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The Relations among Financial and Economic Aspects in the Evaluation of Infrastructures.

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Abstract

Two financial variables have a strong impact on economic evaluation of infrastructure. The first one is rather well known, and is the marginal opportunity cost of public funds (MOCPF), that varies from country to country and from period to period. The second is also well known in theory, but seldom seen within a CBA context: is the pricing policy assumed for infrastructure financing, that can vary from full investment cost recovering (average cost pricing, or ACP) to partial recovering, to zero recovering (short term marginal cost pricing, or MCP). Furthermore, these two financial variables are interlinked: in general, ACP pricing policies are more consistent with high MOCPF.
The paper shows these relations in quantitative terms, and derives some policy recommendations, and areas for further research.

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Keywords: Cost–benefit analysis; Marginal opportunity cost of public funds; Marginal cost pricing; Average cost pricing

1. Introduction

CBA tends still to be focused on social surplus maximizing aspects, recently enriched by the evaluation of environmental impacts, and sometimes also by “wider economic impacts”, or, less frequently, by income distribution considerations (generally in qualitative terms). Financial variables tend to be kept separate, or to be seen just as feasibility constraints. Actually, two financial variables have a strong impact on economic evaluation of infrastructures. The first one is rather well known, and is the marginal opportunity cost of public funds (MOCPF), that varies from country to country and from period to period. The second is also well known in theory, but seldom seen within a CBA context: is the pricing policy assumed for infrastructure financing, that can vary from full investment cost recovering (average cost pricing, or ACP) to partial recovering, to zero recovering (short term marginal cost pricing, or MCP). Furthermore, these two financial variables are interlinked: in general, ACP pricing policies are more

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consistent with high MOCPF.
The paper will explore in the first part the existing "state of the art" on this issue.
In the second part, it will first describe the relation among the result of CBA (NPV) and the assumed pricing policy, then will enrich the description including the MOCPF and demand elasticity issues, in order to provide a broader picture of the results.
In the third part, it will derive graphically the functions emerging from these relations, assuming a fictitious CBA context.
In the fourth part, practical transport policy aspects will be underlined, focusing mainly on the European picture of different infrastructure pricing policies among toll highways and railways. Some analysis of real cases will be illustrated, as well as the space for further research.

2. Literature

The subject of infrastructure pricing has been widely discussed and a broad consensus has been reached. Social surplus maximization is attained in the short term with marginal social cost pricing. If demand outweighs supply, marginal costs increase and lead to higher charges which, however, may not be sufficient to finance new investments. Then, if there is a constraint on the capacity of deficit financing by public funds, the long run marginal cost pricing must be revised so as to increase the revenues generated adopting Ramsey-Boiteux pricing (Boiteux, 1956).
Rothengatter (2003) argues that in the real world, the pricing of infrastructure on the base of marginal costs is not optimal and can lead to sub-optimal outcomes in the long term. In particular, "the introduction of a budget constraint leads to the result that nonlinear, non-uniform pricing such as multipart tariffs are Pareto-superior."
Nash (2003) agrees that several factors mean that pure marginal social cost pricing is not a desirable or sensible aim. However, marginal social cost should be the starting point in the development of a pricing policy, with considerations such as budget constraints, equity, institutional issues, simplicity and price distortions elsewhere in the economy also considered.

Bonnafous & Jensen (2005) elaborate a model to determinate, among several potential projects, those to be selected in order to maximise their total net present value, subject to a public budget constraint. They show that a programme of implementation by decreasing order of financial rate of return generates a higher NPV than the one ranked by decreasing socio-economic rate of return.
Moreover, overall social welfare is maximised when projects are ranked by the ratio of NPV / public euro invested.
Bonnafous (2010) defines the optimal pricing that leads to this result. Three different scenarios are identified:

- if revenues – whatever the toll - cannot cover over half the cost, it is preferable not to levy any toll;
- if there's a toll that covers all the cost, no constrain has to be on the operator;
- if the maximum revenue of the project falls between half and all the total cost, the value of the toll that maximises the welfare function is lower than the revenue-maximising toll.

