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A Comparison of Construction Contract Prices for Traditionally Procured Roads and Public–Private Partnerships

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Abstract Theoretical literature suggests higher asset construction costs in a public-private partnership (PPP) than in traditional public procurement, due to the bundling of construction and operation and the transfer of construction risk, among other factors. Data on *ex ante* road construction prices in Europe suggest a PPP road to be 24% more expensive than a traditionally procured road, *ceteris paribus*. This estimate resembles reported *ex post* cost overruns in traditionally procured roads. Thus, the public sector seems to pay a premium on *ex ante* PPP construction contract prices mostly to cover construction risk transfer. Other reported sources of higher PPP road construction costs, including bundling, seem on average of lesser importance.

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1 Introduction

Involving the private sector in the financing and delivery of public infrastructure services is by no means a new phenomenon, but it has expanded phenomenally in the past decade or two in Europe, following the pioneering private finance initiative (PFI) in the UK. As estimated by Blanc-Brude et al. (2007), more than one thousand public-private partnership (PPP) contracts have been signed in the EU over the past 15 years, representing a capital value of almost 200 billion euro. Fixed capital formation through PPP projects has become big enough to have macroeconomic and systemic significance in a number of countries, including Portugal and Spain in addition to the UK.

The key economic rationale for procuring a project as a PPP instead of traditional public procurement is the higher productive efficiency that can be achieved through the involvement of a private sector partner throughout the lifecycle of the project. The improvement in productive efficiency can, however, come at the cost of service quality—i.e., allocative efficiency. This trade-off between productive and allocative efficiency in PPP-type contracting has been studied in the framework of the literature on incomplete contracts (Williamson 1979; Grossman and Hart 1986; Hart and Moore 1990; Hart 1995). Hart et al. (1997), as well as Hart (2003), show that it is possible to draw some clear-cut conclusions about the conditions under which PPP-type contracting dominates traditional public procurement, and vice versa.

As regards productive efficiency in the delivery of infrastructure assets and services, the literature cited above has identified three channels through which PPP procurement can boost efficiency above the levels that are obtained through traditional public procurement. First, if the private sector partner obtains the residual control (ownership) rights to the infrastructure asset, that partner now has incentives to undertake cost-saving investments in that asset even when the asset is relation-specific and contracts are incomplete. Second, the bundling of asset construction and operation/maintenance into one single contract incentivises the private partner to undertake cost-saving investments already in the construction phase if such investments lower the project's life-cycle operating/maintenance cost. And third, sharing the project risks (and rewards) between the public and private partners so that the party best able to influence each risk is responsible for its management can also boost productive efficiency by lowering costs as a result of better managed risks.

An empirically testable corollary of all this is that a PPP may exhibit higher costs of asset construction than a comparable traditionally procured project. The higher costs arise because the bundling of construction and operation/maintenance contracts in a PPP creates stronger incentives for the private sector partner to undertake investments at the construction stage to lower life-cycle operation and maintenance costs, and because of the transfer and explicit pricing of construction risks to the private-sector partner. The effect of both bundling and risk transfer is further strengthened through the fact that the private-sector partner controls and sometimes owns the infrastructure asset in a PPP.

To the best of our knowledge, there has been no systematic empirical work trying to assess the impact of PPP procurement on productive efficiency in general and on asset construction costs in particular. To help fill this gap, our study focuses on the cost of constructing infrastructure assets under different procurement methods. To test whether PPPs are indeed associated with higher asset construction costs—and to discuss what the results imply regarding the relative importance of the channels that can boost productive efficiency in a PPP—we employ a database of road projects financed by the European Investment Bank (EIB) between 1990 and 2005.

We find that a PPP road is 24% more expensive to build than is a traditionally procured road, *ceteris paribus*. This estimate resembles reported *ex post* cost overruns in traditionally procured roads. Thus, the public sector seems to pay a premium on *ex ante* PPP construction contract prices mostly to cover construction risk transfer. Other sources of higher PPP road construction costs, including bundling, seem on average of lesser importance.

These findings are novel in two respects: First, as pointed out above, there is a paucity of empirical analyses of PPP procurement in general, so this paper is one of the first efforts at assessing its performance, including a comparison with traditional public procurement. Second, much of the theoretical literature has focussed on the bundling of asset construction and operation/maintenance as a key source of efficiency gains in PPP procurement. Our results cast some doubt on the empirical importance of bundling, at least in the road sector, suggesting that a closer consideration of the other sources of efficiency gains should perhaps receive more attention in future research.

It is important to acknowledge that the analysis does not allow us to draw normative conclusions about the broader economic desirability of PPP as a procurement method. After all, the analysis focuses on one cost component in isolation, without being able to quantify its impact on life-cycle costs or benefits. Such analysis can only be undertaken once a sufficiently large number of PPP contracts have completed their life cycles.

The paper is organised as follows: Sect. 2 develops the theoretical arguments relating to construction costs in a PPP and in traditional public procurement. Section 3 presents the empirical analysis, while Sect. 4 interprets the empirical results. Section 5 concludes.

2 Construction Costs in PPPs and in Traditional Public Procurement: Some Theoretical Considerations

2.1 Control Rights to Asset

The most commonly used theoretical framework to analyse PPPs is that of incomplete contracting, formulated by Grossman and Hart (1986); Hart and Moore (1990), and Hart (1995), based on earlier work by Williamson (1979). Williamson's key insight was that contractual relationships involving relation-specific investment—that is, investment in an asset that cannot be readily used for purposes other than that stipulated in the contract—are problematic in an environment that is so complex that it renders the contract incomplete. In other words, relation-specific investment tends to be sub-optimally low in a complex world where contracts can never fully account for all future eventualities.

The reason for this, according to Williamson, is that contractual incompleteness creates incentives for *ex post* bargaining about the profits generated by the investment in the specific asset, as contractual incompleteness implies that it is difficult to distinguish between good-faith renegotiation of the contract (prompted by an unforeseen change in the contractual environment) and bad-faith renegotiation (prompted by the wish to extract unforeseen rents). Given the risk of bad-faith renegotiation, the investment in a specific asset will be smaller than optimal.

