Coping with poor public capital

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Abstract

Despite recent successes in stabilization and structural reforms in many developing countries, the private investment response to date has been mixed, even among the strongest reformers. This disappointing result can be partly explained by the continued poor provision of public capital and services. We test this hypothesis using unique firm-level data on investment and provision of public infrastructure services. The results suggest that poor complementary public capital significantly reduces private investment. However, firms can substitute for deficient public services by investing in complementary capital themselves. But this comes at a cost: less productive capital will be installed.

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1. Introduction

Until recently, the traditional approach to growth in the development economics literature (and even more so in the policy debate) was rather mechanical: growth was constrained by lack of investment which, in turn, was constrained by lack of finance. If finance was made available, it was argued, investment would follow (Easterly, 1997).
Although underdeveloped financial systems are found to be associated with poor economic performance in cross-country regressions (King and Levine, 1993), evidence from several African countries indicate that liquidity constraints at best can only be part of the explanation. Hence, factors other than finance must explain the apparent reluctance of firms to invest and expand.  

In the extensive cross-country growth literature, the role of macroeconomic policy, proxied by government budget deficits, black market premia, and inflation (see for instance Easterly and Rebelo, 1993; Barro, 1991; Fisher, 1993), has been identified as an important determinant of both the efficiency and the level of investment and growth. Despite recent macroeconomic reforms in many developing countries, however, the private investment response has been disappointing, particularly in Africa (Collier and Gunning, 1999). Uganda is a good example. Over the past decade, Uganda has consistently liberalized its economy, and now has one of the best macroeconomic environments in Africa. Still, the investment response by firms is not significantly different from other African countries with significantly worse macroeconomic environments (Reinikka and Svensson, 2001b).

The role of poor infrastructure and deficient public services has received relatively little attention in the economic literature. The existing empirical evidence, based on cross-country data, indicates that the effect of public spending and investment on growth is, at best, ambiguous (Barro and Sala-i-Martin, 1995; Easterly and Rebelo, 1993; Devarajan et al., 1996).  

This ambiguity may simply be a problem of identification: more spending does not necessarily imply more public capital or services (Pritchett, 1996; Reinikka and Svensson, 2001a). In fact, when output measures of public capital, such as telephones per worker rather than spending, have been used to proxy for infrastructure constraints, a positive relationship between infrastructure quality and growth emerges (Easterly and Levine, 1997). As with other outcome measures used in cross-country analysis, however, the direction of causality is unclear, thus making it difficult to assess the relationship.

This paper avoids the identification problem by using unique microeconomic evidence on provision of infrastructure services and private investment in Uganda. We find that poor public capital, proxied by unreliable and inadequate electric power supply, significantly reduces investment in productive capacity by firms. The firm-level data also reveal how firms cope with deficient public capital: when public provision of services and infrastructure is poor, they can invest in complementary capital themselves. The cost of this strategy, however, is that less productive capital is installed.

These results have clear policy implications. Although macroeconomic reforms and stabilization are necessary conditions for sustained growth and private investment, without an accompanying improvement in the public sector’s performance, the private supply response to macroeconomic policy reform is likely to remain limited.

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2 Bigsten et al. (1999) study private investment in four African countries. They find that lack of liquidity partly constrains the capital accumulation of small enterprises, but less so for larger firms.

3 Easterly and Rebelo (1993) find that overall public investment has a very low impact on growth, but that certain types of investment expenditures are correlated with growth. Devarajan et al. (1996) find that the standard candidates for productive expenditures had either a negative or an insignificant relationship with growth.
The rest of the paper is organized as follows. Section 2 explores the stylized facts of deficient public capital from the viewpoint of firms. Section 3 sets out a simple model highlighting the relationship between firms’ productive investment and availability of complementary capital. The model captures salient features of low-income economies by assuming incomplete credit markets, deficient supply of publicly provided complementary capital, and uncertainty about its future improvement. Section 4 tests the model using firm survey data from Uganda. Section 5 concludes.

2. Deficient public capital: a case study of a developing country

This section stylizes some facts about deficient public capital in a typical low-income developing country. The data come from a recent (1998) firm survey in Uganda that collected information on infrastructure services and private investment. The survey covered a total of 243 firms for the period 1995–1997 (Reinikka and Svensson, 2001b).

We define complementary capital as capital that provides support services necessary for the operation of productive private capital (e.g., transport infrastructure, such as roads, ports, and railways; or utilities, such as electricity, water, and telephone). In low-income countries, complementary capital is typically publicly provided. In certain cases, the firm can substitute for deficient public services by investing privately in complementary capital (e.g., electric power generators or waste disposal). However, some types of complementary capital are difficult to substitute, such as transport infrastructure.

Is poor public service perceived to be an important constraint for firms? Fig. 1 ranks firm managers’ perceptions on a wide range of constraints to investment. Managers rated poor infrastructure services (and the cost of these services) as the most binding constraint: unreliable and inadequate electricity was ranked as most binding, followed by telephone services, roads, and waste disposal. Although most firms (94%) were connected to the public grid, power supply was ranked as a major obstacle for every sector and firms of all

![Fig. 1. Major constraints to investment. Note: The managers were asked to rank 24 potential bottlenecks. Those close in both ranking and interpretation (poor utility service and high utility prices; high taxes and poor tax administration; high interest rates and lack of access to finance), were combined. Source: Reinikka and Svensson, 2000b.](image)
sizes, whether foreign or domestic. Responses suggest that the supply of electricity had in fact worsened in the recent years.