The link between financing options and economic desirability of a project in analysed in Prud'Homme (2005). Five main institutional and financing options are considered:

- Pure public option: financed by government, usage free.
- Pure private option: financed by a private enterprise; tolls ensure the financial viability of the investment.
- Public cum toll option; toll proceeds accrue to government.
- Private cum subsidy option: financed by private enterprise; subsidy needed to meet its financial rate of return constraint.
- Shadow-toll option.

The NPV of a project depends upon three basic mechanism: a) users exclusion through pricing; b) greater efficiency of private operation; c) the opportunity cost of tax income

The values of the indicators produced by the model are as follows:

- The public option has the lowest IRR; it is marginally improved by the introduction of a toll (the loss in consumer's surplus is more than compensated by the gain due to a reduction in tax- associated damage).
- The pure private option with or without a subsidy is substantially superior to the public options.

- The shadow toll system is marginally better than the private option in economic terms but in budgetary terms is even worse than the public options.

Four Italian transport projects, taken form a Government priory list, have been analysed by Ponti (2003) using a traditional CBA methodology. The economic NPVs including the MCPF have been estimated. All the projects are characterized by a negative financial NPV and require a government support; moreover, they show (except one case) a negative result in terms of social welfare, which further decreases when the MCPF is introduced in the analysis.

The MCPF has been introduced in the analysis of the new Antewerp Tunnel in Belgium (Proost, 2005). The study has considered five scenarios, three of them characterized by a tolling scheme. For any of these scenarios a cost benefit analysis has been carried out adopting a base case value of MOCPF equal to 1. The sensitivity analysis has shown that setting the MCPF at 1,53 has a more pronounced effect on the welfare gains than the increase of the investment costs. Furthermore, the increase of the MOCPF pushes the two investment regimes with imperfect tolling down in the rankings and raises the regime with no investment and optimal tolling of the old infrastructure up to the second place. Kleven and Kreiner (2006) have given some interesting estimates of MOCPF related to different scenarios of labour market elasticities: the five larger European countries show the following figures: Spain - 1,10; Germany - 1,49; France - 1,41; U.K. - 1,14; Italy - 1,29.
According to Massiani & Picco (2014): “a reasonable provisional MCPF, corresponding to deadweight loss, can be proposed in the range of -1,2, -1,3 for western countries. Additional to that deadweight effect, additional transaction costs linked to administrative costs can be added, considering the situation of a given country.
Nevertheless, price elasticity of demand is never been included as a variable (has been given) and this is an aspect that enters as a crucial factor in this paper.

3. Formulas
Let us define the standard Net Present Value function as:

$$NPV = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+i)^t}$$

In this case, be $B_t = Tr \, . \, b_{unit}$ the annual benefits, and CF_t simplified as the initial investment cost. Be *i* the (given) social discount rate.
Let us assume the traffic Tr as constant in time, and equal to the initial traffic Tr_0, and this traffic varying only as a function of the tariff P, to be paid for the use of the infrastructure (an independent variable). The benefits b_{unit} are the benefit per traffic unit, exogenously given and assumed constant. In turn, the traffic depends upon its elasticity, that is obviously project-specific, to the tariff, from the traffic at 0 tariff (also given, as already specified), and from the tariff variation, $\frac{P}{dP}$, the only independent variable.

$$Tr = T_{r_0} - dTr = f(e, T_{r_0}, P)$$

Elasticity *e* of course can be written as:

$$e = \frac{\frac{T_{r_0}}{dTr}}{\frac{P}{dP}}$$

From which:

$$dTr = \frac{T_{r_0}}{e * \frac{P}{dP}}$$

The function linking the NPV of the project with the tariff P, will be monotonously decreasing with the growth of the said tariff from a maximum value in case of a zero tariff, to values that can become negative for high tariffs.

