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POSITIVE CONSUMPTION EXTERNALITIES IN PUBLIC TRANSPORT

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Abstract

The network "effect" is a well explored concept in transport economics. Nevertheless, this effect can be usefully integrated with the more simple, positive relation existing between public transport patronage and its frequency (Mohring effect). It is possible to derive from this specific relation the existence of a positive externality in the use of public transport services, an externality that in turn generates a market non-optimality. The paper derives a simple model for quantifying this externality and the efficient quantity of traffic. From this model it is possible to calculate an efficient subsidy, symmetric correspondence with efficient pricing rules for road congestion. The paper elaborates an example of quantitative evaluation, assuming a set of realistic figures for a bus service, in terms of value of time, tariffs, cost, patronage and frequency. Furthermore, three possible applications are briefly discussed: the enlargement of the supply of services instead of subsidisation, a possible strategy for airport charges, and the combined use of efficient subsidies and road-pricing in urban situations, even taking into account some equity aspects of "club goods".

INTRODUCTION

Definition of the problem

The concept of positive consumption externality is not new in itself, but has found several applications mostly in handling problems linked to the functioning of telecommunications markets. The concept is, as a matter of fact, very simple: a positive consumption externality occurs when an additional consumer generates economic effects to other consumers (in this case, benefits) for which the consumer himself obtains no perceivable advantages. It is to be kept in mind that this concept is very different from scale economies of some kinds of transport, for which the unit production costs are decreasing while supply is increasing, such as for instance railway services with a given level of infrastructures. Here the supply is not explicitly at stake, and it will be considered, from now on, within the assumption that unit production costs are constant, that is roughly the case of (urban and regional) bus services.

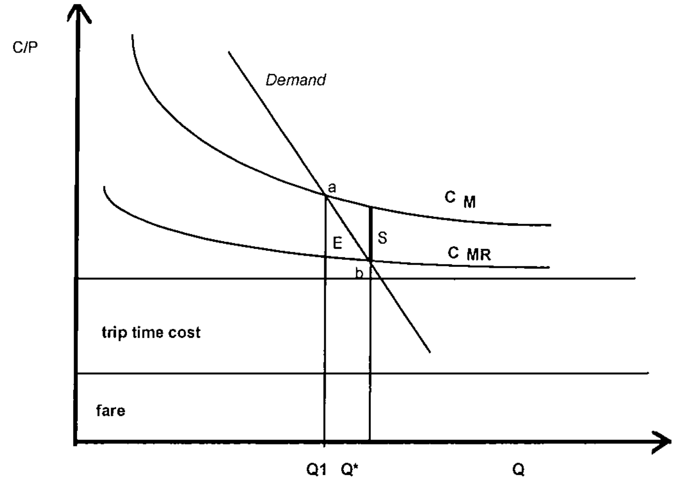
To further simplify the question under consideration, let us assume a competitive context, in which the operating subjects supply for services with constant returns to scale and tariffs equal to the production costs. Which are the positive consumption externalities for a competitive transport service, or anyway a service such as to adapt to demand? Basically the frequency of services, or in a slightly wider concept, the "network effect", that is the number of origins and destinations connected, or a mix of these two factors. A part of the network effect in particular can be seen as a wait phenomenon that is repeated many times in a trip when this asks for many interchanges.

The links between average waiting time and traffic is, besides, strictly dependant upon the size of the single vehicle with respect to the global demand, in other words this can be less meaningful for railways or sea services, that use vehicles with large unit capacity[1]. For sake of clearness, let's go back to the example of the buses (we will see an air transport case shortly). Assuming a standard average occupancy rate, an additional trip is necessary for every multiple of this occupancy rate, a trip that makes the service more frequent for <u>every</u> passenger. The shorter waiting time that results is a positive consumption externality. It must be remembered that waiting time has a clearly higher (perceived) economic value than the travelling time, because of a sort of psychological discomfort it seems to cause.