Based on this analysis of Williamson's, Grossman, Hart, and Moore suggested that the assignment of ownership rights of the relation-specific asset can be designed so as to alleviate the under-investment problem. Ownership rights are in this context taken to mean residual control rights that confer bargaining power, giving the owner of the asset full control over the asset and the final say in case of any disagreement.

In essence, then, an appropriate assignment of ownership (or control) rights of an (infrastructure) asset can increase productive efficiency by encouraging relation-specific investment even when contracts are incomplete. This is an important starting point for considering the economic pros and cons of PPPs: the surrender of control rights for an infrastructure asset to the private sector partner can boost productive efficiency beyond what can be achieved under traditional public procurement, with public sector ownership and an absence of private profit motive.

For our purposes, a notable corollary of this insight is that asset construction costs should be higher under a PPP than under traditional public procurement whenever relation-specific cost-saving investments can be made. Under traditional procurement and public ownership, the gain from any cost-saving investment is likely to accrue to the public sector, so a private operator has weak incentives to seek cost savings. In contrast, if the private operator controls the asset, he will be the (main) beneficiary of cost savings, which makes him more likely to seek them.

2.2 Bundling of Asset Construction and Operation

As alluded to earlier, another reason for possibly higher productive efficiency of PPPs is the bundling of the asset's construction and operation into a single contractual framework, which allows the internalisation of any positive externalities that may exist between the construction and operational phases. In the case of a road project, bundling would allow the private contractor to make choices at the construction stage (i.e., higher upfront investment) that could lower the life cycle maintenance cost of the road. Without bundling, such externalities would not be taken into account in the construction phase, and productive efficiency would be lower.

This insight has been formalised by Hart (2003). In Hart's model, the public sector is assumed benevolent, thus seeking to maximise net social benefit, while private sector firms maximise their profits. The public sector procures a project involving the construction of a specific asset and its operation, and it can choose the procurement method: either the project is procured as a traditional public sector investment project, with the construction and operation procured separately with two different private sector firms, or they are procured as a bundle with just one firm. Obviously, the former corresponds to traditional public procurement, while the latter corresponds to a PPP.

Either way, Hart assumes that the private firm has sufficient control over the asset to be built and operated so as not to expect bad-faith renegotiation, which implies that asset ownership is not considered as a channel to boost productive efficiency in this particular model. This assumption allows a sharper focus on bundling as a theoretical *raison d'être* of a PPP.

The private sector firm that is awarded the construction contract—be it bundled with operation or not—can in turn choose to make two types of investments at the construction stage. While both investments will affect the outcome in terms of the firm's profits and net social benefit as discussed below, either can be undertaken by the firm without violating the contract between itself and the public sector; i.e., contracts are incomplete.

The first investment, call it i, would reduce maintenance costs in the operational phase, and it would also improve the quality of the end-product offered to consumers. An example could be investment in new road surface material that has superior endurance and better safety characteristics compared to older alternatives; thus, it would both reduce maintenance costs and improve the quality of the road. This investment i, if undertaken in the construction phase, therefore yields higher productive efficiency and higher allocative efficiency.

Another possible investment, call it e, is also associated with higher productive efficiency in that it would lower maintenance costs; but as opposed to i, it is associated with lower allocative efficiency. As an example, consider the use of durable but less reflective paint for the purpose of road surface markings. The durability of the paint would again lower maintenance costs, but the fact that it does not reflect as well in the dark would lower the quality of the road by making driving at night riskier.

To examine construction costs in this framework, we present a slightly modified version of Hart's model. Specifically, we amend it by explicitly modelling construction and operation (maintenance) costs.

Let us consider first the case of traditional, unbundled public procurement. Firms bidding for the construction contract face the following profit maximisation problem:

$$\text{Max}\pi = P_C - C_C, \tag{1}$$

where P_C denotes the revenue from the contract and C_C is the construction cost. Assuming a competitive market for the construction contract, $P_C = C_C$, so the firm winning the contract seeks to minimise C_C and will therefore not incur the cost of undertaking the investments i and e, as they would just increase construction costs.

In this case, the net social benefit equals:

$$B_O - C_C - C_O, \tag{2}$$

where B_O denotes the gross social benefit from the operation of the road and C_O denotes the cost of operating (maintaining) it. Note that as none of the potentially cost-reducing investments i or e was undertaken, the maintenance cost does not depend on how the asset was constructed.

Clearly, unbundling is not socially first best, since the choice $i = e = 0$ involves too little of the unambiguously socially beneficial investment i, which would improve both productive and allocative efficiency. Whether the amount of the investment e is in this case socially optimal or not depends on how much it reduces allocative efficiency. If the decline in allocative efficiency from e equals exactly the improvement in productive efficiency then the socially optimal amount of investment in e is indeed zero and can thus be obtained under unbundling.

Let us now consider the same project, but procured with the construction and operation bundled. Now the firm winning the contract would face the following profit maximisation problem:

$$\text{Max}\pi = P_B - (C_C + i + e) - (C_O - b(i) - \beta(e)), \tag{3}$$

where P_B is the value of the contract. Note that the investments i and e increase construction costs but reduce maintenance costs by $b(i)$ and β(e), respectively, where b, $\beta > 0$. The optimal amount of i and e can now be determined by considering the first-order conditions:

$$\frac{\partial \pi}{\partial i} = -1 + b'(i) = 0 \tag{4a}$$

$$\frac{\partial \pi}{\partial e} = -1 + \beta'(e) = 0. \tag{4b}$$

If we denote the optimal values of i and e, obtained from (4a, b), by i^* and e^*, respectively, the net social benefit from the bundled project becomes:

$$B_O + a(i^*) - \alpha(e^*) - P_B = B_O + a(i^*) - \alpha(e^*) \\ - \left[C_C + i + e + C_O - b(i^*) - \beta(e^*)\right], \tag{5}$$

where the value of the bundled contract, P_B, equals the cost of constructing and operating the assets, assuming again that the market for obtaining the contract is competitive; a and α are two positive scaling parameters, denoting how i^* and e^*, respectively, translate into social benefits.

