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Some inescapable tradeoffs

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The economic evaluation of infrastructure investment
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ABSTRACT: Transport infrastructure investment is an inter-temporal decision through which society foregoes its current wellbeing for the future. In the economic assessment of this trade-off, the practical standard method is cost-benefit analysis, which compares the social benefits and costs of the decision. Furthermore, a sound exercise of economic evaluation requires an approach that incorporates other unavoidable trade-offs related to pricing, such as charging short-run *vs* long-run marginal cost or the consequences of budget constraints on the net social value of the investment; intermodal competition and public investment; institutional design and the choice of contracts; and in a particularly important but somewhat neglected point, the long-term consequences of investment decisions. This paper addresses the economic content of this set of essential trade-offs and discusses their inclusion in the economic evaluation of major projects.

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1. Introduction

In the 1970s and first half of the 1980s, the net stock of public capital in the US grew at 1.6%, approximately three times lower than the annual growth rate during the previous 20 years. Aschauer (1989) linked this reduction in infrastructure investment to the productivity slowdown in that period, particularly during the first half of the 1980s. Following this main contribution, many other studies have found similar causal relations between infrastructure and economic growth (Munnel, 1990; Deno, 1991; Deno and Eberts,1991, Eisner, 1991; García-Mila and McGuire, 1992).

In a second wave of econometric research, the estimations were much less optimistic (Evans y Karras (1994), Holtz-Eakin (1994), Holtz-Eakin and Schwartz (1995) and Holtz-Eakin and Lovely (1996)); and beyond the discussion on the value of elasticities, the research on the economic impact of public infrastructure investment has shown that the estimated elasticities of productivity with respect to the stock of public capital are very sensitive to the present level of this stock. Aschauer's high elasticities correspond to a period of low growth in the net stock of public capital. For the case of Spain, De la Fuente and Vives (1995), Goerlich and Mas (2001), Mas et al. (1996), among others, also obtained higher elasticities in the 1970s than in the 1990s when the core infrastructure network was already built (from 0.14 to 0.02).

Moreover, the aggregate approach, followed in the econometric estimations, can only provide an average approximation of what happened in the past. Therefore, their estimates are not going to help much with the key question of where and in which type of infrastructure the marginal investment should be assigned (Gramlich, 1994). This problem is crucial in the allocation of resources and it is mainly addressed within the realm of the public sector. This is the main concern of this paper: how the economic evaluation of transport projects can be improved by detecting some of the weaknesses of their actual practical application.

The somewhat naive and common belief in the economic benefits of transport infrastructure investment, disregarding the opportunity cost of the resources employed in specific projects, rests on some type of "availability cascade" (Kuran and Sunstein, 1999) consisting in a self-reinforcing process through which a collective belief develops without critical thinking or any empirical justification. People usually believe that infrastructure investment is good (and the bigger, faster or taller the better) because other people have adopted this belief. The political discourse reinforces this idea, emphasizing the benefits, overlooking the costs and presenting some irrelevant short-run demand effects as benefits of the specific project (Crompton, 2006). The mantra is: investment in public infrastructure is good for the country. It creates jobs and increases productivity.

This cognitive bias found some academic support in the economic literature of the 1980s and its overoptimistic elasticities of productivity with respect to the stock of public capital. The overflow of papers based on the aggregate approach contrasts with the lack of any practical interest in its results for the key questions regarding infrastructure investment decisions in the real world (Gramlich, 1994).

Infrastructure investment consists of giving up present consumption for future consumption. Reliable transport in the future require deviating resources in the present to build basic infrastructure to keep up with demand growth and technological change for future needs. It is an inter-temporal tradeoff. This is the key point when speaking on investment, and the choice of an appropriate social discount rate is the conventional approach to make the flow of sacrifices and the benefits homogenous over time to determine whether the sacrifice is worthy.

Unfortunately, this tradeoff is not the only one that practitioners must face in the decision-making process.

The economic evaluation of infrastructure investment requires consideration of some additional tradeoffs. Going back to first economic principles, we start with the basic question, is the society better off with the project? To answer this question we need to address which model we previously had in mind and the scope and validity of cost-benefit analysis. In section 2, the basic framework for the evaluation of projects and the issue of the social planner model versus the interest group competition model is discussed along with the role of cost-benefit analysis in these alternative worlds.

Pricing and investment is the content of section 3. Both subjects are interconnected and cannot be treated independently. Investment in capacity requires forecasting demand, being the volume of users sensitive to the level and the structure of charges. Furthermore, once the infrastructure is built, pricing decisions are highly conditioned by sunk costs given the degree of specificity of the assets already built.

