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The Economic Effects of High Speed Rail Investment

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THE ECONOMIC EFFECTS OF HIGH SPEED RAIL INVESTMENT

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ABSTRACT

The allocation of traffic between different transport modes follows transport user decisions which depend on the generalized cost of travel in the available alternatives. High Speed Rail (HSR) investment is a government decision with significant effects on the generalized cost of rail transport; and therefore on the modal split in corridors where private operators compete for traffic and charge prices close to total producer costs (infrastructure included).

The rationale for HSR investment is not different to any other public investment decision. Public funds should be allocated to this mode of transport if its net expected social benefit is higher than in the next best alternative. The exam of data on costs and demand shows that the case for investing in HSR is strongly dependent on the existing volume of traffic where the new lines are built, the expected time savings and generated traffic and the average willingness to pay of potential users, the release of capacity in congested roads, airports or conventional rail lines and the net reduction of external effects.

This paper discusses, within a cost-benefit analysis framework, under which conditions the expected benefits from deviated traffic (plus generated traffic), and other alleged external effects and indirect benefits justify the investment in HSR projects. It pays special attention to intermodal effects and pricing.

KEYWORDS: Cost-benefit analysis, infrastructure investment, high speed rail, intermodal competition.

[*]The author is grateful to Chris Nash, Roger Vickerman, Jorge Valido and Eduardo Dávila for useful comments on early drafts of this paper.

1. INTRODUCTION

Investing in high speed rail is a central planning decision. The government decides the introduction of a new rail technology which allows trains running at a speed of 300-350 kilometres per hour (though the average commercial speed is substantially below the technically feasible speed). At the beginning of 2008 there were about 10,000 kilometres of new high speed lines in operation around the world and, in total (including upgraded conventional tracks), more than 20,000 kilometres of the worldwide rail network was devoted to provide high speed services (Campos *et al*., 2006).

This railway technology is particularly popular in the European Union. High Speed Rail (HSR) investment projects of European member countries are financially supported by the European Commission. `Revitalizing the railways´ (European Commission, 2001a) is the new motto in European transport policy, meaning both introducing competition in the railway industry and giving priority to public investment in the rail network.[1]

Investing in HSR is on the front line of action to revitalize the railways. The ultimate objective is to change modal split in passenger transport with the aim of reducing congestion, accidents and environmental externalities. HSR investment is seen as a second best policy with the aim of changing modal split in the benefit of the railways.[2]

High speed trains require high speed infrastructure, meaning that new dedicated track need to be built at a cost substantially higher than the conventional rail line. Infrastructure maintenance cost is comparable with conventional rail but the building costs and the acquisition, operation and maintenance costs of specific rolling stock make this transport alternative an expensive option. In any case, the cost of the HSR is not the point. The economic problem is whether the social benefits are high enough to compensate the infrastructure and operating costs of the new transport alternative. Even this being the case, other relevant alternatives should be examined and compared with the investment in HSR.

HSR competes with air and road transport within some very specific distances and it is also considered as a substitute of feeder air services to main hub airports (Banister and Givoni, 2006). In any case, spending public money in the construction of HSR lines has been defended as a socially desirable public investment which produces several types of benefits such as passenger time savings,

[1] `The fact is that, almost two centuries after the first train ran, the railways are still a means of transport with major potential, and it is renewal of the railways which is the key to achieving modal rebalance. This will require ambitious measures which do not depend on European regulations alone but must be driven by the stakeholders in the sector´. European Commission (2001a).

[2] `Intermodality with rail must produce significant capacity gains by transforming competition between rail and air into complementary between the two modes, with high-speed train connections between cities. We can no longer think of maintaining air links to destinations for where there is a competitive high-speed rail alternative. In this way, capacity could be transferred to routes where no high-speed rail service exists´. European Commission (2001a).

increase in comfort, generation of new trips, reduction in congestion and delays in roads and airports, reduction in accidents, reduction in environmental externalities, release of needed capacity in airports and conventional rail lines, and wider economic benefits including the development of the less developed regions.

To enumerate the list of the social benefits generated by the HSR, even if some number are associated to the description is as irrelevant as to show how expensive is the new technology. In economic terms, the net balance is what really matters, and this net results cannot be obtained without due consideration of the case base, compared with different `projects´ available for the solution of the `transport problem´ under evaluation. HSR is one alternative whose net benefit has to be compared with those resulting from other actions as the construction or upgrading of a conventional railway line, the construction of new airports or road capacity, or the introduction of congestion pricing, alone or combined with different investment plans.

HSR social profitability is obviously very sensitive to the full price that passengers incur when choosing between different transport alternatives. Modal split is in equilibrium when users have compared the generalized costs of travel for different options available to them and have chosen according to these costs and their willingness to pay. Before HSR is introduced travellers use road and air transport in proportions clearly determined by distance. HSR investment alters the existing equilibrium competing with car in distances up to 300 km and with air particularly in the range 300-600km. These distances are coarse references as the particular conditions of accessibility (access and egress time, parking conditions, security control, etc.) are frequently more determinant than the travel time itself.

The average fare to be charged is an important component of the generalized cost of travel. Producer costs (infrastructure and operation) are basically included in the generalized cost of using the car or the airline. This is not always the case with HSR. Railways are far from cost recovering when infrastructure costs are included. Therefore, the decision on which kind of pricing principle is going to be follow for the calculation of railway fares is really critical. Given the high proportion of fixed costs associated to the HSR option, the decision of charging according to short-term marginal cost or something closer to average cost could radically change the volume of demand for railway in the forecasted modal split, and this unavoidable fact has obviously a profound effect on the expected net benefit of the whole investment.

This paper discusses, within a basic cost-benefit analysis framework, under which conditions the expected benefits from deviated traffic (plus generated traffic), and other external and indirect benefits justify the investment in HSR. The case for the HSR is strongly dependent on the volume of traffic where the new lines are built, the time savings and generated traffic and the average willingness to pay of passengers, the release of capacity in congested roads, airports or conventional rail lines and the reductions of external effects. The magnitude of the traffic volumes and shifts depends heavily on whether infrastructure costs are included in rail fares or financed by taxes. If rail infrastructure charges are based on short-run marginal cost, intermodal substitution will be dramatically affected by HSR public investment decisions. In this case *ex ante* cost-benefit analysis of HSR investment is, more than ever, a key element of transport policy.

The economic evaluation of HSR investment has been covered from different perspectives. A general assessment can be found in Nash (1991), Vickerman (1997), Martin (1997), de Rus and Nombela (2007). The cost-benefit analysis of existing or projected lines in: de Rus and Inglada (1993, 1997), Beria (2008) for the HSR Madrid-Sevilla; Levinson et al. (1997) for Los Angeles-San Francisco; Steer Davies Gleave (2004), Atkins (2004) for UK; de Rus and Nombela (2007), de Rus and Nash (2007) for the European Union. The regional effects of HSR investment in: Vickerman (1995, 2006), Blum, Haynes and Karlsson (1997), Plassard (1994), Haynes (1997), Preston and Wall (2007), and in a broader context Puga (2002).

This paper tries to shed some light on the economic dimension of HSR investment decision, which not only affects the transport sector bus has significant effects on the allocation of resources. The European Commission has opted enthusiastically for this technology; meanwhile countries like UK or USA have been reluctant in the recent past to finance with public funds the construction of a high speed rail network, which is a priority in the European Union. Why some countries like France or Spain are allocating a high proportion of public money to the construction of new lines and others maintain their conventional railway lines? HSR is quite effective in deviating passengers from other modes of transport but the relevant question is whether the sum of the discounted net social benefits during the life of the infrastructure justifies the investment cost.

The description of the costs and benefits of the HSR lines is covered in section 2, where some figures on the average fixed and variable costs per passenger in a standard line are presented to compare with the alternatives. The source of the benefits of HSR is also discussed. The economic analysis of the investment in HSR is the content of section 3 where a simple model is presented to evaluate the social value of this public investment. In section 4 the intermodal effects are covered from the perspective of the deviated traffic and the impact in secondary markets. Pricing is a key element in explaining the economic results of the HSR. Price determines demand volume, social benefits and the financial outcome. In section 5 the economic consequences of pricing HSR services according to different economic principles are discussed as well as some of its long term effects.