As opposed to unbundling, bundling delivers the socially optimal amount of investment in i, but it delivers too much investment in e whenever $\alpha > \beta$. Thus, bundling is also not socially first best. Based on (2) and (5), we can derive the condition for the public sector to prefer bundling to unbundling. Bundling is preferable when (5) > (2), i.e.

$$\left[a(i^*) - \alpha(e^*)\right] + \left[b(i^*) + \beta(e^*)\right] > i + e \tag{6}$$

This inequality has a simple, intuitive interpretation: Whenever the cost of making the two cost-saving investments (right-hand side of the inequality) falls short of their net benefits (left-hand side), bundling is preferable because it internalises the positive externality between the construction and operational phases of the project. Otherwise unbundling is socially preferable.

Note that the net benefits from bundling consist of two components. First, the second square brackets in (6) denote the benefit from improved productive efficiency achieved through the investments i and e. Second, the first square brackets denote the net impact of these investments on allocative efficiency (quality), with i increasing it and e reducing it. Obviously, whether the net impact on allocative efficiency is positive or negative depends on the parameters a and α.

This straight-forward comparison of bundling and unbundling assumes implicitly that both investments i and e are contractible—that is, the public sector can monitor, verify, and sanction the firm's investment in them. In a case where one of the investments is not contractible, the comparison has to be qualified. Recall that, in this model, the private firm possesses residual control rights of the asset, so it can decide whether or not to undertake the investment i or e, unless otherwise specified in the contract. Now if the investment i is contractible but e is not, unbundling is socially preferable because it yields the socially optimal amount of the quality-shading investment e, while the amount of i can be contractually set at the social optimum with the builder. In contrast, if e is contractible but i is not, bundling is socially preferable because it will yield the optimal amount of i, and e can be set at its social optimum in the contract.

Hart's model thus yields clear-cut insights into the choice between bundling and unbundling, including when contracts are incomplete. What is more, it yields an unambiguous hypothesis concerning construction costs in each case: the construction costs under bundling are unambiguously higher than under unbundling, the difference being equal to the cost of the cost-saving investments.

2.3 Risk Sharing Between the Public and Private Sectors

Despite the fact that risk pricing is well addressed in the corporate finance literature on the risk premium and certainty equivalent approaches, the theoretical PPP literature on incomplete contracts has paid much less attention to risk sharing than to asset ownership and bundling. Therefore, we only discuss here briefly the intuition behind the link between risk sharing and construction costs, leaving a more formal analysis for future research to tackle.

At a general level, as elaborated by Grout (1997, 2005), risk transfer from the public to the private sector can lead to a more explicit recognition, quantification, and pricing of the risk that is transferred. One of the principles of PPP procurement is that risks should be transferred to the party best able to manage them. It follows that this party will price the cost of reducing to a minimum the risk that a particular outcome with adverse financial consequences occurs. Consequently, risk transfer *per se* does not affect productive efficiency; rather, it is the likelihood that risk transfer improves risk management that can make a PPP more cost efficient than traditional public procurement.

The risks customarily transferred to the private sector partner in a PPP include those related to construction costs and schedule. At the risk of oversimplification, one may characterise traditional public procurement of an infrastructure asset, at least in the road sector, as cost-plus contracting, with the public sector carrying the majority of construction cost and delay risks. As a result, cost and time overruns are commonplace in traditional public procurement, as vividly illustrated by Flyvbjerg et al. (2003). In contrast, a PPP can be characterised as date-certain fixed-priced contracting, with the private partner instead of the public sector carrying the construction cost and schedule risks.

The fact that the private partner fully carries the construction risks in PPP contracting but not in traditional public contracting should be reflected in the *ex ante* price that the public sector has to pay for the asset. The transfer of construction risk implies that the private sector partner evaluates and prices such risk, which increases the value of his bid for the contract. In other words, construction costs are expected to be higher in PPPs than in traditional public procurement because of the explicit recognition and pricing of construction risks transferred to the private partner.

In the words of the British Treasury: The "Value for Capital Expenditure for the PFI Option is assumed to be higher than the estimated costs under the PSC Option [Public Sector Comparator]. This reflects the fact that more cost and delay risk is transferred to the private sector under the PFI Option and that, typically, the PFI partner succeeds in passing many of these risks, albeit at a capped level, down to the construction contractor through sub-contract arrangements." (HMT 2004b, p. 25)

Why are construction risks not priced in traditional public procurement? Following the argumentation by Klein (1997) and Grout (1997), the fundamental reason is that the public sector can transfer risks to taxpayers and end users of the infrastructure service without remunerating them. In traditional public procurement, the public sector assumes construction risks only to pass them on to the population, who are the final financiers as well as consumers of the infrastructure service to be supplied. Construction cost and time overruns thus hurt taxpayers and end users, who carry the risk of their materialising without receiving any compensation by the public sector.

In sum, the transfer of construction risks to the private sector partner in a PPP, as opposed to the population in traditional public procurement, allows them to be explicitly recognised and priced into the construction contract. Construction risk transfer therefore should make construction costs in a PPP higher than in traditional public procurement.

2.4 Summary

The preceding discussion suggests a clear-cut and empirically testable hypothesis: Asset construction costs should be unambiguously higher in a PPP than in traditional public procurement. This is because: (1) private control of the asset in a PPP improves incentives to seek relation-specific cost-saving investments even when contracts are incomplete; (2) the bundling of construction and operation of an asset in a

PPP improves incentives to invest more in the construction phase with a view to lowering subsequent operation and maintenance costs; and (3) only the PPP construction contract explicitly recognises and prices the construction risks.

3 Empirical Analysis

The objective of the empirical analysis is to examine whether and by how much construction costs differ between PPPs and traditional public procurement in the European road sector, which dominates European PPPs, especially outside the UK, both in terms of number of projects, number of countries, investment volume, and the length of time that such contracts have been used (Riess 2005). To this end, we employ an *ex ante* unit cost database of European road projects between 1990 and 2005, derived from project appraisal files of the European Investment Bank (EIB).

3.1 Model Specification

In the absence of directly applicable formal theoretical models on the determinants of construction costs (contract prices) in the road sector, we resort to specifying a reduced-form empirical model. The challenge in so doing is to ensure the robustness of the estimation results to alternative samples and model specifications. Therefore, special emphasis is placed below on robustness testing.

