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EX ANTE CONSTRUCTION COSTS IN THE EUROPEAN ROAD SECTOR: A COMPARISON OF PUBLIC-PRIVATE PARTNERSHIPS AND TRADITIONAL PUBLIC PROCUREMENT

Frédéric Blanc-Brude, Hugh Goldsmith and Timo Välilä* [†]

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* **Frédéric Blanc-Brude** is with King's College, London. He visited the Economic and Financial Studies Division of the European Investment Bank during this research.
Hugh Goldsmith is PPP Coordinator in the Projects Directorate of the European Investment Bank.
Timo Välilä is Senior Economist, Economic and Financial Studies Division of the European Investment Bank.
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Ex Ante Construction Costs in the European Road Sector:
A Comparison of Public-Private Partnerships and Traditional Public Procurement

Abstract:

Theoretical literature suggests a variety of reasons why a public-private partnership (PPP) should exhibit higher costs of construction than traditionally procured public infrastructure projects. The bundling of construction and operation contracts in a PPP give the private partner greater incentives to make investments in the construction phase to lower subsequent operation and maintenance costs. Also, the transfer of the construction risk to the private partner should be explicitly priced in a PPP. We use data on *ex ante* construction costs of road projects in Europe to test the existence and the magnitude of any such difference between PPPs and traditional procurement. We estimate the *ex ante* cost of a PPP road to be, on average, 24% more expensive than a traditionally procured road, all other things equal. This estimate corresponds by and large to reported *ex post* cost overruns in traditionally procured public roads. To the extent that the two measures are representative, this suggests that the largest part of the *ex ante* construction cost difference originates from the transfer of construction risk. This, in turn, implies that other possible sources of higher PPP construction costs, including bundling, seem to be of second-order importance in the road sector. The analysis does not allow drawing normative conclusions about the desirability of PPP as a procurement method as it focuses only on one cost component in isolation, without being able to quantify its impact on life-cycle costs and benefits.

1. Introduction

This paper compares the relative cost of building public infrastructure assets as public-private partnerships (PPPs) with traditional public procurement. 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 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. Private finance in turn brings in clear risk allocation and incentive mechanisms, which are defining characteristics of PPP.

Involving the private sector in the delivery of public infrastructure services is not a new phenomenon, but has recently known significant developments in Europe. Following early UK experiments with real-toll fixed links (bridges and tunnels), the modern form of PPP was pioneered with the introduction of Private Finance Initiative (PFI) shadow toll roads projects, which made the public granting authority rather than users responsible for payments, whilst demand risk (traffic) was transferred to the private operator. The expansion of the PFI program to social sectors, such as schools and hospitals, with no user charges, introduced the idea of unitary payments, by which government agreed to pay for future services according to pre-defined service standards, in return for the private sector designing, building, operating, maintaining and financing the facilities for a defined period of time. Failure to meet the contracted performance standards normally incurs penalties.

Ideally, the relative costs and benefits of PPPs should be evaluated over the entire project lifecycle, from start of construction through operations and maintenance to the end of the contract period. However, the widespread use of PPP procurement only started to take off in the mid-1990s. Therefore, most projects are either still under construction or in early stages of operation and most available information relates to the construction phase.

This being the case, our comparative study focuses on the cost of constructing infrastructure assets under different procurement methods. Economic literature suggests 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 test whether PPPs are indeed associated with higher asset construction costs we employ a database of road projects financed by the European Investment Bank (EIB) between 1990 and 2005. As it will turn out, the empirical analysis does not only allow us to compare the costs of procuring roads as a PPP with traditional public procurement, it also allows us to draw some tentative conclusions about the relative importance of bundling and risk transfer in affecting construction costs in road projects.

Conversely, it is important to acknowledge that the analysis does not allow us to draw normative conclusions about the 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 rest of this paper is organised as follows: Section 2 summarises the theoretical arguments relating to construction costs in a PPP and in traditional public procurement. Sections 3 and 4 present the empirical analysis. Section 5 interprets the results from an economic perspective, and Section 6 concludes.

2. Construction costs in PPPs and in traditional public procurement: Some theoretical considerations

Economic literature has identified three characteristics of a PPP that may cause its productive efficiency—and asset construction costs—to differ from traditional public procurement. The characteristics are private ownership or at least control of the infrastructure asset procured; the bundling of construction and operation/maintenance contracts into one; and the sharing of project risks and rewards between the public and the private sector partners. These characteristics are discussed in turn below, with a special focus on their impact on construction contract pricing.

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 the seminal work of 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.

