Private v. Public Financing of Infrastructure

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Introduction

The question of whether an infrastructure investment should be undertaken or not has usually been discussed independently of who undertakes it and finances it. Yet, it can be shown that the institutional and financial context and constraints have a direct bearing upon the economic desirability of the project, and also on public budgets. Whether it is constructed and operated by the public sector, or contracted out to private enterprises, or jointly constructed and financed by both actors, might make the project more or less valuable. Whether it is paid and financed by users or by taxpayers also has a direct impact on the socio-economic viability of the project.

This note is a modest contribution to this debate. It focuses on the example of a bridge, or a road[1], and it uses a simple simulation model to provide tentative orders of magnitudes of some of the trade-offs involved.

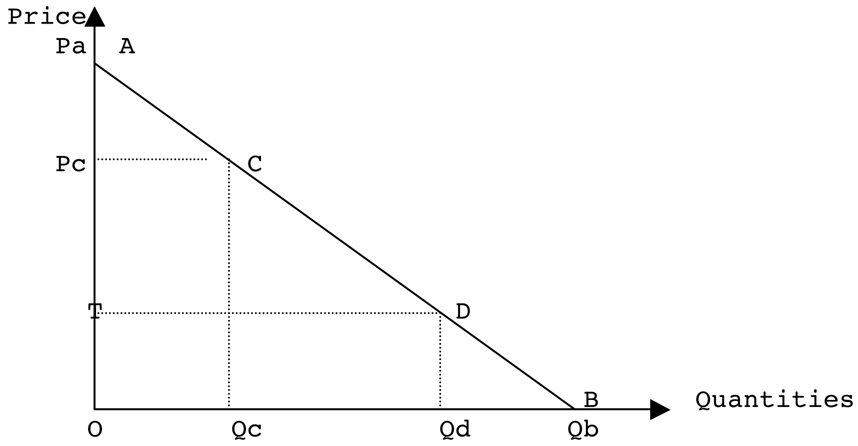
Let us consider a river at a particular point Π. There is a demand for the crossing of this river at Π, which is represented in Figure 1. The quantity Q of vehicles (or of people or of goods) is a function of the price P of the crossing : Q=f(P). This demand AB is assumed to be linear :

$$Q(P) = Qb - (Qb/Pa)*P$$

Presently, because there is no bridge in Π, Pc, the price of the crossing (or more precisely of going from one side of the river to the other), which implies a long detour, is high, and traffic Qc is modest.

[1] Transport infrastructure represent a large, and in many countries dominant, form of infrastructure.

Figure 1 – Demand for River Crossing



The construction of a bridge in Π is envisaged. It can be done and operated by a government, or by an enterprise. It can be financed by taxes, or by a toll, or by a combination of both. It can be done now, or later. The paper estimates the economic IRR (internal rates of return) and DNV (Discounted Net Values) associated with various institutional and financing options for this infrastructure investment. Six cases or options are considered. The paper then estimates the impact of these options on government expenditures and revenues.

Two Polar Cases

Let us begin by comparing the two polar cases of a « fully public » bridge, ie. government operated, tax financed, and toll-free with a « fully private » bridge, ie. enterprise-operated and toll financed.

The public bridge will bring us to B. It will generate a yearly surplus equal to OPcB, which is to be compared with Ig, the public investment cost of the bridge. This can be done by finding out the value of r, the socio-economic IRR (internal rate of return) that equates the two magnitudes :

$$\Sigma_t OPcCB_t * 1/(1+r)^t = Ig$$

The socio-economic IRR r must be sufficiently high to justify the investment. Sufficiently high means higher than r°, with r° in the 10-15% range. This is a *social profitability constraint* without which no government should undertake the investment.

The private bridge will bring us to D, with a toll T and a traffic level Qd. The yearly toll proceeds OTDQd is to be compared with Ie the private investment cost of the bridge :

$$\Sigma_t OTDQd_t * 1/(1+i)^t = Ie$$

The private internal rate of return i must be higher than i°, the prevailing interest rate, the one at which the enterprise can obtain long-term credit, which is probably in the 5-10% range. This is a *financial profitability constraint*, without which no private enterprise will undertake the investment.