The reduced-form model specification is as follows:

$$y_i = \beta_0 + \beta_1 D_{PPP} + \sum_j \beta_j X_j + \varepsilon_i. \tag{7}$$

The dependent variable (y) is the natural logarithm of *ex ante* unit construction costs, in millions of Euros (in real terms, using the CPI as deflator) per kilometre, of physically distinct road sections. Included in the unit construction costs are the price of construction works, design, engineering, and supervision. Excluded are all other costs, in particular, the price of land, technical and price contingencies, taxes, start-up costs, and fees, as well as interest payments during the construction phase. These latter costs are excluded because they are not directly related to the specifications of the project but, rather, depend on other factors such as the duration of negotiations, real estate prices, interest rates, and so on. In addition, they are not directly related to the economic phenomena we seek to observe.

The first explanatory variable (D_{PPP}) captures the procurement method; it is a dummy variable that assumes the value 1 for road sections that are procured as a PPP and zero otherwise. For the purpose of this study, public–private partnerships are defined as infrastructure projects procured under DBFO/M-type contracts that bundle Design, Build, Finance and Operation/Maintenance. When end-users pay directly for the service, such contracts are also referred to as "Concessions". Projects that do not exhibit all four characteristics are not characterised as PPPs. Traditional public procurement in this study means any procurement method that is not a DBFO/Concession. It can encompass a wide range of contracting arrangements including separated design, supervision, and construction contracts and design-build contracts. However, all these forms involve public rather than private finance.[1]

The other explanatory variables, collected in X_j in (7), comprise economic, technical, and country-specific factors that have a bearing on road construction costs. They include real labour costs;[2] technical characteristics such as the type of carriageway for normal roads (single or dual); number of lanes for motorways (modelled as dummy variables); terrain (if urban or mountainous); the proportion of tunnels and bridges; and (log) length of road to allow for the presence of economies of scale in road construction, with longer sections *a priori* relatively cheaper to build.[3,4] Furthermore, we include in the estimation country dummy variables, meant to capture any additional unspecified country-specific effects, be they political, institutional, or other.[5,6]

Finally, ε in (7) denotes Gaussian white noise.

As regards the expected signs of the coefficients for the economic explanatory variables, we would expect the coefficient for the PPP dummy to be positive (based on Sect. 2); for the real labour cost variable to be positive; and for the (log) length to be negative (on the assumption of economies of scale).

3.2 Data

Apart from the labour costs, which originate from the European Commission's Ameco database, all data come from project appraisal files of the EIB. While such data are confidential and cannot be reproduced in all detail, including the identification of individual projects included in the sample, a significant advantage of the data is that they

[1] We consider the choice of procurement method to be exogenous within the road sector. The determinants of that choice (e.g., asset specificity, contract length, externalities between project phases, monitorability of service quality, project risks and their manageability) may well be different across sectors, but they are very similar within any one sector, especially roads. Therefore, the focus on a single sector is arguably the best available control for the potential endogeneity of the PPP dummy.

[2] We consider untransformed real labour costs instead of logs of them, as the latter have an insignificant impact on the estimation results while worsening some diagnostic test results.

[3] This variable captures indeed only scale economies, as our dependent variable is measured in unit cost terms. We also considered the square of the log length of road as an explanatory variable, but it turned out insignificant in all samples and specifications.

[4] Our sample only comprises new roads, so we do not need to control for different types of works, such as road rehabilitation or upgrade.

[5] A number of other explanatory variables were investigated to proxy the institutional environment, including the Transparency International Corruption Index and Government Effectiveness indices, but none was found to have significant explanatory power. Similarly, time effects (base year for the project) were insignificant.

[6] To check the similarity of unit cost determinants between only PPP and only non-PPP projects, we also estimated the model (excluding the PPP dummy) for only PPP roads/motorways and only non-PPP roads/motorways. While the PPP-only samples were small (around 60 observations) for estimation and inference, the sign and significance of the estimated coefficients were the same in both cases, with very few exceptions, and the differences in their magnitude were generally small.

Table 1 Descriptive statistics for the non-dummy variables in the full sample ($N = 227$)

Variable	Mean	Max	Min	SD
y	1.86	4.91	−0.50	1.04
Labour	25.43	47.71	12.74	8.90
Loglength	2.75	5.21	−0.36	1.16
Tunnel/road (%)	7.94	100.00	0.00	20.93
Bridge/road (%)	5.15	100.00	0.00	14.38

have been collected and compiled following a coherent and uniform methodology by sector experts as part of the Bank's appraisal of the project.[7]

The sample comprises road projects financed by the EIB between 1990 and 2005 in all EU-15 countries plus Norway, covering some 6,400 kms of roads. The sample includes 227 separate new road sections, of which 65 are PPPs. Of these, 157 observations are motorway sections, of which 57 are PPPs. The sample also contains six large fixed-link projects, which normally include a length of associated road. The average length of road sections is 28.1 km.

Table 1 shows descriptive statistics for all non-dummy variables in the full sample.

As regards our dependent variable, the data source gives us the project appraisal team's best estimate of what the project should cost to build at the moment that the winning bidder has been awarded the contract for the project. Thus, we observe the *ex ante* costs, or bidders' construction prices, not how much the projects have actually (*ex post*) cost to build.[8]

The engineering cost estimates are based on the latest figures that are available from the promoter at the time of the appraisal, which can vary depending on the timing of the appraisal relative to the start of construction. In the case of PPPs, these are derived from the cost estimates by bidders that are included as part of the financial model for the project. In the case of TP projects, cost estimates are derived either from the actual tender prices or from the latest estimates by the contracting authority using recent contract prices. The important point is that the data represent a homogeneous set of estimates that are based on the best available information from the promoters and are made by the same sector experts and the large sample counterbalances the problems of data quality in individual estimates. There are no reasons for systematic bias in either the PPP or TP data sets.