2. THE COSTS AND BENEFITS OF A NEW HSR LINE

2.1. Total costs of building and operating a HSR line

Total social costs of building and operating a HSR line consist of the producer, the user and the external costs. *User costs* are mainly related to total time costs, including access, egress, waiting and travel time invested, reliability, probability of accident and comfort. *Producer costs* involve two major types of costs: infrastructure and operating costs. *External* costs are associated to construction (e.g. barrier effect and visual intrusion) and operation (e.g. noise, pollution and contribution to global warming). In this section we concentrate on producer and external costs.[3] User costs are dealt with in section 2.3.

2.1.1. Infrastructure costs

The construction costs of a new HSR line are marked by the challenge to overcome the technical problems which avoid reaching speeds above 300 km per hour, as roadway level crossings, frequent stops or sharp curves, new signalling mechanisms and more powerful electrification systems.

[3] The description of HSR costs is based on Campos *et a*l. (2005) and de Rus and Nash (2007).

Building new HSR infrastructure involves three major types of costs: planning and land costs, infrastructure building costs and superstructure costs (UIC, 2005).

Feasibility studies, technical design, land acquisition, legal and administrative fees, licenses, permits, etc. are included in *Planning and land costs*, which can reach up to 10% of total infrastructure costs in new railway lines requiring costly land expropriations. *Infrastructure building costs* involve terrain preparation and platform building. Depending on the characteristics of the terrain, the need of viaducts, bridges and tunnels, these costs can range from 15 to 50% of total investment. Finally, the rail specific elements such as tracks, sidings along the line, signalling systems, catenary, electrification communications and safety equipment, installations, etc., which are called *superstructure costs*.

Railway infrastructure also requires the construction of stations. Although sometimes it is considered that the cost of building rail stations, which are singular buildings with expensive architectonic design are above the minimum required for technical operation, these costs are part of the system and the associated services provided affect the generalized cost of travel (for example, quality of service in the stations reduces the disutility of waiting time.

From the actual building costs (planning and land costs, and main stations excluded) of 45 HSR lines in service, or under construction, the average cost per km of a HSR line ranges from 9 to 40 million of euros with an average of 18. The upper values are associated to difficult terrain conditions and crossing of high density urban areas.

2.1.2. Operating costs

The operation of HSR services involves two types of costs: infrastructure maintenance and operating costs, and those related to the provision of transport services using the infrastructure. *Infrastructure operating costs* include the costs of labour, energy and other material consumed by the maintenance and operations of the tracks, terminals, stations, energy supplying and signalling systems, as well as traffic management and safety systems.

Some of these costs are fixed, and depend on operations routinely performed in accordance to technical and safety standards. In other cases, as in the maintenance of tracks, the cost is affected by the traffic intensity; similarly, the cost of maintaining electric traction installations and the catenary depends on the number of trains running on the infrastructure.

From data corresponding to five European countries (Belgium, France, Italy, The Netherlands and Spain), infrastructure maintenance costs *per km of single track* are, on average, equal to 30,000 euros per year.

The operating costs of HSR services (train operations, maintenance of rolling stock and equipment, energy, and sales and administration) vary across rail operators depending on the specific technology used by trains and traffic volumes. In the case of Europe, almost each country has developed its own technological specificities; each train has different technical characteristics in terms of length, composition, seats, weight, power, traction, tilting features, etc. The estimated acquisition cost of rolling stock per seat goes from 33,000 to 65,000 euros.

The train operating costs per seat goes from 41,000 to 72,000 euros and rolling stock maintenance from 3,000 to 8,000 euros. Adding operating and maintenance costs and taking into account that a train runs from 300,000 to 500,000 km per year, and that the number of seats per train goes from 330 to 630, the cost per seat-km can be as high as twice in two different countries.

2.1.3. External costs

A common place regarding the introduction of HSR services is that negative externalities will be reduced in the affected corridor, thanks to the deviation of traffic from less environmentally friendly modes of transport.

Nevertheless, building a HSR line and operating trains lead to environmental costs in terms of land take, barrier effects, visual intrusion, noise, air pollution and contribution to global warming. The first four of these impacts are likely to be stronger where trains go through heavily populated areas. HSR trains are electrically powered, and therefore produce air pollution and global warming impacts when coal, oil and gas are the main sources to generate the electricity.

The negative environmental effects of the construction of a new HSR have to be compared with the reduction of the externalities in road and air transport when passengers shift to HSR. The final balance depends on several factors (see a more formal discussion in section 4) but basically the net effect depends on the magnitude of the negative externalities in HSR compared with the substituted mode, on the volume of traffic diverted and whether, and in what degree, the external cost is internalised.

To the extent that infrastructure charges on these modes do not cover the marginal social cost of the traffic concerned there will be benefits from such diversion. Estimation of these benefits requires valuation of marginal costs of congestion, noise, air pollution, global warming and external costs of accidents and their comparison with taxes and charges.

The marginal external costs (including accidents and environmental cost but excluding congestion) per passenger-km for two European corridors have been estimated in INFRAS/IWW (2000). The results show that HSR between Paris and Brussels have less than a quarter of the external cost of car or air. It is worth looking not only at the relative values but the absolute ones. In the HSR line Paris-Brussels the external cost of 1,000 passenger-km is equal to €10.4 (43.6 for cars and 47.5 for air transport). The external cost of HSR is highly dependent on the train load factors. In long distances the advantage over air is reduced as much of the environmental cost of the air transport alternative occurs at take-off and landing.

2.2. Some basic arithmetic of HSR costs

Let us try to figure out the average producer cost per passenger-trip of a new HSR line. A railway line, called North-South has 500 km length. The average construction cost per km of this hypothetical line is equal to 18 million of euros, the average cost in Europe. Land and planning cost add 10 per cent to the construction costs. For simplicity we will ignore the cost of building the stations (which varies within a wide range and could be substantial). Under these assumptions the total construction cost is equal to € 9,900 million.

Assuming the infrastructure does not depreciate when properly maintained and a social discount rate of 5 per cent, this asset has an opportunity cost per annum equal to € 495 million. To this fixed cost, the maintenance cost has to be added. This means € 30 million per annum, taking into account that the average infrastructure maintenance cost per km of single track is equal to € 30,000 per year.

Let us calculate the variable total cost, distinguishing three components: rolling stock, operating costs and train maintenance. The average cost of a train is €30 million and the number of seats 330. Each train runs 500,000 km per year. Assuming the average load factor reaches 80 per cent each train provides 132 million of passenger-km. For a expected life of 20 year and no residual value, the annual cost of a train is equal to €2.4 million. Operating costs per train and year are equal to €25 million. Rolling stock maintenance cost is equal to €1.5 per train and year.

To calculate the cost per passenger-trip in the North-South HSR line, we need to know the volume of demand. Assuming 5 million passenger-trips in the first year of operation, with an average trip length of 500 km (a quite favourable assumption), the average fixed cost (construction and maintenance infrastructure) per round-trip is equal to 210 euros. The average variable cost per round-trip is equal to 218 euros. The total cost of a round trip per passenger in the first year of operation reaches 428 euros. This average cost per round trip is obviously very sensitive to the volume of demand and the average trip length.

2.3. Where do HSR benefits come from?

Investing in HSR infrastructure is associated with lower total travel time, higher comfort and reliability, reduction in the probability of accident, and in some cases the release of extra capacity which helps to alleviate congestion in other modes of transport. Last but not least, it has been argued that HSR investment reduces the net environmental impact of transport and boosts regional development.

We have already shown that the environmental benefits of HSR are not so important and that in any case depend heavily on the deviation of traffic from more environmental damaging modes, the source of electricity generation and the density of urban areas crossed. Expected regional development effects are also controversial and are considered in section 2.4.