To compare the relative merits of the two options, and more precisely the merit of the private option relative to the public one, three magnitudes must be taken into consideration :

First, the toll associated with the private option implies a welfare loss ΔW1. If the facility is not congested, imposing a toll reduces traffic, and utility, without decreasing costs, and implies therefore a welfare loss, which is equal, every year, to QdDB.

Second, the private investment cost Ie is likely to be lower than Ig, the public one, which implies a welfare gain of ΔW2. Public operations are usually longer, less flexible, and generally more expensive than similar private operations, by a margin α.

One can think of at least four reasons for this greater efficiency of the private sector[1]. First, the incentive system prevailing in the private sector is more effective than the one that prevails in the public sector; for respectable reasons, the people who deliver are better rewarded (and those who do not more punished) in the private sector. Second, and also for respectable reasons, procurement, accounting and disbursement procedures are more complicated and formal in the public sector; doing things according to the rules is more important that doing them swiftly and efficiently. Third, and somewhat paradoxically, the private often benefits more from economies of scale than the public; this is because the public may consists of relatively small local or regional governments, whereas the private often consists of large companies operating in the entire country or even the entire world. Fourth, technical knowledge and innovation, the mother of productivity, is by now more in the private sector than in the public one. These reasons are unfortunately likely to have even more force in developing than in developed countries.

The value of α varies greatly from case to case and country to country, but a distribution of αs seems to be centered around 20%. We therefore have :

$$\Delta W2 = Ig - Ie = \alpha * Ie$$

Third, tax financing is generally (more or less) distortive, and modifies the incentive system in a way that

[1] The dichotomy public-private oversimplifies the issue : in reality, there are also public enterprises, less flexible and responsive that a private enterprise, but more so than a government ministry.

decreases output or at least welfare[1]. (The fact that public outlays, in bridge construction, for instance, usually increase output, is irrelevant here). This deadweight loss, or opportunity cost of tax income, equal to λ*tax proceeds, varies with the tax/GDP ratio and the structure of the tax system. The value of λ is not well known, but might be as high as 20%. The private option therefore implies a welfare gain $\Delta W3$:

$$DW3 = \lambda * Ig = \lambda * (1+\alpha) * Ie$$

The public option will therefore be preferable when :

$$\Delta W1 > \Delta W2 + \Delta W3$$

$$\Sigma_t QdDB_t * 1/(1+r)^t > (\alpha+\lambda+\alpha*\lambda) * Ie$$

This formula implies the use of a social rate of discount r, which in practice is not easy to define. An alternative way to express the same idea without having to postulate a particular social rate of discount is to compare the socio-economic internal rates of return associated with the two options, ie IRRg, the socio-economic IRR of the public option and IRRe, the socio-economic IRR of the private option[2].

$$IRRg = \text{value of } r \text{ in } \Sigma_t OPcCB_t * 1/(1+r)^t = Ig = (1+\alpha) * (1+\lambda) * Ie$$

$$IRRe = \text{value of } r \text{ in } \Sigma_t (OpcCB - QdDB)_t * 1/(1+r)^t = Ie$$

The public option will be preferable when :

$$IRRg > IRRe$$

Is this likely to be the case ? The answer depends upon the values of a number of parameters : the shape of the demand curve, the pre-bridge situation (the value of Pc), the values of α and of λ, the investment cost, the value of T (which is itself bounded by the values chosen for the financial profitability constraint). A simulation with various sets of realistic values might give some flesh to this skeleton, and produce interesting orders of magnitude of the importance of the various components discussed.

Let us suppose that the demand curve is : $Q=3-0.2*P$, and that the present situation is defined as C(1,10), with a present cost of 10 and a quantity of 1. This defines a price-elasticity of demand that varies along the demand curve, but which is about -0.5 when P=10 and –0.33 when P=5, numbers which are quite reasonable. Let us further assume that Ie, the private cost of

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[1] There is one exception : lump sum taxation ; but this is a textbook curiosity, and there are no tax systems consisting only of lump sum taxes.

[2] The latter should not be confused with the *financial* internal rate of return of the private option.

the investment is 100, and also that α, the public sur-cost is 20%, and that λ, the opportunity cost of taxation is also 20%.