As an example of this ‘hold-up’ problem, consider a fixed-price contract between the public sector and a firm for the maintenance of an existing public road. Assume that a new, cheaper technology for road maintenance becomes available after the fixed price for the maintenance contract has been agreed. Will the firm invest in acquiring this new technology? Possibly not, as it cannot be sure that the investment would pay off. On the one hand, the investment would seem to increase the firm’s profits, as it would continue to receive the agreed fixed payment from the public sector, while its costs for complying with the maintenance contract decline. On the other hand, the public sector would be aware of this increase in the firm’s profits so there is a risk that it would try to renegotiate so as to lower the fixed price it pays the firm by as much as the firm’s costs decline. In this case, the firm’s incentives for adopting the new technology would be eroded, it would not undertake the investment, and the economy would forego an increase in productive efficiency.

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.

To illustrate, consider the earlier road maintenance example. If now the firm was the owner of the road to be maintained, and the public sector paid the firm for the availability of the road, the public sector could not impose a renegotiation of the contract following the introduction of the cost-saving maintenance technology. After all, the firm as the road’s owner controls alone the use of the asset. As bad-faith renegotiation is unlikely in this case, the firm will invest in the new maintenance technology, thus improving productive efficiency (and pocketing higher profits).

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 (*i.e.*, higher upfront investment) at the construction stage 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). A slightly modified version of his model is presented in Appendix 1, with a special focus on construction costs in traditional public procurement and in PPPs. 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 one of the 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, yields therefore 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.

Unbundling is not socially first best, since it 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.

As opposed to unbundling, bundling delivers the socially optimal amount of investment in *i*, but it tends to deliver too much investment in *e.* Thus, bundling is also not socially first best. It is, however, preferable to unbundling whenever the cost of making the two cost-saving investments falls short of their net benefits. Otherwise unbundling is socially preferable.

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 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 yields thus 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 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 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 must 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 them, 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.

Why do construction risks remain un-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 them 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 Conclusions

Our review of economic theory as applied to PPPs suggests that there are several reasons to expect that the cost of constructing an infrastructure asset should be higher in a PPP than in traditional public procurement. Such reasons include the control over the asset by the private sector partner (which incentivises him to undertake cost-saving investments in general); bundling of asset construction and operation into one contract (which incentivises the private sector partner to make extra outlays in the construction phase to achieve life-cycle cost-savings); and transfer of construction risks to the private sector partner and its sub-contractors (who want to be compensated for carrying them).

The impact of both asset ownership and bundling on efficiency has been well articulated in the theoretical PPP literature. In contrast, risk transfer has received much less attention. Nevertheless, practitioners regard the sharing of project risks (and rewards) between the public and private sector partners in a PPP as the key feature separating PPP from traditional public procurement. This gap between the theoretical literature and the view held by practitioners is, however, not of particular concern to our study, as private asset ownership/control, bundling, and risk sharing all suggest the same null hypothesis for the empirical analysis.

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 and estimation strategy

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.

In our reduced-form empirical model we employ as the dependent variable 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 roads 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 explanatory variables can be divided into three broad groups. The first one consists of economic determinants of construction costs, including the procurement method and labour costs. The second set of explanatory variables includes technical determinants of road construction costs, aimed to capture technical characteristics such as the type of carriageway for normal roads (single or dual); number of lanes for motorways; terrain (if urban or mountainous); the proportion of tunnels and bridges, and length of road to allow for the presence of economies of scale in road construction, with longer sections *a priori* relatively cheaper to build.[1] The third group of explanatory variables comprises country dummies, meant to capture any additional unspecified country-specific effects, be they political, institutional, or other.

To summarise, the explanatory variables include:

- PPP dummy, assuming value 1 for projects procured on a Design-Finance-Build-Operate (DFBO) basis;
- Real (CPI-deflated) unit labour costs in the country of the project;
- (Logarithm of) the length of the road section to be constructed, accounting for the possibility that there are economies of scale in road construction;
- Dummies for single and dual carriageways in the case of non-motorway roads;
- Dummies for the number of lanes (2, 4, 6, and 8)[2] for motorways;

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

[2] In the presence of an intercept at least one of the dummy variables has to be excluded to avoid a situation of perfect collinearity (“dummy trap”). The intercept captures the effect of the omitted dummies.

- Dummies for urban and mountainous terrains;
- The length of tunnels and bridges, relative to the total length of the section;
- Country dummies[3].

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 section 2); for the real labour cost variable positive; and for the (log) length negative (assuming economies of scale).

Our estimation strategy is in principle "general to specific"; that is, we start with a specification including all explanatory variables (while avoiding the dummy trap) and then gradually exclude the insignificant ones one by one, using 10 percent significance as the threshold value. The specification thus obtained is then subjected to diagnostic testing. To test the robustness of our findings, we repeat the estimation procedure for a number of different samples and models specifications.

