An assessment of the waste effects of corruption on infrastructure provision through bootstrapped DEA approach

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Abstract.
In this paper we investigate the association between the efficiency of infrastructure provision and the level of corruption, in the province in which the infrastructure takes place, employing a large data set on Italian public works contracts. We, first, estimate efficiency in public contracts execution using a smoothed DEA bootstrap procedure that ensures consistency of our estimates. Then, we evaluate the effects of corruption using a semi-parametric technique that produces a robust inference for an unknown serial correlation between efficiency scores. In order to test the robustness of our results, the parametric stochastic frontier approach has also been employed. The results from both nonparametric and parametric techniques show that greater corruption, in the area where the infrastructure provision is localised, is associated with lower efficiency in public contracts execution.

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1. Introduction

Corruption is recognised as being a major problem affecting all countries in the world, though to a different extent. Several studies investigate the negative effects of corruption on economic growth (Mauro, 1995), on financial markets (Guiso *et al.,* 2000) and on the accountability of institutions (Hunt, 2005; Hunt and Laszlo, 2005). This view is also supported by the reports of international organisations such as, IMF, OECD or the World Bank, suggesting corruption as a major obstacle to economic development. Such a negative role of corruption may be tested using "the sand the wheels" hypothesis simply stating that the costs of corruption make it very difficult to foster economic growth especially in a weak institutional context.

However, according to some scholars, corruption may positively affect economic systems (Leff, 1964; Leys, 1965; Huntington, 1968). These authors suggest that corruption may exert positive effects on economic development, leaving aside any moralistic judgements on it. The line of reasoning is that corruption may be able to solve the problem of bureaucracy inefficiency and bad public policies, being these barriers to economic development. This point of view has been tested using "the grease the wheels" hypothesis (Mauro, 1995; Ades and Di Tella, 1997; Méon and Sekkat, 2005; Méon and Weil, 2010). Opponents of this line of reasoning argue that to evaluate the effects of corruption empirically "institutions matter" (Aidt, 2009). From an empirical point of view, this means that in order to assess the effect of corruption one has to recognise its endogeneity with respect of institution.

Besides the different points of view on the effect of corruption, it is well known that most, if not all, activities run by the public sector may be affected by corrupt behaviour of public servants. Procurement activities are especially prone to corruption phenomenon, as many international agencies stress. A recent analysis provided by Transparency International (2006, p. 15) outlines that "Corruption in public procurement can happen in many different ways. These range from the most common form of upfront bribery and facilitation payments to more subtle forms of political corruption".

This paper contributes to the literature on the effects of corruption on infrastructure provision using a large microeconomic database on Italian public works contracts for roads and highways in the period 2000-2005. Moreover, unlike previous empirical studies on the efficient management of public works which rely on aggregate data (Golden and Picci, 2006), we use microeconomic data to examine whether the environmental characteristics (*i.e.*, in particular the corruption level), in the area where the infrastructure provision is localised, affect the efficient management of the public work contract in terms of delays and cost overruns. For this purpose a two-stage analysis is carried out. In the first stage, a non-parametric approach (Data Envelopment Analysis - DEA) investigates the relative efficiency scored by each single public work execution. In the second stage, the determinant factors of the scores variability are investigated, paying attention on the effect exerted by corruption. Instead of using subjective corruption indexes we use two objective measures of corruption at provincial level: the number of crimes against public administration and the measure of corruption in Italy's provinces proposed by Golden and Picci (2005) obtained by comparing the value of existing infrastructure stocks to past infrastructure spending. Our results show that greater corruption, in the area where the infrastructure is localised, is associated with lower efficiency in public contracts execution. As a robustness test of nonparametric findings we compare them with those computed through a parametric approach using Stochastic Frontier Analysis (SFA).

The analysis develops as follows: we review the main literature in Section 2 and, then, in Section 3 we present the methodological framework and data. In Section 4, we provide technical efficiency estimates for public works contracts whereas the analysis of the determinants is developed in Section 5. Finally, Section 6 offers some concluding remarks.

2. Sand vs. Grease the Wheels hypotheses

2.1. A general overview

International organisations such IMF, OECD, and World Bank support the view

that corruption represents a big hurdle to economic growth. Several empirical works focusing on the negative economic consequences of corruption have confirmed this opinion. In many cases, the negative correlation between costs of corruption and the economic development has been found by testing for the sand the wheels hypothesis. It implies that corruption may be detrimental to the economic performance of countries characterised by weak institutional contexts. For instance, civil servants may cause delay in the provision of public goods to make citizens offering bribes to speed up bureaucratic procedures (Myrdal, 1968; Kurer, 1993). When a new licence has to be assigned, corruption may lower the probability that the winner is the most efficient competitor. For example, he may decrease the quality of the goods or services to be provided given that a portion of his resources have been already wasted to bribe those who award the licence (Rose-Ackerman, 1997). Also corruption is found to negatively affect the efficiency of public investment, being diverted towards unproductive sectors (Mauro, 1995; Mo, 2001). Méon and Sekkat (2005) find that corruption negatively affects growth independently from its impact on investment. However, these effects worsen when the quality of governance deteriorates. Finally, when the political and institutional context appears uncertain, corruption may be seen as an insurance against risks. However, corruption itself is an illegal agreement very difficult to secure. Thus, the uncertainty due to corrupt acts may just add to that caused by political instability enhancing its negative effect on the efficiency of the economic system (Bardhan, 1997; Lambsdorff, 2003). Hence, corruption seems to impose higher costs in the institutional context than those usually related with the production process, providing a rationale for the sand the wheels hypothesis.

The measurement of the cost of corruption is a difficult and risky task with elusive results. The investigation of such a complex issue is outside the scope of this paper: it may be interesting, however, to recall that according to the World Bank such a cost can be estimated as the 3% of GDP[1]; for the World Economic Forum (2011) the overall cost of corruption reaches more than 5% of global GDP. Such an estimate, however, is likely to be conservative since it does not take into account the negative long-term costs deriving by the decreasing trust for

[1] See Kaufmann *et al.*, (2006).

institutions, the lower competitiveness and the reduced of attractiveness for foreign investments, just to mention the most relevant ones. Moreover, the impact of corruption on income inequality cannot be disregarded. As reported by OECD (2013), the World Bank estimates that each year 20% to 40% of official development assistance is misplaced from public budgets.