Moreover, the substitutability and complementarity of some infrastructure are additional reasons to address the price-investment decision jointly, which also have significant long-run consequences beyond allocative efficiency in the short term. This property is the content of section 4, which includes a discussion of the short-run versus long-run consequences of major infrastructure investment projects. This discussion includes the optimal timing of investment but fundamentally concerns the issue of long-run equilibria when mutually exclusive systems or networks compete to solve a common problem.

2. A model for the economic evaluation of projects

The economic evaluation of infrastructure projects through cost-benefit analysis requires a clear understanding of the difference between what economists would like to measure and what they can measure. We are interested in welfare changes, but we have to address the monetary measures of utility changes. Although cost-benefit analysis is trying to measure changes in social surplus brought by a project, the analysis is carried out with money as an alternative to estimating the actual changes in individuals' utility, and finally on social welfare through some type of conversion of individual utility into social values.

Therefore, although money is only an instrument in the economic appraisal of transport infrastructure investment, it is the common unit in which economists express the intangible changes in utility and welfare. This has a price in terms of some well-known ambiguities when comparing or aggregating monetary changes of individuals who differ in their level of income, among other personal characteristics.

The common approach to cost–benefit analysis is to suppose the existence of a social planner, or a benevolent regulator, who acts as a social welfare maximizer and compares benefits and costs before the approval or rejection of projects. In an ideal world, the economic assessment of a project cannot be carried out without considering the interrelation with other projects, which can affect the design, pricing to be applied, etc., of the specific project subject to evaluation.

When the objective is the maximization of social welfare and public funds are limited, the maximum net present value should be calculated for the set of projects, given their interrelation and the existence of a budget constraint. In practice, many projects are subject to individual evaluation without considering the consequences of their implementation with respect to other projects linked with the former through relationships of complementarity or substitutability and the long-run implication of some decisions. Even so, the common assumption is that the government tries to maximize welfare and conduct cost-benefit analysis to guide its decision.

An alternative view (Becker, 1983) explains a government's action by the political power of different interest groups. A new infrastructure investment decision could be the consequence of lobbying by contractors and/or the economic agents of the region receiving direct benefit, instead of the outcome of the maximization of a social welfare function. In this case, the consequences of investing in a particular project with far reaching consequences are much more serious and deserve a detailed treatment (see sections 4 and 5).

There is a well-documented body of evidence showing that the *ex-ante* benefits and costs are usually overestimated and underestimated, respectively, in many projects (Flyvbjerg, Holm and Buhl 2002, 2005). The tendency of people to base their forecasts on the "inside view" in which planned actions and intention dominate the "outside view" based on the statistical evidence from the *ex-post* outcomes of similar projects (Kahneman and Tversky, 1979, Kahneman, 1994) lead to the so-called "planning fallacy", which explains the poor results of many infrastructure projects with apparently positive ex-ante evaluation.

It is crucial to look at the cause of the difference between forecasted and actual outcomes in the planning fallacy. In many cases it is not a problem of individuals' tendency to disregard relevant statistical information and base the predicted results on planned actions and intentions (cognitive bias) but on strategic misrepresentation. In this latter case, inaccuracy is deliberate (Flyvbjerg, 2013); hence, we have to look to the institutional design in which the planning and economic evaluation of infrastructure projects take place.

Though many of the projects approved by the government do not support the view of a social planner being guided by the maximization of social welfare, the analyst can go ahead with the economic evaluation of a project as if the government were pursuing the general interest of society.

The existence of a benevolent government is not required to conduct a cost-benefit analysis. A more prosaic view is compatible with its defense in public policy. We can assume the existence of a government pursuing the maximization of the probability of its reelection, for example, and at the same time estimating the welfare effects of projects. Cost-benefit analysis can help provide relevant information to the economic agents about the associated costs and benefits of government interventions as it is an investment in public infrastructure (Becker, 2001).

It is quite risky to quantify impacts without a clear analytical framework. To derive rules for the practitioner of cost-benefit analysis we need a model. A rigorous approach is needed to derive practical rules to avoid double counting and other errors in the valuation of transport benefits and costs. We assume the existence of a rational individual (or household) who maximizes utility subject to the usual constraints. We overlook here problems derived from distorted preferences (see Adler and Posner, 2001; Brennan, 2014).