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

The sample comprises road projects financed by the EIB between 1990 and 2005 in all EU-15 countries plus Norway, covering some 6,400 kilometres of roads. The sample

[3] 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.

includes 227 separate new road sections[4]. The Bank collects data for each separate road section[5], for which contractors provide a separate price. For the empirical analysis, each project is divided into physically distinct road sections, which constitute our individual observations. Thus, if a project consists of one stretch of road to be tendered alone, it will be recorded as one observation. In contrast, if a project consists of several connecting roads, each road section will be recorded as a separate observation. This leads to a sample of 227 observations, of which 65 are PPPs.[6] Of these, 157 observations are motorway sections of which 57 are PPPs. The sample also contains 6 large fixed-link projects, which normally include a length of associated road. The average length of road sections is 28.1 km.

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 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.

A plot of the dependent variable, split into the PPP and non-PPP sub-samples, is shown in Figure 1. To further illustrate the dependent variable, Figures 2 and 3 show histograms of the dependent variable (log of unit construction costs) in the two sub-samples. The PPP sub-sample includes more large values. This is reflects the fact that PPP is often used for more complex projects and also that the sample includes a number of large fixed link

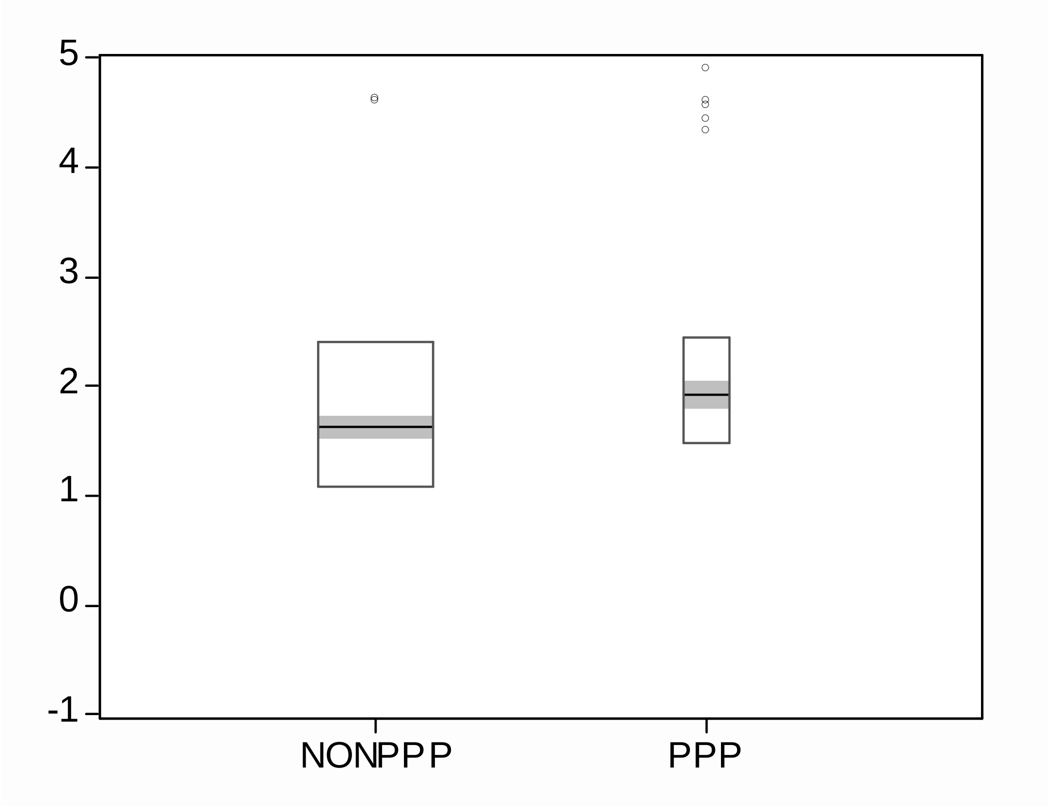
[4] The sample is taken from a larger database of 304 road sections, which also includes rehabilitation and upgrade projects.

[5] Road construction contracts are split depending on the size and scope of works into "Lots" or individual sections for which contractors provide separate prices. In the case of PPPs, a number of lots may be bundled into a single contract, but the individual lots are usually priced as part of the tender procedure. The Bank uses the cost of these individual road sections as the basis for its cost benefit analysis.

[6] There is certain heterogeneity of contract form within the non-PPP data. Discussions with roads sector specialists familiar with the projects confirm that the vast majority are either FIDIC Red Book type contracts, based on a reference design and unit rates, or FIDIC Yellow Book type contracts for design-build. The Fédération Internationale des Ingénieurs Conseils (FIDIC) is the leading body for the development of model standard forms of contract for use in the international construction industry. FIDIC publishes a range of standard forms of contract referred to by their colour. Both red and yellow book contracts have balanced risk sharing and provide fair procedures for administration of contracts. Red is a traditional ad-measurement contract based on a reference design. Yellow book contracts are design-build type contracts with the contractor responsible for final design.

projects developed as PPPs. We control for such large values in the different specifications of our unit cost model (see 3.4, robustness checks).