If we assume that also the elasticity will vary in discrete intervals $e_{(1....n)}$, a family of functions will be generated. A good practical interval of *NPV* values can be the one going from a maximum corresponding to a MCP strategy (implying low tariffs) with a minimum corresponding to a ACP strategy (implying high tariffs). These tariffs will be derived by the investment and operating costs of the infrastructure under evaluation.
The general form of the equation for every *e* will than become:

$$NPV = \sum_{t=0}^{T} \frac{(b_{unit} * T_r) - C_t}{(1+i)^t} = \sum_{t=0}^{T} \frac{\left(b_{unit} . T_{r_0} - \frac{T_{r_0}}{e . \frac{P}{dP}}\right) - C_t}{(1+i)^t}$$

A similar set of functions can be derived assuming a fixed elasticity, and varying instead, in discrete values, the marginal opportunity of public funds (MOCPF) *K*. Being the tariff the independent variable, knowing the financial investment cost and the traffic, we derive the revenues, that are obviously a direct function of traffic. Discounting these revenues with a given social discount rate *i*, we obtain the amount of subsidy that can be required as the difference between the discounted financial investment cost CF_t and the discounted revenues. In turn, the cost of this (possible) subsidy has to be evaluated as a marginal opportunity cost, via the coefficient MOCPF *K*. The value of K in the relevant literature varies between – 1,0 and -1,5, i.e. $K_{(1....2)}$, a function of the level of public deficit and debt of each country. In this case the assumed elasticity *e* is kept constant.
The discounted revenues will be equal to the traffic multiplied by the tariff:

$$\frac{P\left(T_{r_0} - \frac{T_{r_0}}{e * \frac{P}{dP}}\right)}{(1+i)^t}$$

The complete equation for *NPV* then becomes:

$$NPV = \sum_{t=0}^{T} \frac{\left(b_{unit} * T_{r_0} - \frac{T_{r_0}}{e * \frac{P}{dP}}\right) - C_t}{(1+i)^t} - \frac{CF_t - P\left(T_{r_0} - \frac{T_{r_0}}{e * \frac{P}{dP}}\right)}{(1+i)^t} K_{(1...2)}$$

4. The basic diagram, and the diagrams with elasticity and MOCPF.

The basic diagram is shown in Figure 1. Parameters are as follows:

- e = 0,3
- CF_t = 5.668
- C_t = 186 (constant)
- P_{min} = 1 (discounted revenues equal to discounted sum of C_t)
- P_{max} = 5 (discounted revenues equal to discounted sum of C_t plus CF_t)
- T_{r_0} = 200
- $b_{unit} = 4$
- K = 0

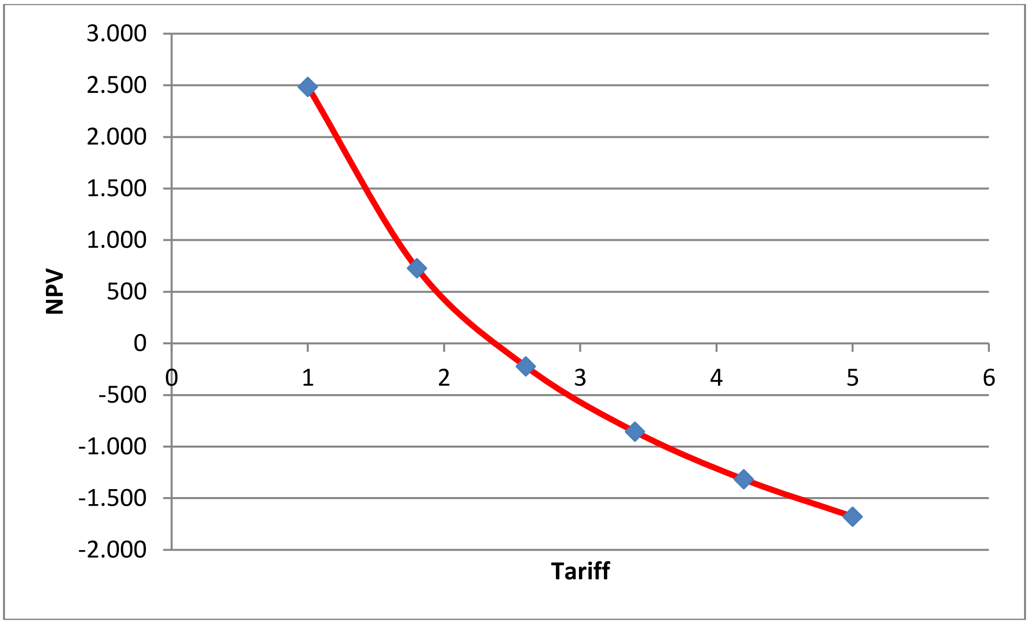

Figure 1 – Basic diagram: NPV vs. tariff

In Figure 2 a family of function with *e* equal to 0,1, 0,3 and 0,5 (and MOCPF = 0) is shown: the higher the elasticity, the faster the decline of NPV with the increase of the tariff.

