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## Socioeconomic Evaluation and Ranking of Infrastructure Projects

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# Socioeconomic evaluation and ranking of infrastructure projects

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## **Abstract**

Over the last decades, the role of private and public sector concerning infrastructure projects was not disputed. Public authorities were generally in charge of financing and building new infrastructure. However, this assertion has recently changed providing more and more room to the private sector as public finance is in jeopardy. Rising pressure to reduce the public sector debt on the one hand and at the same time expand and improve public facilities on the other, has led governments and public authorities to look into private sector financing.

This paper deals with issues raised by this public-private partnership in irrigation water projects. Although several approaches have been employed to handle this matter a discrete optimization analysis can significantly contribute to this problem. The main aim of this paper is to contribute to the definition of the most efficient investment programme in irrigation water infrastructure. More specifically, it explores the optimal ranking of project implementation when these projects are partially self-financed by their own revenues. Results clearly demonstrate that the optimal ranking is not necessarily the ranking of decreasing socioeconomic internal rate of return.

**Keywords:** *Ranking; Water projects; Net Present Value; Internal Rate of Return; Infrastructure; Investments.*

## 1. Introduction

For most of the last century, the roles of private and public actors in the infrastructure sector were clear. For instance, public authorities were generally in charge of financing and building new infrastructures (Grimsey and Lewis, 2005). Nevertheless, an inflexion was observed during the 1990s with a significant development of public-private partnership (PPP). This is paradoxical since the most profitable lines were already service and the subsequent projects show a financial Internal Rate of Return (IRR) below the self-financing level. The paradox of the appearance (or reappearance) of the PPP in these circumstances has already been explained by Bonnafous (2002) who deals with the formalization of the need of subsidies.

This paper deals with the new issues raised by the PPP system or, more generally, by any system in which the new infrastructure is partially financed by its users. Is there, in this case, a new economic rationality of public authorities? Particularly, is there an optimal way to rank projects?

Before answering to these questions, we have to recall the logic of investment for both the private operator and the public sector in order to explore the financial logic of a PPP. From the classical point of view of microeconomics, it is assumed that a private operator implements a project if the expected IRR covers (Bodie and Merton, 2000): (a) the market interest rate, (b) plus a risk premium which takes account of the uncertainties that necessarily affect assessments of, for example, costs and future traffic and revenue (the risk premium may also include an additional amount to cover uncertainties about the stability of the country in question, and (c) plus a profit margin.

Thus, with a market interest rate of 4%, a risk premium of 4% and a profit margin of 4% too, the minimum targeted IRR will be 12%. If the IRR of the project is any lower than this the operator will require a subsidy in order to reach 12%.

The public authority is likewise using the IRR of the project, namely the discount rate which cancels out its Net Present Value (NPV). Nevertheless, the valuation of this NPV takes into account not only the future accounting of the operation but also those

of concurrent operators and, more generally earnings and losses of all the concerned agents, including external effects such as the users surplus, consequences on safety or environmental effects. For this socioeconomic assessment, we will use the notation  $IRR_{se}$  for the internal rate of return.

In the tradition of public evaluation, a project is considered to be implemented when its  $IRR_{se}$  is higher than a standard level. This border-line can be interpreted as a collective profitability condition: for any project having a lower  $IRR_{se}$  than this standard level it is assumed that the destroyed wealth would be higher than the created wealth. That means that the  $NPV_{se}$  of the project, evaluated with the standard level of interest rate, would be negative

In the case of infrastructures exclusively financed by public subsidies (excluding any user contribution), if we consider not only one project but a program of scheduled projects, the objective function is the  $NPV_{se}$  provided by the program. Thus, the question of the optimal ranking is solved by the decreasing order of the  $IRR_{se}$ 's and the rhythm of their implementation depends on the available budget. In the case of a PPP, and more generally when the projects are partially financed by the users, the objective function of the public authority still being the total  $NPV_{se}$  of the program, it is not obvious that the decreasing order of the  $IRR_{se}$ 's provides the optimal ranking.