Figure 1. Distribution of the dependent variable (log construction costs per kilometre of road), in millions of 1999 €



Note: The boxes represent the mid-50% of observations. The line shows the sub-sample median values. The dots show outlier observations.

Figure 2. Histogram of the dependent variable, PPP sub-sample

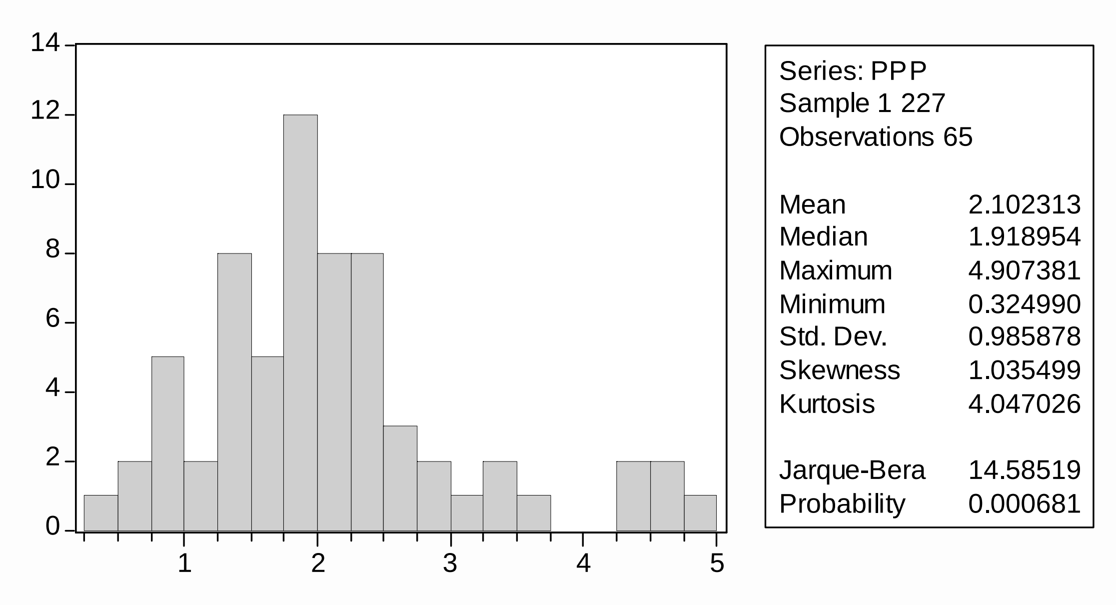
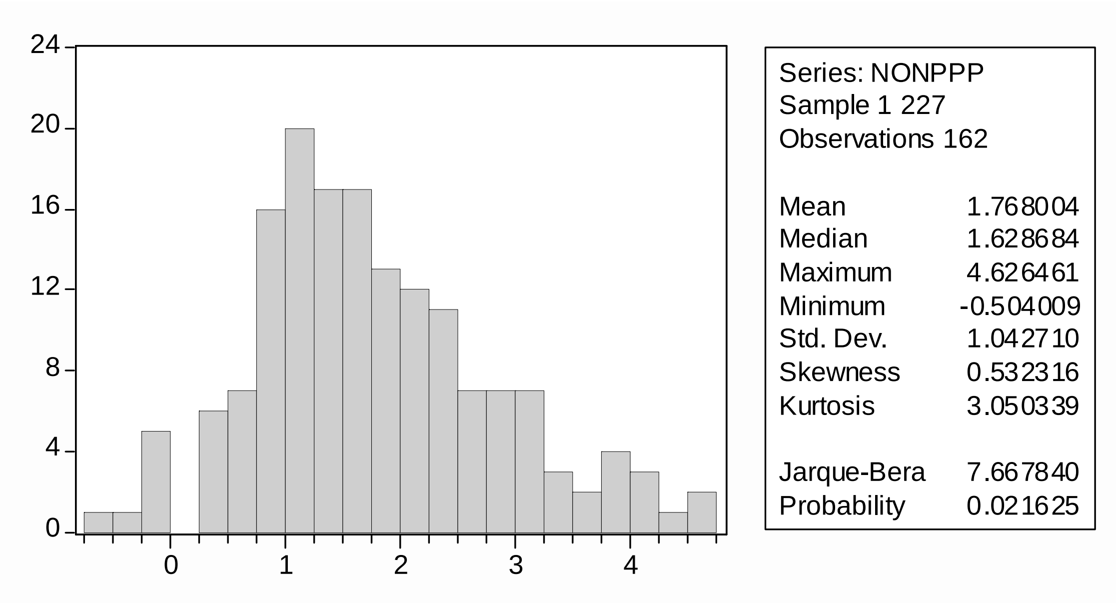


Figure 3. Histogram of the dependent variable, non-PPP sub-sample



Figures 2 and 3 suggest that PPP projects are indeed more expensive in terms of unit construction costs, with the mean (median) for the PPP sub-sample some 19 per cent (18 per cent) above that for the other projects, although this is in part explained by the higher proportion of PPPs in the motorway sub-sample[7].