For the purpose of robustness testing the full sample is divided into eight partly overlapping sub-samples. In addition to the full sample, we estimate the model for motorways only, both with and without fixed link projects (i.e., those with or without a relatively high bridges or tunnels component). Within the full sample and the motorway sub-sample, we run the estimation also with the following sub-samples:

[7] We do not consider sample selection as a possibly significant source of bias. As a matter of policy, the EIB does not take a stance on the procurement method, so the likelihood of EIB financing for a viable project is independent of its being procured as a PPP or otherwise. Also, the geographical and sectoral distribution of EIB funded PPPs is similar to the distributions of PPPs overall.

[8] The relevance of the model for *ex post* costs depends on the correlation between *ex ante* and *ex post* costs, which we discuss in Sect. 4.

- Including only projects whose total value is not below €20 million or above €300 million (thus excluding very "small" and very "big" projects);
- Including only observations with the value of the dependent variable within 1.5 standard deviations from the sample mean (thus excluding outlier observations on the dependent variable);
- Including only observations from countries that had both PPPs and traditionally procured road projects in our sample (thus reducing noise due to unobserved cross-country differences).

3.3 Estimation Results

The detailed Ordinary Least Squares (OLS) estimation results of the preferred model specifications, obtained using the estimation strategy described above, for all eight samples are shown in Table 2.

We note that all estimated coefficients for the economic explanatory variables have the expected sign in all specifications where they are statistically significant from zero, with the exception of the Mountain terrain dummy, which is not significant at the 10% level in any specification. In other words, unit construction costs are higher for PPPs than for traditionally procured roads; increase with labour costs; and decrease with the length of the road, confirming the presence of scale economies in road construction.

As regards the technical explanatory variables in the all road samples, we note that the parameters have their expected signs, but that the dual carriageway dummy variable and the two-lane dummy variable are not robustly significant. The single carriageway dummy is significant and negative. Roads with six lanes are more expensive than roads with fewer lanes (two, or four).[9] Whilst this analysis is useful for confirming the robustness of the PPP parameter estimate, the sample mixes normal roads and motorways, which have different technical specifications and expected unit costs.

In the motorway samples the technical explanatory variables behave similarly. Two-lane motorways are relatively cheaper to construct, while six-lane motorways are relatively more expensive. Motorway construction on urban terrain raises construction costs, as do tunnels and bridges. Construction on urban terrain is more expensive than elsewhere, even excluding the price of land, due to, among other things, a need to displace utilities and other additional costs of working in a dense urban environment. Mountainous terrain does not affect construction costs significantly (the coefficient is insignificant throughout); rather, the higher cost of road construction in the mountains is reflected in a higher proportion of tunnels and bridges, which is captured by the variables "tunnel/road" and "bridge/road". The coefficients for these two variables are positive and significant in all specifications.

Country dummy variables that proved significant were kept in the model while others were dropped. These variables capture aspects of the difference in unit costs between European countries that are difficult to explain otherwise. They can be driven by various aspects of local market conditions that are not captured by our control variables, including economic, technical, and institutional factors, such as the cost of

[9] The omitted dummy variable in this case is a four-lane standard motorway, which acts as a benchmark.

Table 2 OLS estimation results

	All roads				Motorways			
	1/	2/	3/	4/	1/	2/	3/	4/
Constant	1.432	2.196	1.855	0.517	1.310	2.430	1.426	1.161
p-value	0.000	0.000	0.000	0.074	0.000	0.000	0.000	0.000
PPP	**0.313**	**0.330**	**0.268**	**0.280**	**0.293**	**0.331**	**0.285**	**0.232**
p-value	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.006
Labour	0.043	0.024	0.016	0.054	0.021	0.006	0.029	0.035
p-value	0.000	0.000	0.023	0.000	0.000	0.313	0.000	0.000
Dual carriageway	−0.101	−0.172	−0.090	−0.082				
p-value	0.239	0.049	0.302	0.388				
Single carriageway	−0.415	−0.564	−0.245	−0.813				
p-value	0.097	0.039	0.305	0.017				
2 Lanes	−0.504	−0.302	−0.443	−0.092	−0.915	−0.531	−0.858	
p-value	0.032	0.215	0.042	0.773	0.011	0.261	0.004	
6 Lanes	0.401	0.278	0.329	0.337	0.389	0.316	0.286	0.359
p-value	0.000	0.012	0.001	0.001	0.001	0.008	0.003	0.001
Urban Terrain	0.331	0.294	0.177	0.283	0.567	0.393	0.356	0.386
p-value	0.001	0.002	0.049	0.004	0.000	0.002	0.002	0.002
Mountain Terrain	0.129	−0.100	−0.027	0.061	0.109	−0.020	0.103	0.129
p-value	0.301	0.464	0.818	0.625	0.440	0.903	0.436	0.329
Log(length)	−0.241	−0.407	−0.165	−0.187	−0.159	−0.421	−0.178	−0.130
p-value	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.010
Tunnel/road	0.019	0.015	0.019	0.021	0.021	0.017	0.020	0.024
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bridge/road	0.017	0.011	0.017	0.018	0.027	0.025	0.031	0.026
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Denmark	−0.990	−0.674	−0.742				−0.745	
Finland	−0.428		−0.324					
France				0.337				
Germany	−0.427						−0.547	−0.304
Greece				0.698				
Ireland	−0.355							
Italy	−0.499							
Netherlands	−0.730	−0.406						
Norway	−1.016	−0.561	−0.386				−0.674	
Portugal			−0.263	0.556				
Spain	−0.539	−0.294	−0.532				−0.429	−0.482
Sweden	−0.258		−0.294			0.344		
UK	−0.247			0.299				

Table 2 continued

	All roads				Motorways			
	1/	2/	3/	4/	1/	2/	3/	4/
N	227	168	201	175	156	117	138	120
Adjusted R^2	0.82	0.80	0.69	0.79	0.74	0.76	0.64	0.77

Note: Only significant country dummy variables (at 10 % level of significance) are included in the estimation and shown
1/ Full sample
2/ Excluding projects < € 20 million or > €300
3/ Excluding projects with unit construction costs that are more than 1.5 standard deviations from
4/ Excluding projects in countries where either PPP or traditionally procured projects are absent from the sample

supplies, national contractor market conditions, technical standards for roads, or the quality of public procurement.[10]

As shown in Table 2, the coefficient for our key variable, the PPP dummy variable, is estimated at about 0.3, varying between 0.23 and 0.33. The average coefficients in the all roads and motorways samples are 0.298 and 0.285, respectively. Since we are using a log transformation of the dependent variable, the interpretation of the magnitudes of the estimated coefficients is not straightforward. We can obtain semi-elasticity for a dummy regressor by taking the antilog (base e) of the estimated coefficient, subtracting 1, and multiplying the result by 100. This gives us the median predicted value (not the mean) (Halvorsen and Palmquist 1980). By this transformation we conclude that the estimated semi-elasticity for the PPP dummy across all samples and specifications is 35%.