The observation of existing HSR lines shows that user benefits deserve a closer examination. Let us start with total travel time. The user time invested in a round trip includes access and egress time, waiting time and in vehicle time. The total user time savings will depend on the transport mode where the passengers come from. Evidence from case studies on HSR development in seven countries shows that when the original mode is a conventional rail with operating speed of 130 km/h, representative of many railway lines in Europe, the introduction of HSR services yields 45-50 minutes savings for distances in the range of 350-400 km. When conventional trains run at 100 km/h, potential time savings are one hour or more, but when the operating speed is 160 km, time saving is around half an hour over a distance of 450 km (Steer Davies Gleave, 2004). Access, egress and waiting time are practically the same.

When passenger shifts from road or air the situation changes dramatically. For road transport and line lengths around 500 km, passengers benefit from travel time savings but they lose with respect to access, egress and waiting time. Benefits are higher than costs when travel distance is long enough as HSR runs on average twice as fast as the average car. Nevertheless, as the travel distance get shorter the advantage of the HSR diminishes as `in vehicle time´ lost weight with respect to access, egress and waiting time.

Air transport is in some way the opposite case to road transport. Increasing the distance reduces the HSR market share. For a 2,000 km trip (and shorter distances) the competitive advantage of HSR vanishes. But, what about the medium distance (500 km) where the market share of HSR is so high? In a standard HSR line of 500-600 km air transport has lower `in vehicle time´. The advantage of HSR rests on access, egress and waiting time, plus differences in comfort.

The net user benefit of deviating a passenger from air to HSR could even be positive in the case of a longer total travel after the shift. This would be the case if the values of time of access egress and waiting time are high enough to compensate the longer `in vehicle time´. The relative advantage of HSR with respect to air transport is significantly affected by the existing differences in the values of time, and these values are no unconnected with the actual experience of waiting, queuing and passing through security control points in airports.

The generalized cost of air transport is seriously penalized by security controls at airports, and this translates in more attractiveness of the HSR option. Explaining the causes of the reduction in passengers' underlying willingness to pay for air travel it is worth looking at the change suffered by the airline product with increased security, the need to arrive earlier to airports. `Consider as an illustration the effect on air travel of required earlier arrival at airports. If passengers must now arrive at their origin airport one and a half hour earlier than previously, then, under plausible assumptions of relevant parameters, travel could decline 7 percent (a plausible range is 3 percent to 11 percent) ´ (Morrison and Winston, 2005).

Benefits also come from generated traffic. The conventional approach for the measurement of the benefit of new traffic is to consider that the benefit of the inframarginal user is equal to the difference in the generalized cost of travel without and with HSR. The last user with the project is indifferent between both alternatives, so the user benefit is zero. Assuming a linear demand function the total user benefit of generated demand is equal to one half of the difference in the generalized cost of travel.

Where the conventional rail network is congested or the airports affected are working close to maximum capacity, the construction of a new HSR line has the benefit of relieving capacity for suburban or regional passenger services or freight. In the case of airport, the additional capacity can be used to reduce congestion or scarcity. In any case the introduction of HSR would produce this additional benefit.

2.4. HSR and its effects on regional inequalities

The framework of conventional cost-benefit does not include the evaluation of the impact of transport infrastructure projects on regional development. Puga (2002) argues that to concentrate on the primary market and some closely related secondary market may be justified provided that two conditions are met: first, that distortions and market failures are not significant an so no need to worry with the indirect effects of the project; and second, `the changes in levels of activity induced by the project fade away fairly rapidly as we move away from those activities more closely related to it. However, these conditions are often not met. There has been increasing realisation throughout economics that wide ranges of economic activities may be affected by market failure and distortions.

And the type of cumulative causation mechanisms modelled by the new economic geography can make the effects of a project be amplified rather than dampened as they spread through the economy´. (Puga, 2002)

Should we worry about these wider economic benefits in the case of HSR investment? Puga (2002), Duranton and Puga (2001) Vickerman (1995, 2006), Vives (2001) suggest that additional benefits are not expected to be very important in the case of high speed railway infrastructure. The reason is that freight transport does not benefit from high speed and therefore the location of the industry is not going to be affected by this type of technology. Moreover, in the case of the service industry HSR may lead to the concentration of economic activity in the core urban centres.

Recent research (Graham, 2007) suggests that agglomeration benefits in sectors such as financial services may be greater than in manufacturing. This is relevant to the urban commuting case but arguably is important for some HSR services (e.g. the North European network which links a set of major financial centres and may be used for a form of weekly commuting). It may be erroneous to conclude that scale economies and agglomeration economies (productivity impacts) are only found in manufacturing and freight transport.

Investment in HSR as well as other transport infrastructures has been defended as a way to reduce regional inequalities. If the definition of personal equity is difficult, its spatial dimension is even more elusive. European regional funds aim to reduce regional inequalities, but the problem is to define clear objectives so that it is possible to compare the results of different policies.

The final regional effects of infrastructure investment are not clear and depend of the type of the project and other conditions as wage rigidity and interregional migration. There are some ambiguities related to the role of opposite forces which affect the balance between agglomeration and dispersion. It is difficult *a priori* to predict the final effect.

An excellent summary of the main findings regarding the effects of infrastructure investment and regional inequalities is the following (Puga (2002): `Firms producing in locations with relatively many firms face stronger competition in the local product and factor markets. This tends to make activities dispersed in space. However, the combination of increasing returns to scale and trade costs encourages firms to locate close to large markets, which in turn are those with relatively many firms. This creates pecuniary externalities which favour the agglomeration of economic activities.

Reductions in trade or transport costs, by affecting the balance between dispersion and agglomeration forces can decisively affect the spatial location of economic activities. For high trade costs, the need to supply markets locally encourages firms to locate in different regions. For intermediate values of transport costs, the incentives for self sufficiency weaken. Pecuniary externalities then take over, and firms and workers cluster together. However, the price of local factors and the availability of goods tend to increase wherever agglomeration takes place. If this is the case and there is enough mobility, as trade costs continue to fall, rising factor prices simply give an additional kick to agglomeration by inducing immigration. On the other hand, if there is little mobility, for very low transport costs it may be firms that relocate in response to wage differentials.

Whether there is too much or too little agglomeration in the absence of regional policy interventions is not clear. The fact that firms and workers move without taking into account the possible losses for those left behind implies there may be to much agglomeration. On the other hand, since when firms and workers move they do not fully take into account the benefits they bring for other firms and their impact on aggregate growth, there may be too little agglomeration. Thus, there is no general indication of the direction in which governments should push with regional policies when seeking efficiency. Even in terms of equity, the direction of policy is not obvious. Policies that increase agglomeration may nevertheless make those that remain in poorer regions better off by increasing production efficiency and the rate of growth.

Despite these ambiguities, European regional policies have the explicit aim of reducing regional inequalities. One of the main instruments for this is the improvement of transport infrastructure. However, it is not obvious that lower transport costs facilitate convergence. Roads and rail tracks can be used to travel both ways. A better connection between two regions with different development levels not only gives firms in a less developed region better access to the inputs and markets of more developed regions. It also makes it easier for firms in richer regions to supply poorer regions at a distance, and can thus harm the industrialisation prospects of less developed areas.

New economic geography models not only point out this potential ambiguity in the impact of lower transport costs on less developed regions, they also tell us that the overall effect depends on certain aspects of the economic environment (such as mobility and wage rigidities) and on characteristics of the projects. On this respect, the Trans-European Transport Network will give much of the EU better access to the main activity centres. However, the gap in relative accessibility between core and peripheral areas is likely to increase as a result of the new infrastructure, which reinforces the position of core regions as transport hubs. The emphasis on high speed rail links is also likely to favour the main nodes of the network, and is unlikely to promote the development of new activity centres in minor nodes or in locations in between nodes´.

3. THE ECONOMIC EVALUATION OF HSR INVESTMENT

3.1. A simple cost-benefit model for the evaluation of HSR

Suppose that a new HSR project is being considered. The first step in the economic evaluation of this project is to identify how the investment, a `do something´ alternative, compares with the situation *without* the project. A rigorous economic appraisal would compare several relevant `do something´ alternatives with the base case. These alternatives include upgrading the conventional infrastructure, management measures, road and airport pricing or even the construction of new road and airport capacity. We assume here that relevant alternatives have been properly considered.