For the purpose of robustness testing the full sample is divided into 8 partly overlapping sub-samples. In addition to the full sample, we estimate the model for motorways only, both with and without fixed link projects. Within the full sample and the motorway sub-sample, we run the estimation also with the following sub-samples:

- Including only projects whose total value is not below €20 million or above €300 million;
- Including only observations with the value of the dependent variable within 1.5 standard deviations from the sample mean[8];
- Including only observations from countries that had both PPPs and traditionally procured road projects in our sample.

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 8 samples can be found in Appendix 2 Tables A1-A8. Note that in the detailed tables we show all estimated coefficients for the economic and technical explanatory variables even when they turn out insignificant. We do this because the significance of the coefficients for two or three technical variables varies from one sample to another. Besides, dropping the insignificant economic and technical variables would not change the estimation results for the PPP dummy materially.

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 percent

[7] Motorways are more expensive in unit cost terms; the mean (median) is 9 (8) per cent higher for the motorway sub-sample.

[8] This also has the effect of eliminating all fixed-link projects from the sub-sample.

level in any specification. In other words, unit construction costs are higher for PPPs than 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 (*i.e.*, including motorways and non-motorway roads, Tables A1 – A4), we note that the parameters have their expected signs, but that the dual carriageway dummy and the 2-lane dummy are not robustly significant. The single carriageway dummy is significant and negative. Roads with 6 lanes are more expensive than roads with fewer lanes (2, or 4)[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 (Tables A5 – A8) the technical explanatory variables behave similarly. Two-lane motorways are relatively cheaper to construct, while 6 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, among other things, to a need to displace utilities and other additional costs of working in a dense urban environment. Mountainous terrain does not seem to affect construction costs significantly (the coefficient is insignificant throughout), as 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 turn out positive and significant in all specifications.

Country dummies 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 supplies, national

[9] The omitted dummy in this case is a 4-lane standard motorway, which acts as a benchmark.

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

Turning to the estimated magnitude of the PPP dummy coefficient, Table 1 summarises key characteristics of the estimation results for the various sub-samples. The column "N" shows the number of observations in each sub-sample; the column "PPP coefficient" shows the estimated value of the coefficient for the PPP dummy; the column "Adjusted R2" is self-evident; and the last column indicates that only in the last sub-sample does diagnostic testing raise some concern.

[10] We also tested the significance of a dummy variable denoting privatised motorway operators in Italy and Portugal and found the estimated coefficient 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 1. Summary of estimation results

Sample	N	PPP coefficient	Adjusted R2	Diagnostics
Motorways				
full sample	156	0.29	0.74	OK
Total cost (20, 300) Eur million	117	0.33	0.76	OK
Dependent variable w/in 1.5 stdev	138	0.29	0.64	OK
Only countries with both PPP and trad projects	120	0.23	0.77	1/
All roads				
full sample	227	0.31	0.82	OK
Total cost (20, 300) Eur million	168	0.33	0.80	OK
Dependent variable w/in 1.5 stdev	201	0.27	0.69	OK
Only countries with both PPP and trad projects	175	0.28	0.79	OK

1/ There is evidence of residual non-normality at 5% level.

As shown in Table 1, the coefficient for our key variable, the PPP dummy, 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 percent.

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 8 sub-samples in Table 1 to estimate a model specification with all economic and technical explanatory variables as well as all country dummies (bar one to avoid the dummy trap) regardless of their significance, and we also estimate another specification including only the economic and technical explanatory variables, thus dropping all country dummies.

As a further robustness test, we eliminate all fixed-link projects from each sub-sample. Fixed-links projects have a very high proportion of bridge or tunnel 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 models were therefore estimated with no fixed-links and no observations where the tunnel or bridge proportion is greater than 50 percent of the length. It should be noted that the model including only observations within 1.5 standard deviations from the sample mean (Table A7) automatically excludes the fixed links due to their high unit costs.

Table 2 summarises the estimated coefficient for the PPP dummy in these specifications for all sub-samples. We see that the estimated coefficient for the PPP dummy stays in the range 0.23 – 0.38 regardless of the model specification. However, the unrestricted specification and the specification without any country dummies 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 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 3.[11]

- The OLS residuals appear normally distributed, with the Jarque-Bera test unable to reject the null hypothesis of normality at 10 percent level for any sub-sample, except the one indicated in Table 1.
- The White test cannot reject the null of no heteroskedasticity at 10 percent 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 appears thus well specified, and the R^2 exceeds 60 percent for all sub-samples.

