typically standard model. Its processing is described in detail in appendix 1.

⁵Note that the price charged by the airline without coordination between the two firms can integrate partial (or total) refunds of the price of transport to airport A: This is because price $\alpha/3\beta$ is the price paid by a passenger coming from V to airport A for the purpose of using a connecting flight to Z for the A-Z flight, and is not necessarily equal to the price paid for the same flight by a passenger coming from another town or city. The problem for the airline results from the fact that the railway operator integrates the possible refund of the price of the rail travel by the airline. It is therefore not possible for the airline to eliminate the double marginalisation problem by refunding a part of the train fare.

⁶Refer to appendix 2 for full details of how this is processed.

lower than if the firms coordinate themselves with each other.

Moreover, this problem is accentuated by the fact that - without coordination - the railway operator cannot discriminate between passengers who intend to make one complete journey or the other⁷ : the result is a situation in which, at the end of the day, the profits of the "airline and railway operator considered together" are even lower than if the railway operator could discriminate, because this would involve prices which would be even less coordinated.

If the airline takes advantage of sufficiently appropriate margins on its A-Z flights, or if, on airport L, it has to face the competition of airlines established on other Hubs, it will offer L-A-Z fares which are "relatively" close to those of A-Z flights⁸, leaving little room for railway operators in the market for carrying passengers from L to airport A for a connecting flight to Z. So in the end, if there is no agreement, airlines who find that the fares of the railway operators are excessive will have little reason to modify their flights from L to A. People wishing to travel from L to Z will continue to fly to airport A.

1.3 Possible form of an agreement between an airline and a railway operator

What would an agreement between an airline and a railway operator, for the purpose of maximizing all their profits, look like?

First of all, the firms will coordinate their timetables, and above all the frequencies of their flights and trains, in order to minimise connection times. As for timetables, even if no agreement is established, the railway operator will have good reasons to coordinate its timetables with those of the dominant airline. Conversely, the frequency of the railway operator's trains generates positive externality for the airlines, while involving non-negligible expenditure. If no agreement is established, the railway operator's frequency will therefore be sub-optimal⁹. An agreement between the dominant airline and the railway operator would no doubt involve increasing the railway operator's frequency, provided that this does not conflict with the discrimination policy of the firms.

The core of the agreement would be to extend the yield management system to the entire journey, with the result to sell the train ticket and the air ticket

⁷In which case, the problem would simply consist in juxtaposing several independent problems of the preceding type. Refer to appendix 2.

⁸This is indeed what happens in practice.

⁹If several railway operators are in competition on the line, this will not necessarily hold true: This is because a railway operator will add another train for as long as this adds a supplementary positive profit without taking into consideration the negative externality that this induces for other railway operators. As the capacities of the trains are not totally flexible, the result is likely to be an excessive number of trains from the social surplus point of view, resulting in insufficiently filled trains.

together.

Their pricing would avoid the double marginalisation phenomenon: the price of the town of departure-A-Z journey would be less than the sum of the prices of the town of departure-A and A-Z journeys. This reduction would depend on the town of departure, and could be variable on the basis of a number of different characteristics, which would be difficult to achieve without an agreement.

If we use the analysis by Mussa et Rosen [11], it would be necessary to offer high-level services at a high price to high-paying passengers, and to degrade the quality of the service for low-paying passengers in order to dissuade high-paying passengers from choosing the economy fare.

In practice, what form could this discrimination have? Several scenarios are possible:

We should already note that, because landing/take-off slots are scarce resources on saturated airports, their cost of opportunity could make it profitable to abandon L-A flights if the difference between the rail and air journey times is not large enough to significantly degrade the service provided to high-paying passengers. In this case, the differentiation between offers at the routing level would concern comfort, the possibility of checking in luggage at the departure railway station, the refund policy in the case of a delayed train, etc. Since airlines pricing strategies are already based on differentiation, and since the ticket sold would be global, it would not even be necessary to have a differentiation on the train part of the journey.

If the difference in rail and air travel times is fairly large¹⁰, three-tier differentiation will be possible: Offer conditions and prices such that high-paying passengers departing from L and neighboring towns travel by air, high-paying passengers departing from other towns travel "1st class" by train, and low-paying passengers departing from all cities and towns travel "2nd class" by train.

The airlines and the railway operator therefore have every good reason to implement this type of agreement¹¹.

1.4 Factors which make it easier to reach an agreement

Even though an agreement is profitable for both parties, transaction costs and information asymmetry are liable to make it difficult to put the agreement into

¹⁰Or if the link is too profitable for the airline and the powers of negotiation of the railway operator are not strong enough to demand that the link be abandoned.

¹¹The sharing of the profits yielded by these agreements will obviously be highly dependent on the structure of the railway market (closed or open to competition?) and on the structure of the competition between the airlines located on airport A. We will further discuss this matter in part 3, as it is largely such considerations that will influence the firms in their decision whether or not to co-finance the linking infrastructures.

concrete form. There is nevertheless a mechanism which can facilitate this agreement:

It will be to the advantage of the dominant airline on airport A if the railway operator does not establish an agreement with any rival airlines, and better still if it establishes "prohibitive" prices for journeys to airport A that are not followed by flights on its own routes. If obtaining an exclusive agreement makes it advantageous for the dominant airline to abandon or reduce the number of flights between L and A, the railway operator may be well advised to grant exclusive rights (or at least to reduce the requirements for granting exclusive rights) in order to benefit from the customers that are left. Note, however, that this is all the more probable if it is difficult for the non-dominant airlines to enter the market for flights between L and A (otherwise they would reduce the profits expected by the railway operator as a result of the L-A flights abandoned by the dominant airline, by entering this market).

If the dominant airline is "sufficiently" powerful, it may also be prepared to offer, in exchange for the exclusive rights, more than the railway operator could expect to gain by establishing agreements with other airlines.

Finally, we should note that if several railway operators are able to use the railway infrastructures, it will be more difficult to obtain an agreement once the railway has been linked up to the airport (the airline will have the possibility of negotiating with several companies, or even setting up its own rail transport company, reduced double marginalisation, etc.). Conversely, we can see that the dominant airline will, in this case, find it less advantageous for the airport to be connected to a railway line, because it will not be able to prevent its rivals from negotiating routing agreements with certain railway operators (financing problems will be discussed in more detail in Part 3).

1.5 Influence of the intermodality agreement on competition between airlines for medium or long haul flights departing from airport A

For as long as the railway line is not connected to airport A, in a simplified scenario, we can consider that the non-dominant airlines on airport A do not serve travelers who come from towns near L, and are "on a par"¹² with the dominant airline in other markets.

How does the airport railway line change matters? This depends on the number of railway operators who are able to use the L-A connection.

¹²In terms of the conditions offered to passengers for routing them to airport A. This is obviously not the case if we consider the frequencies of the medium or long haul flights, for example.

If rail transport is opened to competition and if access to this market is not too difficult, the non-dominant airlines might have the possibility of negotiating an agreement with a railway operator and could therefore end up "on a par" with the dominant airline in terms of passenger routing capacities. In this case, as the airlines become rivals in markets where they were not rivals before, we can conjecture that connecting the airport to a railway line could increase the intensity of the competition in these markets¹³.