The utility of this representative household is affected by the project, so it can be a winner, a loser or be indifferent with the implementation of the project. As utility cannot be measured, economists estimate the monetary valuation of utility changes, typically the compensating variation or the maximum amount of money that given to or taken from the individual leaves him indifferent with the project compared with the situation without the project (the counterfactual).[1]

There are well known problems when converting this monetary compensation into welfare changes as individuals differ in income and personal characteristics. The so-called social marginal utility of income is expected to be different among individuals even assuming a utilitarian social welfare function where the social marginal utility is identical for all individuals. Moreover, changes in utility happen in different periods of time, and another weighting is

[1] This adds another difficulty for the practitioner as the counterfactual is dynamic. The world changes with and without the project and the prediction has to cover the lifespan of the project, which is quite long in the case of transport infrastructure.

required to calculate the net present value of the projects given the preferences of individuals between present and future consumption. This is the issue of discounting (see Burgess and Zerbe, 2011; Moore *et al*., 2013a, 2013b).

In practice, the Kaldor-Hicks compensation criterion is explicitly or implicitly followed. The conventional calculus of the net present value implies a social marginal utility of income equal for all the individuals in society. This presumes an optimal distribution of income or, perhaps, the possibility/desirability of dealing with equity separately (for distributional issues see Layard and Walters, 1978).

We do not cover here the mechanics of cost-benefit analysis but, for our purposes, it is important to understand that the household´s monetary valuation is based on the impact of a project on prices, income (both external and coming from labor or profits) and taxes, plus the impact on attributes such as air quality, noise, safety or comfort, affecting directly the utility of individuals. Hence, when a infrastructure project changes the level of pollution and the generalized price of transport, for example, it is essential to have the model in mind to ask the right questions and avoid double counting.

Johansson (1993) derives general equilibrium cost-benefit rules for marginal and large projects that affect the environment. The core approach is general and can be applied to any other government intervention, such as the provision of transport infrastructure. The key idea is that the economy is integrated by households and firms, ultimately owned by the former. The indirect utility function of a representative consumer is a function of prices, wages, exogenous income, firms´ profits, taxes and public goods. Under the assumption of well-behaved functions and prices adjusting to equate supply and demand, the monetary valuation of the utility change produced by a large project can be approximated through the conventional rules of adding consumer, producer and taxpayer surpluses, as long as the consumer´s willingness to pay does not include any change in exogenous income, profits or taxes.

Cost-benefit analysis can be contemplated as a set of shortcuts to circumvent the impossible task of measuring the total effects of an infrastructure project in the economy. This involves the effects on many households and markets during the lifespan of the project. The good news is that under some conditions, particularly the fact that prices adjust continuously to equate supply and demand, it is possible to approximate the net present value concentrating the effort in the primary market. The bad news is that the conventional approach loses validity when the project produces significant price changes.

We now move to a more formal discussion of the cost-benefit analysis framework with the aim of making explicit the assumptions behind the practical rules followed to try to answer the demanding question of whether society should put public money into particular infrastructure projects. The general equilibrium cost-benefit rules (Johansson, 1993) will be our basic framework.

Let us assume the existence of an economy with identical households, where firms are ultimately owned by households. The representative household consumes private goods and a public good, interpreted here as the *level* of public infrastructure, and supplies a vector of different type of labor. The indirect utility function of the economy´s representative household is written as:

$$\begin{aligned} V &= V\left[p, w, Y + \Pi(p, w, z) - \tau, z\right] \\ &= \max_{x^d, L^s} \left\{ U(x^d, L^s, z) \quad s.t. \quad Y + \Pi + wL^s - \tau - CV - px^d = 0 \right\} \end{aligned} \tag{1}$$

p: price vector

w: factor prices vector

Y: exogenous income

Π: profit income

τ: lump-sum tax collected by the government

x^d: private goods vector

L^s: labor vector

z: public good

CV: compensating variation

Firms, owned by households, maximize profits (Π):

$$\Pi = pF(L, z, K) - wL - 1.K \,, \tag{2}$$

where the price of capital is equal to 1.

The government controls the variable z. The construction of a new road changes the magnitude of z, but the increase in z requires the use of real resources as production factors and other produced goods.