3.1.1. HSR as an improvement of the railways

The public investment in HSR infrastructure can be contemplated as a way of changing the generalized cost of rail travel in corridors where conventional rail, air transport and road are complements or substitutes. Instead of modelling the construction of HSR lines as a new transport mode we consider this specific investment as *an improvement* of one of the existing modes of transport, the railway. Therefore, it is possible to ignore total willingness to pay and concentrate on the incremental changes in surpluses or, alternatively, on the changes in resource costs and willingness to pay.

We follow here a resource cost approach and ignore the distribution of benefits and costs (see section 5.3.2 for a brief discussion on equity) and concentrate on the change in net benefits and costs ignoring transfers.

The social profitability of the investment in HSR requires the fulfilment of the following condition:

$$\int_0^T B(H)e^{-(r-g)t}dt > I + \int_0^T C_f e^{-rt}dt + \int_0^T C_q(Q)e^{-(r-g)t}dt\,, \tag{1}$$

where:

B(H): annual social benefits of the project.
C_f: annual fixed maintenance and operating cost.
$C_q(Q)$: annual maintenance and operating cost depending on *Q*.
Q: passenger-trips.
I: investment costs.
T: project life.
r: social discount rate.
g: annual growth of benefits and costs which depends on the level of real wages and *Q*.

B(H) is the annual gross social benefit of introducing the high speed rail in the corridor subject to evaluation, where a `conventional transport mode´ operates. The main components of *B(H)* are: time savings from deviated traffic, increase in quality, generated trips, the reduction of externalities and, in general, any relevant indirect effect in secondary markets including, particularly, the effects on other transport modes (the conventional transport mode). Other benefits related to the relocation of economic activity and regional inequalities are not included in *B(H)* and have been discussed in section 2.4. The net present value of the benefits included in equation (1) can be expressed as:

$$\int_0^T B(H)e^{-(r-g)t}dt = \int_0^T [v(\tau^0 - \tau^1)Q_0 + C_C](1+\alpha)e^{-(r-g)t}dt + \sum_{i=1}^{N}\int_0^T \delta_i(q_i^1 - q_i^0)e^{-(r-g)t}dt\,, \tag{2}$$

where:

v: average value of time (including differences in service quality).
τ^0: average user time per trip *without* the project.
τ^1: average user time per trip *with* the project.
Q_0: first year diverted demand to HSR.
C_C: annual variable cost of the conventional mode.
α: proportion of generated passengers *with* the project with respect to Q_0.
δ_i: distorsion in market *i.*
q_i^0: equilibrium demand in market *i without* the project.
q_i^1: equilibrium demand in market *i with* the project.

Equation (2) assumes that alternative transport operators breakeven and the willingness to pay of new passenger-trips are approximated through the proportion of generated passenger-trips (α), (see de Rus and Nombela, 2007)). Substituting (2) in (1), assuming indirect effects -last term of expression (2)- are equal to zero, it is possible to calculate the initial volume of demand required for a positive net present value (de Rus and Nombela, 2007).

The case for investing in a HSR line requires a minimum level of demand in the first year of operation. This minimum demand threshold required for a positive NPV is higher the lower is the value of time, the average time saving per passenger, the proportion of generated traffic, the growth or benefits overtime, the project life and the cost savings in alternative modes; and the higher is the investment, maintenance and operating costs, and the social discount rate.

de Rus and Nombela (2007) and de Rus and Nash (2007) calculate the required volume of demand in the first year of the project (Q_0) under different assumptions regarding the main parameters in (1) and(2). The results show that, with typical construction and operating costs, time savings, values of time, annual growth of benefits and the social discount rate, the minimum demand threshold required for a new high speed line investment to be justified on social benefit terms is around 9 million passenger-trips in the first year of the project. This initial demand volume was obtained under the assumption that benefits come mainly from time savings from deviated traffic, the willingness to pay of generated demand and the avoidable costs of the reduction of services in alternative transport modes. The obvious conclusion is that the case for high speed rail can be rarely justified on time saving benefits.

The economic rationale of spending public funds in HSR new lines depends more on its capacity to alleviate road and airport congestion, and to release capacity for conventional rail where saturation exists, than in the pure direct benefits of time savings and the net willingness to pay of generated traffic. Therefore, the justification of investment in HSR is highly dependent on local conditions concerning airport capacity, rail and road network situation, and existing volumes of demand. This is what one would expect anyway. The economic evaluation of a new technology has to compare these local conditions, reflected in the base case, with the `do something´ of introducing the new alternative of transport.

3.1.2. Optimal timing

The fulfilment of condition (1) is not sufficient. Even with a positive NPV it might be better to postpone the construction of the new rail infrastructure (even assuming that there is not uncertainty and that not new information reveals as a benefit of the delay). Let us assume that the annual growth rate of net benefits is higher than the social discount rate ($g>r$) and that the new infrastructure last long enough to be compatible with a positive NPV. Even in this case of explosive growth of net benefits the question of optimal timing remains. It is worth waiting one year if:

$$\frac{rI}{1+r}+\frac{B_{T+1}-C_{T+1}}{(1+r)^{T+1}}>\frac{B_1-C_1+C_{C1}}{1+r}. \tag{3}$$

From our 500 km HSR line (see section 2.2) and ignoring the net benefit of T+1 (which would be substantial) it is immediate to calculate the value of the benefits for the first year of operation required for the investment to be socially profitable now (assuming the project shows a positive NPV):

$$B_1 > rI + C_1 - C_{C1}. \qquad (4)$$

According to condition(4), the project should be started without delay if the gross benefit of the first year is higher than the first year net social cost: opportunity cost of the capital plus operating and maintenance costs of the new project less the avoidable cost of the conventional transport mode. Using the data from section 2.2 the benefit per passenger for a round trip should be equal to 428 euros when the first year volume of demand reaches 5 million of passenger-trips and the avoidable cost in the conventional mode is equal to zero. This means that the benefit per passenger-trip (one direction only) should be at least of 219 euros. For lower values is better to postpone the investment.

From these data, different calculation can be made for different values of cost savings in the alternative mode. For example, taking the average revenue of 13.8 cents per seat-km in air transport and assuming that the avoidable cost is equal to this figure, the required social benefit per passenger-trip is 145 euros for the 500 km HSR line. This means that, assuming that benefits B_1 come only from time savings and additional willingness to pay of generated demand, and given the present values of time in Europe, the fulfilment of condition (4) requires significant time savings in the projected line where non additional benefits exist. It is worth stressing that the fact of passengers shifting from air to HSR does not prove that the condition is satisfied unless the average passenger is at least willing to pay 290 euros *more* per round trip over the price he was paying in the conventional mode.

4. INTERMODAL EFFECTS

4.1. Intermodal effects as benefits in the primary market

The construction of a new HSR line of a length within the range 400-600 km has a significant impact on air transport. Modal split changes dramatically in the affected corridor as the generalized cost of the railway is lower than the generalized cost of air transport. As the recently launched AVE Madrid-Barcelona illustrates, the introduction of HSR in a corridor of 600 km long gives railways a role unforeseen with the average rail speeds of recent past. The airlines carried 5 million passengers per year in the route Madrid-Barcelona and three months after the HSR services were introduced they are losing traffic at a rate that amounts to 1.2 million passenger-trips per year (see Figure 1 and Table 1). This volume of traffic is approximately 50 per cent of the market. What about other HSR lines?

The intermodal effect of HSR is stronger in lines with a longer period in operation. The effect of the introduction of HSR in medium distance corridors where conventional rail, car and air were the previous alternatives is quite significant as Table 2 and Figure 2 illustrate. The HSR market share is correlated with rail commercial speed and, with the exception of Madrid-Barcelona (recently launched), in those lines where the average speed of rail is around to 200 km the market share of the HSR is higher than 80 per cent.