The quantitative information reveals a similar picture. On average, the firms surveyed did not receive electricity from the public grid, a monopoly supplier, for 89 operating days (the sum of all part or full days) a year (74 days at the median). As a result, many firms invested in a back-up power generator: 77% of large firms, 44% of medium-sized firms, and 16% of small-sized firms owned generators. The cost of generators represented 16% of the value of total investment, on average, and 25% of the value of investment in equipment and machinery in 1997. Moreover, the data suggest that it costs about three times more to run and own a generator than to buy power from the public grid (when it is available).

Despite the generally poor quality of public electricity service, there were large variations across firms in terms of days without power (Fig. 2). These variations were partly the result of unreliable power supply in general, and partly the result of service on specific power lines. For instance, interviews with firm managers suggested that firms connected to “priority” lines (e.g., power lines that connect important army facilities) were more likely to receive reliable power supply.

Access to public telephone service varied by location and firm size. On average, it took 13 weeks to obtain a telephone connection. Over one-half of the firms invested in mobile phones (a privately run service) because public service was so inefficient: the average number of attempts to complete calls was 2.5 for a local call, 4.6 for a long distance call within Uganda, 4 for a call to a neighboring country, and 2.8 for an international call.

One-third of the firms reported having access to public waste disposal services, but few could actually rely on them. Eight percent of firms used a private provider and 77% disposed of their own waste. Similar problems plagued other public capital services, including water supply (firms reported 33 days of inadequate supply a year), postal

![Fig. 2](image-url)
services (only 31% of business correspondence was delivered by the public post office), 
ports and airports, road and rail services.

Altogether, the summary statistics suggest that the magnitude of poor infrastructure and 
deficient public services is considerable, and therefore might have significant effects on 
firms’ investment and business decisions. In Section 4, we formally test if this is the case, 
and in Section 3, we present a simple stylized model to guide the empirical work.

3. Model

Below we set out a simple three-period model to guide the empirical specification. The 
objective is to show that the perceived quality of publicly provided complementary capital 
influences both the investment decision in productive capital, and firms’ decisions whether 
to invest privately in complementary capital. The salient features of the model are the 
assumptions that firms can (partly) cope with deficient public capital, but that it is costly to 
do so, and that information about the quality of the public supply changes over time.

3.1. Basics

A risk-neutral firm has to decide whether to make a capital investment $i > 0$. Investment 
is productive with a one-period lag. The cost of capital is $\delta(i)$, with $\delta(i)>0$ and $\delta_{ii}(i)>0$. The return to $i$ depends (partly) on the stock of complementary capital, which is either 
publicly provided or provided by the firms itself. There is uncertainty about the availability 
and quality of publicly provided complementary capital (e.g., electricity supply). Firms 
can (partly) insure against this uncertainty by substituting public capital for private 
substitutes (e.g., own a generator). However, there is a fixed cost $k>0$ of doing so.4

A firm that has installed private complementary capital can ensure a return $\pi_i$, where 
$\pi > 0$. When complementary public capital is available, the return is also $\pi_i$, while if it is not 
available (or of poor quality), the return is $\pi_i$, where $0 < \varphi < 1$.

The investment decisions are sequential, implying that at the time of the investment in 
private substitutes (generators), the conditions under which investment in production takes 
place are unknown. Specifically, the timing of events is as follows. Initially, in the start of 
Period 1, the firms obtain information about the availability (and quality) of publicly 
provided complementary capital. This information can be used to derive a probability $p$ 
that public capital will be available (and of good quality). To simplify, we assume that 
there are only two possible outcomes: complementary public capital is available with a 
high probability ($p = \overline{p}$), or low probability ($p = \underline{p}$), where $\overline{p} > p$. This set-up captures the 
fact that while the public supply in general is poor, there is a great deal of variation. As 
noted in Section 2, for power supply, the variation is partly due to large differences in the 
priority attached to power lines, but also to local geographical (e.g., distance to nearest 
voltage connection) and political conditions in Period 1 (see also Svensson, 2000). With

4 This seems like a reasonable first approximation. In reality, the private substitute (generator) has two main 
cost components: a fixed installation cost and a running cost, which is typically higher than that of public supply. 
Running costs are assumed to be captured in $k$. 

the ex ante information given, each firm makes a decision whether or not to install private substitutes.

In the beginning of the next period, there is a probability $p > 0$ that new information about the status of the public supply will be revealed. This is a plausible assumption because during the survey period, Uganda was in a process of transformation and many sectors underwent major changes. In addition, local shocks (e.g., weather conditions) may significantly change the entrepreneurs’ initial assessment of the situation. An alternative and our most preferred interpretation is to think of $p$ as the probability of a reform in the electricity sector. Should a reform be initiated (which then occurs with probability $p$), we assume that the old information becomes obsolete. To simplify (without loss of generality), we assume further that the reform in the electricity sector is successful with probability $1/2$, implying that the updated (conditional on reform) probability that public capital is available with a high [low] probability is $1/2$ [1/2]. These assumptions imply that the initial assessment of $p$ changes with probability $p/2$. Should no reform be initiated (i.e., no new information is revealed), which occurs with probability $(1 - p)$, the firm’s initial assessment of $p$ remains unchanged. In Period 2, firms make their investment decision in production capacity. In Period 3, the outcome is realized and production with the newly installed capital takes place:

$$
\begin{array}{c}
\text{Timing} \\
\begin{array}{ccc}
\text{Period 1} & \text{Period 2} & \text{Period 3} \\
p = \{p, \bar{p}\} & \{p, (1-p)\} & \{p\} \pi \\
\end{array}
\end{array}
$$