Totally differentiating the indirect utility function (1) and the profit function (2), the cost-benefit rule (3) is obtained. The reduction in total travel time and accidents in the case of the road, can be interpreted as a small change in z and evaluated according to (3).

$$dV / V_y = (x^s - x^d)dp + (L^s - L^d)dw + \left[(V_z / V_y)dz + pF_z dz - dC - dCV \right] = 0 \tag{3}$$

Even if the change in the level of infrastructure affects other markets, if prices adjust to reach a new equilibrium, the first two terms in (3) net out and so we can concentrate the effort in the primary market. With a project cost, calculated at initial prices, equal to dC, the term dCV measures the representative household's willingness to pay (net of project costs). Applying the Kaldor-Hicks potential compensation criteria, a dCV equal to zero corresponds to a net present value (NPV) equal to zero.

We can then calculate the NPV of a small infrastructure project from the terms within brackets in (3): the households' direct willingness to pay plus the direct impact on profits minus the project costs. Changes in profits or costs due to changes in prices are not accounted for in the evaluation if demand equals supply in the new equilibrium.

The first three terms in brackets in (3) account for the change in resources and willingness to pay due to the infrastructure investment. In (3) the access to the infrastructure is free. In the next section we discuss the effect of charging for the use of the infrastructure. In the case of large projects, the general equilibrium rule is a generalization of (3) as long as the project does not induce significant price changes.

3. Pricing and investment

The social appraisal of infrastructure projects requires addressing pricing explicitly. Investment and pricing cannot be separated out in cost-benefit analysis. The Dupuit's rule of charging zero for the use of an uncongested bridge is an *ex post* rule. In the *ex ante* evaluation, when the bridge is still a project, the total willingness to pay for capacity (assuming free access) has to be at least as high as construction costs (otherwise, the bridge should not be built) but to tell whether this is the case, we need to know the price. Price determines demand and therefore total willingness to pay for capacity. The price to be charged has to be known in advance to carry out the economic evaluation of the investment.

Moreover, when the Dupuit's bridge is congested a positive price is optimal to internalize the cost imposed on other users (Hotelling, 1938). In this case, the total willingness to pay for capacity could be lower than construction costs compared with the previous case given free access in both cases. The same happens when a budget constraint is binding or there is intermodal competition. The point is that pricing determines the volume of demand, which affects optimal capacity, costs and social surpluses.

This can be observed in expression (3) where the household's gross willingness to pay is composed of a direct effect on utility $(V_z/V_y)dz$, and the direct effect on profits *pF(z)dz*. When a price is introduced for the use of the infrastructure, the values of both terms usually change. Although a proportion of the price effect is a transfer that net outs in the first term of (3), unless demand is perfectly inelastic, there are changes in quantities as well as in social surplus (negative if price is above the marginal cost as is the case when all costs are fixed). Therefore, if demand elasticity is positive, in absolute terms, dCV cannot be estimated without previous knowledge of the price to be charged.

The optimal first best pricing rule is to charge the social marginal cost: zero in the uncongested Dupuit´s bridge and positive in other circumstances when costs vary with use, externalities or significant relationships exist with other markets. In the presence of budget constraints, following the optimal pricing rule also solves the problem when there are not indivisibilities in capacity provision and there is perfect information on demand, as short-run and long-run marginal costs coincide.

This set of assumptions does not represent the real world. The common context of infrastructure investment is a second best world with indivisibilities, imperfect information on costs and particularly on demand, relevant connections with other markets (e.g., intermodal competition) and the pervasive existence of budget constraints.

The first problem once we abandon the first best world is that short-run and long-run marginal costs are different and given the high proportion of fixed costs in the short run the economic consequences of applying short-run or long-run marginal costs pricing are significant.

Infrastructure pricing and investment in a first best world consists basically of maximizing total willingness to pay net of costs, including producer and user costs (mainly time in the case of transport infrastructure). Under the assumptions of absence of indivisibilities and separability of operating and capacity costs, the first best rules for pricing and investment are straightforward.

Let us consider the case of investing in road or airport capacity. In both areas the user cost is mainly time, and congestion is the immediate consequence of insufficient capacity.

The regulator charges an access price that includes the unit producer cost, the time costs imposed on others (delays as a consequence of congestion) due to the increase in the number of users (the user cost is already paid by the passenger and any environmental externalities are assumed to be internalized).

The investment rule is: increase capacity until the reduction in delay costs equals the additional producer cost of expanding capacity. The interrelation between pricing and investment is now evident. Pricing according to marginal social costs and expanding capacity according to the reduction of congestion costs allow the internalization of capacity costs and, under some quite demanding conditions, cost recovery (Mohring, 1976). The optimal price, changes the values of $(V_z/V_y)dz$ and $pF(z)dz$ but the final value of dCV is the highest possible given the application of first best marginal cost pricing.