Things are more complicated if only one railway operator can use the line. Unless there is a legislation to prevent this, it becomes possible (or perhaps even probable) for the railway operator to establish an exclusive agreement with the dominant airline¹⁴. Such an agreement would then reinforce the asymmetry between airlines in terms of routing capacity. Should we expect this to increase or reduce competition between airlines? Both outcomes appear to be possible:

If the capacities are limited, the dominant airline may prefer to take advantage of a considerable benefit from high-paying clients for whom it represents an advantage in terms of routing to the Hub, and "leave" other potential customers to the other airlines. In this case, we would see a decrease in the intensity of the competition between the dominant airline and the other airlines.

If, on the other hand, the capacities are not particularly limited, the dominant airline might wish to benefit from the additional advantage generated by its agreement with the railway operator in order to capture the customers of the other airlines, thus increasing the intensity of the competition.

These questions deserve a longer and more rigorous discussion, but are only just within the boundary of this article and therefore will not be covered in more details.

1.6 Conclusion

In the market for routing travelers to airport A in order to connect with a medium or long haul flight, airlines and railway operators are therefore act more as partners than as rivals.

This is because airlines which operate a Hub are not really seeking to use routing as a source of profit, which puts the railway operator in a situation where it cannot compete with them in this particular market.

In this situation, there are many reasons which press airlines and railway operators to reach an agreement : possibility of price discrimination, elimination

¹³This conjecture might nevertheless be mitigated if the airport is highly saturated. In this case, as the link between the airport and the railway line would generate a new demand, there is a possibility that airlines with a limited capacity may find it more advantageous to moderate their competition (tacit collusion).

¹⁴For example, in the Stuttgart - Frankfurt market, the German railway operator, Deutsche Bahn, has an exclusive intermodal agreement with Lufthansa.

of the double marginalisation, coordination of frequencies and timetables.

In certain cases, an exclusive agreement between the railway operator and the dominant airline could lead the airline to spontaneously abandon its routing flight. In this case, the railway operator may find it advantageous to propose an exclusive agreement with the dominant airline, rather than seeking to establish agreements with more airlines.

Finally, the influence of intermodality in the intensity of competition at the hub, can be an increase or a decrease, depending on the structure of the airlines and rail markets, and on the capacity limits of the airports.

2 Intermodality and competition on L-A point to point travel market

In this section, we will look at the air/rail competition in the point to point travel market between a town located near airport L and a town located near airport A.

Although airlines and railway operators can be complementary in the market for connecting passengers on hub A, they are clearly rivals in the market of point to point travel between L and A.

Physically speaking, interconnecting the networks can make the flights offered by the airlines more attractive, because it enables the passengers arriving at airport A to use the rail link to go to the centre of city A. The railway operator can obviously limit this increased advantage for airlines, either by charging a very high fare for the journey between airport A and city A or by degrading the quality of the link.

We have seen, in the previous section, that a certain type of logic could encourage the dominant airline to abandon its flights between L and A, if an exclusive agreement were signed with the railway operator. In any case, we have seen that the railway operator and the dominant airline both have a lot to gain if they sign an agreement in the routing market, and this clearly indicates a potential arrangement (albeit illegal) concerning competition in the market of point to point travel between A and L.

It can also be seen that limiting the capacities of the airlines will also contribute to the same process.

In our model, although we do not take these effects¹⁵ into account, we will see that there are mechanisms which yield results where competition between airlines and railway operators is limited. In this sense, by improving the quality

¹⁵In particular, for the purposes of simplification, we will assume that the railway operator does not charge for the journey between airport A and city A.

of its rival's product (through the link), the railway operator also improves its own situation.

In this model, there are two types of traveler, for whom the time spent travelling is either a relatively important factor or a relatively unimportant one. We will show that this model is equivalent to a model of competition with switching costs, and we will see that, under certain conditions, there is a Nash equilibrium for which the companies choose not to compete with each other: the airline keeps the market for passengers who consider time as an important factor, and the railway operator keeps the market for passengers who do not consider time as an important factor, and each company charges a fare based on a market monopoly. The interest of this model will be to show that the conditions which provide this equilibrium become less stringent when the air travel time becomes shorter, and this is therefore potentially positive for both firms¹⁶.

This model is very simple, but it runs up against Bertrand's paradox: In a certain number of cases, there is no Nash equilibrium. Morgan and Shy[12] propose a concept to work around this problem: the undercut-proof equilibrium, which is an extension of the Nash equilibrium concept in models which include switching cost. The calculations involved, however, are far more complex and the results seem to point in the same direction¹⁷ without giving rise to interpretations which are noticeably different from those of this small model.

2.1 The Model

We will assume that there are two types of traveler: time-sensitive travelers who are characterized by a high value of time v ($v > 0$), and time-indifferent travelers who are characterized by a null value of time. We assume that there is only one airline and only one railway operator who provide links between A and L.

T_1 and T_2 shall designate the (strictly positive) travel times between the centres of cities L and A, for journeys by plane and by train respectively. p_1 shall be the fare between L and A by plane, and p_2 shall be the fare by train. c_1 and c_2 shall be the marginal costs of the journeys by plane and by train¹⁸, and m_1 and

¹⁶The problems addressed in this model are very close to those in Gabzewicz and Thisse(82) and Shaked and Sutton (82). But, unlike them, the demand functions depend on prices, which, contrary to Gabzewicz and Thisse, implies, under some circumstances, the existence of a Nash equilibrium where both firms have positive market shares. As Shaked and Sutton, we find that increasing the quality of the firm selling the high-quality product may increase the profit of the firm selling the low-quality product

¹⁷to see this model, go to leea website : <http://www.enac.fr/recherche/leea/>

¹⁸The cost structure involved in the offer for travel by train and by plane is actually much more complicated, and involves costs which can be either fixed or variable depending on the time-scale concerned. This model can nevertheless demonstrate yield management policies, provided that we represent the competition in a time "range" among others which precede the journey, and that the marginal costs of selling a ticket now integrates the reduction in the profit

m_2 shall be the profit margins ($m_1 = p_1 - c_1$, $m_2 = p_2 - c_2$).

From a semantic point of view, we will refer to the natural market of the airline when speaking of the market for travelers with a high value of time, and to the natural market of the railway operator when speaking of the market for travelers with a low value of time.

We assume that prospective travelers, if they decide to travel¹⁹, use the means of transport whose global cost (integrating the value of time) is the lowest: This means that the time-sensitive travelers, if they decide to travel, go by plane if and only if $p_1 + vT_1 \leq p_2 + vT_2$, i.e. if $m_1 \leq m_2 + (-(c_1 - c_2) + v(T_2 - T_1))$.

As for the time-indifferent, they go by train if $m_2 \leq m_1 + (c_1 - c_2)$.

To simplify the presentation of our problem, we will assume that the firms simultaneously set their margins m_i . From this point of view, values $(-(c_1 - c_2) + v(T_2 - T_1))$ and $(c_1 - c_2)$ which appear in the right-hand term of the above inequality can be considered as switching costs in a model where the marginal costs are nil: They will henceforth be noted μ_1 and μ_2 .

$$\begin{aligned}\mu_1 &= (-(c_1 - c_2) + v(T_2 - T_1)) \\ \mu_2 &= (c_1 - c_2)\end{aligned}$$

The reason is that, for time-sensitive travelers to change from their natural product (travel by air) to the other product (travel by train), it is necessary for the price required by the railway operator + μ_1 to be less than the price required by the airline.

We will assume that if both firms choose zero margins, less time-sensitive travelers will fly and the time-indifferent travelers will travel by train (which is the same as saying that μ_1 and μ_2 are positive). This is why we can speak of natural markets for each of the two firms.