### 3.2. Equilibrium

The problem can be solved by working backwards. At the end of Period 2, three possible histories need to be considered:

1. The firm has invested in private complementary capital, and therefore can ensure a return $\pi_i$. The optimal investment rate following this history is denoted $i_1$.
2. The firm has not invested in private substitutes and believes it is less likely that public supply will be available the next period (i.e., the perceived probability of complementary public capital availability is $p$). The optimal investment rate following this history is denoted $i_L$.
3. The firm has not invested in private substitutes and believes it is likely that public supply will be available (i.e., the perceived probability of complementary public capital availability is $\bar{p}$). The optimal investment rate following this history is denoted $i_H$.

The investor’s problem can formally be stated as:

$$
\max_{\pi} \pi_i - \delta(i_j + k).
$$

Maximizing net profit (Eq. (3.1)) under the different scenarios and rewriting the corresponding first-order conditions, we have:

$$
i_1 = \delta^{-1}(\pi) - k
$$
\( i_L = \delta^{-1}_L(\pi\bar{\psi}) \)  \hspace{1cm} (3.3)

\( i_H = \delta^{-1}_H(\pi\overline{\psi}) \)  \hspace{1cm} (3.4)

where \( \bar{\psi} = [p+(1-p)\phi] \) and \( \overline{\psi} = [p+(1-p)\phi] \).

At the end of Period 1, each firm makes a decision whether or not to install private substitutes, taking into account the investment functions (Eqs. (3.2)–(3.4)). The optimal choice depends on the initial information of the availability (and quality) of publicly provided complementary capital. The condition for installing a private substitute, if at the start of Period 1 \( p=\bar{p} \), is:

\[
ER_1 = \pi i_L - \delta(i_L + k) \geq \left( \frac{2-\rho}{2} \right) \psi[\pi i_H - \delta(i_H)] + \frac{\rho}{2} \overline{\psi}[\pi i_L - \delta(i_L)] = ER_H. \tag{3.5}
\]

The left-hand side of Eq. (3.5) is the expected return if private substitutes are installed. The first term on the right-hand side is the expected return given that the initial assessment of the likelihood of available public supply does not change, which occurs with probability \((1-\rho) + \rho 1/2 = (2-\rho)/2\), and the second term is the expected return given that new information \( (p=\bar{p}) \) has been revealed.

The condition for installing a private substitute, if initially \( p=p_L \), is similarly:

\[
ER_1 \geq \left( \frac{2-\rho}{2} \right) \psi[\pi i_L - \delta(i_L)] + \frac{\rho}{2} \overline{\psi}[\pi i_H - \delta(i_H)] = ER_L. \tag{3.6}
\]

To simplify the exposition, let \( p=\gamma \bar{p} \), where \( 0<\gamma<1 \). The main results of the investment and private complementary capital analysis are summarized below.

**Proposition 1.** If \( ER_H \geq ER_1 \geq ER_L \), then (i) only firms that initially expected a low probability of available complementary public capital will invest in private substitutes; (ii) for these types of firms, the equilibrium investment rate will be independent of the quality of the publicly provided complementary capital; (iii) for firms that rely solely on publicly provided capital, a lower likelihood of public supply reduces investment in production; (iv) when the expected quality of publicly provided complementary capital is high, a firm that also installs private substitutes may invest less than a firm that only relies on publicly provided capital.

**Proof.** See Appendix B.

Proposition 1 summarizes the main result of the model. Provided \( ER_H \geq ER_1 \geq ER_L \), if initially a firm expects poor supply of public capital, it will choose to invest in private substitutes. In this case, the optimal investment rate is independent of \( p \). Due to convex capital costs, the private substitute will crowd out investment in production. Compared to a firm which perceives it to be likely that public supply will be available, the firm with private substitutes may end up investing less. Lower expected quality of the public capital adversely affects the marginal return to productive investment. This leads to lower investment levels for firms lacking private substitutes.
To illustrate the aforementioned effects, we provide a numerical example, illustrated in Fig. 3.5

4. Empirical findings

4.1. Specification

In this section, we test the implications of the model on a sample of 171 Ugandan establishments. The model characterizes two decisions: the complementary capital decision, captured in Eqs. (3.5) and (3.6), and the production investment decision, given in Eqs. (3.2)–(3.4). Proposition 1 summarizes the key findings.

Proposition 1 states that under certain conditions, firms that expect poor supply of public capital will invest in private substitutes. We do not directly observe the initial (or ex ante) likelihood of public supply (Stage 1). However, we do observe (a proxy of) the expected ex post supply; i.e., we do observe a proxy of the end of Period 2 probabilities \( p_{\text{end of Period 2}} = \{p_p, \bar{p}_p\} \). Given \( p_{\text{end of Period 2}} = \{p_p, \bar{p}_p\} \), we can use Bayes’ rule to determine the likelihood that the information received initially suggested a probability \( p = p \) or \( p = \bar{p} \). Specifically:

\[
Pr[p = p \text{ ex ante } | p = p \text{ ex post}] = \frac{1}{2} \rho
\]  
and

\[
Pr[p = \bar{p} \text{ ex ante } | p = \bar{p} \text{ ex post}] = \frac{1}{2} \rho + (1 - \rho).
\]  