The real world of infrastructure investment is characterized by indivisibilities and demand uncertainty. Moreover, the private sector is involved in the construction and operation of public infrastructure. The departure from short-run marginal cost pricing is therefore unavoidable. It could be possible to introduce second-best pricing that minimizes efficiency losses. The idea is to deviate from marginal cost fulfilling the budget constraint at a firm level (see Johansson and B. Kriström, 2012) or at an aggregate level (Nash and Samson, 2001). The practical difficulties of this proposal seem obvious when infrastructure such as airports, roads, ports and railways not only compete within a nation but also in a supranational dimension.

Charging short-run marginal costs when total willingness to pay is lower than capacity costs also has long-run consequences as demand will grow given the misleading price signal in terms of the incremental costs of capacity expansion. This is particularly worrying in the case of alternative technologies to solve the same common problem.

The issue of intermodal competition is also crucial for pricing and investment decisions. Marginal social cost pricing in the primary market is suboptimal in the presence of distortions in secondary markets and when there are significant links with the primary market but particularly when there are intermodal consequences as is the case, for example, with investing in high speed rail infrastructure that disregards the effects on air transport.

Public investments in dedicated high speed rail infrastructure that compete directly with air transport serves as an excellent case for the analysis of access pricing, investment and intermodal competition (de Rus and Socorro, 2014). Currently, some countries with a well-developed airport network are investing, or considering the possibility of investing, in high speed infrastructure for distances (500-600 km) in which both modes of transport compete and where the total volume of demand in the corridor seems insufficient to justify expensive additional infrastructure with comparative advantages in the case of massive demand but extremely inefficient with low traffic.

The generalized cost of transport includes the monetary price, time and service quality. When the government invests in high speed rail infrastructure, the former equilibrium usually changes with a significant variation in the modal split and the allocation of resources. When the determinant of the change in modal split is the price charged by the government for the high speed rail infrastructure, it is crucial to know the content of these charges. If the government is applying short-run marginal cost pricing it is fundamental to evaluate beforehand the options for medium distance intercity passengers before construction costs are sunk.

We show (de Rus and Socorro, 2014) that with airlines in competition and the government charging access prices for airports and rail infrastructure, a positive net present value is not a sufficient condition to invest in high speed rail. The necessary and sufficient condition implies a positive difference in social welfare for the cases in which the new infrastructure is and is not constructed and optimal pricing is applied. This is not a result derived from the presence of uncertainty and the irreversibility of the investment, but from the interaction of pricing and investment decisions and the need to consider alternative policies based on pricing and regulation.

The consequences of recognizing these interdependences for public investment are paramount. The institutional design of the ministry of transport and public works in many countries where the division of management units is usually based on technological characteristics (road, air or rail) may induce to lose the overall picture and to invest in costly infrastructure with an evident reduction in social welfare (see section 4).

4. The economic effects of large projects.

Once we abandon the assumption of perfect divisibility, we enter the world of incremental changes. Then, different sizes may be available and capacity design has to be considered. There are also different technologies available to solve a common transport problem. The evaluation of large projects is difficult when significant price changes are expected and the economic consequences of a particular project may seriously affect the allocation of resources in the long run.

In the case of a large project, we can still follow the insight of expression (3) as long as the first two terms in parenthesis vanish once the project is implemented. In expression (3) the evaluation is conducted following the changes in willingness to pay and changes in resources. An alternative and equivalent approach is to add surpluses as changes in prices which do not add value (mere transfers) net out in the process of aggregation.

Following Johansson (1993), the social willingness to pay can be expressed as the consumer surplus (through a compensated demand), and the change in profits and taxes:

$$V(p^1, w^1, Y^1 + \Pi^1 - \tau^1 - CV, z^1) = V(p^1, w^1, Y^0 + \Pi^0 - \tau^0 - CV^p, z^1) = V^0 \tag{4}$$

Where V^0 refers to the level of utility attained without the project and CV^p denotes the partial willingness to pay for the project as a user of the infrastructure, excluding any effects on lump-sum income, profits and taxes. Superscript 1 and 0 denotes with and without the project. The difference between CV and CV^p is the following:

$$CV = CV^p + \Delta Y + \Delta \Pi - \Delta \tau \, , \tag{5}$$

where ΔY, $\Delta \Pi$ and $\Delta \tau$ are the change in exogenous income, profits and taxes, with and without the project.