The pure public option, a non tolled bridge, will lead us to B(3,0), with a traffic of 3, three times the initial traffic. The yearly surplus OPcCB created by the bridge will be 20. For the sake of simplicity, we assume that this surplus remains constant over time. The investment cost will be 144. This produces a socio-economic IRR of 12.6%, which would justify the bridge. We can also calculate the discounted net value (DNV) of the flow of economic costs and benefits. With a discount rate of 6%, it is equal to 81, which also makes the construction of the bridge worthwhile from a socio-economic viewpoint.

Let us turn to the private option. A plausible value of T, the unit toll, is 5. It will lead to D(5,2), a situation in which traffic will be 2, twice as much as before. We must check that this toll and this traffic are consistent with the financial profitability constraint: they are, because they produce a financial IRR of about 8%. In such a case, the annual welfare loss caused by the toll is 2.5, and the annual surplus (relative to the initial situation) is 17.5. This produces a socio-economic IRR of 16.7%, which makes the private option more desirable than the public option. The DNV, always with a social rate of discount of 6%, is 95, also higher than in the pure public option[1].

What is the value of Ig that would equalize the two options ? It is 111. In other words, if Ig<111, the public option becomes preferable. Since $Ig=(1+\alpha)*(1+\lambda)*Ie$, this would happen when $\alpha+\lambda+\alpha*\lambda<11\%$. Figure 2 represents the combination of α and λ that meet this constraint. It shows, for instance, that a 6% investment sur-cost combined with a 6% opportunity cost of tax income would —all other things equal— justify the pure public option.

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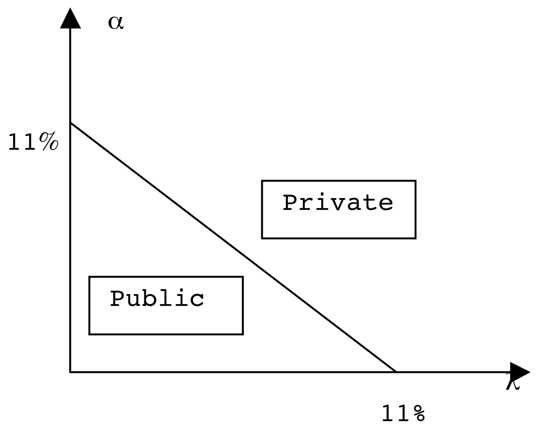
[1] We may note that the toll level selected, 5, is not the one that maximizes toll proceeds. This profit maximizing toll [the one that equals to zero the derivative of P*Q(P)] is actually 7.5. It produces a *financial* IRR of 9.4%. But it also decreases the annual utility of the bridge, and yields an *economic* IRR of only 13.2%, and a DNV of 32. This means that the decision about the toll level should not be left to the private sector.

Figure 2 – Private v. Public Option as a Function of α and λ



If the facility considered is congested, the toll-free solution is no longer optimal, and some form of toll is (at least in principle) welfare improving. The toll included in the pure private solution is motivated by a financing purpose, but it will also serve a congestion reducing purpose. As a result, the socio-economic attractiveness of the private option will be increased. The dividing line of Figure 2 will be shifted downward.

These calculations have been done with an assumed constant demand curve. In reality, the demand curve will in most cases shift upward over the course of time. The yearly flow of financial and social benefits will increase. Taking this into account would increase all the IRR and the DNV; however, in most (not in all) cases, it would not change the ranking.

Non-Polar Cases

The public cum toll option - The public option discussed above assumed free delivery. It need not be so. There can be public tolls. Indeed, this is what happens for many public goods and services, such as water, power, cable, etc. for which a fee is charged. How does it modify the preceding analysis? First, the public toll, just like the private toll, reduces demand, utility, and welfare, and does so by ΔW1. The advantage of the public option resulting from a greater use of the facility therefore disappears. Second, on the other hand, the proceeds from the toll will limit or eliminate the need to use tax income, and save the deadweight loss associated with it, that is ΔW3. This suggests that the comparison between the pure private option and the tolled public option boils down to the difference in the investment costs, that is $\Delta W2=\alpha*Ie$. If this were the case, the private option would always be more attractive than the public one, since α is assumed to be always positive.