The high market share of railways in these medium distances has been an argument in favour of investing in the HSR technology. If passengers freely decide to shift overwhelmingly from air to rail it follows that they are better off with the change. The problem is that a passenger decides to move from air to rail because his generalized cost of travel is lower in the new alternative (certainly, this is not so for everybody as air transport maintains some traffic) and this is not a guarantee that society benefits with the change as it can easily be shown.

The direct benefits in the corridor where the HSR line is built come mainly from the deviation of traffic from the existing modes of transport, railway included. These benefits are accounted for in the term $v(\tau_1 - \tau_0)Q_0$ in equation(2), where time savings $(\tau_1 - \tau_0)$ should be interpreted as the average of the highest benefit obtained by the first user after the change and zero, the value corresponding to the last user, who is indifferent between both alternatives.

The intermodal effects measured in the primary market consist of the product of the value of time, the average time savings and the number of passengers shifting from the conventional mode to the new transport alternative. The interesting point here is that these average values hide useful information regarding user behaviour and the understanding of intermodal competition.

Time savings can be disaggregated in access and egress, waiting and in vehicle time. Each of these categories of time has a different value. Passengers usually give more value to savings coming from access, egress and waiting time than those coming from \`in vehicle time´; therefore, when users shift from road transport to HSR they save substantial amount of \`in vehicle time´ (3 hours in a HSR with a 600km length) but they invest access, waiting and egress time partially offsetting the \`in vehicle time´ savings. Moreover, as the \`in vehicle time´ generates less disutility than the other components, the final user benefits can even be negative.

The opposite case occurs in the case of air transport, where time savings experienced from users shifting to HSR come from a reduction of access, waiting and egress time which hardly offset the substantial increase in vehicle time. Even with a negative balance in terms of time savings, the user benefit can be slightly positive when the different values of time are considered (we do not include the ticket price in this comparison).

Looking at Table 3 it seems apparent that HSR is cheaper than air transport, at least if a non restricted tourist fare is taken as the reference. Though the comparison is not straightforward railway fares seem to be below the air alternative, and as section 2.2 shows the HSR average costs are quite above HSR prices; meanwhile airlines operate in competitive markets and have to cover total producer costs. These facts deserve a closer examination because direct benefits of deviated traffic from air transport are included through the term $v(\tau_1 - \tau_0)Q_0$ in equation (2), and the value in brackets could be very low where air transport provide a good service (let us remember that prices are transfers and do not count as social benefits).

The conclusion is that the case for HSR investment can rarely be justified on the benefits provided by the deviation of traffic from air transport. It seems apparent than higher benefits could be harvested deviating traffic from road transport but this is more difficult in the range of distances considered. The benefits of deviating traffic from road and air exceed the direct benefits discussed above, as other indirect benefits could be obtained in the other transport modes when their traffic volumes diminish *with* the project. Let us examine the conditions required for obtaining additional benefits in the secondary markets.

4.2. Effects on secondary markets

It must be emphasized that time savings in the primary market is an intermodal effect: the direct benefit obtained by users of other mode of transport who become HSR users. The reduction of traffic in the substitutive mode affects its generalized cost and so the cost of travelling of the users who remain in the conventional mode.

The existing transport modes are not the only markets affected by the introduction of the new mode of transport. Many other markets in the economy are affected as their products are complements or substitutes of the primary markets. The treatment of these so called `indirect effects´ are similar for any secondary market, be the air transport market or the restaurants of the cities connected by the HSR services.

Which indirect effects or secondary benefits should be included? The answer is in the expression $\sum_{i=1}^{N}\int_0^T \delta_i (q_i^1 - q_i^0) e^{-(r-g)t} dt$, included in equation (2). There are *N* markets in the economy, besides the HSR product, and the equilibrium quantity changes in some of these markets $(q_i^1 - q_i^0)$ *with* the project. The change can be positive or negative. Suppose these markets are competitive, and unaffected by taxes or subsidies or any other distortion, so $\delta_i = 0$. In these circumstances there are not additional benefits. Therefore, for indirect effects to be translated in additional benefits (or costs) some distortion in the secondary market is needed (unemployment, externalities, taxes, subsidies, market power or any other difference between the marginal social cost and the willingness to pay in the equilibrium).

A similar approach can be used for the analysis of intermodal effects as secondary benefits. Expression $\sum_{i=1}^{N}\int_0^T \delta_i (q_i^1 - q_i^0) e^{-(r-g)t} dt$ in equation (2) includes road and air transport markets. For the sake of the analysis of intermodal effects, let us separate from the set of *N* markets affected by the HSR investment the air transport (or the road transport market), and called generically any of these transport options the alternative mode *A*. The general expression that account for the indirect effect can be slightly modify for the discussion of intermodal effects.

$$\int_0^T (p_A - cm_A) q_A \varepsilon_{AH} \frac{\Delta p_H}{p_H} e^{-(r-g)t} dt, \qquad (5)$$

where:

p_A: full or generalized price of the alternative mode (air and road in this paper)
cm_A: marginal cost of the alternative mode.
q_A: demand in the alternative mode.
ε_{AH}: cross elasticity of air (or road) with respect to the HSR generalized cost.
p_H : full or generalized price of a rail trip.

According to expression (5) the secondary intermodal effects can be positive or negative depending on the signs of the distortion and the cross elasticity ($\frac{\Delta p_H}{p_H}$ is always negative *with* the project). The reductions of road congestion and airport delays have been identified as additional benefits of the introduction of HSR. Expression (5) shows that the existence of these benefits depends primarily on the inexistence of optimal pricing. Where road congestion or airport congestion charges are optimally designed there are no additional benefits in these markets.

Moreover, suppose there is not congestion pricing and so the price is lower than marginal cost. Even in this case, the existence of additional benefits depends on the cross elasticity of demand in the alternative mode with respect to the change in the generalized cost of travelling by train. This cross elasticity is very low (in absolute terms) for roads and air outside the mentioned medium range distances or when the proportion of passenger-trips interconnecting flights is high.

Finally, it is worth stressing that the distortion in airports and road due to capacity problems can be dealt with other economic approaches (congestion pricing and investment) which should be considered in the *ex ante* evaluation of new HSR lines as part of the relevant `do something´ alternatives.

5. PRICING

5.1. Transport accounts of rail, road and air transport

The cost and revenue information provided by the UNITE project allows the comparison of the total social costs of transport and the corresponding transport charges, taxes and revenues for each country included in the study. The methodology is explained in Link et al. (2000) and basically consists in the identification and estimation of transport cost and revenues by mode of transport, with further disaggregating by different categories of vehicle and users. On the cost side, the accounts distinguish between infrastructure costs, supplier operating costs, accident and environmental costs, with a further distinction between internal and external costs.

On the revenue side, the accounts distinguish between user charges and taxes, and the discussion is open on whether fuel tax should be considered part of revenues allocated to road or part of general taxation without any transport relation. Revenues include user charges and transport related taxes such as VAT that differ from the standard tax rate. General taxes that do not differ from the standard rate of indirect taxes are excluded from the accounts as these are not specific to the transport sector.

We have grossly simplified the road, rail and air transport accounts in order to show, in general terms, how far costs are from being covered by revenues in each mode. Tables 4, 5 and 6 show this comparison for France, Germany, Spain and The Netherlands. There are not specific reasons for choosing these countries beyond data quality, and the introduction of the HSR.

The costs and revenues in the tables are infrastructure costs, supplier operating costs, accident costs (external), environmental costs, and, taxes, charges and subsidies. A brief summary is the following. *Infrastructure costs* include capital costs (new investment and replacement), maintenance and operating costs of transport infrastructure. *Supplier operating costs* include vehicles, personnel and administration costs incurred by rail transport operators for the provision of transport services, though due to data availability the final information differ from country to country.

Accident costs only include the external costs of accidents, so the internal costs of accidents, as time costs, are user costs and therefore are not included in the accounts for the purposes of this paper. Internal and external accident costs varied between countries depending on insurance practice, the coverage of their national health systems etc. When these costs are not paid by the transport user they are included in the accounts, as happen to be the case with the loss of production due to accidents, the rehabilitation costs of accident victims when these costs were covered by national health, the costs of police and the costs of material damage to public property when not covered by insurance companies. *Environmental costs* include the environmental impacts of transport, such as air pollution, noise and global warming.