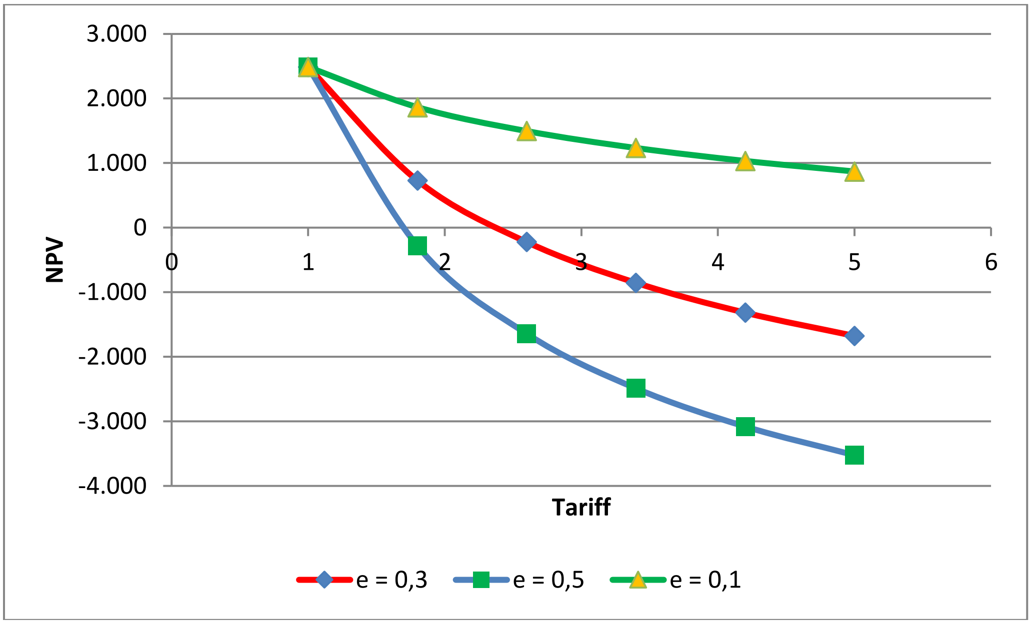

Figure 2 – NPV vs. tariff with three different values of elasticity

In Figure 3 a family of functions with the MOCPF equal to 0, 0,15 and 0,3 (and *e* = 0,3) is shown: the higher the MOCPF, the lower the NPV for each value of P. If P is equal to the average cost, there's no need of subsidies and the NPV is the same for each value of the MOCPF.