Clearly, if the ex post supply is good, \( p = \bar{p} \), then is also more likely that the ex ante information suggested good supply (Eq. (4.2)). Thus, the ex post (observed) likelihood is

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5 The numerical example is based on the following assumptions, \( \delta(i) = 0.2i^2 \); \( \gamma = 0.6 \); \( \varphi = 0.4 \); \( \rho = 0.2 \); \( \pi = 5 \); and \( k = 4 \).
(highly) correlated with the ex ante (unobserved) likelihood. Using this result, we can test the first implication of the model by reformulating the decision as a probit model. Let \( e_i = 1[0] \) be the event that a firm invests [does not] in complementary capital. Then:

\[
Pr(e_i = 1) = \Phi(x_i p_i, \alpha_z z_i),
\]

where \( \Phi \) is the standard normal distribution function, \( p_i \) is the end of Period 2 likelihood that public capital will be available (and of good quality), and \( z \) is a vector of controls. The model suggest that \( x_1 < 0 \).

Proposition 1 also suggests that investment in production depends on the likelihood that public capital will be available, but that the effect is conditional on having private substitutes installed. We can capture these effects by estimating the following model:

\[
i_i = \beta_0 + \beta_1 p_i + \beta_2 p_i e_i + \beta_3 e_i + \beta_4 x_i + \epsilon_i
\]

where \( x \) is a vector of controls. The model suggests that \( \beta_1 > 0, \beta_1 + \beta_2 = 0, \) and \( \lim_{p \to 1} \frac{\beta_1 p_i}{(\beta_2 p_i + \beta_3)} > 0 \).

4.2. Data

We exploit data from a survey in Uganda on firms’ investment responses to structural reforms (see Reinikka and Svensson, 2001b). The survey was initiated by the World Bank in collaboration with the Ugandan private sector primarily to collect data on constraints facing private firms in Uganda. A total of 243 enterprises were interviewed in five locations, in 14 different subindustries (three-digit ISIC). We were unable to collect detailed cost and sales or investment data for all firms. Thus, we ended up with a smaller sample of 171 firms. Appendix A includes a short description of the survey and definitions of the variables.

It is hard to find the data needed for systematic, quantitative, microeconomic (firm) studies on the effects of poor public provision of complementary capital and services. One objective of the Uganda firm survey was to begin collecting quantitative information on the provision of public services and how firms coped with deficient public capital. As briefly discussed in Section 2, firm managers rated poor utility services (and the cost of these services) as the most binding constraint, and in particular problems related to unreliable and inadequate electricity supply. For this reason, our primary focus will be on the effects of poor power supply and the private sectors’ response to it.

Our quantitative measure of unreliable and inadequate power supply is the number of days in 1997 that a firm did not receive power from the public grid (denoted as LOSTDAYS). Our maintained assumption is that the expected number of days without power is equal to LOSTDAYS plus an iid forecast error. The variable LOSTDAYS is then a suitable proxy for \((1 - p_i)\). Focusing on the electricity sector has the added advantage of an identified substitute for deficient public services: electric power generators. Thus, our proxy for \( e_i \), private complementary capital, is electric power generators (GENERATOR). This is a binary variable taking the value 1 if the firm reported that it owned a generator at the end of the sample period, and 0 otherwise.
The dependent variable, the investment rate (denoted by INV), is measured as investment in machinery and equipment in 1997 excluding potential investment in generators, as a share of the previous period’s capital stock.

In the model, firms differ only with respect to $p_i$. In reality, however, firms also differ in many other respects that might influence both the decision to invest in private substitutes and investment in production. So, while there is no theoretical justification for adding other variables to the empirical model, it would be of considerable concern if our results were completely driven by the exclusion of some of the most common controls. For this reason, we include total employment (SIZE) and age (AGE) as additional controls in the investment (Eq. (4.4)). A common argument in the empirical investment literature is that larger and more established firms are more likely to have access to lower cost capital (external finance). If firms face credit (liquidity) constraints, retained earnings should also influence investment.$^6$ We do not have a direct measure of retained earnings. As a proxy, we include profits, measured as sales less operating costs and interest payments (PROFIT). The empirical model is hence:

$$\text{INV}_i = \beta_1 \text{LOSTDAYS}_i + \beta_2 \text{GENERATOR}_i \ast \text{LOSTDAYS}_i + \beta_3 \text{GENERATOR}_i + \beta_4' x_i + \epsilon_i$$ (4.5)

where $x_i = [\text{AGE}_i, \text{SIZE}_i, \text{PROFIT}_i]$. To minimize the heteroskedasticity problem with respect to size, investment and profits are scaled by the inverse of the capital stock at end of the previous period.

For the same reason as discussed above, we also include AGE and SIZE as controls in the complementary capital equation. If there are indivisibilities in $k$, it is plausible that larger firms will find it easier to match available private substitutes to their needs. The impact of age is unclear; mature firms tend to have installed substitutes for lack of public services over the years, but older firms might also have learned to cope with public inefficiencies through other channels (e.g., contacts) and thus in less need of a generator. The empirical model is:

$$\Pr(\text{GENERATOR}_i = 1) = \Phi(x_1 \text{LOSTDAYS}_i, x_2 \text{AGE}_i, x_3 \text{SIZE}_i).$$ (4.6)

Eqs. (4.5) and (4.6) constitute a recursive system. Provided there is no correlation between the disturbances in the two equations, the two equations can be efficiently estimated separately.