Basic diagram

Upon these preliminary remarks, it is to derive that, under this condition of externality, the market balance is inefficient. See fig. 1, in which an equilibrium between generalised costs (monetised time costs and tariff) and demand is shown.

As assumed above, tariffs and production costs (constant) are equal. Let's define a function of marginal waiting time costs (or anyway costs connected to the patronage size - see the "network effect") as decreasing, and lower than the previous function, representing the costs of every traveller net of the savings that such a traveller generates to all other travellers, making the service "denser" and/or more frequent.



Legend

C/P	=	costs or prices
Q	=	traffic
C_M	=	perceived cost
C_{MR}	=	net marginal cost
D	=	demand
Q1	=	equilibrium traffic (market)
Q*	=	"optimal" traffic
S	=	"optimal" subsidy
E	=	net efficiency gain (surplus)
A	=	market equilibrium
B	=	efficient equilibrium

Figure 1 - Demand and supply equilibrium under positive externalities' conditions

Market equilibrium A between generalised costs and demand generates a loss of social surplus equal to the area E. Then, it is possible to estimate an "efficiency subsidy", that increases demand till (it reaches) the optimal value Q_*. As one can see, these statements are exactly symmetrical to the ones derived in case of road congestion: road congestion, because of negative externalities that every motorist generates while slowing down the others, asks for an efficiency tariff (road pricing) to decrease traffic.

A particularly meaningful case is when the external consumption effects are closely related to a frequency increase. We can indeed define costs (and benefits) in terms of waiting time cost.

By putting:

C_W = perceived waiting time costs

B_{MR} = marginal benefits (waiting time reduction induced by the marginal user to other users)

C_{MRW} = net marginal waiting time costs

T_W = waiting time (equal, as average, to half the headway of the vehicle)

V_t = monetary value of waiting time (assumed as twice as the value of travel time)

K = average number of passengers per vehicle

Q = passengers/hour;

one can write:

$$C_W = V_t \, T_W \qquad (1)$$

$$B_{MR} = V_t \; Q \; \frac{d\,T_W}{d\,Q} \qquad (2)$$

$$C_{MRW} = C_W - B_{MR} = V_t\, T_W + V_t\, Q\,\frac{d\,T_W}{d\,Q} \qquad (3)$$

since $T_W = \frac{1}{2}\frac{K}{Q}$, $\frac{d\,T_W}{d\,Q}$ becomes deriving $-\frac{1}{2}\frac{K}{Q^2}$, and substituting: (4)

$$C_{MRW} = V_t\,\frac{1}{2}\frac{K}{Q} - V_t Q \frac{1}{2}\frac{K}{Q^2} = 0. \qquad (5)$$

the consequence is, that in this specific case, the marginal cost is zero and Fig. 1 becomes:

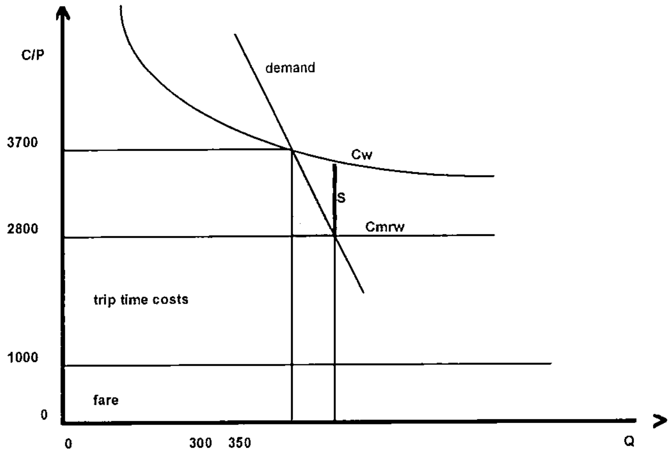


Figure 2 - Positive externalities related to waiting time

From some recent developments of cost-benefit analysis[2], nevertheless an element of "mitigation" of efficiency subsidies must be derived. It is the concept of marginal opportunity cost of public funds, cost that varies according to the level of public debt and the consequent fiscal pressure. Being the reduction of the debt in the last years an explicit and constant objective of the public action, it follows that it is possible and necessary to define a shadow price for such an objective, that is, an economic value to assign to the net variations of public expenditures in order to have a "rule" (or a price signal) for decentralised decisions. This allows for homogenous evaluations among various objectives, or at least among the monetised ones, such as the allocative efficiency of the case under study. In our case, indeed, the "efficiency subsidy" has an opportunity cost to be evaluated in comparison to the net surplus gains.