This is the standard approach of defining the effect of the project as the sum of the consumer compensating variation, producer surplus and taxpayer surplus. The problem with large projects with significant impacts in prices of secondary markets is the near impossibility for the individuals to give a sound answer to the questions involved in expression (5). This shows a serious weakness of cost-benefit analysis when there are significant price effects in the rest of the economy and the assumption of supply equaling demand through the adjustment of prices becomes untenable.

Even assuming either more or less invariance of prices in the rest of the economy or the possibility of measuring the effects of price changes through other methods, there is a quite disturbing problem associated with large projects, which in principle seems to be manageable through planning and evaluation. This is the existence of multiple equilibria in the long run and the possibility of ending up with a bad equilibrium when the evaluation concentrates on individual projects and loses the larger picture of the long-term intermodal effects. This is again a reminder of the inadequacy of dealing with a project in isolation, disregarding relevant interactions with other markets and the dynamic process during the lifespan of the project.

If the reader looks at the keyboard of the topmost row of letters of his computer it is highly probable that the first six letters spell out QWERTY. This is far from having an explanation on the efficiency of this arrangement of letters as opposed to an alternative layout. David (1985) shows that other arrangements, such as the DSK (the Dvorak Simplified Keyboard), were clearly superior and allowed to type faster. Nevertheless, the initial design, invented to address the problem of the type bars to clash and jam if struck in rapid succession, still remains as the standard in computers long after the old type writer and the tendency to jam disappeared.

The reasons why QWERTY became the dominant keyboard arrangement are: technical interrelatedness, economies of scale, and quasi-irreversibility of investment (Davis, 1985). The lessons to be drawn from the sequence of facts and changes and influences explaining the inefficient standard arrangement of the keyboard currently provide some hints for the explanation of what is going on at present with mutually exclusive infrastructure investment, which shows the three features already mentioned and the possibility of ending up with a practically irreversible and suboptimal system in the long term.

The economic planning of infrastructure and the evaluation of particular projects need to look to these insights. Some major transport infrastructure projects present these characteristics, and the decision concerning a particular project influences the future with a type of dynamic process in which initial investment favors the lock in of, perhaps, a less efficient technology than the next best alternative. This is the case of attending the medium distance intercity mobility in low-density countries with regional air transport or a high speed rail network (de Rus, 2011; 2012).

The long-run effects on the allocation of resources can be dramatic. The case of high speed rail versus air transport is illustrative in countries where both systems can be considered mutually exclusive. In countries with low population density, the usual base case is a network of airports with enough capacity to provide infrastructure for point-to-point medium distance trips. High speed rail infrastructure is a technology for high volume corridors; it is expensive and a high proportion of its costs are sunk. The irreversibility of investment is one of its main characteristics. Hence, unless it is carefully evaluated looking at the alternatives and the long-term consequences of the investment, it may well be that the initial decision of building high speed rail lines ends up with an undesirable equilibrium in which the wrong technology displaces a cheaper, more efficient, financially sustainable and reversible alternative.

5. Incentives and institutional design.

One crucial and mostly neglected issue in cost-benefit analysis is the explicit consideration of institutional design. The benevolent planner assumption is harmless when deriving the general equilibrium rules for the economic evaluation of projects but it turns out to be inadequate when we move from theory to the practical application of these rules.

When we apply a model to the real world "… it is reasonable to ask whether it is based on assumptions that are generally in accord with what we know about the world and are capturing factors that are of first-order importance. In other words, we use the background knowledge that we have about the world we live in (knowledge that is based ultimately on empirical evidence) to filter out models that are not useful for understanding what happens in the economy or for making policy decisions"(Pfleiderer, 2014).

Cost-benefit analysis is carried out by public agencies within a specific governance structure, which inevitably affects the incentives required to deliver a sound assessment of projects. The construction of white elephants almost everywhere and the extension and frequency of contract renegotiation of the concessions for the construction and operation of transport infrastructure, worldwide, show that something must be wrong with the institutional design where public agencies plan and evaluate infrastructure projects (Guasch and Straub, 2006; Flyvbjerg *et al*.,2003).

The investment in infrastructure with private participation requires several stages from the initial planning process to the end of the concession. These phases, including the economic evaluation, are usually realized within the same public authority without any clear separation of the different tasks involved. This favors the construction of white elephants given the particular objectives of politicians (e.g., to be reelected) and the role of investing in infrastructure projects to reach their objectives. The common governance structure reduces the incentive to conduct a rigorous cost-benefit analysis and reduces incentives to minimize costs in the construction and operation along the lifespan of projects.