### 4.3. Results

Before proceeding to the results, it is useful to take an initial look at some of the data. Table 1 reports summary statistics for the 171 firms in the sample. Forty percent of the firms owned a generator by the end of the sample period. Not all firms reported the size of

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$^6$ The model assumes no credit constraints. It is, however, straightforward to introduce liquidity constraints. The qualitative results would remain unchanged. The only difference would be that the investment decisions would be conditional on enough funding being available.
the generator. For those that did, the size varied greatly, with a mean of roughly 270 kVA (median 140 kVA) and a standard deviation of 550 kVA.

As depicted in Table 2, firms with installed generators typically are larger and reported more days without power from the public grid in 1997. The two types of firms are similar with respect to age and profit rate (at the median).

Table 3 reports the probit regressions. Column (1) depicts the simple bivariate regression. LOSTDAYS enters significantly and with a positive coefficient. This result is in accordance with the model; the incentive to invest in a private substitute—in this case a generator—increases with the likelihood of poor/no public supply. Column (2) adds the two controls AGE and SIZE. Age appears uncorrelated with the probability of having an installed generator, while SIZE enters significantly with a positive coefficient. A plausible explanation for the latter result is indivisibilities in $k$.

The relationship between LOSTDAYS and the estimated likelihood of owning a generator is illustrated in Fig. 4. As evident, the quantitative effect is large. The probability that a firm with 1 S.D. fewer days with power from the public grid (compared with the average firm) owns a generator is slightly more than 60%. This is roughly 20% higher than the average number.

In Columns (3)–(6), we augment the base specification with several additional variables that might be correlated with the likelihood to invest in complementary capital; PROFIT (Regression 2), percentage of foreign ownership, FOREIGN (Regression 3), change in sales, ΔSALES (Regression 4), and a binary variable indicating if the firm exports part of its output, EXPORT (Regression 5). The significant negative impact of

### Table 1
Summary statistics for all firms

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Median</th>
<th>Minimum</th>
<th>Maximum</th>
<th>S.D.</th>
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<tbody>
<tr>
<td>Employment</td>
<td>114</td>
<td>29</td>
<td>5</td>
<td>2000</td>
<td>252</td>
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<tr>
<td>Log(employment)</td>
<td>3.62</td>
<td>3.37</td>
<td>1.61</td>
<td>7.60</td>
<td>1.41</td>
</tr>
<tr>
<td>AGE</td>
<td>13.10</td>
<td>10.00</td>
<td>1</td>
<td>73</td>
<td>12.4</td>
</tr>
<tr>
<td>AGE (log)</td>
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<td>2.30</td>
<td>0</td>
<td>4.29</td>
<td>0.97</td>
</tr>
<tr>
<td>PROFIT</td>
<td>0.72</td>
<td>0.26</td>
<td>-2.63</td>
<td>9.17</td>
<td>1.55</td>
</tr>
<tr>
<td>LOSTDAYS</td>
<td>88.70</td>
<td>74.00</td>
<td>0</td>
<td>365</td>
<td>69.1</td>
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<tr>
<td>Log(1 + LOSTDAYS)</td>
<td>4.04</td>
<td>4.32</td>
<td>0</td>
<td>5.90</td>
<td>1.24</td>
</tr>
<tr>
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<td>171</td>
<td>171</td>
<td>171</td>
<td>171</td>
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</table>

### Table 2
Summary statistics by ownership of generator

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<th>Owns a generator</th>
<th>Does not own a generator</th>
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</thead>
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<td></td>
<td>Mean</td>
<td>Median</td>
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<tr>
<td>Employment</td>
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<td>100</td>
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<td>AGE</td>
<td>14.9</td>
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<td>PROFIT</td>
<td>0.52</td>
<td>0.28</td>
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<td>LOSTDAYS</td>
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<td>90</td>
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<tr>
<td>CAPACITY (kVA)</td>
<td>273</td>
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<tr>
<td>Observations</td>
<td>69</td>
<td>69</td>
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Table 3
Complementary capital decision

<table>
<thead>
<tr>
<th>Equations</th>
<th>Eq. (3.1)</th>
<th>Eq. (3.2)</th>
<th>Eq. (3.3)</th>
<th>Eq. (3.4)</th>
<th>Eq. (3.5)</th>
<th>Eq. (3.6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent variable</td>
<td>GENERATOR</td>
<td>GENERATOR</td>
<td>GENERATOR</td>
<td>GENERATOR</td>
<td>GENERATOR</td>
<td>GENERATOR</td>
</tr>
<tr>
<td>Method</td>
<td>Probit</td>
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<td>Probit</td>
<td>Probit</td>
<td>Probit</td>
</tr>
<tr>
<td>Constant</td>
<td>1.010*** (0.367)</td>
<td>−3.456*** (0.605)</td>
<td>−3.397*** (0.616)</td>
<td>−3.704*** (0.651)</td>
<td>−3.402*** (0.612)</td>
<td>−3.650*** (0.632)</td>
</tr>
<tr>
<td>LOSTDAYS (log)</td>
<td>0.185 ** (0.097)</td>
<td>0.181 * (0.097)</td>
<td>0.188 * (0.098)</td>
<td>0.212 ** (0.103)</td>
<td>0.188 * (0.098)</td>
<td>0.188 * (0.100)</td>
</tr>
<tr>
<td>Employment (log)</td>
<td>0.646*** (0.101)</td>
<td>0.646*** (0.101)</td>
<td>0.612*** (0.105)</td>
<td>0.651*** (0.101)</td>
<td>0.600*** (0.104)</td>
<td></td>
</tr>
<tr>
<td>AGE (log)</td>
<td>0.040 (0.118)</td>
<td>0.037 (0.119)</td>
<td>0.092 (0.124)</td>
<td>0.025 (0.120)</td>
<td>0.096 (0.124)</td>
<td></td>
</tr>
<tr>
<td>PROFIT</td>
<td>−0.139 (0.098)</td>
<td>0.006 * * (0.003)</td>
<td>−0.028 (0.031)</td>
<td>0.778 * * * (0.265)</td>
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<tr>
<td>ΔSALES</td>
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<tr>
<td>EXPORT</td>
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<tr>
<td>Observations</td>
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<td>170</td>
<td>170</td>
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</tr>
</tbody>
</table>