In case of road congestion, it is nonetheless necessary to highlight that a symmetrical statement cannot be applied: the "efficiency tariffs" produce indirect welfare losses too, in terms of increased fiscal pressure.

Some numerical tests

Assuming likely parameters, that is an average occupancy rate of 30 passengers/bus, 300 passengers in total, a value of the waiting time of 10 EUROs/hour, a value of travelling time of 5 EUROs/hour and a cost of 2.5 EUROs per bus-km, (corresponding to revenues, equal to 0.5 EUROs per passenger on an average 6-km trip) and testing these conditions for a group of values of demand elasticity, the outcome is high values of the "efficiency subsidy" (about 0.4 EUROs per passenger for elasticity equal to 0.5), that, in case of low frequencies, tend to become higher than the average tariff: in other

words this means theoretically that the economical optimal would be achieved with negative tariffs. This conspicuously conflicts with the statements aforementioned about the opportunity cost of public funds, and with every evaluation of practical operability of such high levels of subsidy. One infers though that the subsidy already widely given out to the public transport services on grounds of environmental protection or of lower-income groups protection, produces additional benefits quantifiable in terms of external consumption effects. But in turn, this can not be seen as an acritical acceptance of the monopolistic protection of the sector: high levels of subsidy are perfectly compatible with competition mechanisms for the market, that is appointing the services by tender to those who require for them lower subsidies (or lower tariffs), being constant the performances required.
Direct intervention upon the supply (subsidising the enterprises to expand services till the optimal value) does not automatically achieve the expected result: in fact, the costs perceived by the patronage would remain high and the additional supply would be only partly used. The net result would thus depend critically upon the ratio between the costs of expanding supply and the value of the global users' time savings, a ratio that cannot be defined *a priori*. It is obvious though, that whether the supply expansion costs were relatively low, this path could be less burdensome to the community than the "efficiency subsidy". In graph terms (Fig. 3) it is critical the ratio between the areas ABCD, representing the "non utilised" cost of the supply expansion, a net surplus loss, and area EFGHI, representing the users' additional surplus.

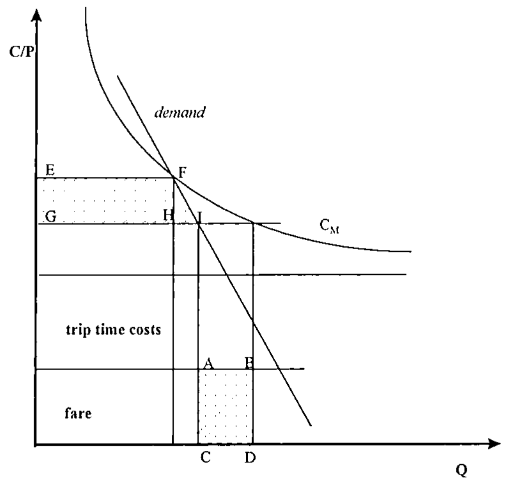


Figure 3 - Welfare balance of supply expansion

Some operating extensions of the principle: the effect of "critical mass" in airports and the combined effect of "subsidies and efficiency tariffs" in urban transport