Therefore, depending on the margins, the travelers will choose their means of transport based on the following outline:

2.2 Demand

Finally, we assume that the inverse demand functions integrate the travelers' values of time and are linear:

The inverse demand for time-sensitive travelers is $p_1 + vT_1 = a_1 - b_1q$ if they prefer to fly, or $p_2 + vT_2 = a_1 - b_1q$ if they prefer to go by train.

Which can be re-stated as follows:

expectation for travel during future time ranges, due to the fact that a ticket sold now cannot be sold later.

¹⁹This is because, in this model, the demand for travel will also depend on the price.

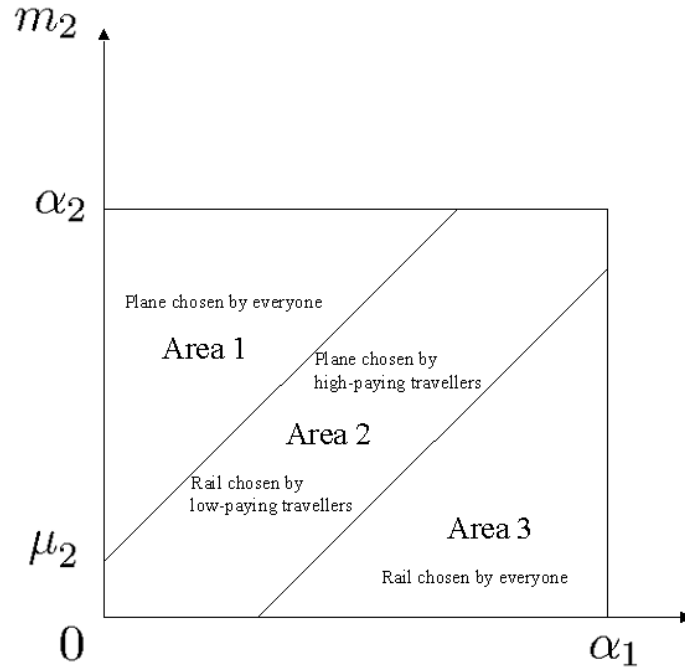


Figure 2: transport choice

- $m_1 = (a_1 - c_1 - vT_1) - b_1q$ if they prefer the plane
- $m_2 + \mu_2 = (a_1 - c_1 - vT_1) - b_1q$ if they prefer the train

Similarly, the inverse demand for time-indifferent travelers is $p_1 = a_2 - b_2q$ if they prefer to fly, or $p_2 = a_2 - b_2q$ if they prefer to go by train.

Which can be re-stated as follows:

- $m_1 + \mu_1 = (a_2 - c_2) - b_2q$ if they prefer the plane
- $m_2 = (a_2 - c_2) - b_2q$ if they prefer the train

2.3 Summary of hypotheses and simplification

In reality, after simplification, this problem can be reduced to a model in which two firms, 1 and 2 (1: airline / 2: railway operator), whose marginal costs are nil, compete with each other by setting their prices m_i simultaneously, where each one has its own captive market which is characterized by a switching cost μ_i and

by an inverse demand $m_i = A_i - b_i q_i$, with the following relations:

$$\begin{aligned} A_1 &= a_1 - c_1 - vT_1 \\ A_2 &= a_2 - c_2 \\ \mu_1 &= -(c_1 - c_2) + v(T_2 - T_1) \\ \mu_2 &= c_1 - c_2 \end{aligned}$$

It will be easier for us to consider, hereafter, the demand functions $q_1 = \alpha_1 - \beta_1 m_1$ and $q_2 = \alpha_2 - \beta_2 m_2$, with

$$\begin{aligned} \beta_i &= \frac{1}{b_i} \\ \alpha_1 &= \frac{A_1}{b_1} = \frac{a_1 - c_1 - vT_1}{b_1} \\ \alpha_2 &= \frac{A_2}{b_2} = \frac{a_2 - c_2}{b_2} \end{aligned}$$

2.4 Profit for the firms

According to the outline and the hypotheses, the profits of the firms will be:

Area	Condition	Firm1's profit (airline)	Firm 2's profit (rail operator)
Area 1	$m_1 + \mu_2 < m_2$	$m_1 (\alpha_1 - \beta_1 m_1 + \alpha_2 - \beta_2 (m_1 + \mu_2))$	0
Area 2	$m_1 - \mu_1 \leq m_2 \leq m_1 + \mu_2$	$m_1 (\alpha_1 - \beta_1 m_1)$	$m_2 (\alpha_2 - \beta_2 m_2)$
Area 3	$m_2 < m_1 - \mu_1$	0	$m_2 (\alpha_1 - \beta_1 (m_2 + \mu_1) + \alpha_2 - \beta_2 m_2)$

or, equivalently

Area	Condition	Firm1's profit (airline)	Firm 2's profit (rail operator)
Area 1	$m_1 + \mu_2 < m_2$	$m_1 (\alpha_1 + \alpha_2 - \beta_2 \mu_2 - (\beta_1 + \beta_2) m_1)$	0
Area 2	$m_1 - \mu_1 \leq m_2 \leq m_1 + \mu_2$	$m_1 (\alpha_1 - \beta_1 m_1)$	$m_2 (\alpha_2 - \beta_2 m_2)$
Area 3	$m_2 < m_1 - \mu_1$	0	$m_2 (\alpha_1 + \alpha_2 - \beta_1 \mu_1 - (\beta_1 + \beta_2) m_2)$

2.5 Why is the pair which consists of the monopoly margins of the firms in their natural markets the only possible Nash equilibrium?

If a Nash equilibrium exists, it must necessarily be located in zone II. This is because, based on our hypothesis according to which the switching costs are positive, whatever the strictly positive margin m_i applied by one firm, the other can benefit from a strictly positive profit by choosing a strictly positive margin such that we are in zone II again. Similarly, (0,0) cannot be a Nash equilibrium because at least one of the firms can then choose a strictly positive margin while remaining in zone II.

- Consider that the pair made up of the monopoly margins of the firms in their natural market, $\left(\frac{\alpha_1}{2\beta_1}; \frac{\alpha_2}{2\beta_2}\right)$, is an element of zone II. In this case, if there is a Nash equilibrium, it should necessarily be the pair $\left(\frac{\alpha_1}{2\beta_1}; \frac{\alpha_2}{2\beta_2}\right)$. Otherwise, at least one of the two firms could increase its profits by coming closer to its monopoly price on its natural market.

- Consider that the pair made up of the monopoly margins of the firms in their natural market, $\left(\frac{\alpha_1}{2\beta_1}; \frac{\alpha_2}{2\beta_2}\right)$, is not an element of zone II, e.g. if it is in zone I (zone where company 1 takes over the entire market). In this case, there is no Nash equilibrium. This is because, for a pair in zone II to be in Nash equilibrium, it would have to belong to the part of the boundary between zone II and zone I such that $m_1 \geq \frac{\alpha_1}{2\beta_1}$ and $m_2 \leq \frac{\alpha_2}{2\beta_2}$, otherwise at least one of the two firms could increase its profits and come closer to its monopoly price, whilst remaining in zone II.

But it is not possible for a part belonging to this boundary to be a Nash equilibrium, because in this case it would be advantageous for firm 1 to lower its price (perhaps only slightly) in order to attract the customers of firm 2.

