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A note on high-speed rail investments and travelers' value of time

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ABSTRACT

High-speed rail (HSR) is designed for travellers with high value of time. HSR offers fast and reliable services and good possibilities for work during the journey. Surprisingly, these benefits of HSR investments are often appraised with travel-time value of people who use conventional train services. This note considers under what circumstances the assumption that the value of time remains unchanged by the speed improvement induces a significant bias in appraisals. We first outline some conceptual points with a modal-mix model where travellers have varying value of time and then discuss how this could affect the social profitability of three recently constructed or proposed HSR lines: Oslo–Stockholm (Norway and Sweden), Stockholm–Göteborg (Sweden) and Beijing–Shanghai Hongqiao (China). We conclude that economic evaluations of HSR line should at the least be complemented by a sensitivity analysis of the possible effect of a change of the composition of travellers with various values of travel time.

1. Introduction

High-speed rail (HSR) is designed for travellers with high value of time. HSR offer fast and reliable services and good possibilities for work during the journey. Surprisingly, these benefits of HSR investment proposals are often appraised by use of travel-time valuations of people who travel with conventional (intercity) trains. This note therefore considers whether benefit–cost assessments of HSR investment proposals using standard appraisal methods underestimate the consumer surplus.

The value of travel time is a central parameter in both travel-demand modelling and in benefit–cost assessment (Small, 2012). It is often defined as an individuaĺs (marginal) willingness to pay for a reduction of travel time, and is then termed the value of travel time savings (VTTS). Based on seminal work by Becker (1965) and deSerpa (1971) the VTTS is usually considered to consist of two parts: the "pure time value", which reflects the opportunity cost of time as an input, and the direct utility (or disutility) of travel time[1]. Obviously there is much heterogeneity in both these components. If work is the alternative use of time, the opportunity cost is likely to vary across travellers with the after-tax wage distribution. However, it can also vary from time to time. Likewise, individuals have different preferences for spending time travelling and their pleasure may vary from trip to trip depending on various circumstances such as whether the train provides Internet access, fellow travellers are talking loudly, some time is spent waiting for a connection, etc.

In doing benefit–cost analysis of a transport investment a balance must be struck between realism and simplicity with regard to how much of such VTTS heterogeneity that will be considered in, respectively, modelling of demand and assessment of benefits (consumer surplus). While ideally one would like to estimate changes of both demand and consumer surplus for each individual traveller and then sum up to the aggregate quantities and values, one often instead has to work directly from aggregate measures such as elasticities and average VTTS for broad categories of travellers. The compromise in accounting for heterogeneity lies in the choice of categories, i.e., in the degree of segmentation. Demand models are often more sophisticated in this respect, while for consumer surplus effects, one or a few VTTS values are used, normally distinguishing between business and leisure travellers, sometimes also with a differentiation across modes. The aim of this note is to investigate under what circumstances a too simplistic segmentation of VTTS may lead to false conclusions on the benefits of HSR investments.

The motivation for the note is some issues concerning the computation of consumer surplus that have been raised in discussions over economic appraisals of high-profile HSR investment proposals. One concern is whether benefits are substantially underestimated by use of VTTS values of users of the old rail mode, even though a large portion of the HSR travellers are diverted air passengers[2] that have revealed preference for going by a fast mode. More

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[1] More exactly: the difference in monetary terms between the utility held from the travelling time and the utility from the best alternative use of this time, see Small (2012).

[2] Nash (2009) reviews evidence indicating that the air–rail mode share falls rapidly when rail travel-time goes under four hours and virtually to zero when rail travel time is below three hours.

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generally, acknowledging that travellers differ with respect to their VTTS raises the question on what VTTS to use when the composition of travellers within each mode changes. Another concern is whether the superior comfort and possibilities for work in HSR trains, compared to car or air planes, are ignored when, in fact, accounting for instance for the value of work during train travel reduces the VTTS of train passengers, and therefore the benefit from faster travel.

To address these issues we first need some theoretical clarification. For this aim, we will here demonstrate within a modal-mix model for travellers with varying VTTS how consumer surplus is affected by an HSR investment that replaces conventional train. We show that the reduction of train travel time in this model should be evaluated with different VTTS values for previous and new users of the rail mode. For previous users, who are at "the intensive margin", the average VTTS can be applied, but for new users, who are at "the extensive margin", marginal VTTS is relevant. The marginal VTTS appears in two versions however, on both a lower and an upper margin.

Some estimates of the upper and lower margin VTTS can be rather easily computed from travel cost and time information. We will here calculate upper margin VTTS values that can be associated to three HSR cases, in Sweden, Norway–Sweden, and China. We find that these values are considerably higher than the VTTS for train passengers that have been used for benefit–cost assessments of these HSR lines. The significance of this finding for the social profitability varies between these projects.