Given the difficulties of gathering the data for the UNITE accounts and the differences in data quality by country it is not sensible to go too far comparing countries or transport modes. Nevertheless, some useful information comes up from a quick look to the data. The following comments are not specific for the countries in the tables and can be applied to a wide group of European countries.

Railways are the transport mode that shows the lower ratio of social cost covered by commercial revenue or specific taxes. Railways companies generate passenger and freight revenue that sometimes is not enough to cover supplier operating costs. This is not the case of road or air transport with a ratio of revenue/total social cost closer to one. Nevertheless, these modes present higher environmental costs, particularly in the case of air transport. When environmental costs are excluded, road and air transport revenue more than cover infrastructure and supplier operating costs.

The average ratio of cost coverage is not homogeneous along the network. In France, for example, infrastructure charges are substantially higher for the HSR lines than for the conventional network (three to four times the marginal cost). Nevertheless, cross-subsidization is not enough to cover full costs. As pointed out in Crozet (2007) in the cost calculation the financial costs of HSR lines are not included. The Frech infrastructure manager pays every year more than € 600 million of financial costs, linked to the construction of new HSR lines.[4]

The immediate conclusion is that the application of the principle of each mode covering its own social costs would lead to a substantial increase in the railway fares compared to the increase of air and road transport. Internalising externalities would affect more to freight than to passenger road transport. Two relevant questions appear here regarding HSR investment and pricing. One affects to

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[4] It is also worth stressing that the social and financial profitability of HSR lines may be decreasing once the investment in the main corridors has been completed. `Currently operating parts of the HSR lines should be distinguished from those which will be brought into service in coming years. These lines are indeed less and less profitable (Paris-Strasbourg, Rhin-Rhône HSL, HSL to Britany or Bordeaux). They require even larger public subsidies or maintain or even increase the French infrastructure manager´s indebtedness´ (Crozet, 2007).

the optimal prices to be charged in the already existing HSR lines, the other concerns the prices that should be considered when evaluating the construction of new ones. Both questions have to be solved together and lead to the discussion of the pricing principles to be followed.

5.2. Optimal pricing, investment and modal split

Both intramodal competition and intermodal competition require a sound and clear pricing policy that allow the transport user to choose the best option (the one he prefers) within a transport mode or when choosing between air, maritime, rail or road transport. It seems clear (equity issues aside) that for the best user option to be the best form the social perspective, prices should reflect the opportunity costs of his choice.

There are two dimensions of optimal pricing regarding HSR, air and road market shares. The first one is to figure out what the opportunity cost is when a significant proportion of total costs in railways are fixed. The second one is the marked differences in the way in which, in general, air, road and HSR infrastructure and operation affect the generalized cost of travel in each mode of transport.

5.2.1. Short-run or long-run marginal cost?

Let us assume that supplier operating costs, variable maintenance and operating infrastructure costs, and external costs are already included in the generalized cost. Should the investment costs and the cuasi-fixed maintenance and operating costs be also included in the full price?

The European Commission proposes a charging system based on each mode of transport internalizing its social costs, to reach an efficient distribution of traffic across different modes and ensure that these operators are treated equally to achieve fair competition

How much a rail operator should be charged for the use of the infrastructure in a particular time or demand conditions? In principle the answer is the `marginal social cost´ of running the train in that particular situation. Given the presence of economies of scale, significant indivisibilities and fixed and joint costs, pricing according to marginal social costs is far from being an easy task.

Moreover, governments pursue other objectives rather than short-term static efficiency, making the application of this charging system more complicated. The European Commission is particularly interested in the development of international transport within the Union, and in the internalization of externalities. Infrastructure charges should differ by mode and location when the local conditions vary, but should not discriminate between users by nationality or location. The “user pays” and “fair competition” principles are also invoked when arguing that each mode of transport should cover its total social costs.

Charging according to short-run marginal cost is incompatible with cost recovery when the infrastructure rail network is built and there is excess of capacity. Some critics argue that the natural alternative is long-run marginal costs. Short-run marginal cost is equal to the change in total costs when new traffic is added, given a constant network capacity. Long-run marginal cost accounts for the change in total cost allowing for an optimal adjustment of capacity.

Long-run and short-run marginal costs are equal assuming perfect demand forecast and perfect divisibility of capital, but both assumptions are unrealistic in transport and consequences of choosing a pricing principle are quite important in practical terms. For the case of HSR investment, short-run marginal cost pricing means prices below average costs and the need for public funds to cover infrastructure costs.[5]

Given the capacity available, any additional traffic willing to pay in excess to the additional cost imposed to the system should be allowed to enter. In the extreme case, when capacity is well above demand (forecasting error, indivisibilities or both) short-run marginal cost can be very low compared with average cost. Should rail infrastructure pricing be exclusively based on short-run marginal costs? The answer is not necessarily.

Pricing according to short-run marginal cost, with indivisibilities and economies of scale, leads to insufficient revenues for the recovery of infrastructure capital costs. Additional taxation needed to cover the gap has an additional cost in term of the distortion imposed on the rest of the economy. The second problem is related to incentives as subsidization usually reduces effort to minimize costs. Another drawback comes from the way in which capacity costs are covered, as users only pay variable costs and non users pay capacity costs. In addition to the equity side (it is difficult to think on HSR passengers as an equity target) we face a dynamic efficiency question: are the users willing to pay for capacity? If the corridors where this is not the case the government would be providing more capacity than optimal.

Even assuming that users are willing to pay for capacity (given prices equal to short-run marginal costs), it may be argued that demand is receiving a misleading signal in terms of the cost of expanding capacity in the long term. It may well be that a price structure which includes some charges for long-term replacement costs would be associated with a social surplus insufficient to justify the investment.

It is not necessary to defend long-run marginal cost to recognize that deviating from short-run marginal cost is the norm. Prices should not only follow costs but also demand considerations. Railway infrastructure managers are expected to pursue economic efficiency when charging for the use of the rail network, but efficiency has a long-term dimension. Revenue adequacy is required for long-term investment. This is a real dilemma and the way out is to price in a way in which short-term marginal cost is covered plus an additional charge to contribution to fixed and common costs. This additional charge should be set to minimize efficiency losses, and the way to achieve this is, in principle, through discrimination depending on the value of service, but political acceptability and information problems make Ramsey pricing difficult to implement.

The European Union faces the problem of equity or fair competition with more intensity than efficiency considerations when setting charges. Ramsey pricing may be compatible with economic efficiency but very difficult to apply in practice when two competing operators are treated differently for the sake of raising revenue minimizing with the lowest efficiency loss. Moreover, it is actually fairly difficult to apply Ramsey pricing to train paths. This is because the infrastructure manager has little knowledge of what traffic individual trains are carrying and its elasticity.

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[5] For a discussion on marginal cost pricing in transport see Rothengatter (2003) and Nash (2003).

Despite some contradictions, the Commission seems to favour a short-run marginal cost pricing (European Commission, 1995, 1998, Nash, 2001). It is expected that marginal cost charging will allow full capital costs recovery, given that prices in congested corridors and the internalization of congestion and external effects will produce enough revenue to satisfy financial constraints, at least across the modes. In the cases of insufficient revenues the Commission recommends additional "non-discriminatory" and "non-distorting" fixed charges (European Commission, 2001b).

The consequences of charging according to short-run marginal cost on the expansion of HSR lines are significant. Low prices favour the reallocation of traffic from competing modes and encourage traffic generation, with a feedback on the future expansion of the network. Pricing according with short-run marginal cost leaves a key question unanswered: are the rail users willing to pay for the new technology? Unless this question is answered before investment decisions are taken, marginal cost pricing is not a guarantee for an efficient allocation of resources.