In reality, the matter is slightly more complicated, because government borrows at a rate lower than the rate at which a private enterprise does. Government can therefore afford a toll lower than the private enterprise, and do not curtail traffic —and welfare— as much as the private enterprise does. In terms of Figure 1, a toll T' (with T'<T) would lead to a point D' (to the right of D) associated with traffic Qd' (with Qd'>Qd), and a welfare loss Qd'D'B smaller than QdDB.

The comparison of the two options would therefore entail a comparison of the difference in investment cost with the difference in welfare losses. The public option would be preferable if:

$$QdDD'Qd' > \alpha * Ie$$

The model outlined above was used with a toll level of 4, lower than the toll level of 5 required for the private option. This is consistent with a 4% financial international rate of return for the government entity, which implies that the public sector can borrow at a rate half as high as the private enterprise (4% instead of 8). The results of the simulation appear in Table 1.

Table 1 – A Simulated Comparison of Various Options

	Public (free)	Private	Public (tolled)	Shadow toll	Private +subsidy
α (Investment surcost)	0.2	-	0.2	-	-
λ (Tax deadweight loss)	0.2	-	-	-	0.2
I (Investment cost)	144	100	120	100	100
T (toll level)	-	5	4	3.3	5
Q (traffic)	3	2	2.2	3	2
T*Q (toll proceeds)	-	10	8.8	10	10
Subsidy	-	-	-	-	30
Financial IRR	-	7.8%	4.0%	7.8%	13.1
Utility (surplus)	20	17.5	18	20	17.5
Tax income cost	-	-	-	2[a]	6[b]
Economic IRR	12.6%	16.7%	13.9%	19.4%	15.6%
Discounted net value[c]	81	95	82	122	89

Notes: [a]Per year; [b]In year 1 only; [c]with a 6% social rate of return.

The introduction of a toll in the public option does improve the socio-economic IRR, and, to a lesser extent the DNV. The deadweight loss associated with tax financing is eliminated, and happens to be greater than the welfare loss caused by the toll. But the private option continues to exhibit higher economic IRR and DNV (in spite of the lower financial rate needed by government borrowing).

The shadow toll option – Another option worth exploring is the shadow toll, a system in which a private enterprise builds and operates the facility, and is paid back by the government over the course of time pro-rata traffic. It is like a toll bridge from the view point of the enterprise, but the toll is actually paid by the government, not the bridge users.

Relative to the pure private option, it has the socio-economic advantage of eliminating the toll-related welfare loss (the surplus becomes OPcCB, just as in the pure public option case) and the financial advantage of increasing the toll proceeds (which become T*Qb). The latter means that, in a shadow toll system, the private enterprise will be content with a lower toll level (than the one it needs to meet the financial profitability constraint).

Relative to the pure public option, the shadow toll financing system has also several advantages. It reduces the investment cost (from Ig to Ie). It also reduces the opportunity cost of tax financing, since the government payments will be delayed over a long period of time rather than paid up-front.

The simulation model shows that —with the parameters utilized above— a shadow toll of 3.33 is sufficient to ensure the financial profitability from the view point of the enterprise. Because this toll is not paid by users it has no impact upon the quantity of users, which is 3. The yearly shadow toll proceeds are therefore 10, just as in the pure private option case. Every year, the government will have to pay 10 to the enterprise, out of taxes. This implies an opportunity cost of tax income of λ*10, or 2, per year, which is a true economic cost. The comparison of economic costs and benefits yields an economic IRR of 19.4%, and a DNV[1] of 122.07, both significantly higher than either the pure private option or the pure public option.

The subsidized private option – In certain cases, the private option is not really opened because the toll that can be charged will never be high enough to meet the financial profitability constraint. Even the profit maximizing toll will not do the job. In such a case, one might still consider a private option, but accompany it with a subsidy high enough to meet the financial profitability constraint. The economic benefits associated with the private construction and operation of the bridge will be retained. The economic costs associated with tax-financed expenditures will be reduced, because the subsidy will not cover the full investment cost. The economic costs associated with excluding part of the users will unfortunately remain.