To sum up, in order to obtain a Nash equilibrium, it is necessary for $\left(\frac{\alpha_1}{2\beta_1}; \frac{\alpha_2}{2\beta_2}\right)$ to be a part of zone II (i.e. $\frac{\alpha_1}{2\beta_1} - \mu_1 \leq \frac{\alpha_2}{2\beta_2} \leq \frac{\alpha_1}{2\beta_1} + \mu_2$). In this case, if it exists, it is this pair.

2.6 Conditions required to ensure that the pair made up of the monopoly margins of the firms on their natural markets is a Nash equilibrium

First of all, as we have just seen, it is necessary to have $\frac{\alpha_1}{2\beta_1} - \mu_1 \leq \frac{\alpha_2}{2\beta_2} \leq \frac{\alpha_1}{2\beta_1} + \mu_2$.

For this point to actually be a Nash equilibrium, it is then necessary that neither of the two firms be tempted to change its price in order to take over the market of its rival.

If one of the firms chooses its monopoly price on its market, the best price that the other firm can choose out of those which enable it to obtain both markets, is located on the boundary (the demonstration is simple, but not so interesting: refer to appendix 3). So, for a firm i not to be tempted to change its price in order to take over the market of its rival, his monopoly profit on his own market $\frac{(\alpha_i)^2}{4\beta_i}$ has to be superior to his profit when he charges $\frac{\alpha_j}{2\beta_j} - \mu_j$ ($j \neq i$) and captures his rival's natural market

We therefore have a Nash equilibrium if and only if these three conditions hold:

$$\frac{\alpha_1}{2\beta_1} - \mu_1 \leq \frac{\alpha_2}{2\beta_2} \leq \frac{\alpha_1}{2\beta_1} + \mu_2 \quad (1)$$

$$\frac{(\alpha_1)^2}{4\beta_1} \geq -(\beta_1 + \beta_2) X^2 + (\alpha_1 + \alpha_2 - \beta_2\mu_2) X \text{ avec } X = \frac{\alpha_2}{2\beta_2} - \mu_2 \quad (2)$$

$$\frac{(\alpha_2)^2}{4\beta_2} \geq -(\beta_1 + \beta_2) Y^2 + (\alpha_1 + \alpha_2 - \beta_1\mu_1) Y \text{ avec } Y = \frac{\alpha_1}{2\beta_1} - \mu_1 \quad (3)$$

In this case, the Nash equilibrium is $\left(\frac{\alpha_1}{2\beta_1}; \frac{\alpha_2}{2\beta_2}\right)$

2.7 Why these conditions become less stringent when the A-L air travel time decreases

We will now study the variations of these three inequalities' terms when T_1 decreases while the other parameters remain unchanged ($a_1, a_2, b_1, b_2, c_1, c_2$ et T_2).

From now on, we shall suppose that the pair made up of the monopoly margins of the firms on their natural markets is a Nash equilibrium, before the decrease of T_1 (or equivalently that the four inequations 1, 2 et 3 are satisfied).

Let's first compute the derivatives in T_1 of the variables α_i, β_i , et μ_i when the other parameters remain unchanged ($a_1, a_2, b_1, b_2, c_1, c_2$ et T_2)

Main variables' derivative in T_1 Using the variables' definition,

$$\begin{aligned} \frac{\partial \mu_1}{\partial T_1} &= -v \\ \frac{\partial \mu_2}{\partial T_1} &= 0 \\ \frac{\partial \alpha_1}{\partial T_1} &= -\frac{v}{b_1} = -\beta_1 v \\ \frac{\partial \alpha_2}{\partial T_1} &= 0 \\ \frac{\partial \beta_1}{\partial T_1} &= 0 \\ \frac{\partial \beta_2}{\partial T_1} &= 0 \end{aligned}$$

When T_1 decreases by 1, the switching cost μ_1 increases by v : The maximum price that each time-sensitive traveler is willing to pay for a flight between A and L increases by v while the maximum price he's willing to pay for the same trip by rail doesn't change. Therefore the margin difference required so that a time-sensitive passenger prefers to use the train on the A-L route must also increase by v (in absolute value).

Similarly, $\frac{\alpha_1}{\beta_1}$ is the maximum margin (which is the maximum price minus a constant) above which no time-sensitive passenger will be willing to buy a plane ticket between A and L. This maximum margin also includes the value of the time spent by a time-sensitive passenger when travelling by plane from A city center to L city center: If T_1 decreases by 1, this maximum margin increases by v .

The first two inequations (inequations 1) The inequations $\frac{\alpha_1}{2\beta_1} - \mu_1 \leq \frac{\alpha_2}{2\beta_2} \leq \frac{\alpha_1}{2\beta_1} + \mu_2$ can be restated as follows

$$\begin{aligned} \frac{\alpha_2}{2\beta_2} - \frac{\alpha_1}{2\beta_1} + \mu_1 &\geq 0 \\ \text{et } \frac{\alpha_1}{2\beta_1} + \mu_2 - \frac{\alpha_2}{2\beta_2} &\geq 0 \end{aligned}$$

By derivating, $\frac{\partial(\frac{\alpha_2}{2\beta_2} - \frac{\alpha_1}{2\beta_1} + \mu_1)}{\partial T_1} = \frac{v}{2} - v = -\frac{v}{2} < 0$ et $\frac{\partial(\frac{\alpha_1}{2\beta_1} + \mu_2 - \frac{\alpha_2}{2\beta_2})}{\partial T_1} = -\frac{v}{2} < 0$.

So, if these two inequations are satisfied for some parameters ($a_1, a_2, b_1, b_2, c_1, c_2, T_1$ et T_2), they will also be satisfied for smaller values of T_1 .

Interpretation:

These inequalities mean that if each firm charges his monopoly margin on his natural market, the difference between these margins is small enough relative to the switching cost so that none of the two firms captures the natural market of the other firm.

When T_1 decreases by 1, the airline 1 monopoly margin increases by $\frac{v}{2}$ while each time-sensitive traveler would be willing to pay an extra v^{20} . Therefore, since the monopoly price of the railway operator does not change, train travels become even less attractive for time-sensitive passengers, and the first inequation is more likely to hold. Moreover, as time-indifferent travelers do not value time, flights between A et L become less attractive to them as their price increases. The second inequation is also more likely to hold.

²⁰This is a classical effect: on a monopoly market, if the marginal willingness to pay increases by a certain amount, the monopoly's price will only bear a fraction of this increase.

The inequation assuring that the airline has no incentive to cut his price in order to capture the time-indifferent travelers' market (inequation 2)

The airline has no incentive to cut his price in order to capture the time-indifferent travelers' market if and only if:

$$\frac{(\alpha_1)^2}{4\beta_1} \geq -(\beta_1 + \beta_2) X^2 + (\alpha_1 + \alpha_2 - \beta_2\mu_2) X \text{ avec } X = \frac{\alpha_2}{2\beta_2} - \mu_2$$

or

$$\frac{(\alpha_1)^2}{4\beta_1} + (\beta_1 + \beta_2) X^2 - (\alpha_1 + \alpha_2 - \beta_2\mu_2) X \geq 0.$$

Here X is the best margin that the airline 1 can choose out of those which enable it to obtain both markets if the railway operator charges his monopoly price on his natural market.