By contrary, some scholars pointed out the beneficial effects of corruption on boosting development. This point of view can be rooted in the work of Leys (1965) reporting that corruption can speed up bureaucrats in the establishment of new firms. On the same line of reasoning, Lui (1985) shows that corruption represents an efficient way to decrease the time wasted dealing with civil servants. The positive effects of corruption can also be seen when a licence has to be assigned. Leff (1964) suggests that awarding a licence in a corrupt environment resembles a competitive auction, where the winner is the most generous briber with strong incentive to use the licence efficiently. Also corruption may be able to control for the negative effects of inefficient regulations or bad public policies (Bailey, 1996). Recently, Méon and Weil (2010) have tested for the grease vs. sand the wheels hypotheses on data from both developed and developing countries and found no evidence of the latter but significant evidence of the former. Thus, corruption seems to be less detrimental in countries where the institutional framework is weaker. Summing up, the grease the wheels hypothesis is based on the idea that corruption may positively affect the productivity of an economic system counterbalancing the inefficiency of the governance.

Finally, it is important to put forward that both hypotheses state that corruption negatively affect economic performance when the institutional framework is efficient. They differ only in the case of inefficient institutional framework suggesting negative (sand) versus positive (grease) effects of corruption on efficiency.

2.2. Corruption and procurement

The relationship between corruption and procurement has been widely investigated from many perspectives and generates several problems. As

Transparency International (2006) points out, the risk of corruption can occur on the various phases of the public procurement cycle, generating different problems: when the demand is assessed, when the process design and the bid documents are prepared; when the contractor is selected and the contract awarded; when the contract is implemented, and when final accounts are certified.

In designing procurement institutional features a trade-off might exist between efficiency objectives and anti-corruption measures; for instance, speeding up the procurement process might require to reduce the time for publication and evaluation in the phase of the contractor selection. The beneficial effects of transparency are stressed by Ohashi (2009) who finds that a transparent procurement procedure weakens the relationship between the officials and firms, and causes a reduction of approximately 8% in the value of winning bids on the supply side.

In the literature, the effects of corruption on the phase of selection have attracted attention. Tran (2008) finds that different types of auctions exert different effects on corruption: open and non-discretionary auctions can significantly reduce corruption, but at some cost to allocative efficiency.[2] Celentani and Ganuza (2002) suggest that the negative association between competition and corruption should not be taken for granted and that the increase in competition in procurement does not necessarily imply the reduction of corruption.

This phenomenon has also been theoretically applied to the assignment of government procurement contracts by Beck and Maher (1986) and Lien (1986) showing that the ranking of corrupt bidders and efficient firms are isomorphic since the most efficient firms are able to pay higher bribes.

As Transparency International (2006) stresses, execution and final accounting phases are just as vulnerable to corruption as the previous phases. Cost overrun is one of the 'red flags' related to the execution of public works contracts[3] and its

[2] Best-value auctions do not reduce corruption and even increase it if buyers could select which vendors to solicit; instead, best-price auctions decrease corruption since they limit officials' discretion in evaluating bids. With respect to Italy, the risk of corruption related to the different types of auctions is investigated by De Carolis *et al.* (2011)

[3] Flyvbjerg et al. (2003) report that some cost overruns occurred in almost 90% of projects in transport infrastructure in 20 developed and developing countries worldwide; Alexeeva *et al.* (2008) show that, in developing countries, public road contracts experienced cost overruns by

widely investigated in the literature (Flyvbjerg *et al*., 2003; Ganuza, 2007), though it is hard to assess whether extra-costs are indicators of inefficiency or of corruption.

Notwithstanding the wide interest for the occurrence of corruption in procurement, its measurement in the various phases is still in its infancy and, therefore, empirical analysis has to rely on aggregate indicators.

3. Methods and Data

3.1 *Methods*

In this study we focus on the technical efficiency of public works execution, comparing the actual performance in the execution of each public work contract with the optimal performance of public work contracts located on the best practice frontier (Guccio *et al.,* 2012a). This approach is based on the efficiency measures proposed by Koopmans (1951) and Debreu (1951), and empirically applied by Farrell (1957).

The analysis relies on the estimation of an empirical frontier based on observed behaviour and the efficiency can be estimated as a distance from the best practice frontier. However, the technically feasible production frontier is unknown and an empirical approximation is needed. Efficiency frontiers can be estimated by applying two main analytical approaches: parametric frontier and non-parametric frontier[4].

The first approach adopts the Stochastic Frontier Analysis (SFA). Aigner *et al.,* (1977) and Meeusen and van den Broeck (1977) have provided the foundation for the SFA with an error model composed of inefficiency and statistical noise, both of which are unobservable.[5]

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more than 20 %; Bajari *et al.* (2006) estimate that cost overruns were about 10% in California highway contracts.

[4] For more details on parametric and non-parametric approaches to frontier efficiency estimation see among the others: Cooper *et al.*, (2007), Fried *et al.* (2008).

[5] In a cross-sectional setting, Jondrow *et al.,* (1982) derived an estimation of one-sided residuals, interpreted as inefficiency scores, which permitted the estimation of inefficiency for individual units. More recently, the assumption of time-invariant efficiency has been relaxed by developing appropriate panel data models. For an extensive survey of parametric methods: Kumbhakar and Lovell (2000); Greene (2008).

The second approach, largely employed here, can be traced back to the pioneering work of Charnes *et al.*, (1978) that generalized Farrell's single input/output measure to a multiple-input/multiple-output technique. This approach measures the productive efficiency by definition of a frontier envelopment surface for all sample observations using linear programming techniques. Data Envelopment Analysis (DEA) and Free Disposal Hull (FDH) are among the most known and applied non-parametric techniques for the measurement of efficiency.

In this paper we apply the DEA non-parametric frontier mathematical programming method for the measurement of the efficiency. By constructing envelopment unitary isoquants corresponding to comparable DMU (Decision Making Unit) across different situations, DEA identifies as productive benchmarks those DMUs that exhibit the lowest technical coefficients, i.e. lowest input amount to produce one unit of output. In doing so, DEA allows for the identification of best practices and for the comparison of each DMU with the best possible performance among the peers, rather than just with the average. Once the reference frontiers have been defined, it is possible to assess what would be the potential efficiency improvements available to the inefficient DMUs if they were to produce according to the best practice technologies of their benchmark peers. From an equivalent perspective, these simulations identify the necessary changes that each DMU needs to undertake in order to reach the efficiency levels of the most successful DMU.