[11] We do not present any test results for serial correlation in residuals, as our sample consists of cross-section data and serial correlation is thus dependent on the ordering of the observations. We have run Durbin-Watson and higher-order Lagrange multiplier tests for different ordering of the observations and found ways to order them so as to eliminate any serial correlation.

Table 2. The estimated coefficient for the PPP dummy across sub-samples and model specifications

Sample	Country dummies: Only significant ones included 1/	Country dummies: Unrestricted specification 2/	Country dummies: None included	Fixed links 3/: N	Fixed links 3/: 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 stdev	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 stdev	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 dummies except one.
3/ Defined as projects comprising > 50% bridges or tunnels.
4/ Estimate of the coefficient for the PPP dummy excluding fixed links, using the specification with the significant country dummies.

Table 3. 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 stdev	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 stdev	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.
3/ Should be < 30 for unlikely collinearity among explanatory variables.

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, 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 nature and hence of different cost structures. Besides, Flyvbjerg (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.

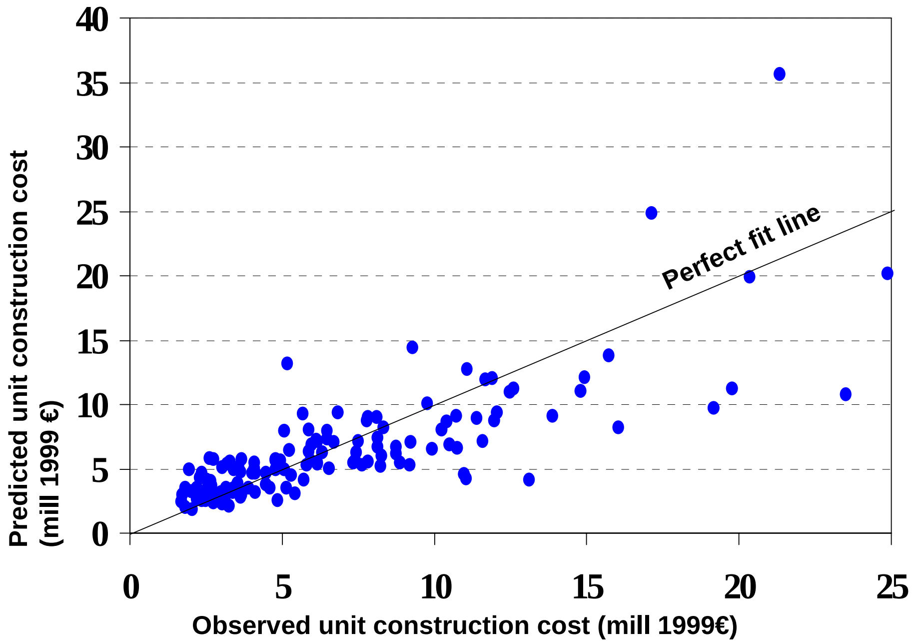
Thus, the preferred sample contains motorway projects only, with no fixed links. The results reported in Table A7 refer to such a sample, which has further more been subjected to diagnostic testing (Table 3). The model coefficients have the expected sign and their magnitudes are plausible. Because of the way 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 kilometres 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 per kilometre (in 1999 prices). This value compares well with international standards seen by the EIB[12]. The same motorway built in an urban context is 42 percent more expensive. A 6 lane motorway is 33 percent more expensive. A similar motorway with 10 percent of its length in tunnels is 23 percent more expensive.

Figure 4 depicts the goodness-of-fit of the preferred model, with the actual observations on unit construction costs on the horizontal axis and the unit construction costs predicted by the model on the vertical axis. If the model were a perfect description of reality, all

[12] 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 2x2 UK motorway in rural, non-mountainous terrain with a normal level of structures. A commonly cited benchmark for traditionally procured EU motorways is 5 million euros/km.

dots would lie on the 45-degree line. As Figure 4 shows, the fit of the model is good for unit costs up to €15 million (in real 1999 terms) but worsens for higher unit costs, suggesting that there are other factors driving very high unit costs that are not captured by our model.

Figure 4. Observed and predicted unit costs from the preferred model



4. Correction for a systematic bias in the data

As reported in Table 2, the range of estimates of the coefficient on the PPP dummy 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 is 0.29. The point estimate of 0.29 would translate into a semi-elasticity of 34 percent (see end of section 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 suffers 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 agreed contract price. To this estimate the Bank adds technical and price contingencies, which can vary from 5 to 15 percent, 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 BAFO stage[13]. The recorded construction cost estimate is based on the price of the EPC 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 works start on site. Based on the technical contingencies assumed at the moment of appraisal for a sample of projects, an interval estimate of this bias is [5, 15] percent, with a point estimate of 10 percent. While this estimate is judgemental in character, it is based on the best available professional judgement of EIB project appraisal teams.