As $\frac{\partial X}{\partial T_1} = 0$,

$$\begin{aligned} \frac{\partial \left(\frac{(\alpha_1)^2}{4\beta_1} + (\beta_1 + \beta_2) X^2 - (\alpha_1 + \alpha_2 - \beta_2\mu_2) X \right)}{\partial T_1} &= \frac{2\alpha_1}{4\beta_1} \frac{\partial \alpha_1}{\partial T_1} - \left(\frac{\partial \alpha_1}{\partial T_1} \right) X \\ &= \frac{\partial \alpha_1}{\partial T_1} \left(\frac{\alpha_1}{2\beta_1} - X \right) \\ &= -v\beta_1 \left(\frac{\alpha_1}{2\beta_1} + \mu_2 - \frac{\alpha_2}{2\beta_2} \right) \\ &\leq 0 \text{ from the inequation 1} \end{aligned}$$

So, if inequations 1 and 2 hold for some parameters ($a_1, a_2, b_1, b_2, c_1, c_2, T_1$ et T_2), they also hold for smaller values of T_1 .

Interpretation:

The inequation 2 is the condition so that the airline 1 prefers charging his monopoly price on his natural market and having only time-sensitive travelers as customers rather than charging a smaller price to capture the time-indifferent travelers' market. If T_1 decreases, α_1 is the only varying parameter of the inequation. The question here is how an increase in α_1 modifies the airline 1's incentives to cut his price in order to capture the time-indifferent travelers' market.

Let's look at the airline 1's profit:

- If the airline's environment is such that it prefers to choose a margin m for which it only has time-sensitive travelers customers, its profit is:

$$m(\alpha_1 - \beta_1 m)$$

with $m = \frac{\alpha_1}{2\beta_1}$ is chosen in order to maximise this profit. From the envelope theorem, the total profit's derivative in α_1 is equal to the margin $m = \frac{\alpha_1}{2\beta_1}$.

- If the airline's environment is such that it prefers to choose a margin m for which it captures both markets, its profit is:

$$m(\alpha_1 + \alpha_2 - \beta_2\mu_2 - (\beta_1 + \beta_2)m)$$

with $m = \frac{\alpha_2}{2\beta_2} - \mu_2$. Here, the influence of an increase in the parameter α_1 is only modifying the profit through an increase in demand: So, the total profit's derivative in α_1 is equal to the margin $m = \frac{\alpha_2}{2\beta_2} - \mu_2$.

In both cases, a small increase $\partial\alpha_1$ of the parameter α_1 generates a small increase of the airline's profit $m\partial\alpha_1$. As the airline 1's margin when it charges its monopoly price is higher than when it cuts its price to capture both markets, its profit increases more when it contents itself with its natural market. So, as T_1 decreases, the airline 1 has less incentives to try and capture the railway operator's natural market.

The inequation assuring that the railway operator 2 has no incentive to cut his price in order to capture the time-sensitive travelers' market (inequation 3) The railway operator has no incentive to cut his price in order to capture the time-sensitive travelers' market if and only if:

$$\frac{(\alpha_2)^2}{4\beta_2} \geq -(\beta_1 + \beta_2)Y^2 + (\alpha_1 + \alpha_2 - \beta_1\mu_1)Y \text{ avec } Y = \frac{\alpha_1}{2\beta_1} - \mu_1$$

or

$$\frac{(\alpha_2)^2}{4\beta_2} + (\beta_1 + \beta_2)Y^2 - (\alpha_1 + \alpha_2 - \beta_1\mu_1)Y \geq 0.$$

Here Y is the best margin that the railway operator 2 can choose out of those which enable it to obtain both markets if the airline 1 charges his monopoly price on his natural market.

$$\text{As } \frac{\partial Y}{\partial T_1} = -\frac{\beta_1 v}{2\beta_1} + v = \frac{v}{2},$$

$$\begin{aligned}
& \frac{\partial \left(\frac{(\alpha_2)^2}{4\beta_2} + (\beta_1 + \beta_2) Y^2 - (\alpha_1 + \alpha_2 - \beta_1 \mu_1) Y \right)}{\partial T_1} \\
&= (2(\beta_1 + \beta_2) Y - (\alpha_1 + \alpha_2 - \beta_1 \mu_1)) \frac{\partial Y}{\partial T_1} - \left(\frac{\partial \alpha_1}{\partial T_1} - \beta_1 \frac{\partial \mu_1}{\partial T_1} \right) Y \\
&= \left(2(\beta_1 + \beta_2) \left(\frac{\alpha_1}{2\beta_1} - \mu_1 \right) - (\alpha_1 + \alpha_2 - \beta_1 \mu_1) \right) \frac{v}{2} - 0 \\
&= \left(\frac{\beta_2 \alpha_1}{\beta_1} - 2(\beta_1 + \beta_2) \mu_1 - \alpha_2 + \beta_1 \mu_1 \right) \frac{v}{2} \\
&= \frac{v}{2} 2\beta_2 \left(\frac{\alpha_1}{2\beta_1} - \frac{\alpha_2}{2\beta_2} - \frac{2\beta_2 + \beta_1}{2\beta_2} \mu_1 \right) \\
&= -v\beta_2 \left(\frac{\alpha_2}{2\beta_2} - \frac{\alpha_1}{2\beta_1} + \mu_1 + \frac{\beta_1}{2\beta_2} \mu_1 \right) \\
&\leq 0 \text{ from the inequation 1}
\end{aligned}$$

So, if inequations 1 and 3 hold for some parameters ($a_1, a_2, b_1, b_2, c_1, c_2, T_1$ et T_2), they also hold for smaller values of T_1 .

Interpretation of inequality 3: The railway operator nř2 prefers to charge a monopoly price on its natural market and have only time-indifferent passengers, rather than practice a more attractive price for time-sensitive passengers. If T_1 decreases, the profit made by the railway operator when charging its monopoly price on its natural market does not change. On the other hand, the optimal margin it has to charge in order to capture the market of time-sensitive passengers decreases : it is so because the airline only increases its price by a fraction of the extra charge that the time-sensitive passengers would be willing to pay (because of the decrease in travel time T_1). As T_1 decreases, the railway operator is less and less interested in capturing the airline's natural market.

2.8 Conclusion

We have seen that, under certain hypotheses²¹, there exist a Nash equilibrium, for which the airline and railway operators have no interests in competing, and will charge their monopoly price on their natural markets. Moreover, we have shown that the shorter the travel time by plane between A city center and L city center, the more likely this equilibrium will exist. This result, demonstrated in a

²¹In our model, we have taken the demand functions to be linear. Our results also extend to more general demand functions.

context where the lowest value of time equals 0, can be extended as long as it is not "too" close to the highest value of time²².

It is so because if the travel time decreases, the airline monopoly price will increase by a fraction of the added value of the flight for the time-sensitive passengers. The monopoly price of the railway operator will be less attractive for the time-sensitive passengers, and conversely, the increased monopoly price of the airline will be less attractive for the time-indifferent passengers. In this setting, the railway operator finds it less interesting to try and capture the time-sensitive passengers, because it will require lower prices. As for the airline, the price required in order to attract time-indifferent passengers does not change, but is further from its monopoly price, and it becomes less interesting to try and capture the natural market of the railway operator.

Thus, the railway operator can find an interest in improving the quality of the airline's product (better interconnection of networks for example), when the products of the firms are substitutes but are differentiated. Other factors we have ignored, which act in the same direction (agreements on routing, limits on the number of slots, etc...), would even reinforce this conclusion.

