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Corruption and inefficiency: Theory and evidence from electric utilities ☆

Ernesto Dal Bó [a,*], Martín A. Rossi [b]

[a] *University of California—Berkeley, California*
[b] *Universidad de San Andrés, Argentina*

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Abstract

We investigate the determinants of the efficiency of firms with a focus on the role of corruption. We construct a simple theoretical model where corruption increases the factor requirements of firms because it diverts managerial effort away from factor coordination. We then exploit a unique dataset comprising firm-level information on 80 electricity distribution firms from 13 Latin American countries for the years 1994 to 2001. As predicted by the model, we find that more corruption in the country is strongly associated with more inefficient firms, in the sense that they employ more inputs to produce a given level of output. The economic magnitude of the effects is large. The results hold both in models with country and firm fixed effects. The results survive several robustness checks, including different measures of output and efficiency, and instrumenting for corruption. Other elements associated with inefficiency are public ownership, inflation, and lack of law and order, but corruption appears to play a separate and more robust role.

JEL: D21; L94; D78
Keywords: Corruption; Efficiency; Regulatory capture; Electricity; Public vs. private

1. Introduction

We investigate the connection between corruption and the efficiency of electricity distribution firms in Latin America. Studying the determinants of the efficiency of firms is

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* Corresponding author.
E-mail addresses: dalbo@haas.berkeley.edu (E. Dal Bó), mrossi@udesa.edu.ar (M.A. Rossi).

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important because the ability of firms to transform inputs into outputs will affect the economic performance of nations. We take advantage of a unique dataset comprising a panel of 80 electricity distribution firms from 13 Latin American countries for the years 1994 to 2001.[1] Our data on corruption were provided by International Country Risk Guide and Transparency International.

We begin by constructing a simple theoretical model to crystallize our explanation for how corruption could affect firm efficiency. Our root assumption is that in corrupt environments the fate of firms is not tightly related to managerial efforts devoted to supervising and coordinating the use of productive factors. Thus, corruption diverts managerial effort away from the productive process, and the way for firms to meet their service obligations is to use more inputs.[2] Thus, the model predicts that more corrupt countries will have less efficient firms. The model is agnostic regarding the impact of corruption on profits, and it is compatible with stories of regulatory extortion against firms, regulatory capture, and internal corruption in firms. We then take the model to the data, and find that more corruption in a country is strongly associated with inefficiency, in the sense that firms employ more inputs to produce a given level of output. The economic magnitude of the effect is large. According to our most conservative estimate (from a firm fixed effects regression), if the median country in our sample (Brazil) had the corruption level of the least corrupt country in the sample (Costa Rica), the firms in the former country would use 7% fewer workers. We also find that private firms use significantly less labor than public ones.

Our main focus is on labor efficiency, so our default empirical strategy is to estimate a parametric labor requirement function to analyze the various determinants of labor use. Our result that corruption raises labor requirements holds under a variety of controls beyond basic firm features such as the size of output and capital inputs. Such controls include firm ownership type and the level of development in the country (as approximated by GNP per capita). Apart from year dummies, our default specification includes country dummies in order to deal with the possibility that corruption and inefficiency may be jointly determined by some omitted country-specific time-invariant variable. To further probe the connection between efficiency and corruption, we estimate specifications with firm fixed effects, and find that the association is still significant.

The characteristics of the industry and the countries in our sample favor comparability. Electricity distribution involves a mature technology that does not differ significantly across countries. Moreover, all the firms in our sample are from Latin American countries having the same colonial origins, relatively similar regulatory regimes, the same legal origins, and quite homogeneous cultural features.[3] Nevertheless, our econometric specification includes

[1] The dataset was constructed using the Regional Electric Integration Commission (CIER) reports, which are based on firm surveys. We complemented the CIER reports with information provided directly by regulators and governmental agencies. See Section 3 for more detail.

[2] The presence of service obligations reflects specific features of electricity distribution. The idea that corruption diverts managerial effort away from productive tasks resonates with classic rent-seeking arguments. Besides the fact that our model is also compatible with stories other than rent-seeking, we take a step forward by specifying the internal reaction of firms. Rent-seeking is compatible with firms duplicating a few managerial positions (some managers will lobby, and others will supervise factor use). This, however, is unlikely to have empirically discernible effects on the overall number of employees. Our model isolates a (complementary) firm reaction that is likely to have empirically discernible effects: more workers are used to make up for worse supervision. See Section 2.

[3] The importance of elements such as colonial and legal origin in the determination of economic and political performance has been stressed, for instance, by Acemoglu et al. (2001) and La Porta et al. (1998), respectively. The only country with different language and colonial origin in our sample is Brazil (a former Portuguese, rather than Spanish, colony). The exclusion of Brazilian firms from the regressions does not alter the results. Indeed, the results are robust to excluding firms from any given country.

controls varying by country and time such as the prevalence of law and order and indicators of macroeconomic instability. These controls help to disentangle the effects of corruption from those of other forces that may also affect efficiency. Corruption remains significant after including all of these controls. Inflation, inflation variation, and deficiencies in law and order appear themselves to be associated with greater inefficiency, especially in the firm fixed effects specification. This is interesting because it suggests that corruption plays a separate role that is distinct from the impact of a highly unstable or insecure environment. Of all the factors varying by country and time that we analyze, corruption is the only one that is both invariably significant and economically important across specifications.

To check our focus on labor efficiency, we also estimate a model where we measure efficiency in terms of operation and maintenance expenditures, rather than in terms of labor. The significant negative association between corruption and efficiency persists. We also address several potentially serious problems for our estimation, such as the possibility of survey selection bias or results being driven by heterogeneity in degrees of vertical integration. We find no evidence that any of these elements drives results. A crucial aspect in the measurement of efficiency in energy distribution is the measurement of output. Our default measure of output is energy sales (in gigawatt hour—GWh). If energy theft is higher in more corrupt countries, the use of energy sales to measure output would make firms in more corrupt countries appear less efficient than they are. We provide a different treatment using sales plus losses as the output variable (which includes stolen energy) and find again that corruption is significantly associated with inefficiency.[4]

A relevant concern with corruption studies is whether results are affected by an endogeneity bias. In Section 6 we argue that our use of corruption data at the country level in combination with firm-level efficiency data can be exploited to reduce the chances of an endogeneity problem, given that our controls cover effects specific to country, year, and country–year combinations. Additionally, when we run an instrumental variable specification using openness to trade as instrument, corruption remains significantly associated with firm inefficiency.

There are a number of studies addressing the consequences of corruption at the macro level, including Mauro (1995) and Ades and Di Tella (1997).[5] Work examining consequences at the micro level should be important because it will help pin down the ways in which corruption damages the economic performance of nations. Work on corruption using micro data is rare either in connection with the causes or the consequences of corruption. In connection with the causes of corruption, Svensson (2003) studies characteristics of firms that pay bribes, Clarke and Xu (2004) study the characteristics of firms that pay bribes to utilities, and the characteristics of utilities whose employees collect bribes from customers. Di Tella and Schargrodsky (2003) analyze the role of wages and monitoring in the context of hospital procurement. Fisman (2001), in turn, studies the value of political connections at the firm level, and Khwaja and Mian (2004) analyze the provision of loans to politically connected firms.

We still rely on country-level corruption indices, which is less desirable than having a more objective measure of corruption affecting each firm. However, the use of such indices facilitates conducting our study on a continental scale, which has some interest for external validity reasons.

[4] We also used the percentage of lost energy as a regressor in order to proxy for the seriousness of energy theft (which could require extra employment to combat illegal use). This did not alter the results either.

[5] These papers study the association between corruption and national growth and investment. Lambsdorff (2003) looks at the association between corruption and capital to GDP ratios at the national level.