(i) Dependent variable is GENERATOR (binary variable taking the value 1 if the firm reported owning a generator at the end of the sample period, and 0 otherwise). (ii) Probit regressions. (iii) Standard errors in parenthesis.

* Denotes significance at the 10% level.
** Denotes significance at the 5% level.
*** Denotes significance at the 1% level.
LOSTDAYS remains in all regressions. The variables FOREIGN and EXPORT are also significantly correlated with the likelihood of having an installed generator.

Table 4 reports the investment regressions. Column (1) depicts the regression without the basic controls (x). All three variables of primary interest, LOSTDAYS, GENERATOR, and the interactive term enter both individually and jointly as highly significant.⁷ In accordance with the model, there is a significant difference in investment behavior conditional on $p$ between firms with installed generators and firms without. The investment level of firms with installed generators is quantitatively independent of $p$. Specifically, we cannot reject the null hypothesis that $\beta_1 + \beta_2 = 0$.⁸ For firms without a generator, however, investment is negatively related to number of lost days. As predicted by the model, conditional on few lost days, firms that have installed complementary capital invest less than firms that did not have a generator. This supports the result that private complementary capital crowds out private investment; i.e., firms that install complementary capital invest less than firms that do not, provided that the quality of public capital is sufficiently good.

In Regression 2, we add the set of controls. LOSTDAYS, GENERATOR, and the interactive term remain highly significant. PROFIT also enters significantly, with a positive coefficient, suggesting that many firms do indeed face binding credit (liquidity) constraints. Regression 2 is illustrated in Fig. 5. The estimated magnitude of deficient public capital on investment is large. For a firm that relies solely on public capital, a 1 S.D. deterioration in power supply (evaluated at the mean) would result in an 11-percentage point drop in the investment rate. At the mean value of LOSTDAYS (89 days), the

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⁷ One extreme outlier is dropped. Including this, observation increases the standard errors on GENERATOR and the interactive term (GENERATOR-LOSTDAYS). However, the three variables of main interest; LOSTDAYS, GENERATOR, and GENERATOR-LOSTDAYS are still jointly significant ($F$ statistic on the joint hypothesis of zero coefficients is 3.0 in Column (1), Table 4).

⁸ The $F$ statistic is 0.21 with $p$ value 0.65.
Table 4
Investment regressions

<table>
<thead>
<tr>
<th>Equations</th>
<th>Eq. (3.1)</th>
<th>Eq. (3.2)</th>
<th>Eq. (3.3)</th>
<th>Eq. (3.4)</th>
<th>Eq. (3.5)</th>
<th>Eq. (3.6)</th>
</tr>
</thead>
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<tr>
<td>Dependent variable</td>
<td>INV</td>
<td>INV</td>
<td>INV</td>
<td>INV</td>
<td>INV</td>
<td>INV</td>
</tr>
<tr>
<td>Method</td>
<td>OLS</td>
<td>OLS</td>
<td>OLS</td>
<td>OLS</td>
<td>OLS</td>
<td>OLS</td>
</tr>
<tr>
<td>Constant</td>
<td>0.382*** (0.085)</td>
<td>0.407*** (0.110)</td>
<td>0.386*** (0.112)</td>
<td>0.398*** (0.120)</td>
<td>0.411*** (0.111)</td>
<td>0.413*** (0.112)</td>
</tr>
<tr>
<td>LOSTDAYS (log)</td>
<td>−0.076*** (0.021)</td>
<td>−0.073*** (0.020)</td>
<td>−0.068*** (0.020)</td>
<td>−0.076*** (0.020)</td>
<td>−0.074*** (0.020)</td>
<td>−0.074*** (0.020)</td>
</tr>
<tr>
<td>LOSTDAYS (log)*GENERATOR</td>
<td>0.091*** (0.38)</td>
<td>0.087*** (0.037)</td>
<td>0.081*** (0.037)</td>
<td>0.089*** (0.037)</td>
<td>0.084*** (0.037)</td>
<td>0.089*** (0.037)</td>
</tr>
<tr>
<td>GENERATOR</td>
<td>−0.371*** (0.166)</td>
<td>−0.329*** (0.159)</td>
<td>−0.301* (0.161)</td>
<td>−0.336*** (0.161)</td>
<td>−0.311* (0.160)</td>
<td>−0.330* (0.160)</td>
</tr>
<tr>
<td>AGE (log)</td>
<td>−0.041* (0.021)</td>
<td>−0.037* (0.021)</td>
<td>−0.040* (0.022)</td>
<td>−0.044* (0.022)</td>
<td>−0.042* (0.022)</td>
<td>−0.042* (0.022)</td>
</tr>
<tr>
<td>PROFIT</td>
<td>0.054*** (0.014)</td>
<td>0.047*** (0.015)</td>
<td>0.052*** (0.014)</td>
<td>0.054*** (0.014)</td>
<td>0.054*** (0.014)</td>
<td>0.054*** (0.014)</td>
</tr>
<tr>
<td>Employment (log)</td>
<td>6.8E−4 (0.018)</td>
<td>−0.001 (0.018)</td>
<td>5.5E−4 (0.018)</td>
<td>0.005 (0.018)</td>
<td>0.002 (0.018)</td>
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<tr>
<td>ΔSALES</td>
<td>0.021 (0.017)</td>
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<tr>
<td>CAPACITY</td>
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<tr>
<td>FOREIGN</td>
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<tr>
<td>EXPORT</td>
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<td></td>
</tr>
<tr>
<td>F statistic</td>
<td>4.57 (0.004)</td>
<td>4.51 (0.005)</td>
<td>3.88 (0.010)</td>
<td>4.65 (0.004)</td>
<td>4.59 (0.004)</td>
<td>4.55 (0.004)</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.06</td>
<td>0.15</td>
<td>0.15</td>
<td>0.14</td>
<td>0.15</td>
<td>0.14</td>
</tr>
<tr>
<td>Observations</td>
<td>170</td>
<td>170</td>
<td>170</td>
<td>168</td>
<td>170</td>
<td>170</td>
</tr>
</tbody>
</table>