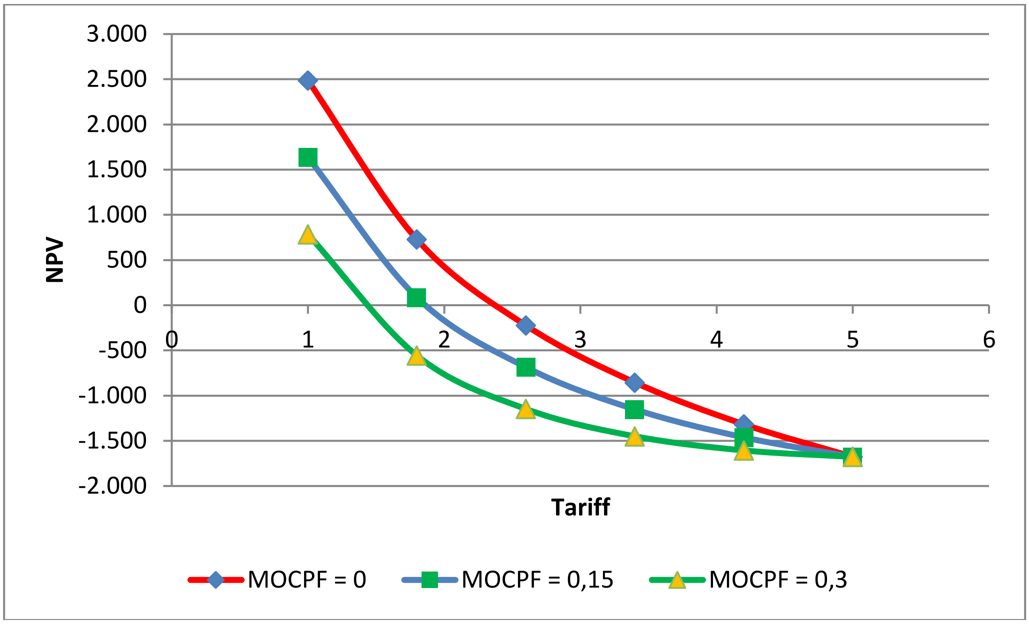

Figure 3 – NPV vs. tariff with three different values of MOCPF

5. Some practical policy considerations

What are the possible practical consequences of the relation between MOCPF and NPV in different contexts? Apparently quite obvious: in case of a severe scarcity of public funds, the "mainstream" MCP approach for investment loses its social surplus-maximizing role, and therefore the projects where this pricing strategy is used will tend to become less and less feasible, against the ones where ACP is used.

Let us now use an example in a sector where pricing strategies seems to be very random and inconsistent: transport infrastructure.

In the U.S., railways are mainly private, therefore pricing is mainly AC based, since investment or renewal cost are to be met by the users. Highways at the contrary are mainly un-tolled, and even the relation between gasoline taxation and the overall costs of the system are weak. Provisionally, we can assume a regime near a MCP one.

For the European context, the reverse is true: the dominant pricing policy in place for the two main land transport modes is mainly MCP for railways and ACP (even if often partial) for toll highways. This policy is also obviously inconsistent, like the American one, and has the same immediate effect to alter an efficient modal competition. For Europe, the widely used environmental argument looks rather weak, forgetting the almost-universal observation that on medium-to-long distances, where the two modes really compete, the gasoline taxation on average internalizes all the external costs of the road mode (see IMF 2014, OECD 2016).

For specific European countries, the role of the MOCPF is particularly relevant: the debate of its assumed value across Europe remains blurry (see Ponti 2007), but it is out of doubt that it has to be definitely higher for heavy indebted countries and less so for countries with a balanced public sector.

In the former ones, apparently investment in the rail sector has to be minimized, or the pricing strategy has to become average cost-oriented also for railways.

Nevertheless, the problem is far less simple than this. The "mainstream" theory that demonstrates that MCP is surplus-maximizing, returns to play a significant role. MCP is more effective for that aim, and this, more so when the demand is highly elastic to price. The demand for rail services, both for freight and for passengers, is very elastic to price, at the contrary of the demand for road services .

This fact is easily demonstrated by the evident consequence of fifty year of very high taxation on the road mode, and very high subsidies for the rail mode: the modal split has remained basically unchanged (Ponti et al. 2013).

If this is true, the alternative of shifting from MCP to ACP for new rail investment becomes unrealistic: demand will be too reduced by the tariff for infrastructure use to produce economically feasible projects. And this, especially because the negative mechanism is self-reinforcing: given even a partial ACP (i.e. some level of public financing for the investment) the demand reduction will in turn generate a further need to increase of tariffs in order to cover the (residual) part of the investment, and so forth.

A rigid demand of course will reduce this negative circular effect, but this will be valid for toll highways and not for unpriced roads.

6. Some real cases

A toll highway built in Lombardy from Milan to Brescia (BREBEMI) presents in an ex-post CBA the following discounted economic results, at the current level of Italian tariffs:

Table 1- Results of an ex-post economic analysis of the BREBEMI toll highway: base case (millions € 2010)

Economic Investment Cost	**Surplus**				**Environmental and Safety benefits**	**ENPV** (social discount rate 3,5%)	**EIRR**
	Consumer Surplus	**Producer Surplus**	**State Revenues**	**Total**			
	753.0	679.8	-137.3	1.295.5	62.0	159.3	4.0%

Source: TRT feasibility study, unpublished, 2013

A simulation analysis has been performed, assuming that the same infrastructure as free (0 € tariff). This assumption can well represent a case of MCP, since the average fuel taxation in Italy is one of the highest in the world, and for inter-urban traffic exceeds the external costs generated (see IMF 2014).