The use of firm-level data, in turn, allows us to avoid relying solely on national accounts data where valuation issues and public sector participation make it more difficult to assess the channels through which corruption affects economic performance. The measurement of the magnitudes in our firm-level data is fairly uncontroversial (mostly physical units), allowing us to address empirically a hypothesis that to our knowledge remains untested: corruption destroys wealth because it is associated with firms that are technically inefficient. This finding is distinct from the more vague statement that corruption will cause managers to engage in activities that are not directly productive. Courting officials could help firms circumvent unreasonable regulations, allowing firms to be more, not less, efficient.

The plan for the paper is as follows. The next section presents our simple theoretical model. Section 3 describes our data. Section 4 describes the electricity distribution industry, defines our measure of efficiency, and presents the econometric model. Section 5 shows our empirical results, and provides evidence of their robustness. Section 6 presents further checks on robustness. Section 7 concludes.

2. The model

All firms in our sample are either publicly or privately owned, and are all engaged in a regulatory relationship with a governmental agency. In the case of private firms, they are regulated by an agency that is typically specific to the industry (electricity) or the sector (energy). In the case of publicly owned firms, they are under the oversight of a ministry-type governmental agency. The firms in our sample have the obligation to provide the service of electricity distribution to a given number of customers in a given geographical area. For modeling purposes, we will assume that firms are requested to produce an output of fixed size $\bar{Q}$, which here is assumed to be a positive real number.

The provision of this service requires the use of labor, capital, and managerial effort in the form of coordination and supervision of the use of labor and capital. Managers are able to improve the technology of the firm by exerting effort, in the sense that they can increase the rate at which capital and labor are transformed into output. Capital inputs are tightly dependent upon the extent of service, and treated in the literature on electricity distribution as exogenous in the short run (see Neuberg, 1977; and Kumbhakar and Hjalmarsson, 1998). For example, the firm's transformation capacity and the extension of its network are tightly related to the number and type of customers to be served and the area over which customers are scattered. Thus, variations in efficiency are largely connected with the use of labor. Unless stated otherwise, we say a firm is inefficient when it is not minimizing labor use given its output and capital stock. Given the exogeneity of capital, to save on notation we will consider the following production function,

$$Q = A(e_s)f(l),$$

where e_s—the managerial effort devoted to supervision and coordination—has the effect of raising total productivity $A(.)$. The amount of labor used is denoted by l. We assume that labor and managerial supervision both raise output at decreasing marginal rates. Formally, $A_{e_s}>0$, $A_{e_s e_s}<0$, $f_l>0$, and $f_{ll}<0$ (subscripts next to functions indicate arguments of differentiation throughout). The rationale for this formulation is that, given the number of workers, managers that tightly coordinate and supervise workers will elicit better performance and more output. Conversely, maintaining output in the face of less attentive supervision will typically require more workers. For example, a manager that devotes all his time to overseeing employees can receive information on the state of different transformers and connections from many inspectors scattered on the field. He can then direct a single repair team to each location that comes to need attention. A manager that is not available to receive information and give orders may have to rely on associating repairmen to each one of the inspectors, so that they can execute repairs if needed (thus raising the number of employed repairmen). With variations, this basic story can be told to capture what happens at different levels of the hierarchy in an electric utility.

Note that, given the contractual obligation to provide $\bar{Q}$ units of output, the use of l units of labor will imply that managers must provide exactly $A^{-1}\left[\frac{\bar{Q}}{f(l)}\right]$ units of supervision effort. This is an important part of our model: a feature specific to the industry analyzed (an exogenous service obligation) determines the relationship between supervision and labor use. Another important part of the model is managerial payoffs. We assume that managers care about their total material rewards y and about the total effort e they exert:

$$y-\psi(e), \tag{1}$$

where the cost of effort $\psi(.)$ is increasing and convex.[6] As will be explained shortly, the total effort e is the sum of effort deployed in two different activities: supervising inputs, and affecting the price obtained by the firm.

The total rewards y to those running the firm stem from various sources. Managers are typically not the owners of the firm, but they can be expected to care about profits if higher profits trigger higher compensation and perks. Often managers may also pursue objectives that do not generate profits, like rendering services to a political party. In the discussion at the end of the section, we explain how such objectives can be incorporated in the model. For expositional reasons, here we adopt the simplest model that captures the effect of interest. So for now, we assume that managers have a stake in profits. Even in public firms where managerial incentives may be less high-powered—and conditional on the pursuit of other objectives—higher profits are likely to benefit managers, if only because higher profits allow more latitude in pursuing other goals. Given this, and to maximize simplicity, we will now abstract from the difference between managers and owners, and suppose that managers care directly about profits (in the discussion at the end of the section we explain how to reintroduce the distinction between owners and managers in the model). Thus, we will write $y=\pi$. Profits, in turn, are given by,

$$\pi=p\left(e_p,c\right)\bar{Q}-wl, \tag{2}$$

where w are wages paid to workers, and $p(.)$ is the price of a unit of output. This formulation captures the fact that the price charged by the firm may depend on its efforts e_p at negotiating with the government and on the degree of corruption in the country c. Moreover, we assume that the degree of corruption affects the productivity of price negotiation efforts. This is captured in our,

Assumption 1. Higher corruption in the country increases the marginal return to effort in activities different from factor coordination (i.e. $p_{e_pc}=\frac{d_2p}{de_pdc}>0$).

[6] The utility from material rewards can be made concave without affecting the analysis.

This assumption captures the central element of our theory of diversion of managerial effort: in more corrupt countries, tasks that do not help the productive process are more rewarding at the margin.[7] The motivation for this assumption is that in non-corrupt countries prices are seen as being close to what industry jargon calls the "technical price", and efforts devoted to moving the price away from the technical benchmark are largely irrelevant. When regulators can be captured instead (or they can blackmail firms), price negotiation matters. Similarly, $p(.)$ can be seen as a price net of certain costs over which procurement managers of the firm have power. When procurement managers can collude with providers and overcharge the firm, top managers of the firm may want to devote more effort at curbing overcharging and improving the net price for the firm.[8] Thus, our model is compatible with at least two ways in which corruption can damage the efficiency of firms. One concerns external corruption—or the possibility that public officials are corrupt. The other concerns internal corruption—as when procurement by the firm is subject to abuse.

Note that corruption need not lower nor raise profits (or other sources of managerial payoffs) for a *given* level of effort. When corruption takes the form of regulatory extortion or internal procurement abuse, profits will tend to suffer. In other circumstances, such as those associated with active rent-seeking, corruption may mean that the regulator can be captured easily. In this case, for any level of effort, the firm's profits are likely to be higher than otherwise. We remain agnostic regarding the effects of corruption on the level of profits. To abstract from these differences, we assume that, around equilibrium,

Assumption 2. Corruption does not directly raise nor lower profits (i.e. $p_c=0$).

This assumption is mainly made for simplicity. Our results go through when corruption has both a negative and a not strongly positive level effect on managerial payoffs. Thus, our theory is compatible with firms in more corrupt environments making both more or less money (in other words, the theory can accommodate rent-seeking and extortion or internal corruption stories). We also assume that both forms of effort face decreasing marginal returns (so on top of $A(.)$ being concave, we have $p_{e_p e_p}<0$).

In the world we have characterized, managers allocate effort and choose the labor requirements of the firm to solve (using Eq. (2) into Eq. (1), the equality $y=\pi$, and recalling that $e_s=A^{-1}\left[\frac{\overline{Q}}{f(l)}\right]$),

$$\underset{e_p,l}{\text{Max}} \quad \left[p\left(e_p,c\right)\overline{Q}-wl\right]-\psi\left\{e_p+A^{-1}\left[\frac{\overline{Q}}{f(l)}\right]\right\}. \tag{3}$$

The first-order conditions for this problem are,

$$p_{e_p}\overline{Q}-\psi_e=0$$

$$-w+\psi_e\overline{Q}\frac{dA^{-1}}{d(.)}\frac{f_l}{f(l)^2}=0\ .$$

[7] Corruption may have additional effects to those captured by Assumption 1. For example, it may increase workers' predisposition to shirk, which would in turn affect managers' incentives to monitor workers. Our assumption captures a sufficient condition for increases in corruption to lead to worse managerial supervision. Thus, our assumption is complementary to additional effects from corruption further increasing inefficiency.