3.4 Robustness and Diagnostic Testing

To test the robustness of the estimated coefficient for the PPP dummy not only across samples but also across model specifications, we use all eight sub-samples in Table 2 to estimate a model specification with all economic and technical explanatory variables as well as all country dummy variables (excluding one to avoid the dummy variable trap) regardless of their significance, and we also estimate another specification including only the economic and technical explanatory variables, thus dropping all country dummy variables.

As a further robustness test, we eliminate all fixed-link projects from each sub-sample. Fixed-links projects have a very high proportion of bridges or tunnels in the section length. The presence of these observations may help in estimating the coefficients for the bridges and tunnels variables, but they also have very high unit costs, which have more to do with the construction of major structures than roads or motorways. The

[10] We also tested the significance of a dummy variable denoting privatised motorway operators in Italy and Portugal and found the estimated coefficient to be insignificant. This test was warranted, as road projects in these countries are contracted by a privatised operator but without a DFBO structure to them.

Table 3 The estimated coefficient for the PPP dummy variable across sub-samples and model specifications

Sample	Country dummy variables			Fixed links 3/	
	Only significant ones included 1/	Unrestricted specification 2/	None included	*N*	Excluded from sample 4/
Motorways					
Full sample	0.29	0.26	0.29	9	0.32
Total cost (20, 300) Eur million	0.33	0.32	0.30	4	0.37
Dependent variable w/in 1.5 SD	0.29	0.24	0.31	0	–
Only countries with both PPP and trad projects	0.23	0.24	0.21	4	0.24
All roads					
Full sample	0.31	0.34	0.32	18	0.29
Total cost (20, 300) Eur million	0.33	0.38	0.29	12	0.31
Dependent variable w/in 1.5 SD	0.27	0.28	0.28	8	0.26
Only countries with both PPP and trad projects	0.28	0.29	0.23	10	0.27

1/ As shown in Tables A1–A8
2/ Including all economic and technical regressors and all country dummy variables except one
3/ Defined as projects comprising > 50% bridges or tunnels
4/ Estimate of the coefficient for the PPP dummy variable excluding fixed links, using the specification with the significant country dummy variables

models were therefore estimated with no fixed-links and no observations where the tunnel or bridge proportion is greater than 50% of the length. It should be noted that the model including only observations within 1.5 standard deviations from the sample mean automatically excludes the fixed links due to their high unit costs.

Table 3 summarises the estimated coefficient for the PPP dummy variable in these specifications for all sub-samples. We see that the estimated coefficient for the PPP dummy variable stays in the range 0.23–0.38 regardless of the model specification. However, the unrestricted specification and the specification without any country dummy variables have not been subjected to the same rigorous diagnostic testing as the preferred specifications, so their results should not be considered as solid as those of the preferred specifications. Nevertheless, the robustness of the coefficient for the PPP dummy variable across different samples and model specifications is reassuring, suggesting that our PPP dummy does indeed capture the impact of procurement method on the dependent variable and nothing more than that.

To conclude, the key diagnostic test results for the different specifications are summarised in Table 4.

- The OLS residuals appear normally distributed, with the Jarque-Bera test unable to reject the null hypothesis of normality at 10% level for any sub-sample, except the one indicated in Table 2.

Table 4 Summary of diagnostic test results

Sample	Jarque-Bera	Prob. 1/	White	Prob. 2/	Condition number 3/
Motorways					
Full sample	0.277	0.871	11.143	0.599	18.364
Total cost (20, 300) Eur million	0.826	0.662	12.474	0.568	26.0782
Dependent variable w/in 1.5 SD	0.978	0.613	13.383	0.710	21.1169
Only countries with both PPP and trad projects	8.504	0.014	13.301	0.503	19.8105
All roads					
Full sample	2.103	0.349	20.980	0.694	20.771
Total cost (20, 300) Eur million	3.940	0.139	13.889	0.790	24.685
Dependent variable w/in 1.5 SD	0.036	0.982	21.424	0.433	26.853
Only countries with both PPP and trad projects	2.697	0.260	12.009	0.885	27.214

1/ Should be >0.1 for residual normality at 10% significance level
2/ Should be >0.1 for residual homoskedasticity at 10% significance level
1/ Should be >30 for unlikely collinearity among explanatory variables

- The White test cannot reject the null of no heteroskedasticity at 10% level for any sub-sample. This test also tests for the appropriateness of the linear model specification and for correlation between the explanatory variables and the residuals, so it also confirms that our linear specification is correct and that omitted variables are unlikely (as evidenced by the absence of correlation between the explanatory variables and the residuals).
- The condition number tests confirm that collinearity is unlikely for all specifications and samples.

Overall, the preferred model thus appears well specified, and the R^2 exceeds 60% for all sub-samples.

3.5 Preferred Model

We have reported above the results from 31 regressions, and although the results are robust across samples and model specifications, it still remains to select the preferred model and the preferred point estimate of the coefficient for the PPP dummy variable, deemed to best approximate reality. Sub-samples mixing motorways and other types of roads, in some cases including significant tunnel or bridge links, are "noisy" in that they contain observations of very different technical natures and hence of different cost structures. Besides, Flyvbjerg et al. (2002) documents that the average cost overruns for these different categories of infrastructure are very different, so that risk pricing would be expected to vary in each case.