As illustration of DEA, let us consider n DMUs to be evaluated, a DEA input-oriented efficiency score θ_i is calculated for each DMU solving the following program, for $i=1,\ldots, n$, in the case of constant returns to scale (CRS):

$$\begin{aligned} &\text{Min}_{\lambda,\theta_i} \quad \theta_i \\ &\text{subject to } Y\lambda - y_i \geq 0 \\ &\qquad \theta_i x_i - X\lambda \geq 0 \\ &\qquad \lambda \geq 0 \end{aligned} \qquad [1]$$

where x_i and y_i are, respectively, the input and output of *i-th* DMU; $\boldsymbol{X}$ is the matrix of inputs and $\boldsymbol{Y}$ is the matrix of outputs of the sample; λ is a $n\times 1$ vector of variables. The model [1] can be modified (Banker *et al.,* 1984) to account for

variable returns to scale (VRS) by adding the convexity constraint: $e\lambda=1$, where e is a row vector with all elements unity, which allows to distinguish between Technical Efficiency (TE) and Scale Efficiency (SE).

DEA is among the most known and applied non-parametric technique for the measurement of efficiency public sector activities. The reasons of this widespread use of DEA are summarised as follow: it is capable of handling multiple inputs and outputs without a priori assumptions of a specific functional form on production technologies; it does not require a priori a relative weighting scheme for the input and output variables; it returns a simple summary measure for the efficiency of each DMU, and it identifies the sources and amounts of relative inefficiency for each DMU. Notwithstanding their large use, DEA estimators have received some criticism since they rely on extreme points, and they could be extremely sensitive to data selection, aggregation, model specification, and data errors. Nevertheless, recent literature has shown that it is possible to define a statistical model allowing for the determination of statistical properties of the non-parametric frontier estimators (Simar and Wilson, 2008).

To account for DEA limitations, which do not allow for any statistical inference and measurement error, Simar and Wilson (1998, 2000) introduced a bootstrapping methodology to determine the statistical properties of the DEA estimators. Thus, to overcome traditional DEA limitations and to provide a robustness check of our findings, we employ in the first stage the bootstrapping approach that allows us to investigate bias, variance, and confidence intervals of the attained efficiency scores and to get unbiased efficiency rankings.

As illustrated in Section 1, in the second step we investigate the impact of environmental variables (or non-discretionary inputs) on public work contracts technical efficiency and, in particular, we try to assess the relation between the specialisation of the contracting authority and the DEA efficiency scores obtained in the first stage.

We perform the second-stage analysis running a regression with the efficiency scores as dependent variable and the environmental variables as the independent

ones[6]. Thus, we assume that the efficiency scores can be regressed on a vector of environmental variables in the following general specification:

$$\theta_i = f(z_i)+\varepsilon_i \qquad [2]$$

where θ_i represents the efficient score that resulted from previous stage, z_i is a set of possible non-discretionary inputs and ε_i is a vector of error terms.

However, there is no general consensus on the best method to apply to second-stage DEA analysis: two distinct rationalisations have recently been proposed in the literature that are based on different assumptions for the DEA-score data generating process and sample variation (Banker and Natarajan, 2008 Simar and Wilson, 2007; 2011).

The two-step bias-corrected semi-parametric estimator proposed by Simar and Wilson (2007) ensures a feasible and consistent inference on the parameters for estimation in the second stage of the regression[7]. Nevertheless, recently Banker and Natarajan (2008) proposed statistically consistent estimator for the two-stage procedure, which involve nonparametric estimation of productivity in the first stage followed by OLS regression. However, Simar and Wilson (2011) show that Banker and Natarajan (2008) estimator depends on quite restrictive assumptions for the production process.

In our empirical investigation, we are interested in testing the impact of environmental variables suggested by the literature on public work contracts execution technical efficiency. As argued by Simar and Wilson (2011), the approach proposed by Simar and Wilson (2007) produces a robust inference with an unknown serial correlation between efficiency scores and ensures a feasible, consistent inference for the parameters estimated in the second stage of the regression. Moreover, in Sect.5, second stage parametric techniques (Banker and Natarajan, 2008) and the parametric stochastic frontier approach will be applied to test the robustness of our findings.

[6] An alternative approach would be to include as many environmental variables as inputs when estimating the efficiency frontier (Banker and Morey, 1986).

[7] Moreover, Simar and Wilson (2007) show that estimating [2] with Tobit leads to the violation of the assumption of the independence between ε_i and z_i.

3.2 Data

We apply the above-mentioned estimation technique on a large sample of 3,113 Italian public works contracts for roads and highways, whose engineering estimated costs[8] range from 150,000 euros to 5 million euros, awarded in the period 2000-2004 and completed by 2005.

The Italian system of public work procurement represents a good example for our investigation because of its inefficiency levels characterised by huge delay and cost overruns, that are usually regarded as one of the reasons for the present under-provision of infrastructures (Banca d'Italia, 2011) and because it is not immune to corruption, collusion and bribery[9].

The analysis builds on the database of the Italian Authority for Public Contracts "*Autorità di Vigilanza sui contratti pubblici di lavori, servizi e forniture*" (hereafter, AVCP). The observation unit is given by the single public work and several further details are available on the various steps of the procedure – project, selection of the contractor, execution and conclusion. Table 1 provides the distribution of the contracts included in the sample, by class of reserve price.

- TABLE 1 around here –

In the period under consideration, the relevance of inefficiency in the execution of public works in Italy has been very high. For instance, several investigations conducted by AVCP (2005, 2007) for all the public works carried out in Italy show that delay and cost overruns have badly affected contracts execution. Table 2 reports the results of a study conducted in 2007 on a sample of 31,982 public work contracts, with reserve price above 150,000 euros (AVCP, 2007). For this

[8] Engineering estimated costs are used as reserve price in tendering procedures.

[9] The Italian procurement system, during the last 20 years, has been subject to continuous changes "to improve the efficiency, the effectiveness, the transparency and the quality of public works", *e.g.,* the so-called *legge Merloni* (Law 11/2/94, no. 109, art.1). More recently, new rules have been devised and a law was passed (*Codice dei contratti pubblici di lavori, servizi, forniture*) which transposes the EU Directive no. 2004/18/CE on the coordination of procedures for the award of public works, public supply and public service contracts into the Italian legislation.

sample, only 8,023 contracts have been completed without cost overruns (25.09%), whereas 7,235 have not experienced any delay (22.62%).

- TABLE 2 around here –

This data set has been used for the first stage of the analysis to compute the efficiency scores of infrastructures provision on the same line of Guccio *et al.,* (2012a). The authors measure the efficiency of execution of public work contracts using the following production function specification: actual time of completion and actual cost are regarded as inputs, and planned time of completion and agreed cost as outputs. Table 3 reports the description of the variables used in the first stage, the sources and some descriptive statistics.