[8] See Laffont and Martimort (1999) for a model in which the way to limit collusion in hierarchical agency is to separate powers. Because duplicating procurement officials is expensive, top managers can be expected not only to separate powers but also to increase their monitoring of those employees, which will detract from the ability top managers have to oversee the productive process.

These two first-order conditions characterize solutions e_p^*, and l^* (the second order conditions for a maximum are shown in the Appendix). Given the obligation of service provision at level $\bar{Q}$, the amount of labor chosen is inversely related to the amount of effort provision in supervision and coordination e_s^*. Our focus is now on how corruption affects the level of price negotiation effort e_p^*, labor use l^*, and supervision effort e_s^*, in order to derive the effects of corruption on firm efficiency.

Proposition 1. *Firms in more corrupt environments will be more inefficient: their managers will exert more effort at improving prices, less effort at coordinating the use of factors, and as a consequence they will employ more labor to produce a given level of output (i.e.* $\frac{de_p^*}{dc}>0$, $\frac{de_s^*}{dc}<0$, and $\frac{dl^*}{dc}>0$*).*

The proof to this comparative statics proposition is in the Appendix. The intuition for the result is that managers placed in more corrupt environments do not see their rewards tied to the efficiency of the productive process. Therefore, corruption causes an increase in forms of effort that do not help production. Because all effort is costly to managers, they find it optimal to reduce the effort they put into overseeing production. Although this might seem a very general intuition, note that in our model it is associated to a specific feature of the industry we study. The way to make up for diverted managerial effort is to hire more workers because firms face a service target obligation. Hence, production being fixed, excess employment is unambiguously inefficient.

2.1. Discussion

Our modeling strategy avoids precisions on the sources of discretion that firms and regulators must have in order to, for example, negotiate a price of service that is not what consumers, the ultimate principal, would desire. Our model is compatible with introducing more structure and deriving this behavior as a response to various distortions. One of these is asymmetric information; another is badly functioning institutions that, even under symmetric information, hinder accountability.[9] Our current model can be seen as a reduced form for a model of regulatory capture in the spirit of Laffont and Tirole (1993), where informational asymmetries are central. But it is also compatible with other sources of power for those who end up participating in corrupt transactions.

Our model can also accommodate more classic accounts of the way corruption operates, such as in rent-seeking models (see for instance Krueger, 1974). In this literature, the presence of a distortion (such as an importing quota) provides agents with incentives to lobby officials, which is an unproductive activity. This type of account, however, does not explain what may occur inside firms. Lobbying is typically a task performed by managers at the very top of an organization. A manager that must spend time lobbying may produce less, or hire another manager just like himself to oversee production. In electricity distribution, producing less is not an option. As a result, managerial positions may be duplicated, but it is unlikely that the duplication of managerial positions at the top would have easily discernible effects on the overall size of the workforce. Our conjecture—captured in our modeling approach—is that managers also respond by over-

[9] In fact, some of the countries in our sample have not had very healthy democracies during the sample period. Presumably, imperfectly functioning democracies yield unchecked power to regulators, as their political bosses do not face very stringent controls from citizens.

employing factors. In the case of labor this would include workers and perhaps middle and low level managers, so we expect to see clearly discernible effects on labor requirements.

Lastly, this model can be enriched to consider the possibility that (i) managers are different from owners, and that (ii) managers pursue objectives different from profit generation. The first point implies that managers care about profits only to the extent to which these affect their compensation. A way to study this possibility is to assume that profits affect compensation according to some "managerial compensation package" function $m(\pi)$. What is required for our results to go through is just that this function is increasing and not too convex.

Regarding non-profit objectives, it is possible that by devoting effort e_n to practices such as nepotism or other types of private agendas, managers can obtain rewards $n(e_n,c)$. These rewards are likely to depend on managerial effort and on the level of corruption in the country (for example, the extent to which a public company may be used to pursue employment objectives may be related to the level of accountability at all levels in the hierarchy formed by managers, politicians, and, ultimately, citizens, which may depend on corruption.).

In this more complex world, assume managers care about total rewards according to the concave utility function $U(.)$. Managers will then solve the following problem,

$$\max_{e_p,e_n,l} \; U\left\{m\left[p\left(e_p,c\right)\overline{Q}-wl\right]+n\left(e_n,c\right)\right\}-\psi\left\{e_p+e_n+A^{-1}\left[\frac{\overline{Q}}{f(l)}\right]\right\}.$$

Under the assumption that managerial incentives $m(.)$ are not too convex in profits, the solution to this problem is analogous to the simpler one we have exposed. An increase in corruption will not necessarily raise all forms of non-productive effort, but it will raise at least one, while decreasing effort devoted to running production, causing inefficiency.

3. The data

We use three different sets of data. We use country-level data on corruption, firm-level data on inputs and outputs of electricity distribution, and a number of control variables that can fall into either the country or firm-level categories.

Our firm-level data correspond to 80 Latin American firms between 1994 and 2001. Data on firms were collected from several sources. Data for South America in the period 1994–2000 were mostly compiled from reports produced by CIER (*Comisión de Integración Energética Regional*, a commission that coordinates the different participants in the electricity sector in South America). The reports used are: *Datos Estadísticos*. *Empresas Eléctricas*. *Año 1994*; *Datos Estadísticos*. *Empresas Eléctricas*. *Años 1995–1996–1997*; *Información Económica y Técnica de Empresas Eléctricas*. *Datos 1998–1999*; and *Información Económica y Técnica de Empresas Eléctricas*. *Datos 2000*. Data for Argentina in the year 2001 were provided by ADEERA (*Asociación de Distribuidores de Energía Eléctrica de la República Argentina*, an institution that coordinates firms in the Argentine electricity sector). Other South American data corresponding to the year 2001 were obtained from firms' balance sheets. Data for Costa Rica were provided by the energy department of ARESEP (*Autoridad Reguladora de los Servicios Públicos*, the regulator of public services in Costa Rica). Data for Panama were obtained from the firm's balance sheet. Data for Mexico were provided by CFE (*Comisión Federal de Electricidad*, the authority in charge of the electricity sector in Mexico).

Most of the data were verified using information provided by regulators and governmental agencies. In this respect, we used information provided by ADEERA, ENRE (*Ente Nacional*

Regulador de la Electricidad, the regulator of the electricity sector in Argentina), ANEEL (*Agência Nacional de Energia Elétrica*, the regulator of the electricity sector in Brazil), CONELEC (*Consejo Nacional de Electricidad de Ecuador*, governmental agency in charge of the electricity sector in Ecuador), CTE (*Comisión de Tarifas Eléctricas*, an agency in charge of setting electricity prices in Peru), and URSEA (*Unidad Reguladora de Servicios de Energía y Agua*, regulator of the water and energy services in Uruguay).

The database includes the following variables: sales to final customers, in GWh; number of final customers; service area, in square kilometres; total distribution lines, in kilometres (including high and low voltage power lines); total transformer capacity, in mega-volt-ampere, MVA; and number of employees. Given our empirical strategy, an important input measure for firms is employed labor. Labor is measured as the number of full-time equivalent employees. We constructed this measure using raw information on full-time employees, part-time employees, and employees under temporary contracts.[10] We included the latter to account for the possibility of different subcontracting practices.