Things would be different if several airlines proposed flights between A and L, or if entry on that market were easy. Nevertheless it seems to us that this does not invalidate this mechanism (especially if one airport is saturated), as long as competition between airlines remains imperfect²³.

3 Financing rail access to airports

As we can read in the European Commission White paper [2], the financing of rail infrastructure is a major concern in the European union. Rail infrastructure is costly, and finding funds in order to finance rail access to airports may not be an easy task. Since 1991, in Europe, there is a separation of railways operators and rail infrastructure managers (Council Directive 91/440/EEC of 29 July 1991 on the development of the Community's railways Official Journal L 237 , 24/08/1991 P. 0025 - 0028). According to this directive, the infrastructure manager is "any public body or undertaking responsible in particular for establishing and maintaining railway infrastructure, as well as for operating the control and safety systems". Since public funds are limited, and that the infrastructure manager has to balance revenues (fees and State contributions)and spendings, private funding can be a favored alternative (or complement), as long as it does not have adverse effects on the structure of the markets afterwards.

After giving a few examples, in order to identify different types of link, we

²²A working paper will soon be downloadable on the leea site

²³this will be the subject of a future research

shall examine in turn the possibilities of private investments in rail links to airport as well as their consequences. In particular we will explain that there is a contradiction between the efficiency of infrastructure use *ex post*, and the factors favoring private investments. The case of railway operators is more particularly discussed.

3.1 examples and typology of links

At this point, it seems useful to give a few examples, and to note that there are two main types of rail links to airports. The first that comes to mind is the link between the airport and the nearby city. This is the case, for example, of the Hong Kong Airport Express [5] which is a dedicated link from the city of Hong Kong to its new Chek Lap Kok airport; it reduces the trip time from 30 to 45 minutes by car, to 23 mn. It is also an example in intermodality, since passengers can check in at the railway station, including the baggage check.

The second solution is to connect the airport to the national rail network (classical or high speed), with or without a direct connection to the nearby city.

One example of a railway station in an airport, connecting to the high speed rail but **not** to the city itself is the TGV station in Paris Charles de Gaulle Airport [7]. There is nevertheless a connection between the airport and the city of Paris but it is by the local slow rail (45 to 50 minutes trip), without any intermodal feature.

In Sweden, the Stockholm airport (Arlanda airport) is connected **both** to the center of the city by a fast service (20 mn) and to the rest of the rail network. The airport station was built first with a view to linking the airport to the city by a high speed connection, and a new rail link was later built towards the north of the country. The airport station is now an important railway station part of the national network. It is also an example of private funding of rail infrastructure, since the tracks were totally financed by a private consortium.

The strategic effects of those different types of links for air and rail operators will be different. Links to city centers will have more effects on point to point markets (than on connecting markets) by decreasing travel time by plane, and will have impact on airlines and railways seen as providing substitute goods..

On the other hand, links to (high speed) national rail network will have more effects on connecting markets than on point to point markets. We have seen that on those markets, airlines and railways operators have incentives to act as partners rather than rivals.

In our approach to financing, we must therefore keep in mind those aspects, which will influence the incentives of firms to set up a financing scheme.

3.2 Private investments : who may finance

Private funding for rail airport access is possible only if the projected infrastructure is seen as a viable and profitable project by the investors. Outsiders, namely private investors not involved in the air or rail operations business, may be deterred by the long term aspect of the projects : they may only recoup their investment in 20-25 years, if ever. Another problem is that this type of investment is characterized by heavy investments and proportionally small operating costs, and at the same time appears clearly desirable for the public authorities. Private investors may therefore be suspicious of potential future regulations, aiming at setting access pricing closer to operating costs. Moreover, the future of competition in rail transport is not so far very clear, and it seems difficult to set up contracts not likely to be renegotiated later on. Finally, The channel tunnel financial failure has dampened whatever enthusiasm there may have been and finding private funds on financial markets may prove difficult.

To invest in rail, this leaves us with the air and rail operators (or infrastructure providers) , who may be willing to finance part of the infrastructure, if they can derive enough profit afterwards from the use of the infrastructure. As we shall see later, this may depend on the "ex-post" competition level of both of the markets, as well as on the expectation on what would otherwise do the public authorities.

The airports, although they may gain passengers if there is a direct rail link from the city to the airport, may have to trade off more passengers with less cars, and therefore less revenues from parking lots. Today parking spaces are an important source of revenues, and even if the increase of passengers may make up for the loss of parking revenues, airports do not have strong incentives so far to finance rail infrastructure, unless road access becomes really problematic. While today this is the case for airport-city links, for links to the national rail network, the case is not so clear cut. Airports may become more attractive for regional travelers and decreasing travel time may result into more traffic for the airport. The rail connection may also increase the attractiveness of the hub of the dominant airline, compared to other nearby hubs.

We can remark first that airlines and rail operators have less incentives to invest in rail infrastructure if they expect that the public authorities will invest in case they do not. If the operators foresee that this is a priority for the authorities, their best interest lies in waiting until the project is built.

Today, the airlines are not willing to invest in rail infrastructure, whatever it is. In their 2003 study [3], IATA interviewed several airlines representatives ²⁴and found out that they see air/rail intermodality favorably. It may increase their catchment area, and give them an edge on competitors if they have an exclusive

²⁴British Airways, Air France, Lufthansa, Easyjet, British Midland, European Regional Airline Association

agreement. Nevertheless, their expectations of intermodality are not high, and they are also uncertain about their relations with train operators (which can be competitors on routes and possibly partners on others, as we saw earlier). For these reasons, and since they are also operating on low margins, they are not willing to invest in infrastructure. They may also have already partly solved the access problems by operating bus links to the cities (see Air France in Paris for example)²⁵. Thus, the uncertainty concerning the public authorities' future actions acts as a brake on the building of infrastructure. Another limiting factor is the future level of competition between the railway operators : the interest of interconnecting networks depends strongly on the number of railway operators exploiting the infrastructure. So far, in Europe, railway operators are operating mainly under monopoly provisions, but this should change, at least on international links, the European commission having adopted a third railway package (3rd march 2004) proposing the opening up of the market for international passenger services in 2010; but today nobody can predict the intensity of competition between railway operators.

If there is only one rail operator, and it is (legally) possible for the dominant hub airline to sign exclusive intermodal agreements with the rail operator, then the infrastructure become more desirable for the airline, and the possibility of co-financing via a joint venture may also appear desirable, in the sense that it can commit both partner to a long term relationship. This is all the more true, that an exclusive agreement can in some cases lead the airline to abandon certain routes, leaving the rail alone on those routes²⁶ (which makes the agreement more interesting for the railway operator). This is clear that this will limit competition between railway operators and airlines. In a sense, intermodal agreements could be seen for an airline as something quite similar to agreements with regional airlines, feeding the hub with passenger coming from medium sized markets. ²⁷

If there are several rail operators, the setting is somehow different : first the dominant airline will be unable to secure an exclusive agreement with all potential railway operators, and faces the threat that some railway operator or other signs agreements with its competitors. The incumbent railway operator being on a competitive market will get less profit from an intermodal agreement. Therefore, the dominant airline and incumbent railway operator will have less incentives to finance. The other airlines and railway operators could be seen as potential investors, but there may be a free rider problem, since an operator investing in the infrastructure can not secure exclusive access, and is obliged to share benefits

²⁵the same could have been argued for airports

²⁶Low costs airlines could enter the market, but their competition is so far limited by limitations on airport slots, and it is likely that the low costs airlines, in the near future, will go on operating routes where they have no direct competitors.