In this case, this is typically the case of water infrastructures, the socioeconomic efficiency of each unit of subsidy result not only of the  $IRR_{se}$  of each project but also of its need of subsidy, which is itself depending of its financial IRR. Thus, we have to use the relationship between the need for subsidies and the level of the IRR (Bonnafous, 1999).

## **2. A fundamental relationship**

In order to formalize this relationship we shall consider a standard project for which an investment  $C$  will be made for a duration  $d$ , which is the number of years over which it has been assumed that expenditure will be evenly spread. The net profit made

by the operation of the project once it has come into service is denoted by  $a$ , and it has been assumed that this will increase by an annual amount  $b$ .

This corresponds to the stylized, but nevertheless quite familiar, account of costs and benefits. If it is assumed that the project comes into service at the date  $t=0$ , annual expenditure between the dates  $-d$  and  $0$  will be given by  $c=C/d$ . The profit made once the project comes into service is assumed to take the form  $(a+bt)$ .

The Internal Rate of Return (IRR) of the project, namely the discount rate which cancels out its Net Present Value (NPV), is therefore a function of the four parameters  $c$ ,  $d$ ,  $a$  and  $b$ . We must compare this IRR to the Rate of Return that an operator can reasonably expect.

In what follows we shall use the following notation:  $\alpha$  is the discount rate used to calculate the Net Present Value (NPV),  $\alpha_0$  is the discount rate which cancels out the NPV of the project, which is therefore its IRR,  $\delta$  is the amount by which the subsidy increases the IRR,  $\tau$  is the rate of subsidy, i.e. the percentage of  $c$  which is financed by subsidies.

For a discount rate  $\alpha$ , and the present value of cost and benefits from date  $-d$  to date  $T$ , the Net Present Value is given by the following expression (Bonnafeous and Jensen, 2005):

$$NPV = \int_{-d}^0 -ce^{-at} dt + \int_0^T (a+bt)e^{-at} dt \quad (1)$$

In order to simplify the calculations that follow, we shall assume that the present value calculation has been extended to infinity, which will have little effect on the results because of the small influence of the distant future (and the known convergence of these integral functions). Eq. (1) therefore becomes:

$$NcPV = \left[ \frac{c}{a} e^{-at} \right]_{-d}^0 + \left[ -\frac{a}{a} e^{-at} \right]_0^{+\infty} + \left[ -\frac{bt}{a} e^{-at} \right]_0^{+\infty} + \left[ -\frac{b}{a^2} e^{-at} \right]_0^{+\infty} \quad (2)$$

or alternatively:

$$NPV = \frac{1}{a} \left[ c(1 - e^{-ad}) + a + \frac{b}{a} \right] \quad (3)$$

The IRR of the project,  $\alpha_0$  is therefore given by (Bonnafous and Jensen, 2005):

$$c(1 - e^{-\alpha_0 d}) + a + \frac{b}{\alpha_0} = 0 \quad (4)$$

A rate of subsidy  $\tau$  lowers the annual cost of construction  $c$  to  $c(1-\tau)$  and raises the IRR  $\alpha_0$  to  $(\alpha_0+\delta)$  such that Eq. (4) becomes (4'):

$$(1-t)c(1 - e^{-(\alpha_0+\delta)d}) + a + \frac{b}{\alpha_0 + \delta} = 0 \quad (4')$$

which allows us to express the required rate of subsidy:

$$t = 1 - \frac{a(\alpha_0 + \delta) + b}{c(\alpha_0 + \delta)(e^{(\alpha_0+\delta)d} - 1)} \quad (5)$$