Our sample is representative of the electricity distribution sector in the region. It covers the following countries: Argentina (29 firms supplying electricity to approximately 80% of the total number of customers in the country), Bolivia (2, 31%), Brazil (4, 19%), Chile (2, 18%), Colombia (4, 30%), Costa Rica (4, 91%), Ecuador (12, 61%), Mexico (1, 79%), Panama (1, 62%), Paraguay (1, 100%), Peru (11, 97%), Uruguay (1, 100%), and Venezuela (8, 92%). Summary statistics of the unbalanced panel are presented in Table 1. A total of 352 observations are available for estimation.

Our measure of corruption is the Corruption Index produced by International Country Risk Guide (ICRG) in December of each year. This index is widely used in the economics literature (going back to, for example, Knack and Keefer, 1995). The ICRG corruption index is meant to capture the likelihood that government officials will demand special payments, and the extent to which illegal payments are expected throughout government tiers as ranked by panels of international experts. The index is specifically designed to allow for cross-country comparability and is therefore particularly suited to our approach. The ICRG index ranges between six (highly clean) and zero (highly corrupt), so note that a higher corruption index corresponds to a less corrupt country. Summary statistics of the ICRG corruption index are presented in Table 1.

4. Efficiency in electricity distribution: background, definition, and econometric model

Electricity distributors use their network and transformer capacity, together with labor, to deliver energy to a specified set of customers in a given geographical area. Our econometric model of electricity distribution reflects this: it includes a labor input (the number of employees), two capital inputs (transformer capacity and kilometers of distribution network), and three outputs (the number of final customers, the total energy sold to final customers, and the service area).[11]

[10] Part-time employees and employees under temporary contracts were counted as half-time employees. In vertically integrated firms, the number of employees of firm j was calculated as follows: $l_j = l_{1j} + l_{2j} + \left[\sum_{k=1}^{2} l_{kj} / \sum_{k=1}^{4} l_{kj}\right] l_{5j}$, where l_{1j}=distribution (proper); l_{2j}=billing and collection; l_{3j}=generation; l_{4j}=transmission; and l_{5j}=administrative and general.

[11] Jamasb and Pollitt (2001) review the different input and output variables used in models of electricity distribution. They find that the most frequently used outputs are units of energy delivered, number of customers, and the size of the service area, whereas the most widely used physical inputs are number of employees, transformer capacity, and network length. Our measure of energy supplied to customers is actually energy sold to them, which does not include technical energy losses or energy theft. This omission is potentially important so we will also estimate an alternative specification including energy losses, which is an alternative measure for the actual output of the firm.

Table 1
Summary statistics

Inputs and outputs	Mean	Standard deviation	Maximum	Minimum
Number of employees	2151	5929	41,063	95
Sales (in GWh)	5962	21,628	175,498	61
Number of customers	868,290	2,592,453	19,760,000	17,782
Service area (in km^2)	107,558	302,328	1,889,910	78
Distribution lines (in km)	29,748	89,861	595,170	380
Transformer capacity (in MVA) (number of observations=352)	1790	4475	33,078	38
O&M expenses (000 US Dollars, PPP) (number of observations=210)	154,628	251,376	1,833,086	695
International Country Risk Guide Corruption Index				
Argentina	2.69	0.46	3.00	2.00
Bolivia	2.88	0.35	3.00	2.00
Brazil	2.88	0.35	3.00	2.00
Chile	3.75	0.46	4.00	3.00
Colombia	2.13	0.64	3.00	1.00
Costa Rica	4.75	0.71	5.00	3.00
Ecuador	2.94	0.68	4.00	1.50
Mexico	2.75	0.71	4.00	2.00
Panama	2.00	0.00	2.00	2.00
Paraguay	1.88	0.35	2.00	1.00
Peru	3.00	0.53	4.00	2.00
Uruguay	3.00	0.00	3.00	3.00
Venezuela	2.88	0.35	3.00	2.00
Full sample	2.88	0.85	5.00	1.00
Corruption Perception Index—Transparency International				
Argentina	3.41	0.80	5.24	2.80
Bolivia	2.52	0.50	3.40	2.00
Brazil	3.65	0.54	4.10	2.70
Chile	7.11	0.59	7.94	6.05
Colombia	3.01	0.60	3.80	2.20
Costa Rica	5.26	0.74	6.45	4.50
Ecuador	2.50	0.36	3.19	2.20
Mexico	3.31	0.31	3.70	2.66
Panama	3.35	0.49	3.70	3.00
Paraguay	1.73	0.25	2.00	1.50
Peru	4.30	0.23	4.50	4.00
Uruguay	4.73	0.43	5.10	4.30
Venezuela	2.60	0.17	2.80	2.30
Full sample	3.72	1.49	7.94	1.50

Note: All data correspond to December of each year.

As observed by Kumbhakar and Hjalmarsson (1998), while productivity in electricity generation is mainly determined by technology, productivity in distribution is, to a large extent, driven by management and efficient labor use.[12] Accordingly, unless stated otherwise, the concept of efficiency used throughout the paper is labor efficiency: a firm X is inefficient relative to a firm Y if, given the capital inputs, X uses more labor than Y to produce a given output bundle. Labor is measured as the number of full-time equivalent employees, as described in the previous section.

[12] Typically, the labor cost share in generation amounts to less than 10% while in distribution the figure is around 50%.

Our goal, then, is to produce a model that can explain the determinants of labor use, including a variety of technological factors, the characteristics of service, corruption, and a set of controls.

Latin American electricity distribution firms have the obligation to meet demand; therefore we consider the amount of electricity sold to final customers (in gigawatt hours, GWh) and the number of final customers served as exogenous outputs. We include the service area (in square kilometers) as an output, since an increase in the service area either increases the use of resources or reduces the supply of other products (Førsund and Kittelsen, 1998). Although there is an occasional redrawing of service area boundaries due to mergers or takeovers, for practical purposes each firm has little direct control over the size of its service territory; hence, the service area may be considered an exogenous variable.

As noted by Neuberg (1977), Kumbhakar and Hjalmarsson (1998), and Hattori (2002), distributors have limited control over the length of distribution lines, since the amount of capital embodied in the network reflects geographical dispersion of customers rather than differences in productive efficiency. And this is also the case, although perhaps to a lesser degree, for transformer capacity (in mega-volt-ampere, MVA). Therefore, we treat distribution lines (in kilometers) and transformer capacity as exogenous capital variables representing the characteristics of the network.[13]

Following the considerations above, our approach to studying the determinants of labor use in electricity distribution is to estimate a parametric labor requirement function.[14] We use a translog functional form because it provides a good second-order approximation to a broad class of functions, and admits the Cobb–Douglas as a special case. A translog labor requirement model with three outputs and two exogenous capital inputs, for a panel of $i=1,\ldots, N$ firms producing in $c=1,\ldots, C$ countries, and observed over $t=1,\ldots, T$ periods, may be specified as

$$l^{i,t} = \alpha + \alpha_c + \psi_t + \sum_{m=1}^{3} \varpi_m y_m^{i,t} + \frac{1}{2}\sum_{m=1}^{3}\sum_{n=1}^{3} \varpi_{mn} y_m^{i,t} y_n^{i,t} + \sum_{k=1}^{2} \beta_k x_k^{i,t} + \frac{1}{2}\sum_{k=1}^{2}\sum_{j=1}^{2} \beta_{kj} x_k^{i,t} x_j^{i,t} + \\ + \sum_{k=1}^{2}\sum_{m=1}^{3} \kappa_{km} x_k^{i,t} y_m^{i,t} + \lambda_1 \mathrm{Corruption}^{c,t} + \lambda_2 \mathrm{DPub}^{i,t} + \nu^{i,t} \ , \tag{4}$$

where l, y_1, y_2, y_3, x_1 and x_2 are the natural logarithms of labor, sales, customers, area, lines' length, and transformer capacity, DPub is a public ownership dummy variable, and v is the random error term. To account for time effects in a flexible way we include year fixed effects (ψ_t). The year fixed effects measure the efficiency impact of sector-level shifts over time, such as secular technology trends, international macroeconomic fluctuations or energy price shocks. To control for potential biases caused by any omitted variables that are country specific and time invariant, we include country fixed effects (α_c). We also estimate an alternative specification with firm fixed effects rather than country fixed effects. In order to test the model derived in Section 2 we include the corruption index corresponding to the country in which the firm operates. In terms of the model in Eq. (4), Proposition 1 predicts $\lambda_1 < 0$ (firms operating in more corrupt environments are more inefficient).[15]

A usual approach in efficiency studies employs stochastic frontiers, which allow for the measurement of the *level* of inefficiency in each firm (a magnitude we do not focus on). See

[13] The Dutch regulator also specifies network length and transformer capacity as exogenous to the firm (DTe, 2000). The DTe argues that network length and transformer capacity can be seen as variables for customer dispersion.