- TABLE 3 around here –

4. DEA efficiency estimates

In this section we report the estimates of DEA efficiency scores[10]. As frontier estimates are based on finite samples, the DEA measurements built on these estimates are subject to sampling variation in the frontier. To control for sampling variation, we use a bootstrap procedure with 1,000 bootstrap developed by Simar and Wilson (1998, 2000) to correct the DEA estimate bias, generate confidence intervals and control for sampling variation.

Figure 1 shows the scatterplot between DEA and bias corrected DEA efficiency scores, whereas Table 4 reports the distribution of the estimate results by different class of relative reserve prices.

- FIGURE 1 around here –

- TABLE 4 around here –

[10] Differently by Guccio *et al.*, (2012a) we perform our DEA estimates on the whole sample without distinguishing between new and maintenance public works and between different levels of reserve price. However, the results do not substantially differ from those of Guccio *et al.*, (2012a).

Our results show that the efficiency scores ranges from 41.06% to 100% and that the mean efficiency is about 92.73%. It needs to be underlined that the fully efficient observations, those on the DEA frontiers, are not necessarily the ones that simultaneously fulfil time and cost efficiency[11].

- FIGURE 2 around here –

Of course, it is also important to stress that the mean efficiency value of 92.75% does not imply that public contracts for roads in Italy are overall executed in an efficient way. In fact, as it is showed by Figure 2, the variability of efficiency scores is very high: more than 25% of the contracts have a level of inefficiency between 10% and 60% and about the 75% of contracts has a level of inefficiency below 10%, confirming that cost overruns and delays are relevant phenomena. In addition, the average level of DEA efficiency remains almost unaffected by the different classes of reserve price. Finally, our results indicate that, on average, each DMU can reduce both actual time and costs proportionally by 7.3%, given the targets values (that is, the time and costs agreed on in the contract).

5. Determinants of public work efficiency

The application of DEA in the previous section provided us with a measure of the relative performance in public works execution. However, given that our aim is to investigate systematic differences across different decision-makers and different level of corruption in the province in which the infrastructure takes place, we follow the two-stage approach, as suggested by Coelli *et al.* (1998) and outlined in section 3.1, so as to regress DEA efficiency scores on a set of explanatory variables. Table 5 shows the environmental variables adopted.

[11] The bootstrap bias correction procedure slightly affects the estimates (92.58%). This is clearly shown by Figure 1 that jointly scatters DEA efficiency scores and bias corrected ones.

- TABLE 5 around here –

The first two environmental variables refer to corruption indexes. Due to the nature of our data set, we adopt, as measures of corruption at provincial level, the number of crimes against public administration per 100,000 inhabitants (CORR_PA) computed by ISTAT and the index of corruption (CORR_G&P) proposed by Golden and Picci (2005).

The former is based on data coming from the judicial system and it has been widely adopted in the literature (e.g. Del Monte and Papagni, 2007). However, this index appears to be affected by some problems, mainly due to the fact that the differences across provinces may depend not only on the 'objective' different degree of corruption but also on differences in the efficiency of the judicial system or on the different trust of citizens toward such a system (resulting, *ceteris paribus*, in different number of denunciations). Thus, alternative indexes of corruption perceptions or objective measures of corruption have been suggested. Some studies on public procurement have adopted objective measures of corruption looking at the prices paid for goods and services provided by the public sector. For instance, Olken (2007) measures corruption by comparing the official prices of road-building project in Indonesian villages with an independent estimate of the cost of project realisation provided by a team of engineers. Di Tella and Schargrodsky (2003) analyse the prices of some input purchased by the hospitals of Buenos Aires before and after an investigation on corruption has been run. Bandiera *et al*., (2009) use detailed data on the prices of goods obtained by Italian public administrations from an approved supplier, CONSIP. They distinguish between the corruption (called "active waste") and inefficiency in managing purchases (called "passive waste"). Their results show that the weight of passive waste is four times stronger than the one of active waste. Finally, Golden and Picci (2005) suggest an index of corruption applied to the public works sector in Italy at provincial level. Whereas the advantage of this index is that it has been computed using objective data, it has several problems. First, if we assume that corruption and inefficiency are somehow related, this index cannot disentangle the effects of these two phenomena. In addition, it has to be noted that

the index of Golden and Picci (2005) captures the effects of long-run phenomena. Thus, the value of the index for one specific year refers to the sum of all the effects cumulated across previous years. However, in line with the literature in the field, we have chosen this index of corruption that fits with the economic phenomenon under analysis. On the basis of the above-mentioned considerations, we expect that the Golden and Picci (2005) index should be able to explain a larger portion of inefficiency than the index provided by ISTAT.

We also control for other environmental factors that may affect the performances in the execution of public works. First, public works vary in terms of complexity. It is, thus, reasonable to assume that contract execution becomes more uncertain as the degree of complexity of the work increases. Previous works on this subject (e.g., Bajari *et al.,* 2009; Guccio *et al.,* 2012b) use the total value of the work and duration of the work, as estimated by the contracting authority at the bidding stage, as proxies for complexity. However such variables are strictly correlated with the variables used in the first stage. Thus, we use the weighted composition index of a work, calculated on the different sub-categories involved in the work, weighted for their relative amount (WCI)[12]. We also differentiate between "new" works (NEW) and repair/restructuring works. We expect that the degree of complexity and, thus, the likelihood of waste of time and cost are higher for new works than for repair/restructuring ones.

Previous studies on public works execution find that competition exerts a positive effect on infrastructures provision and seems to moderate the weight of corruption (Rose-Ackerman, 1996). To capture this influence we employ the number of bids (BIDDERS) and the rebates of the winning bidder (REBATE). Thus, when the level of competition is higher the most efficient firm should be chosen and the management of public works should be efficient. However, the Italian system of public works award seems to provide considerable chances of opportunistic behaviours to firms that may offer strong rebates to win the procurement and

[12] The WCI is constructed taking into account the sub-categories involved in each project as well as their relevance. Complexity may be assumed to be decreasing in the concentration of works in one or few subcategories. More formally the Weighted Composition Index (WCI) is defined as a follows. If $W_{[i]j}$ is the amount of money to be spent, within the *j-th* project, with (*j;1,...,n*), for works of the *i-th* sub-category (*i; 1, ..,G*), and $W_{[i]_j} \geq W_{[i+1]_j} \forall i$, then $WCI_j = \sum_i i \ \frac{W_{[i]j}}{\sum W_{[j]}} \in \left[1, \frac{G+1}{2}\right]$.

exploit the possibility of further renegotiation (Guccio *et al.,* 2009)[13]. To control for this effects we employ the rebate of the winning bidder (REBATE). The rebate may depend on the behaviour of the winning bidder during the awarding procedure, since as he lowers his bid to increase the chance of being awarded the work, he will have a stronger incentive to exploit any opportunity to renegotiate the contract and to ask for larger increases of the original compensation. As it has been pointed out by Guccio *et al.,* (2009), opportunistic behaviour is favoured by the fact that in the Italian system, competitive tendering does not leave room for taking into account firm's reputation. Thus, we expect that large rebate negatively affects public works execution.