(i) Dependent variable is investment in machinery in equipment to capital stock in previous period. (ii) OLS regressions. (iii) Standard errors in parenthesis. (iv) $F$ statistic is the test statistic for the null hypothesis that the coefficients on LOSTDAYS, LOSTDAYS*GENERATOR, GENERATOR are zero, with $p$ values in parentheses.

* Denotes significance at the 10% level.
** Denotes significance at the 5% level.
*** Denotes significance at the 1% level.
investment rate for firms with installed generators is higher than the investment rate for firms with no generator. However, the picture is reversed at low values of LOSTDAYS.

To test the robustness of these results, we added additional controls to the base specification. Regression 3 adds a change in sales. According to a traditional accelerator model, investment is positively related to demand changes (see for instance Tybout, 1983). However, once we control for profit, \( \Delta \text{SALES} \) has no significant impact. In Regression 4, the base specification is augmented with a measure of capacity utilization (CAPACITY), in Regression 5 with the percentage of foreign ownership, and in Regression 6 with EXPORT. As evident, neither variable enters significantly. In all three regressions, LOSTDAYS, GENERATOR, and the interactive term remain highly significant.

As a further check on robustness, we report the results of some additional sensitivity analysis in Table 5. The estimated residuals tend to be larger for the larger firms in the sample (as measured by log of employment). As a possible correction for heteroskedasticity, we reestimated the model by weighting observations with employment. The results, shown in Regression 1, remain intact. In Column (2), Table 5, we reestimate the model with all variables in logs. This has the well-known advantage that the coefficients can be interpreted as elasticities. However, since both PROFIT and INVESTMENT can take negative values, we have to add constants to these terms, implying that the elasticities are not constant. Column (3) displays the estimated elasticities evaluated at the mean. For a firm lacking private substitutes of complementary capital, a 1% increase in the number of days without power results in a 0.45% reduction in investment. As in previous regressions, we cannot reject the hypothesis that \( \beta_1 + \beta_1 = 0 \). Thus, an increase in number of days lost has no statistically significant effect on investment for firms with their own generators.

So far, we have relied on the stylized model to identify the relationship between the set of regressors and INV. However, it is plausible that some of the explanatory variables are influenced by the level of investment, or the error term in Eq. (4.5). SIZE and PROFIT are obvious cases in point. It is difficult to find exogenous instruments in firm-level data. We
deal with the possible endogeneity problem by instrumenting for SIZE and PROFIT using lagged values of the same variables. While concern could be raised about autocorrelated errors, making the use of lagged variables questionable, the instrument strategy at least mitigates contemporaneous correlation. The instrumented regression is reported in Column (4), Table 5. The main difference is that profit no longer enters significantly, thus raising doubts on the robustness of the finding of a binding liquidity constraint. The variables LOSTDAYS, GENERATOR, and the interactive term remain highly significant.

The relationship between investment and LOSTDAYS may suffer from a similar problem. As noted above, there is evidence that certain power lines are more reliable. Why do more firms not locate around these more reliable lines? There is likely to be some of this selection going on, although African entrepreneurs (just like African households) are not traditionally mobile (Collier and Gunning, 1999). We do not have data to control for the possible selection problem. However, it is worth noting that allowing a choice of location would most probably strengthen our results (i.e., due to possible sorting, our estimates are biased towards zero). If more sensitive firms (i.e., firms with more sensitive production processes with respect to power supply) locate around the more reliable lines,
the bulk of the variation in $p$ occurs for the less sensitive firms. The fact that we still do
find a strong negative correlation between LOSTDAYS and investment for these types of
firms suggests that the effect is quantitatively important.