[14] The idea of input requirement functions goes back to Diewert (1974). For an application, see Kumbhakar and Hjalmarsson (1995).

[15] Recall that higher values of the corruption index imply a lower level of corruption.

Kumbhakar and Knox Lovell (2000) for a discussion of stochastic frontier techniques; for applications taking into account firm heterogeneity, see for instance Orea and Kumbhakar (2004), El-Gamal and Inanoglu (2005) and Greene (2005). Because we are only interested in testing the comparative static effects of corruption on efficiency—not on the level of efficiency per se—, and the stochastic frontier approach requires further distributional assumptions, we do not rely on it here (previous versions of the paper included stochastic frontier specifications, which yield significant estimates of the impact of corruption on efficiency). The concept of inefficiency we use is broad: any environmental factor that, given output and technical characteristics, raises labor requirements will be said to cause inefficiency. The reason is that, absent those factors, the firm would utilize fewer resources to produce the same output. The extra use of resources due to adverse environmental conditions is a waste given what is technically feasible, and we therefore call it technical inefficiency. Note that managers may be devoting a lot of effort to tasks that are necessary to keep the firm successful. In this sense, inefficiency may be unrelated to shirking by workers or managers, but be instead a reflection of a bad business climate.

5. Empirical results

Ordinary least squares (OLS) estimates of the labor requirement function model are reported in Table 2. A concern in this type of study is that the shocks affecting all firms in a given country in

Table 2
Estimates of labor requirement function

Variable	Dependent variable: number of employees, in logs			
	(1)	(2)	(3)	(4)
Corruption	−0.096 [a]	−0.091 [a]	−0.095 [a]	−0.114 [a]
	[0.019]	[0.018]	[0.018]	[0.024]
Public dummy	0.415 [a]	0.410 [a]	0.414 [a]	0.370 [a]
	[0.088]	[0.091]	[0.092]	[0.094]
Ln (GNP per capita)		−0.137	−0.111	−0.061
		[0.090]	[0.090]	[0.089]
Ln (wages)			0.152	0.418
			[0.218]	[0.274]
Ln (Law and order)			−0.116	−0.099
			[0.091]	[0.105]
Inflation			0.00014 [a]	0.00015 [a]
			[0.00002]	[0.00003]
Inflation variation			0.00007 [b]	0.00008 [a]
			[0.00003]	[0.00003]
Time dummies	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes
R-squared	0.95	0.95	0.95	0.96
Number of firms	80	80	80	78
Observations	352	352	352	340

Notes: Country–year clustered standard errors are shown in brackets.
In the model in column (4) Ln (sales) was replaced by Ln (sales + network losses).
In all cases we estimate a translog labor requirement function using Ordinary Least Squares. To save space, technological parameters of the translog function are not shown. In all models, the Cobb–Douglas specification is rejected against a translog, at the 1% level.
A higher index for corruption implies that the country level of corruption is lower.
[a] Significant at the 1% level.
[b] Significant at the 5% level.

the same year may be correlated, thus biasing standard error estimates. To address this issue, all standard errors are clustered on country–year combinations.

We begin by reporting some estimates regarding technological parameters. The time dummies are significant in all models we estimated and imply labor productivity growth of about 5% per year—the null hypothesis of no technical change is rejected at the 1% level, according to a likelihood ratio (LR) test.[16] These results are similar to those reported in the specialized electricity literature (see Rudnick, 1998; Fischer and Serra, 2000; Rudnick and Zolezzi, 2001). We test the null hypothesis of a Cobb–Douglas specification against the more general translog using a LR test and we are able to reject the null at the 1% level. This result is also in line with conventional wisdom. In summary, the estimation of the technological parameters conforms to expectations.

As shown in column (1) of Table 2, the coefficient of the corruption variable is negative and significant at the 1% level, suggesting that firms operating in countries with lower levels of corruption use fewer employees to produce a given bundle of outputs than distributors operating in more corrupt environments. This is the result predicted by Proposition 1. The economic magnitude of the effect is large: an improvement in one point in the corruption index is associated to a 10% decrease in the use of labor, *ceteris paribus*.[17] This result obtains in a specification which, as said before, includes fixed effects by country. Notably, the results do not change when omitting country fixed effects. Including lagged corruption (one and two year lags) does not affect the results, in the sense that current corruption continues to be significant. The first lag is also significant and its coefficient has a smaller absolute value.

In order to control for ownership type we include an indicator variable that takes the value of one if the firm is public and zero otherwise.[18] The coefficient on the public dummy is positive and significant at the 1% level, indicating that private firms outperform public firms. The coefficient associated with the public firm dummy is also significant in economic terms: public firms use about 41% more labor to produce a given bundle of outputs, conditional on corruption and the capital inputs. We experimented with the interaction between corruption and the public dummy, but found no consistently significant effects across the estimated models.

In order to avoid possible omitted variable biases caused by country–year unobserved heterogeneity, we extend our baseline model by including GNP per capita, which varies over time and across countries and should control for productivity shocks at the national level.[19] In column (2) of Table 2 we report the results of including GNP per capita in our model. GNP per capita is not significant at any of the usual confidence levels and it appears not to have any impact on the sign or significance of other coefficients. In particular, corruption remains

[16] The likelihood ratio (LR) statistic is defined by $LR=2[L_U-L_R]$, where L_R is the log likelihood of the restricted model and L_U is the log likelihood of the unrestricted model. Under the null hypothesis, LR is asymptotically distributed as a chi-square with degrees of freedom equal to the number of restrictions involved.

[17] A note of caution is needed in the interpretation of these results. As pointed out by Mauro (1995), when using perception indexes it is unclear whether the difference between a grade of one and two is the same as that between four and five, which leads to difficulties in the interpretation of the coefficients.

[18] Information on ownership type comes from CIER reports and was checked by asking directly to regulators. 49% of the observations correspond to public firms. Corruption and ownership seem to be orthogonal to each other in our sample. The correlation between the ICRG corruption index and the share of private sector participation in the distribution activity—a proxy for ownership at the country level, is equal to −0.10, a figure that is not significantly different from zero at the usual confidence levels.

[19] GNP per capita (US Dollars) is in purchasing power parity units, as obtained from the World Bank database (for details, see the technical notes to the *World Development Reports*).

negatively associated with efficiency, and private firms appear significantly more efficient than public firms.[20]

5.1. Other controls varying across countries and time

Apart from GNP per capita, we experimented with several other potential explanatory variables that vary across countries and time, including average wages at the country level. To avoid the possibility that the corruption measure simply picks up the insecurity of property rights or a more chaotic environment, we included a measure of law and order, and measures of macroeconomic instability, namely inflation and inflation variation.[21]

The estimates, including all the additional controls, are reported in column (3) of Table 2. Inflation, inflation variation, and law and order have the expected signs in terms of our theoretical model. These are forces that could also divert managerial efforts and raise factor use. However, the law and order variable does not appear to play a statistically significant role; inflation and inflation variation, although significant, do not have large economic effects. Including these variables in the model does not significantly affect the relationship between corruption and labor requirements.[22]

5.2. The problem of energy theft

Our use of energy sold as a measure of output could bias our corruption estimate. The countries that are more corrupt are also poorer, and poverty is likely to generate a more serious problem of energy theft because of higher criminality and lower enforcement capabilities. Thus, firms in those countries would appear to be less efficient, because part of the energy they effectively distribute gets stolen, rather than sold. A second possibility is that firms facing more energy theft may have to use inputs to combat it.