A possible, relevant, application of the afore described approach to consumption externalities in transport, regards the "start up" problem i.e. the ways by which a system can reach an efficient size. Let's focus on the much debated question of the creation of an airport "hub", that is an airport having such a traffic size to operate as a switching station among long-distance (intercontinental) flights, connecting short- or medium-range flights (the "spokes" in a system of "hub and spokes"). Also in this case market equilibrium may not bring about efficient results[3]. Let's see how.
Let us assume, as in fig. 4, using the same abbreviations as in fig. 1, the demand curve is "skewed", i.e. it is rather rigid for small quantities of traffic and elastic for large quantities. This is likely to happen when "local" air services have actually no alternatives, whereas the longer-distance ones are

on a semicompetitive regime (for example, a traveller from Milan can fly to South America via Rome or Madrid or Paris in absence of direct flights). Such a demand curve D crosses the curve of perceived costs twice, in *A* and *B*, and it's apparent the second intersection represents a market equilibrium generating a greater surplus than the first, thus presenting a greater allocative efficiency.
The fact the curve of perceived costs is monotonic and decreasing as traffic increases, and this just represents the "hub" effect; greater traffic allows for minor waiting times and/or more direct links. In this case an efficiency subsidy is justified, subsidy that for the nature of the phenomenon, is higher than it would be needed to make the perceived costs equal to the marginal ones (see the case of buses). This subsidy nevertheless will be temporary, being the start-up of a self-sustaining phenomenon. One can in fact observe that the "efficient subsidy " S_1 would stop the phenomenon in C, whereas a subsidy equal to S_2 would cause an indefinite growth of the demand (once set up the subsidy S_2, the perceived costs would always be lower than the willingness to pay in the elastic part of the curve). It would therefore be possible to remove gradually the subsidy itself, until the demand reached the value corresponding to B (then the demand would go on growing "efficiently" till the saturation of the capacity of the airport).
It is surely possible to achieve the same effect on a normative way, commanding the carriers to operate at the new airport, until the optimal conditions above described are reached. Without the need to dwell on demonstrations, it is anyway generally agreed upon that, "coeteris paribus", regulatory solutions are less efficient then pricing ones, as one cannot discriminate different subjects on grounds of their utility.
In this case, the subsidy could moreover be made of initial tariffs lower than the ones necessary for covering the full costs of investment spent for the "hub".

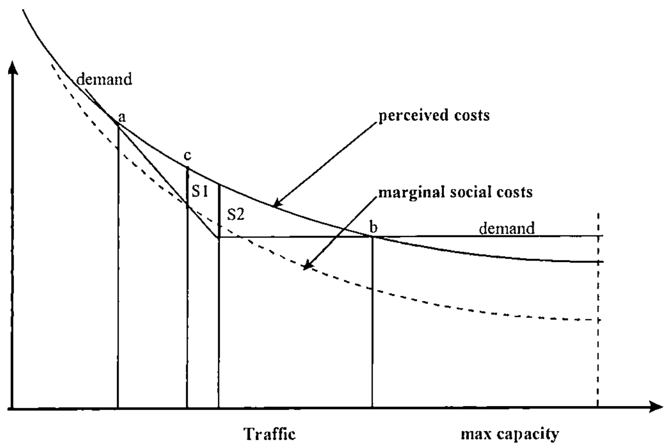


Figure 4 - The "critical mass" problem

This is the very problem of the distribution of the traffic between Linate and Malpensa airports: even though Linate is congested and Malpensa under-utilised, only few carriers serve Malpensa, for the demand has not reached a "critical mass". The forced move of carriers to Malpensa would cause net surplus losses in the short term also because of the greater access costs to Malpensa; a pricing strategy (landing fees etc.), such as to encourage using Malpensa and discourage the congested Linate airport, could start a more efficient equilibrium of the Milanese airport system (without financial losses for the operator, that is the same for both airports). The matter would be to "dose" adequately congestion tariffs and the subsidies above described.

Such a "dosing method" is represented at large in the following graph, valid under every circumstance under which conditions of "positive consumption externalities" are against congestion phenomena.