The other features of public works that can significantly affect their performance at the execution stage are: the presence of subcontractors in the execution of the work (SUB) and the existence of legal disputes between the firm and the contracting authority (DISPUTE). We hypothesise that both variables tend to increase the completion time and the likelihood of a low performance in infrastructure provision.

Moreover, we think that "institution matter": different models of governance affect appointment methods, soft or hard budget constraints provide different incentives to monitoring the implementation of the work. This is especially important in the Italian case since public works are carried out by very different contracting authorities with different governance and levels of decentralisation.

To grasp the relation between the governance and the efficiency of the public work contracts execution, contracting authorities have been grouped into the following categories: CENTRAL (State administrations even with autonomous organisation; public institutions which enjoy budget autonomy and public ownership companies); LOCAL (local governments such regions, provinces and municipalities; and CONCESSIONAIRES (private company that holder a public concession *e.g.,* transport; highway; etc.). The omitted category is (LOCAL). Indeed, the effect of decentralisation on corruption is ambiguous. On the one hand, some findings show that decentralisation is associated with low corruption levels (Fisman and Gatti, 2002). On the other hand, decentralising decision-

[13] According De Carolis (2009), the Italian procurement rules to exclude anomalous bids turns out not to work properly and to cause significant efficiency losses in bidder selection.

making may result in the lack of accountability and misallocation of public resources, special interests and corruption of local public officials (Prud'homme, 1995).

Moreover, it is possible that the different levels of efficiency in public works management and the different institutional characteristics of the contracting authorities respond simultaneously to some omitted factors. Such factors could be related to different environmental and social characteristics, different levels of efficiency of the public bureaucracy, etc. To avoid this problem, we include a full set of regional fixed effects. Finally, we control for the year of award (YEAR) and for different dimensions of public work with a set of dummies computed according to different value of works (CLASS)[14].

To provide the most robust evaluation of our empirical findings, we decided to use a parsimonious strategy to evaluate the relative marginal effects. Table 6 provides the results of our estimate. Column (1) shows the results for baseline specification; whereas columns from (2) to (5) show the results of the estimations for different effects of corruption index on the performance in public works execution.

- TABLE 6 around here -

The results reported in Table 6 are robust and generally in line with the main conclusions reached in the literature. Both coefficients of the two corruption indexes (CORR_PA and CORR_G&P) turn out to be significant. Their effects are quite similar although, as expected, the index of Golden and Picci (2005), CORR_G&P, has a stronger marginal effect. This implies that if we measure the effects of corruption in terms of efficiency losses, they would be stronger than if we adopt the other index (CORR_PA). In addition, both indexes show negative signs in specification (2) and (3) supporting the "sand the wheels" hypothesis against the "grease the wheels" one, though indirectly. A corrupted environment is somehow related to a low level of social capital that, indeed, is a strategic factor

[14] We computed 3 classes referred to public works with reserve price between 150,000 to 500,000; 500,000 to 1,500,000 and 1,500,000 to 5,000,000 of euros.

enhancing the accountability of political institutions[15]. Therefore, a corrupted environment affects negatively the execution of public works. In other words, we provide some support to the well-established result stating that corruption has detrimental effects on the efficiency of institutions. However, it has to be noted that the marginal effects of both indexes are quite low.

To check whether the, relationship between corruption and efficiency is linear or U-shaped, we add a quadratic term of each of the two corruption indexes (CORR_PA_SQ and CORR_G&P_SQ) to capture non-linearities in the effect of corruption on performance. Table 6 shows that, when quadratic terms of corruption indexes are added, the sign of both corruption indexes turns positive and only one index (CORR_G&P) remains slightly significant. Thus, our results do not provide clear evidence of the U-shaped effects of corruption on efficiency.

Finally, among the other variables included in the empirical analysis, WCI, COMPETITION, REBATE and CENTRAL show to be significant and with the expected signs. It is worth mentioning that our results provide support to the idea that in competitive environment firms tend to adopt opportunistic behaviour; therefore, the common wisdom that competition is always beneficial on efficiency is not confirmed. Moreover, the negative sign of CENTRAL seem to show that the execution of public works is more efficient at central level than at local level[16].

5.1 Robustness tests

To validate the robustness of our second stage results, we apply the Banker and Natarajan procedure (2008) by regressing the (CRS) DEA efficiency scores obtained in section 4 on the environmental variables discussed above. Table 7 reports results from the regression that largely validated our previous findings.

- TABLE 7 around here -

[15] When social capital is lower politicians face weaker incentives to pursue social welfare and corruption is more likely to occur (Nannicini *et al*., 2010).

[16] Similar results are obtained by Guccio *et al*., (2013) showing that local governments do not seem to be under sufficient and effective pressure to behave efficiently in the execution of public works.

Then, we use the SFA approach, as an alternative one to DEA, to examine the efficiency of public works execution. Following well-established conventions in the literature reported in section 3, we estimate a Cobb-Douglas production function with half-normal distribution and we employ an input distance function to make it more comparable to DEA estimates. The correlation between the efficiency estimates using SFA distance function and the DEA approach is illustrated in Figure 3. The scatter plot in Figure 3 shows that the difference in the estimates between the two approaches is relatively small.

Table 8 reports the parameter estimates of the environmental variables in SFA distance function that confirm the robustness of the main findings of our analysis[17].