Thus, the preferred sample contains motorway projects only, with no fixed links. The model coefficients have the expected signs, and their magnitudes are plausible. Because of the way that the model is specified, the constant term does not have a simple interpretation. However, by substituting values into the model we can calculate a benchmark. For a 25 km long 4 lane motorway section, in non-urban and non-mountainous terrain, with no tunnels or bridges, not procured as a PPP, in an EU country with average labour costs, the model estimates a unit cost of €4.9 million/ km (in 1999 prices). This value compares well with international standards seen by the EIB.[11] The same motorway built in an urban context is 42% more expensive. A six-lane motorway is 33% more expensive. A similar motorway with 10% of its length in tunnels is 23% more expensive.

3.6 Correction of a Systematic Bias in the Data

As reported in Table 3, the range of estimates of the coefficient on the PPP dummy variable varies between 0.21 and 0.38, with an average of 0.29. About one-half of the estimates are in the range between 0.25 and 0.30. For the preferred model, the coefficient of the PPP dummy variable is 0.29. The point estimate of 0.29 would translate into a semi-elasticity of 34% (see end of Sect. 3.3).

We cannot, however, infer yet that this would be our best estimate for the difference in construction costs between a PPP and traditional public procurement, given that the data used in the estimation suffer from a systematic bias, as explained below.

The timing of the cost estimate is not systematically recorded in the database. The stage in the project cycle when the cost estimate is made varies between projects and varies systematically between PPP and traditionally procured projects. In the latter case, the EIB appraisal report is prepared based on a mission to meet the project promoter that typically occurs between six months to one year before the start of construction. Cost estimates are based either on updated feasibility studies, detailed design, or, whenever available, the contract price. To this estimate the Bank adds technical and price contingencies, which can vary from 5 to 15%, depending on the status of the cost estimate. The data in our sample are the base cost estimates, without technical and price contingencies.

In the case of PPP projects, the final appraisal mission usually takes place later in the project cycle, either once the winning bidder is known or at the “BAFO” stage.[12] The recorded construction cost estimate is based on the price of the EPC (engineering, procurement, and construction) contract with the construction consortium. Although this may change slightly following contract negotiations, it is subject to far less uncertainty than data on traditionally procured projects.

Therefore, there is a known, systematic bias in the data, which would tend to make observations on traditionally procured projects lower than the final contractual construction price at the moment that work starts on site. Based on the technical contingencies assumed at the moment of appraisal for a sample of projects, an interval

[11] As part of the due diligence technical reporting for many PPP motorway projects, international consultants prepare comparisons of construction costs with benchmarks derived from other projects. For example, the Spon’s database gives a unit cost of 4.5 million euro/ km in 2005 for a 2 × 2 UK motorway in rural, non-mountainous terrain with a normal level of structures (Langdon 2004). A commonly cited benchmark for traditionally procured EU motorways is 5 million euros/ km.

[12] At the “best and final offer” (BAFO) stage, there are usually two identified preferred bidders who must give their final price to win the contract.

estimate of this bias is [5, 15] percent, with a point estimate of 10%. While this estimate is judgmental in character, it is based on the best available professional judgement of EIB project appraisal teams.

Correcting for this bias, we finally arrive at an estimate of the difference in construction costs between a PPP road and a traditionally procured road. With 34% semi-elasticity of the PPP dummy variable, the point estimate is 24%. An interval estimate, allowing for deviations from the mean of one standard deviation, would cover the range [18%, 29%], and a 95% confidence interval would include deviations of about $+/-10\%$ points from the average.

At first glance this may seem high, but in fact it fits well with other evidence. Edwards et al. (2004) calculated that the average premium on construction costs for the first four DBFO roads projects in the UK was 25%. In certain projects, the EIB sees tendered costs for directly comparable PPP and traditionally procured contracts, for instance where a section of a project is first procured traditionally and then adjacent sections are procured under a PPP. In such cases, the difference in unit costs for the PPP contracts typically ranges between 10 and 30%.

4 Interpretation of the Results

We have estimated that, on average and across a wide portfolio of European road projects, the *ex ante* cost of construction is 24% higher through PPPs than through traditional public procurement, all other things held equal. Section 2 suggested that this difference can represent higher construction-phase investment to achieve cost savings in the operations phase and the pricing of the construction risk that is transferred to the private-sector partner. In addition, the PPP could also represent more mundane factors, such as the recovery of higher bidding costs[13] by contractors or limited competition for the PPP market.[14]

While our empirical analysis does not provide a quantification of the relative importance of these various possible sources, it is possible to discuss them qualitatively.

To start, let us consider the cost of transferring the construction risk to the private-sector partner. The purpose of such risk transfer is to avoid the time and cost overruns ("optimism bias") that are customarily associated with traditional public procurement. While data on the optimism bias in traditional public procurement is scarce, some studies have sought to quantify it. Using a global sample of major projects, Flyvbjerg et al. (2002) found average cost escalation during construction of 28% overall and significant differences between sectors and regions. For the EU roads sector he found an average cost escalation of 22.4%. For large capital projects (greater than €150 million)

[13] Bidding costs are very significant for PPP projects. Dudkin and Välilä (2006) estimate overall PPP transactions costs (including the costs incurred by failed bidders) related to the procurement phase to be above 12% of construction costs.

[14] Ekene et al. (1997) suggest that competition in the PPP (DBFO) market is different from that in the construction sector more broadly. Their survey concludes that smaller contractors tend to prefer traditional procurement to PPPs, as they are unfamiliar with the skills required to develop such projects and often not in a position to inject equity.

across different sectors, MacDonald (2002) identified an average cost escalation from the date of contract award of 21%.

These estimates of the optimism bias in traditionally procured European roads are obtained using samples of European road projects that are different from the sample analysed in our study. Consequently, caution is warranted in comparing the two sets of results. However, to the extent that both sets of samples are representative of European road projects, the close correspondence between the average optimism bias or cost escalation in traditional public procurement and the premium in *ex ante* costs in PPPs suggests that the public sector is paying more for a PPP road *ex ante* primarily to avoid time and cost overruns; that is, the largest part of the estimated difference represents the cost of passing on the construction risk to the private sector partner.