The simulation exercise begins as in the pure private case. But the financial profitability constraint is raised. It is considered that the 7.8% financial IRR obtained is not sufficient, and that a rate higher than 13% is required. This can be obtained with an investment subsidy of 30%, that is of 30. It can be verified that this subsidy raises the financial IRR from 7.8% to 13.1%.

What does it mean in socio-economic terms? The investment cost, and the yearly surplus, are as in the pure private option case. The difference is that there is now an additional cost, the opportunity cost of the tax financed subsidy, λ*subsidy, or 6. This yields a socio-economic IRR of 15.6%. This rate is lower than the rate obtained in the pure private option case (16.7%),

[1] Always with a 6% social rate of discount.

but it is interesting to note that it is nevertheless higher than the rate for the pure public option case (12.6%). Alternatively, one can say it produces a DNV (at 6%) of 89.4, also lower than the DNV of the pure private option and higher than the DNV of the pure public option.

A Purely Budgetary Approach

So far, we have examined the problem in purely economic terms. In practice, the problem has also a budgetary dimension, which is often a dominant one. Ministries of Finance (even when they are not separate from Ministries of the Economy) try, all other things equal —and, at times, even when they are not equal— to minimize budgetary expenditures. This means spending less, and spending as late as possible. An infrastructure investment, however, when it is successful and produces utility, also produces additional taxes and public revenues. Additional utility is not exactly additional economic output, but it is akin to it, and a large fraction of it. As a first approximation, we can say that, every year, additional tax output ΔR is a fraction γ of additional utility or welfare ΔW:

$$\Delta R = \gamma * \Delta W$$

The value of γ varies with the type of infrastructure investment, and with the nature of the tax system. It also varies with the level of government considered. It is much higher for a central government than for a local government, because local government tax rates are much lower than national ones, and also because welfare benefits usually leak out of the area where the investment is made. Let us assume that γ = 20%. This would be commensurate with a 30% tax to GDP ratio and a two third ratio of GDP to welfare.

We utilized this value to figure out, in each of the financing options discussed, the flow of government revenue generated by the infrastructure investment considered, and compared it with the associated government expenditure. This is done by calculating the DNV (Discounted Net Value) with a 6% discount rate. This rate need not be identical to the rate of discount utilized above for the economic DNV, but 6% seems a reasonable figure to express the governmental preference for the present. In conformity with a Ministry of Finance approach, the investment expenditure is negative, the additional revenues are positive, and therefore the higher the DNV, the better. The results appear in Table 2 below.

From a budgetary viewpoint, the best options are the shadow toll option and the pure private option: they contribute much more (in discounted terms) to the public coffers than they draw from them. At the other end, the pure public options, including the delayed variety, are the least attractive solutions, always from a narrow public finance perspective. The do-nothing, the tolled public and the private with subsidy options are somewhere in the middle.

Table 2 – Ranking the Economic Efficiency, and Showing the Budgetary Implications, of Various Institutional-Financial Options for Infrastructure

Rank	Option	Economic IRR	Economic DNV[a]	Budgetary DNV[a]
1	Shadow toll	19.4%	122	46
2	Pure private	16.7%	95	40
3	Private + subsidy[b]	15.6%	89	10
4	Public + toll	13.9%	82	21
5	Pure public	12.6%	81	-70
6	Pure public delayed[c]	12.6%	67	-62
7	Do nothing	-	0	0

Sources and notes: calculated as indicated in Table 1; [a]both discounted net values are calculated with a 6% social rate of discount (but the rates could well be different) ; [b]with a subsidy equal to 30% of the investment cost ; [c]delayed by 3 years/

Conclusion

This note has focused on the various *economic* benefits and costs attached to different financing and institutional options. They vary because financing and institutional options impact upon behaviors. In the infrastructure case considered, a non-congested bridge, the benefit component consists mostly of time savings, and is a function of usage, which is itself a function of the potential toll. The main cost components are (i) construction costs (a proxy for construction and operation costs), assumed to be higher by α when construction is public rather than private, on the one hand, and (ii) the opportunity cost of tax resources λ, which is assumed to be positive.