As pointed out by Bagdadiouglu at al. (1996), network losses reflect the quality of the network system in terms of how much power is lost in the transformers and during distribution, and how much power is uncounted due to other reasons, such as illegal use. Technical losses are strictly related to the square of the distance transmitted, and hence our econometric model captures them. Our main concern is related to non-technical losses associated with illegal use. In order to address the problem of whether or not including network losses as part of output has any impact on the estimated coefficients, we replace "sales" by "sales + energy losses". As shown in column (4) of Table 2, corruption is still significantly associated to higher labor requirements.[23] The same applies to public ownership.

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[20] Similar results are obtained when corruption is included in the model in natural logarithms rather than in original units.

[21] The source of countries' average wages, inflation, and inflation variation is ECLAC (Economic Commission for Latin America and the Caribbean). We use a Law and Order index in order to proxy the country's respect for property rights. In the Law and Order index, law and order are assessed separately, with each sub-component going from zero to three. The Law sub-component is an assessment of the strength and impartiality of the legal system, while the Order sub-component is an assessment of popular observance of the law. The source for the Law and Order index is International Country Risk Guide (ICRG). Recall that a high value of the index means that the country in question has "good" institutions.

[22] The coefficients on corruption and the public dummy are also significant when country dummies are not included in the regression model.

[23] Due to lack of data on network losses for some firms, including losses in the model reduces the number of observations to 340—instead of 352; the mean of network losses (in percentage of energy sold) is 15%, with a standard deviation of 8%.

In another specification (not reported) we included the percentage of energy sales that are lost as an independent regressor. This would proxy for the relative seriousness of the theft problem, which could induce the use of more employees to combat it. The results were unchanged.

We now address some other concerns that are specific to the type of data we use and the problem we investigate.

5.3. Survey bias and vertical integration

As described in Section 3, our data comes from two types of sources: survey responses by the firms and information collected directly by regulators and governmental agencies. First, we consider the possibility that survey responses by firms may suffer from a selection bias—i.e. perhaps only the most efficient firms may be willing to answer a survey. To determine how sensitive the results are to this potential bias, we constructed a source dummy variable that takes the value one when the observation comes from a survey and zero otherwise. The source dummy is not significant, indicating that there are no systematic differences in efficiency between the firms that answered the survey and the other firms in our sample.

Second, some firms in our sample are vertically integrated—i.e., they produce and transport electricity, as well as distribute it. To explore the possibility that labor productivity might be correlated with different degrees of vertical integration, we added a dummy variable for vertically integrated firms. The vertically integrated firm dummy has a positive and significant coefficient, suggesting that vertically integrated firms use more labor, *ceteris paribus*, than the other firms in our sample. The inclusion of the vertically integrated dummy, however, does not have any impact on the value or significance of other coefficients. Hence, the negative and significant association between corruption and efficiency is not driven by varying vertical integration patterns across firms in the power industry.[24]

In summary, our empirical findings indicate that corruption at the country level is negatively associated with the labor productivity of firms. Additionally, we find that private firms have higher labor productivity than public firms. Other features of the macroeconomic and institutional environment facing firms, such as macroeconomic instability and the prevalence of law and order, play a significant but separate role.

6. Robustness checks

To further address the validity of the results we estimate four alternative specifications. In the first specification we use operating and maintenance expenditures instead of employed labor as dependent variable; in the second specification we use an instrumental variable specification; in the third we use an alternative corruption index; and in the fourth we include firm fixed effects instead of country fixed effects. In addition, we examine the possibility that adding data on the quality of service would alter our results.

6.1. Operating and maintenance expenditures

We estimate an alternative model in which the dependent variable is the firms' operating and maintenance expenditures (O&M, in thousands of US Dollars) instead of the number of

[24] The three checks just described involve regressions that are unreported but available upon request.

employees.[25] Using O&M expenses as the dependent variable has the advantage of including expenditures for work contracted outside the firm, thus making the measure of variable inputs more comparable between firms with different levels of horizontal integration. In many cases, labor compensation packages have allowed privatized firms to outsource labor intensive services (e.g., cleaning services), which is not an option to most state owned firms due to the power of unions. The O&M data also allow us to address some potential substitution effects between labor and maintenance expenditures.

In order to harmonize O&M expenses over time and across countries, our approach was to convert O&M expenses into 2001 price levels and express them in terms of purchasing power parity (PPP).

Our data on O&M expenses was obtained mainly from CIER reports. In vertically integrated firms, O&M expenses for firm j were calculated as $O\&M_j = O\&M_{1j} + O\&M_{2j} + \left[\sum_{k=1}^{2} O\&M_{kj} \Big/ \sum_{k=1}^{4} O\&M_{kj}\right] O\&M_{5j}$, where $O\&M_{1j}$=distribution (proper); $O\&M_{2j}$=billing and collection; $O\&M_{3j}$=generation; $O\&M_{4j}$=transmission; and $O\&M_{5j}$=administrative and general. We have a total of 210 observations corresponding to 73 firms operating in 10 countries—we do not have O&M data from Panama, Costa Rica, and Mexico. Summary statistics of O&M expenses are reported in Table 1.

Results corresponding to the O&M specification are reported in columns (1) and (2) of Table 3. The coefficient on corruption is negative and significant at the 10% level, thus providing additional support to the hypothesis that higher corruption at the country level has a negative impact on firms' efficiency. The absolute value of the coefficient is substantially higher than in the labor requirement specifications suggesting that corruption has a higher impact on O&M costs than on labor requirements. An improvement in one point in the corruption index is associated to a 25% decrease in the O&M costs, *ceteris paribus*. The coefficient on the public dummy is not significant in this specification. This might indicate that public and private firms have different degrees of horizontal integration; public firms might contract fewer activities outside the firm, thus appearing more inefficient in regressions where labor is the dependent variable.[26] Results are unchanged when wages are included as a control in the O&M specification.

6.2. Instrumental variables

We will argue that our use of corruption data at the national level together with firm-level data from one particular industry can be exploited to avoid endogeneity problems. Although it is likely that corruption at the country level may affect the efficiency of a subset of its firms, it is less likely that the inefficiency of a few firms in one industry will affect the country's overall corruption level. The use of micro data corresponding to one industry, however, does not eliminate the possibility that the efficiency of all firms in the country might be correlated, so that reverse causation from firm efficiency to corruption cannot be ruled out. This problem is addressed in our empirical strategy. If there are country-specific elements that affect both corruption and the efficiency of all firms in the country, they should be captured by the country dummies we include as controls. If there are year-specific elements affecting both corruption and the efficiency of firms, they should

[25] The simple correlation between number of employees and O&M expenditures is 0.88.

[26] Using the reduced sample—210 observations, 73 firms, 10 countries—the public dummy is positive and significant at the 1% level in a labor requirement specification. This suggests that the drop in the significance level in the ownership dummy is due to changing the dependent variable, and not to the change of sample.