The measure of cost escalation given by Flyvbjerg and other researchers is an arithmetic mean, which, since his sample is skewed to the right, leads to the conclusion that the median value is likely to be to the left of the mean and thus lower than 22%.[15] Our estimation measures a median effect and produces a preferred result of 24%. Since our sample is also skewed to the right (large projects), the mean value predicted by our model is likely to be higher than 24%. From this, and to the extent that both sets of samples are representative of European road projects, we can conclude that the estimate of the average difference in pure construction cost between PPPs and traditionally procured projects is higher than is the average cost escalation proposed by Flyvbjerg. It seems, however, that the largest part of the cost difference should correspond to risk pricing.

One unambiguous benefit to the public sector from paying the higher construction price in a PPP is that delays are eliminated and the cost is contractually committed upfront through the unitary payment or an agreed level of tolls. If the private partner fails to deliver the project or fails to perform, it must shoulder the extra construction cost. From a public policy perspective this provides greater certainty in budgeting future expenditures and passes performance risk to the private party.[16]

Indeed, on-time and on-budget delivery has been hailed as one of the main success stories of PPP programmes to date. Treasury (2003) reports that 88% of Private Finance Initiative (PFI) schemes were built on time or early, compared to only 30% of traditionally procured projects, and that changes to the unitary charge only occurred in 21% of PFI projects, whereas 72% of traditionally procured projects experienced cost overruns. The performance of the PFI roads sector was particularly impressive, with 100% delivered early. The *ex post* review by EIB (2005), based on a sample of 10 in-depth PPP case studies mainly from the transport sector, found that "*…the underlying [PPP] physical projects evaluated in-depth were largely completed on-time, on-budget and to specification…*"

While it would thus seem that the transfer of the construction risk is successful in PPPs, one can nevertheless not conclude that it unambiguously creates "value for money". First, the public sector could transfer construction risk in traditional pub-

[15] This is not an absolute rule, but in the case of a continuous variable following a unimodal distribution, this is a reasonable assumption (see Hippel 2005 for a discussion).

[16] Strictly, this argument does not apply to real toll motorway concessions as revenue risk is passed to the private party.

lic procurement by entering fixed-price, date-certain construction contracts. More recent evidence from the performance of UK procurement other than PFI has shown substantial reductions in the frequency of cost and time overruns due to improved procurement methods (NAO 2005). Indeed, traditional procurement should not be seen as a static model of cost-plus contracts; rather, it is increasingly making use of schemes to provide incentives and transfer risks through client-leadership, value-based procurement, partnering, and early contractor involvement (ICCF 2005).

Sometimes it is, however, desirable to retain some flexibility to change the specification (and thereby the schedule and budget) during the construction phase (Dewatripont and Legros 2005). In fact, changes due to client requirements are identified as the main cause of cost overruns in both PPP and traditionally procured projects. One of the arguments for PPP is that the process of preparing output-based specifications makes the public sector focus on exactly what it wants. Hence changes that cause cost increases become less likely.

Besides, the comparison of cost overruns in PPPs and traditional public procurement is arguably a comparison of apples and oranges. The incentives to present realistic construction budgets are weaker in traditional procurement, given weak accountability in the event of cost overruns.

Thus, if construction risk is correctly priced in a PPP, there must be other sources of value for money (at least in terms of cost savings) during the project's lifecycle for PPPs to be economically superior to traditional procurement.

Interestingly, the close correspondence between the *ex ante* difference between a PPP and traditionally procured road on the one hand, and the *ex post* cost overruns in traditionally procured roads on the other hand, suggests that other sources of higher *ex ante* construction costs in PPPs are likely to be of second-order importance at best. Again, this conclusion rests on the assumption that the estimates quoted above are representative of the underlying population of European roads. If so, it is not evident that the bundling of construction and operation/maintenance contracts systematically increases construction costs by a significant amount, with a view to lowering operation and maintenance costs through higher investment in the construction phase. If such investment were present, the estimated construction cost difference would be significantly higher than the observed optimism bias in traditional public procurement.

Ex-post evaluation reports from PPP projects (EIB 2005) and other anecdotal evidence suggests that whole-life costing can prompt developers to increase the quality of construction. For instance, an EIB-funded DBFO motorway project in Greece was built to a higher standard than are normal motorways in the opinion of the Transport Ministry. The same contractor now maintains and operates the motorway under a 20-year contract. However, whole-life costing may be more linked to design options involving very limited additional costs and to greater attention to quality during construction than to significant upfront additional investment. As Drucker (1984) argues, innovation is often not about grand architectural design but about the cumulative impact of a large number of small, perhaps unexciting, but cost-effective changes.

The slight difference between our estimate and the average European level of cost escalation could spring from other sources than those suggested by theory: competition issues in the PPP market can, among other things, push the 'loading' of profits or past bidding costs into the construction contract costs. It is difficult, however, to know to what extent such phenomena drive systematic differences in the sample. Because competitive and institutional issues tend to be nationally determined and the sample is a Europe-wide one, the methodology used should help limit national 'noise' (thanks to the use of country dummies in particular).

Over the long term, the additional *ex ante* construction cost identified will have to be weighed against the benefits of timely delivery, contracted service quality, and life-cycle costs of operation and maintenance. Only then can an objective assessment be made of whether PPP procurement represents value for money.

5 Conclusions

Based on an analysis of more than 200 observations during the past decade and a half, the *ex ante* unit construction cost of a road to the public sector is estimated to be 24% higher in a PPP than in traditional public procurement. In theory, there are several reasons why one would expect PPP construction costs to be higher, including the bundling of construction and operation into one contract that may generate additional upfront investment, construction risk transfer to the private partner, and even the recouping of higher transaction costs.

The estimated difference in *ex ante* construction costs of 24% is of a similar magnitude as the cost overruns that are typically observed in traditional public procurement in the European road sector. This observation suggests that the largest part of the difference reflects the price that the public sector pays in order to avoid cost and time overruns as well as specification changes. Other possible sources of higher PPP construction costs, including bundling, seem therefore to be of second-order importance in the road sector.

Whether PPPs do or do not deliver lower life-cycle costs, and how sizeable the life-cycle cost savings are, will remain open issues for some time to come. The material presented in this study cannot address these issues, which are key to drawing sensible conclusions about "Value for Money" in PPPs.

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