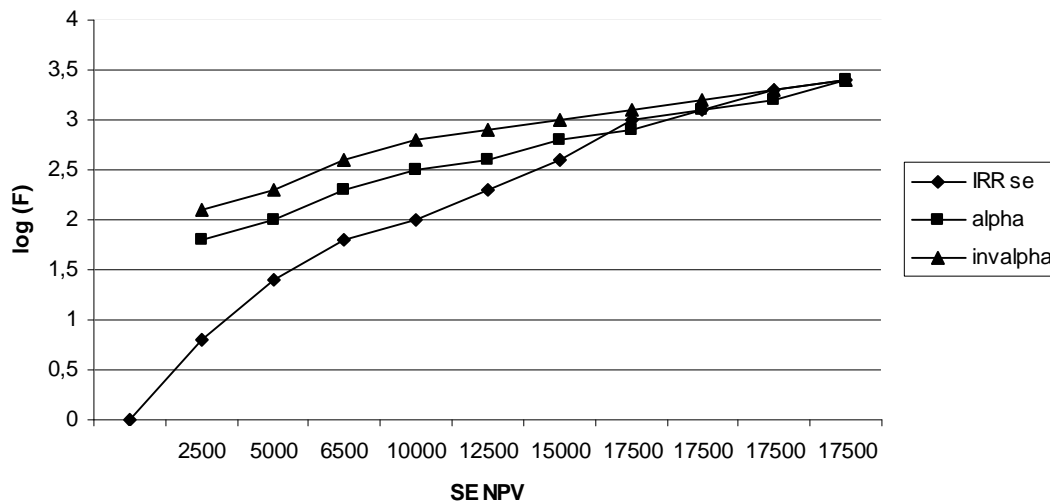
What is of prime importance to us in this function is clearly the relationship between  $t$  and  $\delta$ . However, Eq. (5) also shows that this relationship obviously depends on the values of the parameters  $c$ ,  $d$ ,  $a$ ,  $b$  and, of course,  $\alpha_0$ , which characterize the economics of the project and which are moreover linked together by Eq. (4) which established the IRR of the project  $\alpha_0$ . If we wish to represent Eq. (5) we, therefore, need to keep some of these five parameters constant and vary just those whose role we wish to demonstrate. This is the well-known nomogram technique (Bonnafous and Jensen, 2005).

### 3. Optimal order for a set of PPP projects

To confirm this point, we will take a set of eleven water infrastructure projects for which homogeneous economical data can be obtained. Subsidizing rates have been calculated from Eqs. (4) and (5), taking 8% as the target IRR. We assume that there exists a budget constraint the first year ( $F$ , in MEuros), this constraint increasing by

2.5% yearly. To make clear the role of the budget constraint, we have changed its value between 1 and 1,000 MEuros. For a given order of the projects, the value of  $F$  determines the rhythm of completion of projects, since each project needs to draw on this budget an amount  $\tau \cdot c$  of public subsidies each year.

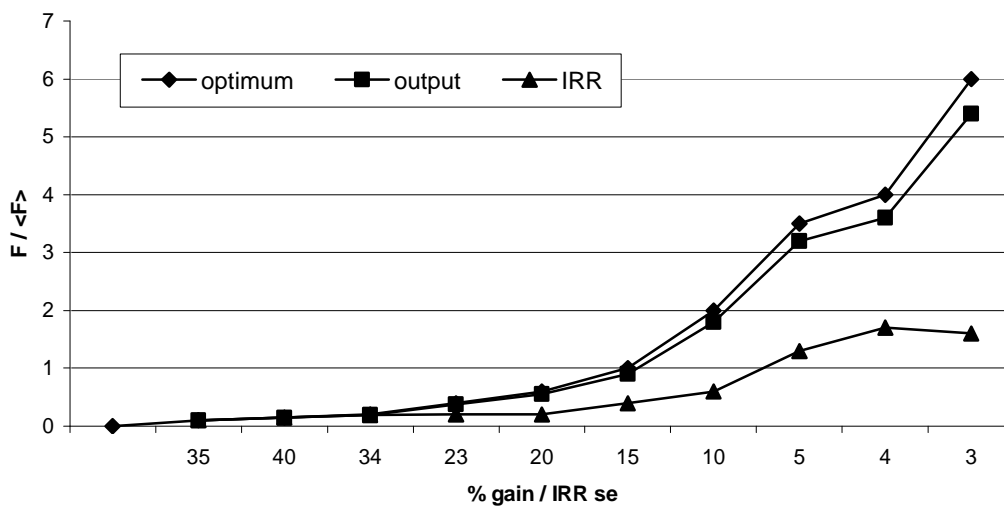
We first examine the interest of using the IRRse as a ranking criterion. For this, we calculate the NPVse returned by three different programs obtained by ranking the projects by alphabetical or inverse alphabetical order (simulating a random combination of the projects) or by decreasing IRRse. Fig. 1 shows that the IRRse is clearly more efficient as a ranking criterion than randomness, which is not surprising.