- FIGURE 3 around here -

- TABLE 8 around here -

6. Concluding remarks

Corruption is recognised as being a major problem affecting all countries in the world, though to a different extent, and with special impact on the procurement field. Our paper contributed to the literature on the effects of corruption on infrastructure provision using a large microeconomic database on Italian public works contracts for roads and highways in the period 2000-2005. As first step, we estimated efficiency in public contracts execution using a smoothed DEA bootstrap procedure that ensures consistency of our estimates. Then we evaluated the effects of the corruption levels on efficiency scores using a semi-parametric technique that produces a robust inference for an unknown serial correlation

[17] The whole model is available from the authors upon request. Beside the Cobb-Douglas production function with half-normal distribution, we have also estimated a Cobb-Douglas production function with exponential distribution and a truncated-normal distribution with results similar to those reported. Also these further estimations are available from the authors upon request.

between efficiency scores. In doing so, we control for several environmental factors that may affect the performances in the execution of public works. Moreover, in order to investigate the potential differences between alternative approaches, the results of parametric stochastic frontier approach has also been reported.

The results from both nonparametric and parametric analyses show that lower efficiency in public contracts execution is associated with greater corruption, in the area where the infrastructure provision is localised and this result provide support to the well-established result stating that corruption has detrimental effects on the efficiency of institutions.

The limits of the measures used for corruption imply caution in drawing conclusions; anyway, our results would suggest that the efficiency of the execution of public works could be improved increasing the accountability of contracting authorities; among the others, enhancing transparency and supporting the development of social capital might be useful tools.

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TABLES AND FIGURES

Table 1 - Distribution of public works in the sample by class of reserve price – 2000-2005

Class	Number of contracts	Ex ante agreed cost of works (i.e., value of the winning bid)	
		Average amount	*St. Dev,*
150,000 - 500,000	2,621	223.81	83.89
500,000 - 1,500,000	351	584.07	141.46
1,500,000 - 5,000,000	141	1,410.03	725.91
Total	**3,113**	**318.15**	**318.39**

Note: Monetary values in thousand Euros at current prices.
Source: Our elaboration on data provided by Autorità di vigilanza sui contratti pubblici di lavori, servizi e forniture.

Table 2 – Inefficiency of public works execution in Italy

CLASS	COST OVERRUNS [a]		DELAYS [b]	
	No.	***%***	***No.***	***%***
≤ 0	8,023	*25.09*	7.235	*22.62*
> 0 < 5	9,748	*30.48*	592	*1.85*
≥ 5 < 10	5,006	*15.65*	840	*2.63*
≥ 10 < 20	5,570	*17.42*	2,282	*7.14*
more than 20	3,635	*11.37*	21,033	*65.77*
All sample	**31,982**	***100.00***	**31,982**	***100,00***

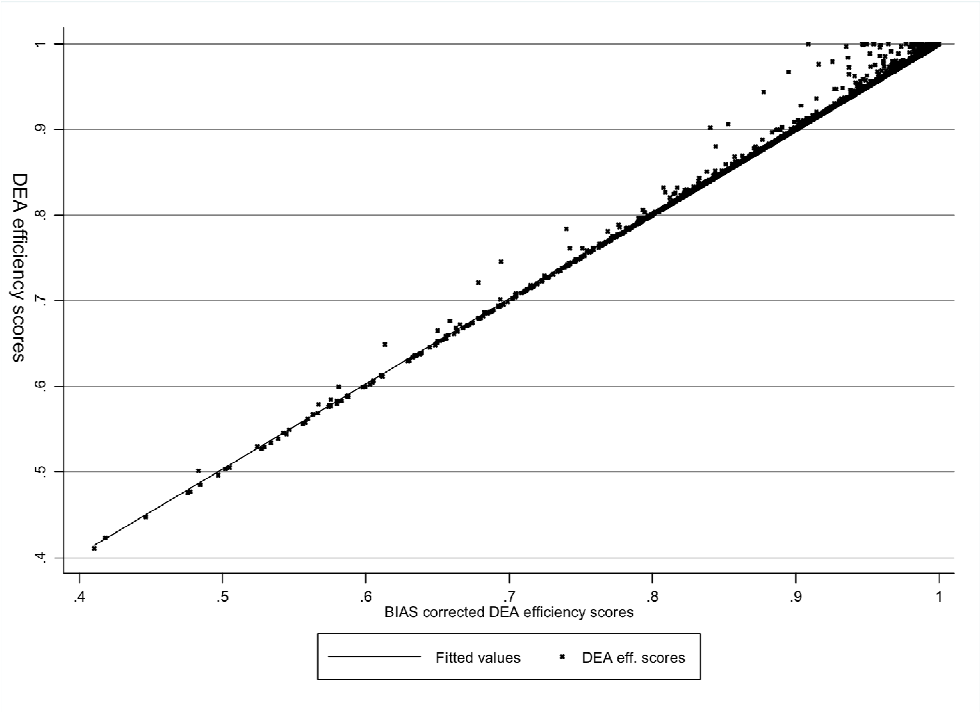
Source: AVCP (2007)
Note: Public work contracts above 150,000 euros
[a] As a percentage of deviation from contracted cost
[b] As a percentage of deviation from contracted time of completion.

Table 3 – Variables employed in DEA first stage

Variables	Definition	Mean	St. Dev.	Minimum	Maximum
A_TIME	Actual time of infrastructure completion	277.07	184.60	6.00	1,553.00
A_COST	Actual cost of infrastructure completion, in thousand	345.01	356.10	95.25	5,884.72
P_ TIME	Planned time of infrastructure completion and cost	176.65	123.45	7.00	1,095.00
W_BID	Agreed cost of infrastructure completion, in thousand (winning bid)	318.15	318.39	94.11	4,278.35

Source: Osservatorio per i lavori Pubblici, AVPC
Note: monetary values in thousand euros at current prices

