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The Economic Effects of High Speed Rail Investment

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Abstract- 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.

Index Terms- Cost-benefit analysis, infrastructure investment, high speed rail, intermodal competition**.**

I. Introduction

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.

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 & 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.

This paper tries to shed some light on the economic dimension of HSR investment decision, which not only affects the transport sector but 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.

II. THE COSTS AND BENEFITS OF A NEW HSR LINE

A. 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 train 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. User costs are dealt with in section 2.3.

A.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. 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.

A.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 maintenance and 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 several European countries, infrastructure maintenance costs per km are, on average, equal to €100,000 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 traffic volumes and the specific technology used by the trains. 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 (2002). The operating and maintenance costs vary considerably. 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 as it is in different countries

A.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.

B. 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. 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. 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.

III. THE ECONOMIC EVALUATION OF HSR INVESTMENT

A. 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.

B. 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

IV. INTERMODAL EFFECTS

A. 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. 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.

B. 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.

V. PRICING

A. 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. 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 “nondiscriminatory” 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.

B. 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.

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 the 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.

VI. 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 to 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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