Under this assumption, as expected, the economic performance of the project improves, as obviously the traffic increases, and the results are as following:

Table 2 - Results of an ex-post economic analysis of the BREBEMI toll highway: 0 tariff case (millions € 2010)

Economic Investment Cost	**Surplus**				**Environmental and Safety benefits**	**ENPV** (social discount rate 3,5%)	**EIRR**
	Consumer Surplus	**Producer Surplus**	**State Revenues**	**Total**			
-1.198.2	3.799.5	-1.670.3	-1.422.0	1.987.1	205.7	994.5	6,7%

In order to guarantee the financial feasibility of the project, a group of public agencies have paid a total of 600 Mln € to the private concessionaire (the real case).

Now let us see the role of MOCPF in the two cases. In the first one, we have to add the financial loss of the State (due to the reduction of gasoline-related revenues) to the financial subsidy: (137.3 + 600.0) = 737.3 Mln €. In the second case (0 tariff), the total financial cost for the State is 1.422.0 Mln €.

Let us consider now a possible range of MOCPF from the mentioned literature (see point 3). In Italy, given the very high level of public debt and the European constraints, the real MOCPF is probably near, or even over, the highest limit: 1.3 (to be taken as the multiplier of the financial public cost).

In the real case, the result will be (737.3 x 1,3) = 958.5, an increase of the economic cost of the project of 221.2 Mln €, and a subsequent shift of the ENPV from positive, to a negative one of 61.9 Mln €.

In the case of the free alternative, the result is as following: (1.422.0 x 1.3) = 1848.6, an increase of the economic cost of the project of 650.4 Mln €. The ENPV will remain positive at 344.1 Mln €.

These simple figures show the critical role both of the MOCPF and the pricing policy of infrastructure, but mainly of their interplay, that looks far from obvious.

Let us now consider the main Italian HST project, the Turin-Milan-Naples line, where we also have an ex-post economic analysis (with social discount rate 3,5%), even if the result exposed in a different form, as following:

Table 3– Result of an ex post economic analysis of the Turin – Naples HST (millions € 2010, Social Discount Rate 3,5%)

Investment	-25.451
Residual value	4.579
Travel time benefits	6.346
Waiting time benefits	1.640
Reduction in fares (due to competition)	2.612
New operating costs of lines and services	-12.479
Saved operating costs of lines and services	7.872
Revenues generated by new rail users	16.244
Saved external costs (car)	2.773
Saved external costs (air)	1.095
Lost fuel taxes and motorway tolls (car)	-4.502
Generated rail services external costs	-960
Saved rail services external costs	492
ENPV (Benefits - Costs)	261

Source: P. Beria, R. Grimaldi, 2016

Here some simplification is needed, since some financial data are not available, i.e. neither the level of state subsidy on electric energy, nor the amount of investment cost recovery that for several years has been made from the tariff for the use of the infrastructure (this mark-up has been recently cancelled).
If we assume, for this reason, only the "certain" financial costs for the State, i.e. the economic cost (net of taxes etc.) of investment (25.451 Mln€) and the losses of fuel taxes (4.502 Mln€), these costs amount to 29.953 Mln€.
Using the same 1.3 MOCPF as for the BREBEMI case, the resulting economic cost becomes: (29.953 x 1.3) = 38.939, and the ENPV becomes highly negative, to -8.726 Mln€.
In this case, given the minimal positive ENPV, even a much lower MOCPF looks sufficient to reverse the sign of the net benefits of this very large project. And any possible change of pricing policy, at present basically a marginal cost-based one, toward a one more able to recover part of the investment, this will sharply reduce the ENPV of the project, given the high elasticity to prices of the rail demand.
We have tested the same procedure for the section of this mega-project, the Milan-Bologna link, that shows the most positive results, and that shows the following relevant figures:

Table 4– Result of an ex post economic analysis of the Turin – Naples HST (section Milan – Bologna) (millions € 2010, SDR 3,5%)

Investment	-6705
Residual value	1206
Travel time benefits	2777

Waiting time benefits	257
Reduction in fares (due to competition)	613
New operating costs of lines and services	-2640
Saved operating costs of lines and services	1646
Revenues generated by new rail users	3814
Saved external costs (car)	651
Saved external costs (air)	257
Lost fuel taxes and motorway tolls (car)	-1057
Generated rail services external costs	-203
Saved rail services external costs	103
ENPV (Benefits - Costs)	719

Source: own calculation with data from P. Beria, R. Grimaldi, 2016

Even in this case, the ENPV becomes negative, to -1607 Mln€., not a minor variation.