The theoretical analysis is conducted in next section, followed by the discussion of the three HSR cases in Section 3. Section 4 concludes.

2. Analysis

2.1. Model

In this section, we expose our arguments in a modal-mix model, focusing on the competition for travellers between three travel modes: coach, assumed to be cheap and slow; air, assumed to be expensive and fast; and train, assumed to be in the mid-range with respect to both travel time and travel expenditure.[3] The effect of a HSR investment is thought to shorten the train travel time. Consistent with the "cost savings" long-run approach to VTTS for business travellers leisure time is not considered to be affected by the travel-time reduction.

We assume that travellers' opportunity cost of time per hour (before consideration of work during travel) is uniformly distributed and given by $v \in [0,1]$. We normalize the (monetary) cost of coach to zero, so p_r is the additional cost of train and $p_r + p_a$ is the additional cost of air travel compared to coach.

We assume that indirect utility is linear in income[4]

$$U = y = (L - \lambda_c t_c - \lambda_a t_a - \lambda_r t_r)v - \lambda_r p_r - \lambda_a p_a + \lambda_r t_r w, \tag{1}$$

where y is income; λ_i takes value one for the chosen travel mode and zero otherwise; $(L - t_i)$ is time spent in office; and t_i is travel time used in coach ($i = c$), rail ($i = r$) or air travel ($i = a$). w is the value of work during journey per unit of travel time (and can be interpreted more broadly as representing direct utility from the travelling time).

[3] The model builds on Hotelling (1929). For the moment we abstract from the car mode. The car can be shared by several passengers and can transport door-to-door, so depending on circumstances car can be more or less costly and more or less rapid than train.

[4] Thus the marginal utility of income is unity and therefore constant, which facilitates aggregation over individuals.

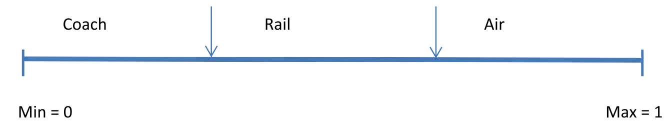

Fig. 1. The modal split between the rail mode, a slower mode (coach) and a faster mode (air) on a uniform distribution of the opportunity cost of time.

This is, for several reasons,[5] expected to be lower than the wage rate. Eq. (1) implies that although the time devoted for leisure is constant, total labor supply can be enhanced either by travel time reductions or by a larger portion of total travel time spent in train.

Finally, assume that the benefit at the destination, z, is "large enough" to always motivate travel. Then there are two unique switching points (v_1 and v_2) that determine the modal split between coach, train and air travellers, as shown in Fig. 1. At v_1 there is a traveller that is indifferent between choosing coach or train, so the following condition is met:

$$t_r(v_1 - w) + p_r = t_c \cdot v_1 \tag{2}$$

Likewise, at v_2 there is a traveller that is indifferent between choosing train or air, so the following condition is met:

$$t_a \cdot v_2 + p_a = t_r(v_2 - w). \tag{3}$$

Thus, switching points v_1 and v_2 define the lower and upper VTTS margin for train passengers, respectively.

2.2. Evaluation of a travel-time reduction for the rail mode

Now let train travel time be shortened by Δt_r; $\Delta t_r < t_a - t_r$. From Eqs. (2) and (3) we find that the switching points changes:

$$\Delta v_1 = -\frac{(v_1 - w)}{t_c - t_r} \cdot \Delta t_r < 0 \tag{4}$$

and

$$\Delta v_2 = -\frac{(v_2 - w)}{t_a - t_r} \cdot \Delta t_r > 0 \tag{5}$$

Thus, demand for the rail mode will increase by inflow from both the slower and the faster mode.

Using Fig. 1, we see that the total welfare gain of the train travel time reduction for "old" train passengers, i.e., those that were already using the train mode, is

$$\Delta U^{\text{old}} = (v_2 - v_1) \cdot \frac{v_2 + v_1}{2} \cdot \Delta t_r. \tag{6}$$

The total gain made by attracted travellers at the lower and upper margins are, respectively:

$$\Delta U^{\text{low}} = \Delta v_1 \cdot \frac{v_1 - w}{2} \cdot \Delta t_r \tag{7}$$

and

$$\Delta U^{\text{up}} = \Delta v_2 \cdot \frac{v_2 - w}{2} \cdot \Delta t_r. \tag{8}$$

Thus, the value of the travel time reduction for "old" train travellers and "new" train travellers at the two margins, should be

[5] First, only part of the travel time can be used for work. Second, while people sometimes state that they work better at train than at office, because of fewer disturbances from colleagues and clients, part of their productivity from the employer's point of view may emerge from such "disturbances".