The outcomes for the various financing options considered vary with the value of α and λ, the shape of the demand curve for infrastructure usage, the pre-investment situation. With arbitrary, but plausible values of the parameters (α=0.2, λ=0.2, a price elasticity of demand of 0.3-0.5), we examined seven financing and institutional options (including the do-nothing option). They can be ranked in terms of *economic* IRR or of DNV (discounted net values, for the calculation of which a social rate of discount –here 6%– must be postulated). As shown in Table 2, it turns out that (with the parameter values chosen) both indicators provide the same ranking.

We also estimated the budgetary impacts of each of these options by comparing the associated Treasury expenditures and revenues. Treasury revenues were assumed to be equal to λ*socio-economic benefits of the infrastructure usage. A plausible value of this parameter (λ=0.2) and of the budgetary rate of discout (6%) were assumed. Obviously, here also different values of the parameters would produce somewhat different outcomes, but they would not change much the "budgetary ranking" of the various options.

Let us repeat that other values of the parameters would produce different numbers and in certain cases different rankings. Nevertheless, the numbers shown in Table 2 are not unreasonable, and the rankings obtained deserve attention. They suggest several conclusions.

First, it appears that the three rankings are quite similar. The two economic rankings are practically identical[1]. The budgetary ranking is more erratic and dichotomic, but it tells a story which is not basically different from the economic one.

This story is that the pure public option does not fare well. It can be improved by the introduction of a toll: what is lost in terms of consumer' surplus is more than compensated by what is gained through a reduction in the tax-associated damage; and in addition, the toll is attractive from a budgetary viewpoint. Delaying the pure public option by a few years is worst in economic (DNV) terms, and not much better in budgetary terms.

The pure private option appears –in the example studied– to be substantially superior in economic terms, and also in budgetary terms. Even the combination of a private provision and a subsidy is *in socio-economic terms*, more attractive than the pure public option, although it does not fare very well in budgetary terms (it fares better than the pure public option, though, but not as well as the tolled public option). Strikingly, all options are easily dominated by the shadow toll system, both in socio-economic and in budgetary terms.

Finally, it appears that, in budgetary terms, the do-nothing option is more attractive than the pure public option. This provides a justification for doing nothing. But it is a bad justification. Doing nothing is (in the example studied) the worst option in socio-economic terms; and even in budgetary terms it is worst than the private options.

[1] The exception is that the change from the pure public to pure public delayed options deteriorates the DNV but does not change the IRR.

COMPARING VARIOUS FINANCING OPTIONS

Year	0	1	2	3	4	5	
Pure public option							
Cost	-144						
Benefits		20	20	20	20	20	
Costs+benef	-144	20	20	20	20	20	
IRR	12,59%						
DNV	80,56						
Pure private option							
Cost	-100						
Toll (proceeds)		10	10	10	10	10	
IRR (Financial)	7,75%						
Benefits		17,5	17,5	17,5	17,5	17,5	1
Cost+benef	-100	17,5	17,5	17,5	17,5	17,5	1
IRR (eco)	16,7%						
DVN	95,02						
Tolled public option							
Cost	-120						
Toll (proceeds)		8,8	8,8	8,8	8,8	8,8	
IRR (Financial)	3,96%						
Benefits		18	18	18	18	18	
Cost+benef	-120	18	18	18	18	18	
IRR (eco)	13,89%						
DNV	81,56						
Shadow toll option							
Cost	-100						
Toll (proceeds)		10	10	10	10	10	
IRR (Financial)	7,75%						
Tax cost		-2	-2	-2	-2	-2	
Benefits		20	20	20	20	20	
Costs +benef	-100	20	20	20	20	20	
IRR (eco)	19,43%						
DNV	122,07						
Private+subsidy option							
Cost	-100						
Toll (proceeds)		10	10	10	10	10	
Subsidy	30						
Income+exp	-70	10	10	10	10	10	
IRR (Financial)	13,06%						
Benefits		17,5	17,5	17,5	17,5	17,5	1
Tax costs	-6						
Costs+benef	-106	17,5	17,5	17,5	17,5	17,5	1
IRR (Economic)	15,60%						
DNV	89,36						
Pure Public Option Delayed							
Cost				-144			
Benefits					20	20	
Costs+Benefots	-0,1	-0,1	-0,1	-144	20	20	
IRR (éco)	12,55%						

DNV	67,38