7. Conclusions and further research

The basic conclusions seem rather straightforward: if social surplus maximization is the main goal of infrastructure investments, MCP is a sound strategy (as the mainstream theory goes) when the MOCPF is low, but the contrary is true in the case of severe budget constraints. This in turn implies for the transport sector that railways are in a sense a “luxury” mode (i.e. for rich public purses), compared to toll highways, but even to non-toll roads, given the benefits in terms of social surplus of a MCP approach.
And this, even taking into account the environmental objectives, fully present in actual CBA techniques.
A second possible conclusion is that an overall optimization both of investment and pricing is possible, having as a national input for the value of the MOCPF, that in fact is a macro-factor, like the social discount rate and other important shadow prices.
Further research is needed on a possible symmetry: if under severe budget constraints there is a MOCPF as a “shadow value” of scarcity of that factor, also projects generating positive revenues for the State may well have a similar and opposite over economic value to be taken into account.
Another field for further research is linked more in general with the micro-macro relations among growth objectives and CBA. The latter measures social surplus gains, while the former is more related with GDP, that is not including directly many aspects of social surplus. In transport, this issue is especially evident: time savings for passengers are often a substantial part of the benefits of transport investments, but their link with GDP are either weak or non-existing at all.

References.

Beria, P., Grimaldi, R. 2016. An ex-post cost benefit analysis of Italian High-Speed train, five years after (Unpublished)

2016Bonnafous, A., 2010. Programming, optimal pricing and partnership contract for infrastructures in PPPs. Res. Transp. Econ. 30 (1), 15–23.

Bonnafous, A., Jensen, P., 2005. Ranking transport projects by their socioeconomic value or financial interest rate of return? Transport Policy, 12, 131-136.

Kleven H.J., Kreiner, C. T., 2006. The Marginal Cost of Public Funds: Hours of Work versus Labor Force Participation," CEPR Discussion Papers 5594, C.E.P.R. Discussion Papers.

IMF, 2014. Getting Energy Prices Right, Washington DC.

Massiani, J., Picco, G., 2014. The Opportunity Costs of Public Funds Concepts and Issues (November 26, 2014). University Ca' Foscari of Venice, Dept. of Economics Research Paper Series No. 20/WP/2014.

Nash, C., 2003. Marginal cost and other pricing principles for user charging in transport: A comment. Transport Policy 10, 345-348.

OECD, Effective Carbon Rates, Paris 2016.

Ponti, M., 2003. Welfare basis of evaluation, in Mackie P.J., Nellthorp J., Pearman A. D. (edited by, 2003), Transport projects, programmes, and policies: evaluation needs and capabilities, Ashgate Publishing Ltd, Aldershot (UK).

Ponti, M., Zecca, E., 2007. The role of budgetary constraints on cost-benefits analysis of transport infrastructure investments and on environmental taxation, 11th WCTR, Berkeley, 24-26 June.

Ponti, M., Boitani, A., Ramella, F., 2013. The European transport policy: Its main issues. Case Studies on Transport Policy 1, 53-62.

Proost, S., 2005. A cost-benefit analysis of tunnel investment and tolling alternatives in Antwerp, ETE working papers N°2005-07, Katholieke Universiteit Leuven, Leuven.

Prud’homme, R. 2005. “Infrastructure and Development”, in: Bourguignon, François & Boris Pleskovic, ed. 2005. Lessons of Experience (Proceedings of the 2004 Annual Bank conference on Development Economics). 2005. Washington: The World Bank and Oxford University Press, 153-181.

Rothengatter, W., 2003. How good is first best? Marginal cost and other pricing principles for user charging in transport, Transport Policy 10, 121-130.