Table 3
Robustness checks

Variable	Dependent variable: O&M, in logs		Dependent variable: number of employees, in logs			
	(1)	(2)	(3)	(4)	(5)	(6)
	O&M		Instrumental variables		TI index	
Corruption	−0.256 [a]	−0.252 [a]	−0.129 [b]	−0.145 [b]	−0.041 [b]	−0.039
	[0.130]	[0.130]	[0.065]	[0.062]	[0.017]	[0.024]
Public dummy	−0.029	−0.039	0.410 [c]	0.413 [c]	0.534 [c]	0.537 [c]
	[0.164]	[0.155]	[0.091]	[0.092]	[0.082]	[0.083]
Ln (GNP per capita)	0.890 [b]	0.753 [a]	−0.120	−0.082	−0.100	−0.135
	[0.397]	[0.391]	[0.096]	[0.098]	[0.126]	[0.104]
Ln (wages)		0.308		0.200		−0.192
		[1.122]		[0.242]		[0.353]
Ln (Law and order)		0.990		−0.174		0.184
		[0.605]		[0.135]		[0.133]
Inflation		0.003		0.00015 [c]		−0.0016
		[0.004]		[0.00003]		[0.0018]
Inflation variation		0.00001		0.00008 [b]		0.00003
		[0.0001]		[0.00003]		[0.00004]
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.90	0.90	0.95	0.95	0.96	0.96
Number of firms	73	73	80	80	78	78
Observations	210	210	352	352	270	270

Notes: Country–year clustered standard errors are shown in brackets.
In all cases we are estimating a translog labor requirement function. To save space, technological parameters of the translog function are not shown. In all models, the Cobb–Douglas specification is rejected against a translog, at the 1% level.
IV estimates the use M/GDP as an instrument for corruption.
A higher index for corruption implies that the country level of corruption is lower.
[a] Significant at the 10% level.
[b] Significant at the 5% level.
[c] Significant at the 1% level.

be captured by the time dummies we include. And if there are shocks affecting both corruption and nationwide firm efficiency that differ by country and year, they should have an impact on GDP per capita for the corresponding country and year, which is also included as a control.

Still, we report instrumental variables (IV) estimates which might help not only because corruption might be endogenous, but also because corruption is probably measured with error and IV estimates ameliorate attenuation bias.

In order to run the IV specification we need to identify factors determining corruption that do not enter the labor requirement function for our sample of electricity distribution firms. We have data for the share of imports in GDP, which proxies a country's openness to trade. This variable has been shown to play an important explanatory role in corruption regressions (Ades and Di Tella, 1997; Gatti, 1999), and can be expected not to enter directly into the labor requirement regression. As suggested by Shea (1997), we test the relevance of the instrument by means of the partial *R*-squared between the ICRG corruption index and the share of imports in GDP. Testing the relevance of the instrument is important because if the instruments exhibit only a weak correlation with the endogenous regressor, the normal distribution provides a very poor approximation to the true distribution of the IV estimator, even if the sample size is large (Verbeek, 2004, Chapter 5).

After controlling for all exogenous variables, the partial R-squared between the ICRG corruption index and the share of imports in GDP is 0.28. The F-statistic associated to the coefficient of the share of imports in GDP in a regression of corruption on all the exogenous variables is equal to 36. According to Stock and Watson (2003, Chapter 10) an F-statistic that exceeds 10 suggests that the instrument is not weak. In addition, trade openness can be assumed not to directly affect the performance of electric utilities.[27]

Results from the IV specification are shown in columns (3) and (4) of Table 3. The coefficient on corruption remains negative and significant at the 5% level. Its value, however, is higher than in previous specifications suggesting that measurement error might be present in the corruption index.

We also test the hypothesis of exogeneity of corruption by means of a version of the Hausman (1978) test proposed by Davidson and MacKinnon (1989), which consists in obtaining the residuals from a first-stage regression—a regression of corruption on all the exogenous variables —and then testing whether those residuals are significant in the original OLS equation of interest. If they are not significant, then exogeneity cannot be rejected. In the first-stage regression the coefficient on the instrument has the expected sign and is significant at the 1% level. Since the residuals corresponding to the first-stage regression are not significant when included in the second stage regression—the p-value is 0.71—we cannot reject the hypothesis that country-level corruption is exogenous in our firm-level specification.

6.3. Alternative corruption index

We want to make sure our results are not an artifact of a particular measure of corruption. Therefore, we now report results using the Corruption Perceptions Index (CPI) provided by Transparency International (TI). This index captures the perceptions of business people, academics, and risk analysts. This index is less consistent than the one we have used so far, because it relies on different sources for different years. Therefore, the index is not strictly comparable along the years, which is important in a panel setting where the within country variation over time plays a key role. It is for this reason that we do not use the TI index as our main measure. However, because the TI index is a composite of a wide array of corruption measures, it would be reassuring if we could replicate our basic regressions and obtain somewhat similar results. The exercise would allay fears that our results may be an artifact of a corruption measure that is at odds with most other accepted measures.

The CPI ranges between ten (highly clean) and zero (highly corrupt). Since there are no data for the CPI in 1994, nor CPI figures for Costa Rica in 1995, Ecuador (1996), Panama (1995–1999), Paraguay (1995–1996 and 1999–2000), Peru (1995–1996), and Uruguay (1995–1996 and 1999), the sample is reduced from 352 to 270 observations. The sample has now only 7 time periods (1995–2001), 12 countries (we lost all observations for Panama), and 78 firms (instead of the 80 firms used in the previous section). Summary statistics of the CPI are presented in Table 1. The simple correlation between the CPI and the ICRG index is 0.60, which already tells us that the main index we have used is highly correlated with the more widely sourced TI index.

OLS estimates of the average labor requirement function using the TI corruption measure are reported in columns (5) and (6) of Table 3. In the basic specification controlling for ownership type and development level, the coefficient on corruption is negative and significant at the 5% level, indicating that higher corruption has a negative impact on efficiency. The coefficient on the

[27] Openness to trade is not significant when included in the labor requirement specification. This holds regardless of whether GNP per capita, the public dummy, or any combination of these, are included in the regression.

Table 4
Robustness checks — firm fixed effects

Variable	Dependent Variable: number of employees, in logs			
	(1)	(2)	(3)	(4)
Corruption	−0.036 [a]	−0.034	−0.046 [b]	−0.045 [c]
	[0.022]	[0.022]	[0.019]	[0.018]
Public dummy	0.305 [c]	0.299 [c]	0.260 [c]	0.158 [a]
	[0.078]	[0.080]	[0.084]	[0.085]
Ln (GNP per capita)		−0.053	−0.003	0.009
		[0.077]	[0.084]	[0.076]
Ln (wages)			0.363	0.484
			[0.298]	[0.326]
Ln (Law and order)			−0.416 [c]	−0.392 [c]
			[0.120]	[0.116]
Inflation			0.0001 [c]	0.0001 [c]
			[0.00004]	[0.00004]
Inflation variation			0.00008 [b]	0.00007 [b]
			[0.00003]	[0.00003]
Time dummies	Yes	Yes	Yes	Yes
Firm dummies	Yes	Yes	Yes	Yes
R-squared	0.99	0.99	0.99	0.99
Number of firms	80	80	80	80
Observations	352	352	352	352

Notes: Country–year clustered standard errors are shown in brackets.
In all cases we are estimating a translog labor requirement function. To save space, technological parameters of the translog function are not shown. In all models, the Cobb–Douglas specification is rejected against a translog, at the 1% level.
In the model in column (4) Ln (sales) was replaced by Ln (sales+network losses).
A higher index for corruption implies that the country level of corruption is lower.
[a] Significant at the 10% level.
[b] Significant at the 5% level.
[c] Significant at the 1% level.

public dummy remains positive and significant at the 1% level, again suggesting that public firms are less efficient than private firms. When we add further controls for wages, law and order, inflation, and inflation variation the coefficient on corruption remains almost the same, although a higher standard error takes the p-value of the coefficient to 11%. It is noteworthy that none of the added controls are themselves significant.

The issues of intertemporal comparability of the TI index prevent us from reading too much into these results. With those issues notwithstanding, we believe that the exercise contained in this subsection can be seen to support our initial findings. The results using the TI index tend to go in the same direction as our initial results using the ICRG index, suggesting that the latter results were not an artifact of a particular corruption measure.