[13] At Best and Final Offer (BAFO) stage, there are usually two identified preferred bidders who must give their final price to win the contract.

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 percent semi-elasticity of the PPP dummy variable, the point estimate is 24 percent. An interval estimate, allowing for deviations from the mean of one standard deviation, would cover the range [18%, 29%], and a very rough 95 percent confidence interval would cover the values 24 percent plus/minus 10 percentage points.

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 percent. 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 percent.

5. Interpretation of the results

We have estimated that, on average, the *ex ante* construction cost of a European road is 24 percent higher if the road is procured as a PPP rather than through traditional public procurement, all other things 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 transferred to the private sector partner. In addition, the PPP could also represent more mundane factors, such as the recovery of higher bidding costs[14] by contractors; lower competition in the PPP market[15]; or even corruption in the award of PPP contracts.

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[14] 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 percent of construction costs. For EU roads sector PPPs, average bid costs for the winning bidder are about 3 percent, but that this includes costs in addition to the construction consortium costs such as the high cost of financial/legal advisors.

[15] 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 contractors tend to prefer traditional procurement to PPPs, as the latter reduces the standard pipeline of contracts that the industry relies on.

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

To start with, 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 (2002) found average cost escalation during construction of 28 percent overall and significant differences between sectors and regions. For the EU roads sector he found an average cost escalation of 22 percent. For large capital projects (greater than €150 million) across different sectors, Mott MacDonald (2002) identified an average cost escalation from the date of contract award of 21 percent.

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 in traditional public procurement and the (median) increase 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. A corollary of this proposition is that the *ex post* construction costs of a PPP road and a traditionally procured public road would not be expected to differ by a wide margin.

Consequently, 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 as required under the contract then the public sector pays less. 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. HM Treasury (2003) reports that 88 percent of Private Finance Initiative (PFI) schemes were built on time or early, compared to only 30 percent of traditionally procured projects, and that changes to the unitary charge only occurred in 21 percent of PFI projects, whereas 72 percent of traditionally procured projects experienced cost overruns. The performance of the PFI roads sector was particularly impressive, with 100 percent 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 public 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

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

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 causing 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 weaker accountability in the event of cost overruns.

Even when the 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 PPP to be economically superior to traditional public 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 estimates quoted above are representative for 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 clearly higher than the observed optimism bias in traditional public procurement.[17]

[17] 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, a DBFO motorway project in Greece was built to a higher standard than 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 maybe linked more to design options involving very limited additional costs and to greater attention to quality during construction than to significant upfront additional investment. Higher upfront capital investment costs have a larger weighting in the discounted cash flow of the project. Thus, in practice, net cost increases due to the whole-life cost optimisation are unlikely to be very significant.

Other possible sources of the *ex ante* construction cost difference than those listed above (higher transaction costs, lack of competition, even corruption) are possibly important in some individual PPP projects; however, our analysis suggests that at the level of averages they do not play a significant role in raising PPP construction costs above those in traditional public procurement of roads. Again, if that were the case, we would observe a difference well in excess of the observed optimism bias in traditional public procurement.

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.

6. Conclusions

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

The estimated difference in *ex ante* construction costs of 24 percent is of a similar magnitude as the cost overruns 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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Appendix 1: Modified version of the model in Hart (2003) to compare construction costs in traditional public procurement to those in a PPP.

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

(1) $$Max\pi = P_C - C_C$$

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:

(2) $$B_O - C_C - C_O$$

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:

(3) $$Max\pi = P_B - (C_C + i + e) - (C_O - b(i) - \beta(e))$$

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

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

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

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

(5) $$B_O + a(i^*) - \alpha(e^*) - P_B = B_O + a(i^*) - \alpha(e^*) - [C_C + i + e + C_O - b(i^*) - \beta(e^*)]$$

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.

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.

(6) $[a(i^*) - \alpha(e^*)] + [b(i^*) + \beta(e^*)] > i + e$

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.

Appendix 2: Estimation results

Table A1. Estimation results for all roads (full sample)

	Coefficient	Prob.
(Constant)	1.432	0.000
PPP	**0.313**	0.000
Labour	0.043	0.000
Dual carriageway dummy	-0.101	0.239
Single carriageway dummy	-0.415	0.097
2 Lanes	-0.504	0.032
6 Lanes	0.401	0.000
Urban Terrain	0.331	0.001
Mountain Terrain	0.129	0.301
Log(length)	-0.241	0.000
Tunnel/road	0.019	0.000
Bridge/road	0.017	0.000
N	227	
Adjusted R2	0.82	

Note: Significant country dummies included in the estimation include Denmark, Finland, Germany, Ireland, Italy the Netherlands, Norway, Spain, Sweden, and the UK.