Engel, Fisher and Galetovic (2014) provide a proposal to change the institutional design in which the provision of infrastructure with public private partnerships takes place. This proposal separates the project planning, design and delivery from the economic evaluation of projects in independent units. It also separates the unit awarding the contracts for the construction and operation of the project and the unit supervising the compliance with these contracts. Another unit addresses renegotiation and conflict resolution.

The creation of an independent agency conducting cost-benefit analysis sheltered from political interference could be an important step in the search of the best projects for society reducing the risk of costly inefficiencies associated with the present governance structure. The Public Investment System (SNI) in Chile is an interesting experience with the application of some of these principles. It is probably the most consolidated investment appraisal system in Latin

America. The SNI covers different infrastructure areas and it separates the agency promoting projects from the agency evaluating them (Gómez-Lobo, 2012).[2]

A related and highly relevant subject concerning institutional design is the presence of various levels of government. Projects are evaluated within a framework in which different governments are implied and where the objectives of the agents involved are not usually aligned. This is probably one of the main issues concerning the practical application of cost-benefit analysis at present. If the incentive of agent A is to get his project approved and financed by agent B, and a positive net present value is a requirement to get the project through, the incentives to overestimate benefits and underestimate costs are evident, as well as the loss of incentive to reduce costs and charge users to raise revenues. This separation between who promotes and who pays also affects decisions on infrastructure capacity and technology.

There are several reasons explaining why some supranational organization finance infrastructure projects or why national governments finance regional projects. Some of the alleged ones are to enable countries and regions to converge, to improve regional competitiveness and create jobs, and for international territorial cooperation. De Rus and Socorro (2010) have analyzed the consequences of the existence of two different levels of government regarding national infrastructure investment when a national project is financed by a supranational organization in a context of asymmetric information. This analysis is equally valid for a national government financing infrastructure projects in its regions.

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[2] Another interesting initiative is the Major Project Authority in the UK. Launched in 2011, "It is a collaboration between the Cabinet Office, HM Treasury and departments and has the fundamental aim of significantly improving the delivery success rate of major projects across central government" https://www.gov.uk/government/groups/major-projects-authority

The practical implications of this analysis are significant as it applies to the institutional design in the European Union where the Commission co-finances national and cross-frontier infrastructure projects of its member countries. It is also relevant for the common case of a national government financing regional projects in many countries with a structure of regional autonomous governments. The basic scheme has two stages. In the first, a supranational (national) planner selects and finances projects presented by a national (regional) government. In the second stage, the national (regional) government selects a type of contract for the construction, maintenance and operation of the infrastructure projects. The role of cost-benefit analysis in this framework changes substantially from a method to select projects with the objective of maximizing welfare to an administrative procedure to be overcome to obtain the public funds.

The supranational agency is interested in financing a large infrastructure project in some member country to comply with some strategic objectives. The member country is expected to construct and maintain the infrastructure, minimizing costs and raising revenues compatible with optimal pricing. With asymmetric information, the supranational agency has to design a contract that provides the incentives to the national government to minimize costs and raise revenues compatible with optimal pricing.

There are three types of funding mechanisms used in reality: total cost-plus, sunk cost-plus, and fixed-price financing mechanisms. With a total cost-plus contract a percentage of the difference between investments costs and the present value of profits is subsidized by the supranational agency. In the case of free access to the infrastructure (zero revenues), construction, maintenance and operating costs would be eligible. With a sunk cost-plus contract the percentage applies only to the difference between investments costs and the present values of net revenues (revenues minus maintenance and operating costs, and therefore, variables costs are not eligible). The sunk cost-plus contract is the basic mechanism of co-financing infrastructure investments in member countries by the European Commission in the European Union. The last type of contract is the fixed-price. With this contract the agency finances a fixed amount of the cost of the project.

When the economic evaluation of projects happens in this context of supranational (national) or national (regional) levels of government, asymmetric information and conflict of interests between the financing authority and the agent receiving the financial support, the social effectiveness of cost-benefit analysis strongly depends on the type of financing mechanism.

De Rus and Socorro (2010) show that a total cost-plus financing mechanism provides no incentives to minimize costs and charges for the use of the infrastructure. This type of contract leads to an excessive market quantity as well as an excessive use of public funds. As there is not incentive to charge for the use of the infrastructure, negative externalities such as congestion, noise or pollution can be another side effect of the contract. Despite the apparent inadequacy of this type of contract, it is not uncommon when national government finance with national budget infrastructure projects are presented by regions.