5.2.2. Road, airport congestion and the generalized cost of travel

Airport delays and road congestion increases the generalized cost of travel. HSR is punctual and reliable. This is not always the case with air transport. Road congestion is pervasive at peak times. The asymmetries between HSR and road are self evident. Road infrastructure and operations are vertically separated. HSR infrastructure and operations are vertically integrated in practice. There is a single HSR operator by country. There are thousands of motorists entering simultaneously into a limited-capacity infrastructure without any planned scheme.

The standard treatment of congestion is well known in the economic literature: users should pay for costs imposed on other users who share the road, thus internalizing the costs they impose upon other will take decision according to marginal social costs. A practical implementation of this principle is to charge users during peak-hours, aiming to redistribute those users with a lower valuation for trips to alternative routes or time periods (Walters, 1961; Vickrey, 1963).

Airport demand is close to capacity at peak time and similar solutions to road are offered: managing demand by peak-load pricing and capacity investment.[6] Nevertheless airport congestion and road congestion are far from being the same phenomenon. Air side and land side airport infrastructure are shared among a relatively small number of agents. Decisions of entry are not random, but scheduled and controlled by a planner. In principle, airport congestion should be the consequence of bad weather or any other uncontrolled factor. If the planner decides the number of arriving and departing number of flights per hour, delays should be an infrequent event, like with HSR services.

The point is that there are other reasons beyond bad weather or other exogenous causes that explain airport congestion. A flight can be out of schedule due to problems experienced at the airport of origin, at the destination airport, or during the flight itself. A combination of all these factors frequently occurs, but the explanation of these delays are quite often attributable to the decisions of the airlines regarding fleet size, personnel, maintenance schemes, etc. Moreover, delays can be also the consequence of the airport management policy.

[6] Airport peak load pricing is treated in: Levine, 1969; Carlin and Park, 1970; Morrison, 1983; Fisher, 1989; Morrison and Winston, 1989; Oum and Zhang, 1990; Daniel, 1995, 2001; Wolf, 1998; Daniel and Pawha, 2000; Hansen, 2002; Brueckner, 2002a, 2002b.

When airport managers and airlines take decisions on flight schedules, they impose some external costs on themselves and also on passengers. Airports' decisions concerning slot allocation usually pursue to attend as much latent demand as possible, disregarding the occasional system overload. In the same way, airlines design flight schedules to maximize their profits, without taking into account the external costs imposed on passengers and other airlines, when timetables are impossible to fulfil because of minor disruptions.

New investment capacity can be use for new slots but also to reduce delays, but this last policy implies less activity and less profits for the airport manager. The airport does not internalizes the externality imposes on passengers who suffer the increase in the generalized cost of air transport.[7] Therefore, airport congestion should not be reduced to a peak pricing problem. Congestion occurs as an externality which is not internalized, and this happen in the peak and the off-peak. Agents causing delays should pay for the marginal cost of congestion. Internalization of congestion costs could be achieved, simply by using congestion fees which force airlines and airports to compensate each other and passengers for the external congestion costs imposed by flight delays (Nombela, de Rus and Betancor, 2004).

5.3. The long term effect of pricing

Prices have different economic functions. Prices act as a device to maintain the equilibrium in markets avoiding both excess of demand or underutilized capacity; moreover, prices are signals in competitive markets guiding the allocation of resources where the consumer willingness to pay is at least equal to the opportunity costs of these resources elsewhere. Entry and exit in these markets follow the price adjustment when demand is higher or lower that supply.

Transport prices are not different in this way to other prices in the economy. Competitive transport markets behave in the same way. Therefore, when price is lower or higher than marginal social costs in a particular mode of transport, the level of economic activity in this mode, and the traffic volume is suboptimal unless this is compensated in other markets related to the primary market through substitutability or complementarily relationships.

It is well known that when a transport user chooses a particular mode of transport in a particular place and time imposes a marginal cost to himself (user cost and the share of the producer cost –infrastructure and vehicles- included in the price), to the rest of society (external cost of accidents and environmental externalities) and to the taxpayers (the share of the producer cost that has been subsidized). When the generalized price is lower than the marginal social cost, as happen to be when freight is transported by a heavy vehicle in a congested road, the amount of freight transport on that road and time is higher than the optimal one. Pricing according to marginal social cost would increase the generalized price of this transport option, reducing the amount of road traffic and inducing long-term adjustments from increasing rail freight transport share to reducing the need of specialized labour in the production of spare parts for trucks.

[7] Air passengers are agents who bear congestion costs but are only compensated in limited occasions. Usually payments are only received from airlines as a compensation for long delays or lost connections.

What is the difference when HSR fares are short to cover infrastructure costs? It might be argued that economies of scale and strong indivisibilities justify the deficits, but the question is that users should be willing to pay for the HSR infrastructure before new lines are built. HSR prices act as signals that transport users take as key information on where, how and when to travel, or even whether to travel or not. When infrastructure costs are not included in transport prices, according to the rationale of short-term marginal social cost, the problem is that the price signal is telling consumers that is efficient to shifts from road or air transport to rail transport, and this, of course, could be true in the short-term when optimal prices are not affected by the fixed costs of the existing HSR network, but he world is dynamic.

The problem is that prices that do not reflect infrastructure costs in a transport mode where these costs exceed 50% of total producer costs, act as long-term signals for the consumers in their travel decisions and consequently in the future allocation of resources between transport modes or between transport, education or health. An extensive HSR network can be developed based on suboptimal prices decided by the government which keep no relation to the opportunity costs of its existence, but once the network is built bygones are bygones and the speculation on the counterfactual with a different allocation of resources and their effect on welfare is not very practical.

The defence of cost-benefit analysis in this context is quite relevant. Even accepting that short-term marginal cost is the right pricing policy, investing in a new HSR line requires that the willingness to pay for capacity be higher than the investment costs and any other demand unrelated cost during the lifetime of the infrastructure. This does not solve the problems of fair competition between different transport modes or the equity issue of taxpayers paying HSR fixed costs, but at least it puts a filter on the most socially unprofitable projects.

6. CONCLUSIONS

Investment in high speed rail (HSR) infrastructure is being supported by governments and supranational agencies with the declared aim of working for a more sustainable transport system. HSR is considered more efficient and less environmentally damaging that air or road transport. The truth in both arguments rests heavily on the volume of demand of the affected corridors and several key local conditions, as the degree of airport or road congestion, the existing capacity in the conventional rail network, values of time, travel distance, construction costs, or the source of electricity generation and the proportion of urban areas crossed by the trains.

The engineering of HSR is complicated but its economics is very simple. High proportion of fixed and sunk costs, indivisibilities, long life and asset specificity make this public investment risky, with a very wide range of values for the average cost per passenger-trip. The social profitability of investing public money in this technology depends in principle on the volume of demand to be transported and the incremental user benefit with respect to available competing alternatives.

The lack of private participation in HSR projects increases the risk of losing money; or reworded in more precise terms, of losing the net benefits in the best alternative use of public funds. HSR investment may be adequate for some corridors, with capacity problems in their railway networks or with road and airport congestion, but its convenience is closely related to the mentioned conditions and the volume of demand to be attended. Moreover, even in the case of particularly favourable conditions, the net present value of HSR investment has to be compared with other `do something´ alternatives as road or airport pricing and/or investment, upgrading of conventional trains, etc. When the investment cost associated to new HSR lines does not pass any market test, and the visibility is reduced by industry propaganda, short-term political interests and subsidized rail fares, conventional cost-benefit analysis can help to distinguish good projects from simple `white elephants´.