Figure 1 – Scatter plot between bias corrected and DEA efficiency scores



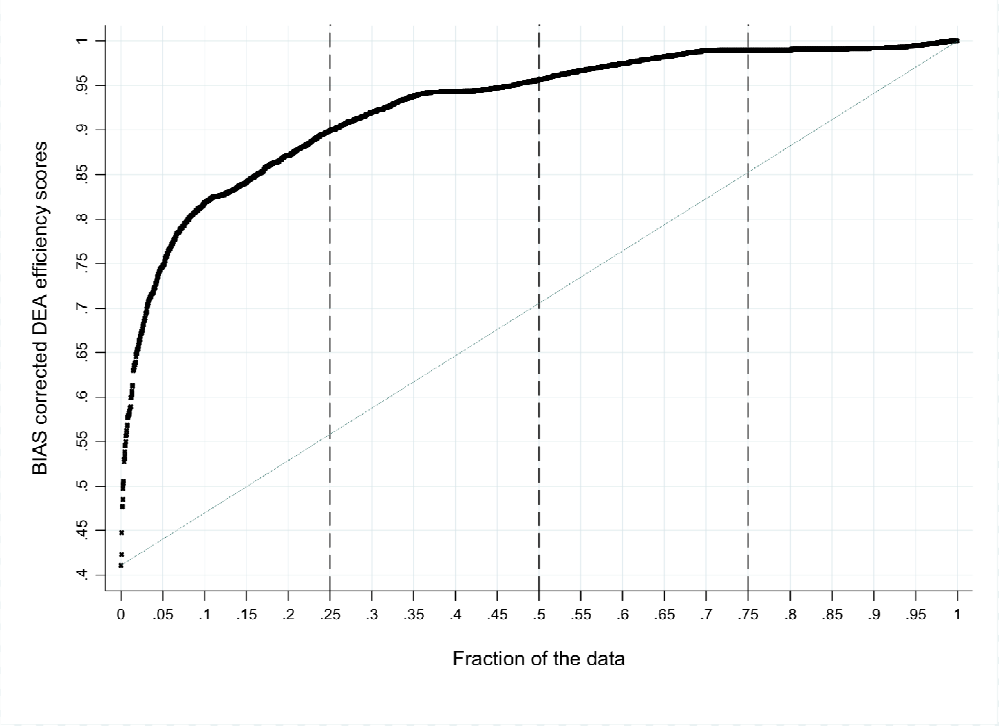
Source: our computation

Table 4 – Distribution of bias corrected and DEA efficiency scores, by different classes of reserve price

Classes of reserve prices		Mean	St. dev.	Median	Min	Max
150,000 - 500,000	DEA eff. scores	0.9298	0.0850	0.9607	0.4111	1.0000
	BIAS corr eff. scores	*0.9286*	*0.0851*	*0.9587*	*0.4106*	*0.9999*
500,000 - 1,500,000	DEA eff. scores	0.9149	0.0969	0.9463	0.4479	1.0000
	BIAS corr eff. scores	*0.9131*	*0.0971*	*0.9446*	*0.4464*	*0.9978*
1,500,000 - 5,000,000	DEA eff. scores	0.9101	0.0939	0.9406	0.5016	1.0000
	BIAS corr eff. scores	*0.9052*	*0.0944*	*0.9322*	*0.4833*	*0.9987*
All sample	**DEA eff. scores**	**0.9273**	**0.0870**	**0.9566**	**0.4111**	**1.0000**
	BIAS corr eff. scores	***0.9258***	***0.0872***	***0.9548***	***0.4106***	***0.9999***

Source: our computation

Figure 2 – Cumulate distribution of bias corrected DEA efficiency scores



Source: our computation

Table 5 – Variables employed in DEA second stage

Variables	Definition	Mean	St. Dev.	Minimum	Maximum
CORR_PA*	Crimes against public administration per 100,000 inhabitants at provincial level	4.86	3.10	0.27	17.35
CORR_G&P$	Corruption index proposed by Golden and Picci (2005), at provincial level	1.12	0.93	0.41	6.44
CORR_PA_SQ*	CORR_PA square	33.18	44.26	0.07	301.02
CORR_G&P_SQ$	CORR_G&P square	2.11	5.91	0.17	41.47
WCI°	Weighted public work composition index	1.14	0.36	0.00	3.92
NEW°	Dummy for new infrastructure	0.31	0.46	0.00	1.00
BIDDERS°	Number of bidders	32.92	33.42	1.00	250.00
REBATE°	Rebate of the winning bidder (percent)	13.78	9.88	0.00	57.00
SUB°	Dummy for subcontracting	0.76	0.43	0.00	1.00
DISPUTE°	Dummy for legal dispute	0.02	0.13	0.00	1.00
CENTRAL°	Dummy for central body	0.14	0.34	0.00	1.00
LOCAL°	Dummy for local body	0.81	0.39	0.00	1.00
CONCESSIONAIRES°	Dummy for private concessionaires	0.06	0.23	0.00	1.00
$YEAR_i$°	Dummies for year of public work award: 2000, 2001, 2002, 2003.				
$REGION_j$°	Dummies for region in which the infrastructure takes place				

Source: * ISTAT, *Statistiche giudiziarie*, several years; $Golden and Picci (2005); ° Our computation on data from *Osservatorio per i lavori Pubblici*, AVPC.

Table 6 – Truncated regressions second stage estimation results

Bias-adjusted coefficient (a)					
Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Intercept	0.883***	0.883***	0.898***	0.879***	0.981***
	(0.011)	(0.010)	(0.011)	(0.011)	(0.014)
CORR_PA		-2.38^{-4} ***		4.82^{-5}	
		(5.36^{-5})		(1.23^{-4})	
CORR_G&P			-0.003***		0.005*
			(0.001)		(0.003)
CORR_PA_SQ				-2.93^{-5} ***	
				(6.81^{-6})	
CORR_G&P_SQ					-0.002***
					(0.000)
WCI	-0.015***	-0.014***	-0.014***	-0.014***	-0.014***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
BIDDERS	-2.32^{-4} ***	-2.30^{-4} ***	-2.34^{-4} ***	-2.34^{-4} ***	-2.43^{-4} ***
	(5.11^{-5})	(5.10^{-5})	(5.11^{-5})	(5.11^{-5})	(5.12^{-5})
NEW	0.001	0.001	0.001	0.001	0.001
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
REBATE	-0.003***	-0.003***	-0.003***	-0.003***	-0.003***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
SUB	-0.002	-0.001	-0.002	-0.002	-0.002
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
DISPUTE	-0.003	-0.003	-0.004	-0.003	-0.004
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
CENTRAL	0.031***	0.029***	0.029***	0.029***	0.029***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
CONCESSIONAIRES	-0.009	-0.010	-0.010	-0.011*	-0.012*
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Control for YEAR	*yes*	*yes*	*yes*	*yes*	*yes*
Control for CLASS	*yes*	*yes*	*yes*	*yes*	*yes*
Control for REGION	*yes*	*yes*	*yes*	*yes*	*yes*
Observation	3,113	3,113	3,113	3,113	3,113

***, ** and *: coefficients are significantly different from zero at the 99%, 95% and 90% confidence levels respectively.
(a) Double bootstrap truncated estimates algorithm 2 (n=500), (Simar and Wilson, 2007)