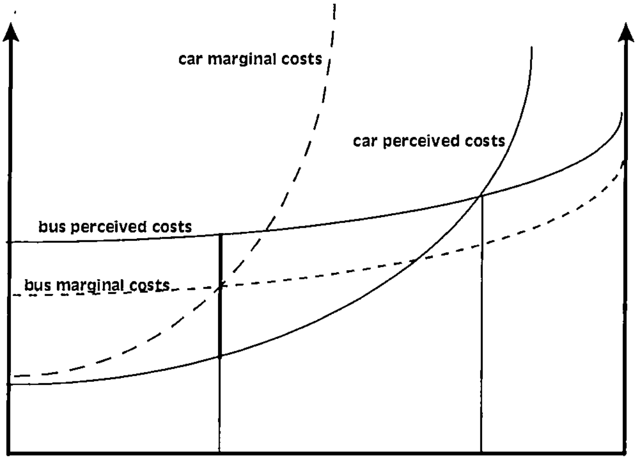


Figure 5 - Urban modal split optimization

If we represent in fig. 3 the given traffic split (for example between cars and public transport in an urban context), the "market" split, that is based upon the costs perceived by users, is R, whereas the optimal split, that minimises the global costs corresponds to R*, where the marginal social costs of the two transport modes are equal. To achieve such an efficient split, a subsidy S and a congestion tariff T are needed.

Considerations about environmental costs and opportunity costs of public funds would effect the optimal split along opposite directions, that we disregard for clearness' sake[4]. It is enough to note nonetheless that it is not relevant the relative amount of S and T lest their total does not vary. X-efficiency considerations and opening of the sector market would seem to push to keep high values of the tariffs or zero values for the subsidies, but relevant problems of political acceptance are against this.

Conclusions

The concept of positive consumption externality, applied to transport, can cause a meaningful improvement both in cost - benefit analysis, by quantifying surplus variations often not taken into account, and in the decisions of transfers of public resources supporting public transport, most in low-density areas, where the phenomenon has great relevance. It can also be an analysis tool for "start up" problems of new services characterised by critical size (such as big airports), and the principle seems to be at large extensible to innovative network systems as well.

Main references

Li Donni, V. (1991) **Manuale di Economia dei Trasporti**, La Nuova Italia Scientifica, Roma.

Masatoshi, A. (1978) Reciprocal Consumption Externalities in Urban Transportation: Problems of Optimal Tolls and Investments", in **Economic Studies Quarterly**.

Mohring, H. (1972) Optimisation and scale economies in urban bus transportation, in **American Economic Review**, No. 62, September 1972.

Nash, G.A. (1982) **Economics of public transport**, (cp. 6), Longman, London.

Newbery, D.M. (1990) Pricing and congestion: Economic principles relevant to pricing roads, in **Oxford Review of Economic policy**, Vol. 6, n. 2.

Ponti, M. (1994b) Aspetti economici e finanziari nella gestione del traffico, in AA.VV., **Il sistema mobilità: verso una gestione manageriale**, Etaslibri, Milan.

Ponti, M. (1992) Elementi teorici dei prezzi di efficienza per trasporto stradale, in **Atti della 48.ma conferenza del Traffico e della Circolazione**, Stresa, October 1992.

Stano, M. (1977) Consumption externalities in Models of Urban Transportation, in **Public Finance Quarterly**, No. 2, April 1977.

Walters, A. (1965) **The economics of Roads User Charges**, John Hopkins Press, Baltimora.

FOOTNOTES

1 In these cases, the phenomenon is more complex, as the travellers schedule their trip, waits are short, but the choice is constrained, thus generating other kinds of cost. In case of connection airports (the so-called "hubs", that will be seen further), headways between a flight and the other are anyway unavoidable. For sake of clearness, every kind of headway is treated in the text in a simplified and uniform manner.

2 See for example, N. Economides, *The Economics of Networks* in International Journal of Industrial Organization, March 1996. See Ponti, Petretto, Quinet, *Articolo*.

3 In this case scale economies are at stake too, given the fixed airport costs. Without deepening the problem of the optimal sizing of infrastructure, we note that the aforementioned concepts are valid "a posteriori" if in the decreasing function of costs, scale economies of infrastructure are also included.

4 High value of encironmental costs would produce an optimal split shifted toward public modes, whereas conditions of high public debt would shift such a optimum toward car mode.