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ANNEX

Figure 1. Air passenger-trips Madrid-Barcelona (both ways), 1999-2008

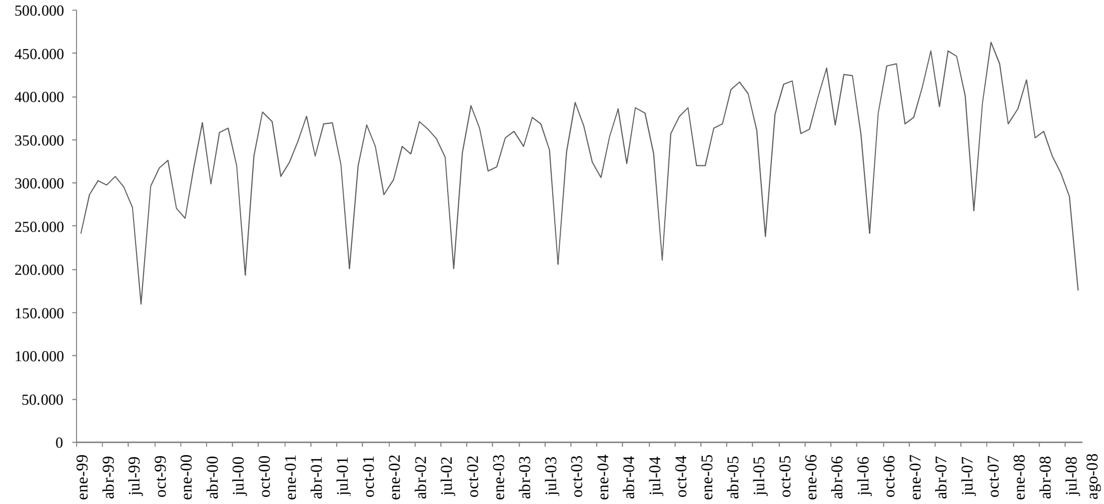

Table 1. The effect of the introduction of the HSR line in the air route Madrid-Barcelona

Variable	Coefficient	Std. Error	t-Statistic
T	1085.647**	52.51942	20.67135
D1	1086.346	8013.471	0.135565
D2	39493.1**	8011.922	4.929291
D3	63200.28**	8058.094	7.843081
D4	36942.43**	8055.184	4.586169
D5	66001.19**	8052.615	8.196242
D6	57633.64**	8050.389	7.159113
D7	16882.79*	8048.504	2.097631
D8	-106664.7**	8046.962	-13.25527
D9	26849.61**	8218.743	3.266875
D10	71301.29**	8217.904	8.676336
D11	60510.31**	8217.401	7.363681
AVE	-102085.3**	8136.273	-12.54694
C	259042.1**	6609.939	39.18978

R-squared: 0.927483; Adjusted R-squared: 0.918240; Durbin-Watson stat: 1.317196; *,** significant at the 5 or 1 per cent level.
D1: January, AVE: Months with HSR in operation (March to August)

Table 2. Travel time and market share in some high speed rail lines.

	Length (km)	Travel time (h:min)	Speed (km/h)	Market share (%)	
				Rail	Air
Madrid-Barcelona	630	2:45	229.09	50	50
Madrid-Seville	471	2:25	194.90	83	17
Paris-Amsterdam (1)	450	4:00	112.50	45	55
Paris-Brussels	310	1:25	218.82	95	5
Paris-London	444	2:15	197.33	81	19
Paris-Lyon	430	2:00	215.00	90	10
Rome-Bologna (2)	358	2:30	143.20	75	25
Rome-Milan (3)	560	4:30	124.44	35	65
Stockholm-Gotteborg (4)	455	3:00	151.67	62	38
Tokyo-Osaka	515	2:25	213.10	85	15

(1) High speed only Paris-Bruselles
(2) High speed only Rome-Florence
(3) High speed only Rome-Florence
(4) Upgraded conventional line

Figure 2. HSR market share and railway speed

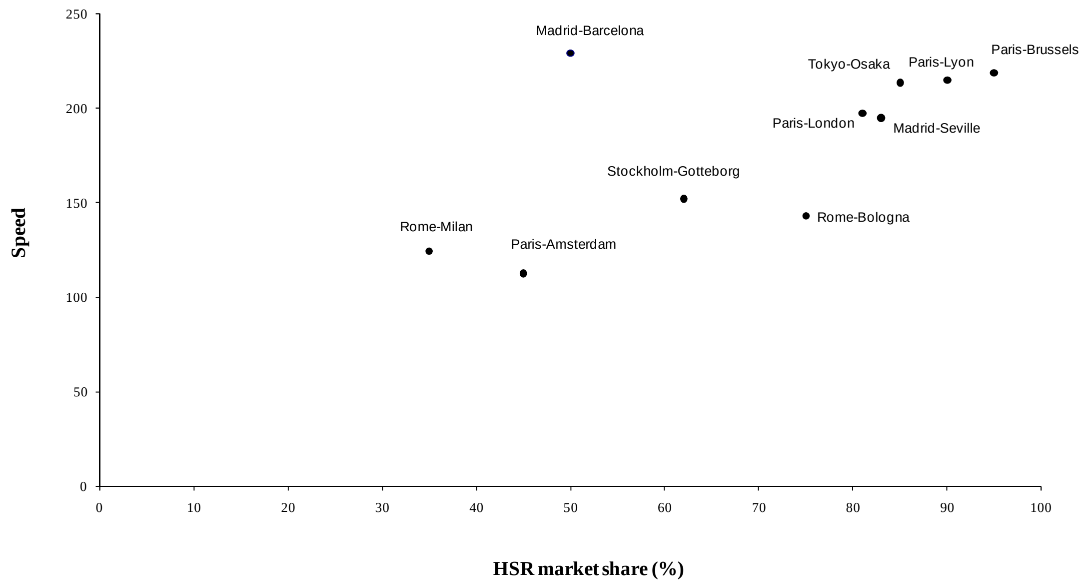

Table 3. Rail and air fares (return ticket) in some corridors with HSR

	Railway		**Airline**		**Ratio (Railway/Airline)**	
	Minimum price (with restrictions)	Tourist fare	Minimum price (with restrictions)	Tourist fare	Minimum price (with restrictions)	Tourist fare
Madrid-Barcelona	211	249	111	421	1,90	0,59
Madrid-Seville	134	149	81	530	1,66	0,28
Paris-Amsterdam	116	210	760	788	0,15	0,27
Paris-Brussels	90	164	324	337	0,28	0,49
Paris-London	124	435	218	653	0,57	0,67
Paris-Lyon	79	136	225	623	0,35	0,22
Rome-Bologna	78	78	233	517	0,33	0,15
Rome-Milan	110	118	165	652	0,66	0,18
Stockholm-Gotteborg	78	155	150	224	0,52	0,69

Table 4. Road Accounts

(€ millions, 1998)

	France	**Germany**	**Spain**	**Netherlands**
Costs				
Infrastructure Costs	25 520	25 176	6 224	4 411
Accident costs (user external)	1 528	14 549	2 307	1 421
Environmental costs	18 157	18 505	6 506	2 479
Total	**45 205**	**58 230**	**15 037**	**8 311**
Revenues				
Directly related to a specific cost category	4 167	411	919	91
Vehicle taxes	4 983	7 757	2 174	4 298
Fuel tax	18 720	28 983	8 428	5 040
VAT	16 146	4 565	1 349	857
Total	**44 016**	**41 716**	**12 870**	**10 286**

Table 5. Rail Accounts

(€ millions, 1998)

	France	Germany	Spain	Netherlands
Costs				
Infrastructure costs :	4 790	12 621	3 500	1 095
Supplier operating costs	9 998	7 336	2 013	2 339
Accident cost (external)	3	83	19	59
Environmental costs	129	1 403	296	34
Total	**14 920**	**21 443**	**5 828**	**3 527**
Revenues				
Passenger and freight revenue	7 326	8 614	1 495	1 365
Subsidies for concessionary fares	296	4 244	n.a.	81
Other specific revenues	504			
Fuel tax	35	217	n.a.	n.a.
VAT	280	34	n.a.	n.a.
Total	**8 441**	**13 109**	**1 495**	**1 446**

Table 6. Air transport accounts

(€ millions, 1998)

	France	Germany	Spain	Netherlands
Costs				
Infrastructure costs	1 080	3 488	411	98 (2)
External accident costs	0	35	4	0.5
Environmental costs	97	874	458	226
Total	**1 177** (1)	**4 397**	**873**	**325**
Revenues				
Airport revenues	1 687	3 121	501	224
Air traffic control revenues	1 117	815	341	n.a.
Total	**2 804**	**3 936**	**842**	**224**

(1) Excluding noise costs. (2) Excluding running costs.