²⁷Going further, we could imagine airlines investing in railway operators in the same way as they have invested in regional airlines. But this is still much further down the road...

with others.

The conclusions to draw are that infrastructure private financing is all the more likely that competition (present and future) is limited in the air and rail sectors. The question of public intervention can therefore legitimately be asked, if socially desirable infrastructure is to be built.

3.3 Policy implications

As we mentioned, the European Commission wants to boost the railways in Europe and would like to divert traffic from the road to the rail. The main problem with rail is its high infrastructure cost, and we saw in the last section the problems involved with private funding. Private funding is possible, but is more the more probable that there is no ex post competition, and if exclusive agreements are enforceable. This is the case for example, in the Arlanda express link to the city, where the consortium A-Train financing the infrastructure got an exclusive operating franchise, for a duration of 40 years (until 2040, it operates and receives all revenues from fares).

If building the infrastructure and having competition are seen as desirable, turning to public funds may be an alternative solution. Public funding is actually possible, at different levels. If the public authorities finance the infrastructure with a view to have an open access policy and set socially optimal prices (prices set at marginal operating costs), it may not reimburse costs through access charges. Public funds are costly, and therefore, the public authority may prefer a second best policy of budget balance : the access charges will be set, in this case, to reimburse infrastructure costs.

Caillaud and Tirole [1], in a setting of information asymmetry between the infrastructure manager and an incumbent operator, show that the infrastructure manager (subject to a budget constraint), deriving funding from access charges and funding contributions, may have to limit access in order to get the project built. Since competition lowers profits, an open access policy to the infrastructure, which would be better from a social welfare point of view, may result in a situation where the access charges are too low (considering what the operators would be willing to pay) to ensure viability of the project. Under perfect information, the infrastructure manager will have an open access policy if demand is high, because in this case profits in a competitive situation (duopoly) will enable the manager to charge access fees sufficient to balance its budget. If demand is low, the project will not be built. In intermediate situations, the manager will grant an exclusive franchise to the incumbent and use high access fees to cover investment costs. If there is asymmetry of information, it may be the case then, that the infrastructure manager is led to grant an exclusive franchise right to the incumbent, rather than face the risk of the project not being built, since it is not possible to design a

mechanism to reveal the incumbent's information. They also suggest that in some cases, it is possible to improve upon the exclusive franchise policy, by setting a time limited exclusive franchise, followed by an open access policy. They suggest furthermore that the infrastructure manager, since it cannot elicit information from the incumbent, has to get as much information as it can get on its own, about demand for the new infrastructure.

This paper suggests that incumbent operators can orient somehow the choice of infrastructure being built, because of the asymmetry of information. Their interests being profit and not social welfare maximizing, the manager should be wary : linking airports to city centers may be social welfare maximizing, but railway operators may prefer to link airports to their national network, in order to exploit complementarity with airlines for fear of direct competition. Avoiding improving its competitor's travel time was for example the goal of the French railway operator, in the 70's, when the high speed network was first designed, and Roissy airport linked to the national network, without being linked to the center of Paris. This attitude has changed now, and our paper suggests that improving their competitor's product may not be such a bad idea for the railway operators, in a setting of differentiated products. The possibility of signing intermodal agreements can also be a determinant element of the profitability of the future link for the operator. This may be a key element in deciding whether it should be built or not. In this setting, it may again be advisable to limit the duration of the exclusive agreement, or even to prevent it, so that competition do not disappear in the airline markets.

Finally, financing the infrastructure with budget constraint appears as a compromise between private funding and public funding (without budget constraint), in the sense that it is less costly for the public authority, but will result in sub-optimal competition or less infrastructure being built.

So far, public funding can come from the European Commission, or the national States.

The European Commission is willing to finance somehow, but the share of financing would not exceed 20% for the time being . In its 2001 White paper on transport [2], it proposes to enable cross subsidies inside a region : a new rail link having consequences on other traffics, revenues from other infrastructure in a region (mainly toll road) could be used partly to help financing rail infrastructure. It is not clear whether this scheme would apply to airport rail access.

The State has many projects to finance, and airport rail link may not be high on its priority list. The same can be said with the regional and local authorities, which have a limited budget. They may look for private partnerships, or turn toward less costly solutions, like bus services, which have the advantage of flexibility and of low infrastructure costs. The choice between rail and bus access to airports is currently the subject of a debate in the United States [7], where the

share of public transport to airports is quite low (around 15%, compared to 35% in the 4 main airports in Europe, and 66% in Hong Kong and Tokyo [5]), and the congestion on access roads severe.

To conclude, let us note one important point about public funding: the public authorities have to commit or at least announce some clear policy in order for the private firms to know what to expect from them, and to avoid "wait and see" strategies.

Conclusion

In this paper, we have looked at the competitive aspects of air/rail intermodality. In the first and second parts, we considered an airport conveniently connected to the rail infrastructure, and looked at the incentives the airlines and rail operators have to set up intermodal transport.

Considering passengers connecting at the hub, we found that on those markets, airlines and railway operators acts more as partners than as rivals. Since airlines which operate a Hub are not really seeking to use routing as a source of profit, this puts the railway operator in a situation where it cannot compete with them in this particular market. In this situation, there are many reasons which press airlines and railway operators to reach an agreement : possibility of price discrimination, elimination of the double marginalisation, coordination of frequencies and timetables.

Considering point to point markets, where airlines and railway operators are competitors, we have seen that, under certain hypotheses, there exist a Nash equilibrium, for which the airline and railway operator have no interests in competing, and will charge their monopoly price on their natural markets, provided that the products of the firms are differentiated substitutes. In this case, the railway operator can find an interest in improving the quality of the airline's product by better interconnection of networks for example.

In the third part, after reviewing the types of airport access that can be found, we draw the implications of part 1 and 2 models in terms of financing infrastructure. Private funding, or public funding with a budget constraint appears easier if competition ex post is limited, and exclusive intermodal agreements signed. If competition ex post is desirable from a social point of view, public funding may be an alternative, although public funds are costly, and limitations of intermodal exclusive agreements considered. Exclusive agreements with the dominant airline may indeed have adverse effects on competition on the airline markets, by advantaging the "intermodal" airline. Whether this advantage may be determinant in the competitive airlines market remains to be seen, and we leave this question open for further research.

Appendix 1

Let p_1 and p_2 be respectively the airlines's and the railway operator's prices.

In order to maximise the sum of the firms' profits, we need to maximise $p_1(\alpha - \beta(p_1 + p_2)) + p_2(\alpha - \beta(p_1 + p_2))$, that is $(p_1 + p_2)(\alpha - \beta(p_1 + p_2))$.

This is maximised when $(p_1 + p_2) = \frac{\alpha}{2\beta}$ (the middle of the roots of the second degree polynomial $X(\alpha - \beta X)$)

Now, let's look at what happens if the firms simultaneously choose their prices, without concertation. In order to find the Nash equilibria, we first need to find each firm's best reaction to any of the other's action.

Should the railway operator choose a price p_2 , the airline's profit $p_1(\alpha - \beta(p_1 + p_2))$ is maximised for $p_1 = \frac{\alpha - \beta p_2}{2\beta}$.

Identically, should the airline choose a price p_1 , the railway operator's profit $p_2(\alpha - \beta(p_1 + p_2))$ is maximised for $p_2 = \frac{\alpha - \beta p_1}{2\beta}$.