The opposite case is the fixed-price contract, a high-powered incentive scheme. The financing agency does not cover either insufficient revenues or cost overruns. With this contract optimal pricing is implemented. Finally, the sunk cost-plus contract produces intermediate results because, though optimal pricing is guaranteed, the incentives of the subsidized agent to minimize costs and choose the right technology are weak.

The sunk cost plus contract has been used to co-finance thousands of infrastructure investment projects in the European Union. It is called the "funding-gap" and it is plainly the difference between the present value of the investment costs and the net present value of revenues and variable costs during the life-span of the project. Thus, the funding-gap expresses the part of the investment costs which cannot be financed by the project itself and therefore need to be financed (European Commission 2006). The final amount of subsidy is the result of applying the co-funding rate, which could reach 80% of the financial net present value of the project. The higher the total amount to be co-financed, the higher the total investment costs are and the lower the net revenues are, so it is a type of sunk cost-plus financing mechanism that penalizes revenue generating projects and favor the introduction of the last and more expensive technology.

The incentives with this type of contract are straightforward: national governments have a weak incentive to minimize costs or charge a price different from marginal maintenance and operating costs. Thus, though there is no incentive in being efficient, in the absence of externalities the socially optimal price is implemented. With the funding-gap method only a percentage of the difference between investment costs and revenues (net of maintenance and operating costs) are financed. In this case, contrary to the simple sunk cost-plus financing mechanism, there are some incentives in being efficient. Nevertheless, as being efficient require effort, the cost of being inefficient for the county or region are always lower than in the case of a fixed-price financing mechanism.

Another problem with the funding-gap method is the existence of externalities, common in the case of energy and transport infrastructure projects. When there are externalities associated with the use of the new infrastructure, optimal pricing requires the price to be equal to social marginal costs. Nevertheless, with the funding-gap method national governments may have no incentives to charge a price higher than marginal operating costs. In particular, if the externality does not have a visible negative effect on the welfare of voters (or its negative effect is lower than the effect of pricing on consumer surplus) national governments have incentives to charge a price equal to marginal operating cost instead of a price equal to social marginal cost. This financing mechanism therefore has negative effects concerning the internalization of externalities.

It is not a surprise that there is a lack of interest of subsidized European member countries in a sound economic evaluation of projects. They have contemplated the requirement of the European Commission to present a cost-benefit analysis before co-financing is approved as an obstacle, a cumbersome administrative procedure to be overcome to obtain financial support for national projects. An ex-post evaluation of a sample of projects co-financed by the Cohesion Fund in the period 1993–2002 (ECORYS Transport, 2005) showed that national governments have been focusing primarily on timely commitment of the available funding, paying less attention to the technical contents and economic priority of projects.

6. Conclusions

Cost-benefit analysis is largely the quantification in monetary terms of the incremental changes, as derived from the implementation of a transport project, in individuals′ surplus with respect to a counterfactual. If the incentives are adequate, the evaluation will be conducted with the aim of examining whether society is expected to be better off with the project. There are several reasons why this may not be the case in the real world and unless the governance structure changes, we have enough evidence to suspect that the economic evaluation will not serve the public interest, playing the role of another administrative procedure to be overcome for the interest groups to obtain access to public funds. This is basically the case with the supranational co-financing of transport infrastructure projects and with the financing of projects of the regions from the budget of the central government when a type of cost-plus contract is used.

We believe that the institutional design is so important for the social significance of the economic evaluation of infrastructure projects that unless the promoters of projects are interested in a sound evaluation, cost-benefit analysis will play a minor role in the decision of what, when and where to construct the new infrastructure projects.

Once this problem is solved the practitioner has to deal explicitly with the issue of pricing. The relation between pricing and investment is paramount and nothing relevant can be obtained without the consideration of the relationship between pricing, demand and capacity, particularly when significant relationships exist between different transport infrastructures. The main conclusion in this area is the inadequacy of conducting cost-benefit analysis without and explicit consideration of pricing and its effects on social surplus, particularly when infrastructures characterized by intermodal competition or complementarities exist.

Finally, the long-term effects of projects should be considered in the planning and evaluation procedures. Some major infrastructure projects present technical interrelatedness, economies of scale, and quasi-irreversibility of investment. These features can lead to lock in a less efficient technology than the next best alternative, unless the evaluation of the initial investment explicitly take into consideration the dynamic process associated with this initial investment and its probable consequences in the long run. This is not an easy task but a short-run evaluation disregarding the long-run effects can lead to profound consequences in the allocation of resources.

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