**Figure 1.** Comparison of the NPVse returned by ‘random’ (alphabetical or inverse alphabetical) ranking of projects or by ranking with IRRse.

However, our previous discussion suggests that the IRRse is probably not the best ranking criterion, mainly if budget constraints are important. Therefore, we can calculate the NPVse outputs obtained by ranking the projects with two other criteria: the financial IRR and the *output*, defined as  $O(i)=NPVse(i)/sub(i)$ , where  $sub(i)$  represents the amount of public subsidies required by this project to obtain the targeted IRR (8%, as assumed above). In Fig. 2, we compare the total NPVse returned by the projects for different rankings, as a function of the mean subsidy required by all the projects ( $\langle F \rangle = 305$ ). More precisely, we plot the % of gain obtained by

choosing the specified ranking criterion compared to the total NPVse returned by using the IRRse as the ranking criterion. Note that the curve labelled ‘Optimum’ (triangles) will be discussed below. The results presented in Fig. 2 confirm our intuition: the pure financial IRR is a better ranking criterion than the IRRse, and this is the truer the tighter the budget constraint. When this constraint is lower than some value (close to one third of the average subsidy needed for a project), the NPVse output of the program obtained with the IRRse ranking is frankly disastrous when compared with the pure financial IRR order.



**Figure 2.** Comparison of the total NPVse returned by the 11 water infrastructure projects for different rankings (we plot the % increase of the program NVPse compared to that obtained by the IRRse ranking).

Fig. 2 also shows that our ‘output’ criterion is even better than the IRR, for all the values of the public budget constraint. The point now is: can we find a better criterion? Can we be sure to have found the best possible ranking? The problem is that, since a program is a *discrete* combination of all the single projects, we cannot use the standard analytical optimization techniques such as *Lagrangian* multipliers or functional derivatives to find rigorously the best criterion. Therefore, we are left with exploring the different combinations of projects to find the one that yields the highest NPVse. However, the number of possible orders (11!) forbids an exhaustive



examination of all the possibilities. Fortunately, several tools to explore efficiently the 'landscape' of different combinations have been developed by several disciplines.

#### **4. Conclusion**

Let us summarize here our two main results, which may seem paradoxical but are a direct consequence of the present financial constraints: (a) When financial constraints are tight, the social return of a program of investments is higher when projects are ranked according to their pure financial characteristics (such as financial IRR), instead of their pure socioeconomic characteristics, and (b) we have also confirmed the *hybrid* optimum ranking criterion (Bonnafous and Jensen, 2005): the 'output', defined as the ratio of the socioeconomic NPV to the amount of subsidy it needs. In the case of infrastructure financed exclusively by public subsidies, the public objective function has traditionally been the NPV<sub>se</sub> provided by the program of scheduled projects, the question of their optimal ranking being solved by the decreasing order of their IRR<sub>se</sub>'s and the rhythm of their implementation depending on the available budget. We have shown that in the case of a PPP, and more generally when the projects are partially financed by the users, the objective function of the public authority still being the total NPV<sub>se</sub> of the program, the decreasing order of the IRR<sub>se</sub>'s does not provide the optimal ranking: the pure financial IRR is a better ranking criterion, and this is the truer the tighter the budget constraint. The ratio of the socioeconomic NPV to the amount of subsidy required is a still better criterion - in fact, the best. We can conclude, therefore, that both the tyranny of financial profitability and the error of ranking by the IRR<sub>se</sub> become issues as soon as the user becomes involved in the financing of water infrastructure.

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