So there exists a Nash equilibrium. It is the solution of the system $\begin{cases} p_1 = \frac{\alpha - \beta p_2}{2\beta} \\ p_2 = \frac{\alpha - \beta p_1}{2\beta} \end{cases}$,
that is $p_1 = p_2 = \frac{\alpha}{3\beta}$, which yields a total price $(p_1 + p_2) = \frac{2}{3} \frac{\alpha}{\beta}$

Appendix 2

Let p_1 and p'_1 be respectively the airline's price for a travel from A to Z or Z' for passengers coming from V.

Let p_2 be the railway operator's price for a travel from V to airport A.

We suppose the firms simultaneously choose their prices, without concertation. In order to find the Nash equilibria, we first need to find each firm's best reaction to any of the other's action.

If the railway operator chooses a price p_2 , the airline's profit is $p_1(\alpha - \beta(p_1 + p_2)) + p'_1(\alpha' - \beta'(p'_1 + p_2))$, which is maximised for $p_1 = \frac{\alpha - \beta p_2}{2\beta}$ and $p'_1 = \frac{\alpha' - \beta' p_2}{2\beta'}$.

If the airline chooses prices p_1 and p'_1 , the railway operator's profit is $p_2(\alpha - \beta(p_1 + p_2) + \alpha' - \beta'(p'_1 + p_2))$, which is maximised for $p_2 = \frac{\alpha + \alpha' - \beta p_1 - \beta' p'_1}{2(\beta + \beta')}$.

Solving the system

$$\begin{cases} p_1 = \frac{\alpha - \beta p_2}{2\beta} \\ p'_1 = \frac{\alpha' - \beta' p_2}{2\beta'} \\ p_2 = \frac{\alpha + \alpha' - \beta p_1 - \beta' p'_1}{2(\beta + \beta')} \end{cases}$$

yields

$$\begin{cases} p_1 = \frac{\alpha}{2\beta} - \frac{\alpha+\alpha'}{6(\beta+\beta')} \\ p_1' = \frac{\alpha'}{2\beta'} - \frac{\alpha+\alpha'}{6(\beta+\beta')} \\ p_2 = \frac{\alpha+\alpha'}{3(\beta+\beta')} \end{cases}$$

which is the Nash equilibrium of the game.

So, passengers going from V to Z pay $p_1 + p_2 = \frac{\alpha}{2\beta} + \frac{\alpha+\alpha'}{6(\beta+\beta')}$ and passengers going from V to Z' pay $p_1' + p_2 = \frac{\alpha'}{2\beta'} + \frac{\alpha+\alpha'}{6(\beta+\beta')}$.

Should the firms cooperate in choosing their prices so as to maximise their global profit, they would charge $\frac{\alpha}{2\beta}$ for travels from V to Z and $\frac{\alpha'}{2\beta'}$ for travels from V to Z'. When firms don't cooperate, they charge on each travel higher prices than those that would maximise their joint profit.

Moreover, the joint firms' profit is less than if the railway operator could discriminate between passengers going to Z or Z' (in which case both firms charge $\frac{\alpha}{3\beta}$ for passengers going to Z and $\frac{\alpha'}{3\beta'}$ for passengers going to Z'). In this sense, we can say that the double-marginalisation problem is emphasized when the airline proposes more flights from airport A.

Appendix 3

Imagine the railway operator 2 sets his margin equal to his monopoly margin on his natural market, that is $m_2 = \frac{\alpha_2}{2\beta_2}$. In order to get the railway operator's natural market, the airline must choose his margin m_1 such that $m_1 < \frac{\alpha_2}{2\beta_2} - \mu_2$, in which case his profit is $m_1(\alpha_1 - \beta_1 m_1 + \alpha_2 - \beta_2(m_1 + \mu_2)) = m_1(\alpha_1 + \alpha_2 - \beta_2 \mu_2 - (\beta_1 + \beta_2)m_1)$.

The expression $m_1(\alpha_1 + \alpha_2 - \beta_2 \mu_2 - (\beta_1 + \beta_2)m_1)$ is maximised for $m_1 = \frac{\alpha_1 + \alpha_2 - \beta_2 \mu_2}{2(\beta_1 + \beta_2)}$, is non-decreasing for values below $m_1 = \frac{\alpha_1 + \alpha_2 - \beta_2 \mu_2}{2(\beta_1 + \beta_2)}$, and non-increasing for values above $m_1 = \frac{\alpha_1 + \alpha_2 - \beta_2 \mu_2}{2(\beta_1 + \beta_2)}$ (because it is a concave second-degree polynomial in m_1 , with roots equal to 0 and $\frac{\alpha_1 + \alpha_2 - \beta_2 \mu_2}{(\beta_1 + \beta_2)}$).

To find the best m_1 for the air company among those that enable it to capture the railway operator's market, we need to find whether $\frac{\alpha_1 + \alpha_2 - \beta_2 \mu_2}{2(\beta_1 + \beta_2)}$ is inferior or superior to $\frac{\alpha_2}{2\beta_2} - \mu_2$:

$$\begin{aligned} & \frac{\alpha_1 + \alpha_2 - \beta_2 \mu_2}{2(\beta_1 + \beta_2)} \geq \frac{\alpha_2}{2\beta_2} - \mu_2 \\ \iff & 2\beta_2(\alpha_1 + \alpha_2 - \beta_2 \mu_2) \geq 2(\beta_1 + \beta_2)\alpha_2 - 4(\beta_1 + \beta_2)\beta_2 \mu_2 \\ \iff & \beta_2(\alpha_1 - \beta_2 \mu_2) \geq \beta_1 \alpha_2 - 2(\beta_1 + \beta_2)\beta_2 \mu_2 \\ \iff & \beta_2 \alpha_1 + \beta_2 \mu_2 (2\beta_1 + \beta_2) \geq \beta_1 \alpha_2 \\ \iff & \frac{\alpha_1}{2\beta_1} + \mu_2 + \frac{\beta_2}{2\beta_1} \mu_2 \geq \frac{\alpha_2}{2\beta_2} \end{aligned}$$

So, if $\frac{\alpha_1}{2\beta_1} - \mu_1 \leq \frac{\alpha_2}{2\beta_2} \leq \frac{\alpha_1}{2\beta_1} + \mu_2$, these inequalities are true.

As $m_1(\alpha_1 + \alpha_2 - \beta_2\mu_2 - (\beta_1 + \beta_2)m_1)$ is non-decreasing in m_1 for values below $\frac{\alpha_1 + \alpha_2 - \beta_2\mu_2}{2(\beta_1 + \beta_2)}$, the profit maximising m_1 such that $m_1 \leq \frac{\alpha_2}{2\beta_2} - \mu_2$ is $m_1 = \frac{\alpha_2}{2\beta_2} - \mu_2$ (that is the highest margin that enables the air company to capture the rail company's market)

Symmetrically, if the airline 1 sets his margin equal to his monopoly margin on his natural market, and if $\frac{\alpha_1}{2\beta_1} - \mu_1 \leq \frac{\alpha_2}{2\beta_2} \leq \frac{\alpha_1}{2\beta_1} + \mu_2$ the best m_2 for the railway operator among those that enable it to capture the airline's market is $m_2 = \frac{\alpha_1}{2\beta_1} - \mu_1$ (that is the highest margin that enables the railway operator to capture the airline's market)

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