6.4. Firm fixed effects

Each of our previous specifications has established a negative association between corruption and efficiency when controlling for country fixed effects. These models assume that time-invariant effects are uniform across firms within the same country. In Table 4 we replicate the estimates provided in Table 2, this time replacing country fixed effects with firm effects. In all models the coefficients on corruption and the public dummy keep their signs and remain statistically significant. In the firm effects specification the coefficient on corruption is smaller than reported in Table 2, but still economically relevant. According to the estimate in the specification with full controls in column (3) of Table 4, if the median country in terms of corruption in our sample (Brazil) reduced its corruption to the sample mininum (that of Costa Rica), its utilities would use 7% fewer workers.

Once firm effects are accounted for, inflation and inflation variation retain their (expected) sign and significance. However, the economic relevance of macroeconomic instability appears tiny in comparison with that of corruption. Law and order, which was not significant in the specification with country fixed effects, becomes strongly significant, economically relevant, and has the expected sign: countries with less law and order have more inefficient firms. We believe it is noteworthy that corruption appears to play a separate role from that of variables capturing the general traits of the environment facing firms (law and order, macro instability), and that the effect of corruption is more robust across specifications.

6.5. Quality of service

Thus far, the only variable related to quality of service included in the model is energy losses. We could not systematically include other measures of quality of service in our model because of lacking comparable data across countries. However, we are interested to know whether it is likely that the absence of data on quality of service may affect our estimate of corruption.

To do this, we take advantage of some information available for a widely used measure of quality of service: mean frequency of interruptions per customer (FC), defined as $\mathrm{FC} = \frac{\sum_{i=1}^{n} \mathrm{Ca}_i}{\mathrm{Cs}}$ (where Ca_i is the number of customers affected by interruption i, Cs is the total number of customers, and n is the total number of interruptions). Table 5 presents sample summary statistics, by country, for FC.[28]

To address the potential impact on the corruption coefficient of the omission of quality of service variables from the model, we provide the simple correlation between corruption and FC. The correlation of the ICRG index of corruption with FC is equal to 0.12, a number that is not significantly different from zero; thus, we cannot reject the hypothesis that this measure for quality of service is orthogonal to the corruption variable and therefore that the coefficient of the latter should not be significantly biased due to the omission of FC from the model.[29]

7. Conclusions

We have presented what we believe is the first attempt at using firm-level data to test a theory of how corruption affects the technical efficiency of firms. We derived a testable hypothesis from a simple model in which corruption causes a diversion of managerial effort away from the supervision and coordination of the productive process. Firms then employ more factors in order to make up for the poorer coordination of their use, and this extra use of resources constitutes an inefficiency.

[28] In order to maximize the sample size, we include in Table 5 information on quality of service for some firms that were not in our original sample.

[29] We ran a regression adding FC to the model in column (2) in Table 2. The coefficient on corruption is negative and significant at the 20% level and the coefficient on the public dummy is positive and significant at the 1% level. These results, however, have to be interpreted with great care. Given that we have information on quality of service for some firms for which we do not have information on transformer capacity, we only have 83 observations when FC is included in the regression model.

Table 5
Summary statistics of quality of service

Country	Mean frequency of interruption per customer (FC)	
	Number of observations	Sample mean
Argentina	22	6.98
Bolivia	7	11.23
Brazil	113	21.08
Chile	0	
Colombia	6	9.00
Ecuador	4	24.63
Paraguay	0	
Uruguay	2	17.58
Venezuela	6	6.42
Peru	4	22.15
Costa Rica	15	15.02
Panama	0	
Mexico	0	
Total	179	17.62
Public firms	107	19.11
Private firms	72	15.41

Our main finding is that corruption is strongly associated with inefficiency at the firm level in the sense that in more corrupt countries more labor is used to produce a given level of output. We also find that public firms are substantially less efficient in their use of labor than private firms. The estimated effects are large in economic terms.

The association we identify between corruption and firm efficiency is robust. To deal with problems of omitted variable bias we controlled for GNP per capita, time effects, country or firm effects, as well as a set of country-specific time-varying regressors. This set includes measures of prevailing wages, law and order prevalence, and macroeconomic instability. The association between corruption and inefficiency remains significant in the presence of all of these variables, which are particularly significant in the firm fixed effects specification. Inflation, inflation variation, and deficiencies in law and order appear themselves to be associated with greater inefficiency, but their inclusion does not affect the significance of corruption. This is interesting because it suggests that corruption plays a separate role that is distinct from the impact of an unstable or insecure environment. Of all factors varying by country and time that we analyze, corruption is the one that is invariably significant and economically relevant across specifications, which we believe is noteworthy. The effect of corruption remains significant when taking into account problems like energy theft and firm heterogeneity in terms of size and integration patterns.

We use national level data on corruption while efficiency is tied to input–output data at the firm level from a single industry. When combined with our set of controls, the type of data we have used makes it unlikely that an endogeneity bias is present in our estimate of how corruption affects firm efficiency. Still, because of any remaining concerns with endogeneity, as well as concerns with attenuation bias, we used a standard instrument for corruption, namely openness to trade as proxied by the ratio of imports to GDP. We found that the instrumental variable estimate of the effect of corruption on efficiency is significant.

In order to check our focus on labor use, we investigated the effects of corruption using a measure of efficiency based on operation and maintenance expenditures. We found that public firms do not appear to be less efficient, while they appeared so in term of labor use. This divergence might reflect differences in subcontracting practices across private and public firms. However, corruption is significantly associated with inefficiency for all firms. Although the use of country-level corruption indices may not be as desirable as having data on how corrupt is the environment facing each, the use of such indices allowed us to conduct our study on a continental scale, which is important for external validity reasons.

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Appendix A. Second-order conditions for the manager's problem

The Hessian matrix has a typical element a_{ij} in row i and column j. The sufficient second-order condition for a maximum states that the principal minors should have the following signs, $|H_1|=a_{11}<0$, $|H|=a_{11}a_{22}-a_{21}a_{12}>0$. In our model, the elements of the Hessian are:

$$a_{11}=p_{e_pe_p}\overline{Q}-\psi_{ee}<0,\ a_{12}=a_{21}=\psi_{ee}\frac{dA^{-1}}{d(.)}\frac{\overline{Q}f_l}{f^2}>0,$$

and

$$a_{22}=-\psi_{ee}\left[\frac{dA^{-1}}{d(.)}\frac{\overline{Q}f_l}{f^2}\right]^2-\psi_e\frac{d^2A^{-1}}{d(.)^2}\left[\frac{\overline{Q}f_l}{f^2}\right]^2+\psi_e\frac{dA^{-1}}{d(.)}\overline{Q}\frac{\left(f_{ll}f^2-2f_l^2f\right)}{f^4}<0.$$

The first principal minor is then clearly negative. The second can be seen to be positive:

$$|H|=p_{e_pe_p}\overline{Q}a_{22}-\psi_{ee}\left[a_{22}+\psi_{ee}\left[\frac{dA^{-1}}{d(.)}\frac{\overline{Q}f_l}{f^2}\right]^2\right]>0.$$

Proof of Proposition 1. The first-order conditions to problem (3) satisfy the conditions for the implicit function theorem. Then the comparative static effects of c on e_p^*, and l^* can be written as,

$$\frac{de_p^*}{dc}=\frac{b_1a_{22}-a_{12}b_2}{|H|}$$

$$\frac{dl^*}{dc}=\frac{-b_1a_{21}+b_2a_{11}}{|H|},$$

where $b_1=-p_{e_pc}\overline{Q}<0$ and $b_2=0$ capture the direct effects of corruption on the first-order conditions for e_p and l respectively. We then obtain,

$$\frac{de_p^*}{dc}=\frac{b_1a_{22}}{|H|}>0 \text{ and } \frac{dl^*}{dc}=\frac{-b_1a_{21}}{|H|}>0,$$

which in turn implies $\frac{de_s^*}{dc}<0$, concluding the proof.

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