Table 7 – OLS second stage estimation results

DEA efficiency scores					
Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Intercept	0.942***	0.946***	0.953***	0.940***	0.948***
	(0.037)	(0.037)	(0.037)	(0.037)	(0.039)
CORR_PA		-1.62^{-4} ***		-4.58^{-5}	
		(5.24^{-5})		(1.20^{-4})	
CORR_G&P			-0.009***		0.003
			(0.002)		(0.009)
CORR_PA_SQ				-1.28^{-6} ***	
				(6.27^{-7})	
CORR_G&P_SQ					-0.004***
					(0.001)
WCI	-0.012***	-0.012***	-0.012***	-0.012***	-0.014***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
BIDDERS	-2.56^{-4} ***	-2.72^{-4} ***	-2.70^{-4} ***	-2.72^{-4} ***	-2.70^{-4} ***
	(4.27^{-5})	(4.25^{-5})	(4.26^{-5})	(4.26^{-5})	(4.32^{-5})
NEW	0.002	0.002	0.002	0.002	0.001
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
REBATE	-0.003***	-0.003***	-0.003***	-0.003***	-0.003***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
SUB	0.000	0.001	0.000	0.001	-0.002
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
DISPUTE	-0.003	-0.003	-0.003	-0.003	-0.005
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
CENTRAL	0.027***	0.028***	0.027***	0.027***	0.029***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
CONCESSIONAIRES	0.005	0.007	0.007	0.007	-0.007
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Control for YEAR	*yes*	*yes*	*yes*	*yes*	*yes*
Control for CLASS	*yes*	*yes*	*yes*	*yes*	*yes*
Control for REGION	*yes*	*yes*	*yes*	*yes*	*yes*
Observation	3,113	3,113	3,113	3,113	3,113
F test (Prob > F)	0.000	0.000	0.000	0.000	0.000
R-squared	0.218	0.221	0.221	0.222	0.238

***, ** and *: coefficients are significantly different from zero at the 99%, 95% and 90% confidence levels respectively.

Figure 3 – Efficiencies of public work execution based on DEA and SFA distance function

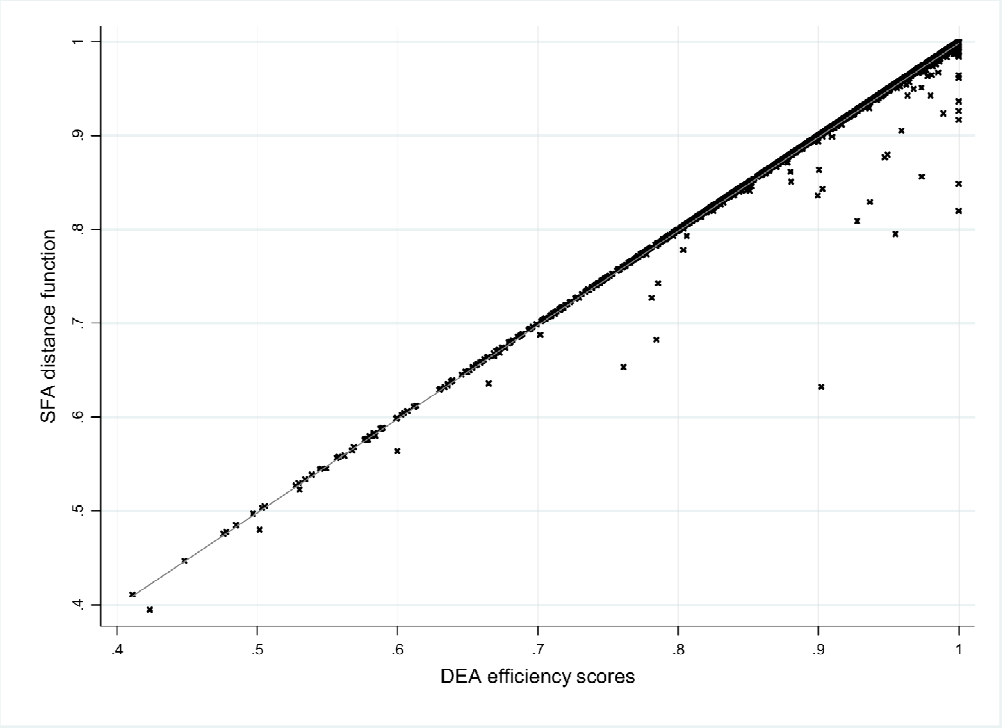


Table 8 – SFA model second stage results

Environmental variables					
Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Intercept	-5.912***	-5.920***	-6.150***	-5.843***	-6.084***
	(0.184)	(0.184)	(0.192)	(0.187)	(0.261)
CORR_PA		-0.003***		-0.002	
		(0.001)		(0.002)	
CORR_G&P			-0.212***		0.154
			(0.048)		(0.162)
CORR_PA_SQ				-3.06^{-4} **	
				(1.32^{-4})	
CORR_G&P_SQ					-0.028***
					(0.009)
WCI	-0.433***	-0.431***	-0.420***	-0.431***	-0.422***
	(0.076)	(0.076)	(0.076)	(0.076)	(0.076)
BIDDERS	0.003***	0.003***	0.003***	0.003***	0.003***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
NEW	-0.027	-0.011	-0.027	-0.028	-0.028
	(0.059)	(0.059)	(0.059)	(0.060)	(0.059)
REBATE	-0.072***	-0.071***	-0.070***	-0.071***	-0.070***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
SUB	0.006	-0.029	-0.036	-0.028	-0.035
	(0.069)	(0.070)	(0.070)	(0.070)	(0.070)
DISPUTE	-0.174	-0.152	-0.145	-0.163	-0.149
	(0.204)	(0.204)	(0.204)	(0.204)	(0.204)
CENTRAL	0.573***	0.573***	0.579***	0.571***	0.578***
	(0.092)	(0.092)	(0.092)	(0.092)	(0.092)
CONCESSIONAIRES	0.785***	0.758***	0.790***	0.775***	0.788***
	(0.131)	(0.131)	(0.131)	(0.131)	(0.131)
Sigma	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Control for year of award	*yes*	*yes*	*yes*	*yes*	*Yes*
Control for category	*yes*	*yes*	*yes*	*yes*	*Yes*
Control for region	*yes*	*yes*	*yes*	*yes*	*Yes*
Observation	3,113	3,113	3,113	3,113	3,113
Log likelihood	4364.215	4370.346	4373.931	4373.529	4374.009
Wald (Prob > chi2)	0.0000	0.0000	0.0000	0.0000	0.0000

***, ** and *: coefficients are significantly different from zero at the 99%, 95% and 90% confidence levels respectively.