Finally, we tested the null hypothesis of no correlation between the errors in the two
equations. The Lagrange multipliers statistic suggested by Breusch and Pagan (1980)
gives no support for the alternative hypothesis, thus strengthening our estimation strategy.9

5. Conclusion

The role of poor infrastructure and deficient public services in determining level of
private investment has received relatively little attention in the economic literature. The
existing empirical evidence suggests that the effect of public spending and investment on
growth is at best ambiguous. This ambiguity may simply be a problem of identification: more spending does not necessarily imply more productive public capital or services. By
using firm-level data on outcomes we overcome this identification problem. We show that
poor public capital significantly reduces productive investment by firms. The firm-level
data also reveal how firms cope with deficient public capital: when public services are
poor they can invest privately in complementary capital. The cost, however, is the
installation of less productive capital.

The results have clear policy implications. If a substantial share of firms’ costs is
attributable to the poorly functioning public sector, which is beyond firms’ control, private
supply responses to macroeconomic policy reform are likely to remain limited without an
accompanying improvement in the public sector’s performance. Thus, although stabiliza-
tion and structural adjustment are necessary conditions for sustainable improvement in the
private sector, they may not be sufficient to achieve sustained growth and capital
accumulation.

Acknowledgements

We are grateful for comments by seminar participants at Oxford University and The
World Bank. We also thank an anonymous referee for very constructive comments and
suggestions.

Appendix A. Data description and sources

All data used in the paper are from the Ugandan Industrial Enterprise Survey (see
Reinikka and Svensson, 2001b). The survey was initiated by the World Bank in
collaboration with the Ugandan private sector to primarily collect data on constraints

9 To apply the Breusch–Pagan test for independent equations, we run a linear probability model. The results
for the linear model are very similar to the probit results reported in Table 3.
facing private enterprises in Uganda. The survey was implemented during the period January–June 1998 by the Ugandan Manufacturers Association (an employers’ association). The enumerators were trained by World Bank survey experts. The sampling frame was based on an industrial census from 1996 and was confined to five general industrial categories (commercial agriculture, agro-processing, other manufacturing, construction, and tourism). Based on number of enterprises, these five sectors constituted 52% of the private sector, and almost 80% of employment in 1996. The chosen sample size was 250 establishments (out of 1282 enterprises in the census in the five industrial categories). Within these five industrial categories, commercial agriculture made up 26% of employment, agro-processing 28%, other manufacturing 32%, construction 12%, and tourism 2%. Balancing the importance of the different industrial categories at present with the likely importance in the future, the initial plan prescribed selecting 50 establishments in commercial agriculture, 50 in agro-processing, 100 in other manufacturing, 25 in construction, and 25 in tourism. Five geographical regions were covered in the sample (Kampala, Jinja/Iganga, Mbale/Tororo, Mukono, and Mbarara). These regions constitute more than 70% of total employment. Three general criteria governed the choice of procedure in selecting the sample from the eligible establishments. First, the sample should be at least reasonably representative of the population of establishments in the specified industrial categories. Second, the establishments surveyed should account for a substantial share of national output in each of the industrial categories. Third, the sample should be sufficiently diverse in terms of firm size to enable empirical analysis on the effects of firm size. To account for these three considerations, a stratified random sample was chosen using employment shares as weights. The final sample surveyed constituted 243 firms and was fairly similar to the initially selected stratified sample, both with respect to location and size.

A.1. Variables

\begin{align*}
\text{AGE} & = \text{age of firm 1997} ; \\
\text{CAPACITY} & = \text{capacity utilization in 1997} ; \\
\text{EXPORT} & = \text{binary variable indicating if the firm exports part of its output in 1997} ; \\
\text{FOREIGN} & = \text{foreign ownership in percent} ; \\
\text{GENERATOR} & = \text{binary variable taking the value 1 if the firm reported owning a generator at the end of the sample period, and 0 otherwise} ; \\
\text{INV} & = \text{investment rate is investment in machinery and equipment in 1997 excluding potential investment in generators as a share of the capital stock for the previous period} ; \\
\text{LOSTDAYS} & = \text{reported number of days in 1997 that the firm did not receive power from the public grid} ; \\
\text{PROFIT} & = \text{gross sales less operating costs and interest payments as a share of the capital stock of the previous period} ; \\
\text{SIZE} & = \text{employment size 1997} ; \\
\Delta \text{SALES} & = \text{change in sales in 1995–1997 as a share of the capital stock in 1996}. \\
\end{align*}

Appendix B. Proof of Proposition 1

Proof: (i) If \( \text{ER}_{1} \geq \text{ER}_{1} \geq \text{ER}_{1} \), then it follows from Eqs. (3.5) and (3.6) that only firms with initial assessment \( p = \rho \) will invest in private substitutes. (ii) The equilibrium investment rate for these types of firms, given in Eq. (3.2), is independent of \( p \). (iii) For
firms that rely solely on publicly provided capital, the equilibrium investment rates are given in Eqs. (3.3) and (3.4). Differentiating these investment functions yields:

\[ \frac{d_{i_H}}{d\bar{p}} = \frac{\pi (1 - \varphi)}{\delta_{i_H}} > 0, \quad \frac{d_{i_L}}{d\bar{p}} = \frac{\pi (1 - \varphi)}{\delta_{i_L}} > 0. \]

(iv) \( \lim_{\bar{p} \to 1} (i_H - i_L) = k > 0 \). Note further that as \( \bar{p} \to 1 \) Condition (i) can still hold. This is more likely to be the case if \( \rho \) is low. \( \square \)

References