Table A2. Estimation results for all roads, including only projects worth between €20 and €300 million

	Coefficient	Prob.
(Constant)	2.196	0.000
PPP	**0.330**	0.000
Labour	0.024	0.000
Dual carriageway dummy	-0.172	0.049
Single carriageway dummy	-0.564	0.039
2 Lanes	-0.302	0.215
6 Lanes	0.278	0.012
Urban Terrain	0.294	0.002
Mountain Terrain	-0.100	0.464
Log(length)	-0.407	0.000
Tunnel/road	0.015	0.000
Bridge/road	0.011	0.000
N	168	
Adjusted R2	0.80	

Note: Significant country dummies included in the estimation include Denmark, the Netherlands, Norway, and Spain.

Table A3. Estimation results for all roads, including only observations with the dependent variable within 1.5 standard deviations from the full sample mean

	Coefficient	Prob.
(Constant)	1.855	0.000
PPP	**0.268**	0.000
Labour	0.016	0.023
Dual carriageway dummy	-0.090	0.302
Single carriageway dummy	-0.245	0.305
2 Lanes	-0.443	0.042
6 Lanes	0.329	0.001
Urban Terrain	0.177	0.049
Mountain Terrain	-0.027	0.818
Log(length)	-0.165	0.000
Tunnel/road	0.019	0.000
Bridge/road	0.017	0.000
N	201	
Adjusted R2	0.69	

Note: Significant country dummies included in the estimation include Denmark, Finland, Norway, Portugal, Spain, and Sweden.

Table A4. Estimation results for all roads, including only observations in countries with both PPP and traditionally procured road projects

	Coefficient	Prob.
(Constant)	0.517	0.074
PPP	**0.280**	0.001
Labour	0.054	0.000
Dual carriageway dummy	-0.082	0.388
Single carriageway dummy	-0.813	0.017
2 Lanes	-0.092	0.773
6 Lanes	0.337	0.001
Urban Terrain	0.283	0.004
Mountain Terrain	0.061	0.625
Log(length)	-0.187	0.000
Tunnel/road	0.021	0.000
Bridge/road	0.018	0.000
N	175	
Adjusted R2	0.79	

Note: Significant country dummies included in the estimation include France, Greece, Portugal and the UK.

Table A5. Estimation results for motorways

	Coefficient	Prob.
(Constant)	1.310	0.000
PPP	**0.293**	0.001
Labour	0.021	0.000
2 Lanes	-0.915	0.011
6 Lanes	0.389	0.001
Urban Terrain	0.567	0.000
Mountain Terrain	0.109	0.440
Log(length)	-0.159	0.002
Tunnel/road	0.021	0.000
Bridge/road	0.027	0.000
N	156	
Adjusted R2	0.74	

Note: The specification with significant country dummies does not pass diagnostic tests.

Table A6. Estimation results for motorways, including only projects worth between €20 and €300 million

	Coefficient	Prob.
(Constant)	2.430	0.000
PPP	**0.331**	0.001
Labour	0.006	0.313
2 Lanes	-0.531	0.261
6 Lanes	0.316	0.008
Urban Terrain	0.393	0.002
Mountain Terrain	-0.020	0.903
Log(length)	-0.421	0.000
Tunnel/road	0.017	0.000
Bridge/road	0.025	0.000
N	117	
Adjusted R2	0.76	

Note: Significant country dummy included in the estimation includes Sweden.

Table A7. Estimation results for motorways, including only observations with the dependent variable within 1.5 standard deviations from the motorway sample mean

	Coefficient	Prob.
(Constant)	1.426	0.000
PPP	**0.285**	0.000
Labour	0.029	0.000
2 Lanes	-0.858	0.004
6 Lanes	0.286	0.003
Urban Terrain	0.356	0.002
Mountain Terrain	0.103	0.436
Log(length)	-0.178	0.000
Tunnel/road	0.020	0.000
Bridge/road	0.031	0.000
N	138	
Adjusted R2	0.64	

Note: Significant country dummies included in the estimation include Denmark, Germany, Norway and Spain.

Table A8. Estimation results for motorways, including only observations in countries with both PPP and traditionally procured motorway projects

	Coefficient	Prob.
(Constant)	1.161	0.000
PPP	**0.232**	0.006
Labour	0.035	0.000
6 Lanes	0.359	0.001
Urban Terrain	0.386	0.002
Mountain Terrain	0.129	0.329
Log(length)	-0.130	0.010
Tunnel/road	0.024	0.000
Bridge/road	0.026	0.000
N	120	
Adjusted R2	0.77	

Note: Significant country dummies included in the estimation include Germany and Spain.

Note: Specification only passes diagnostic tests if the dummy for 2 lanes is dropped and the dummy for Germany, even though insignificant at 10% level, is included. Even so, the Jarque-Bera test suggests non-normality of residuals at 5% level.