Firms Operating under Infrastructure and Credit Constraints in Developing Countries.
The Case of Power Generators

Philippe Alby[1], Jean-Jacques Dethier[2] & Stéphane Straub[1]

[1]Toulouse School of Economics, ARQADE.
[2]World Bank, Development Economics Department.

Plan of the talk

1. Motivation
2. A simple model of investment by firms when infrastructure and credit constraints are present
3. Econometric specifications to be tested
4. Results
5. Policy implications

Motivation

- Growing evidence that better electricity infrastructure significantly boosts economic growth and improves a range of development outcomes.
- In LDCs, firms face:
  - Difficulties getting connected to the grid
  - Frequent scheduled and unscheduled power cuts
  - Fluctuations in voltage and frequency
- As a result:
  - Production volumes, manufacturing costs and output quality are adversely affected
  - Technological choices biased away from energy intensive ones
  - firms invest less or in less efficient technologies and have lower productivity growth.

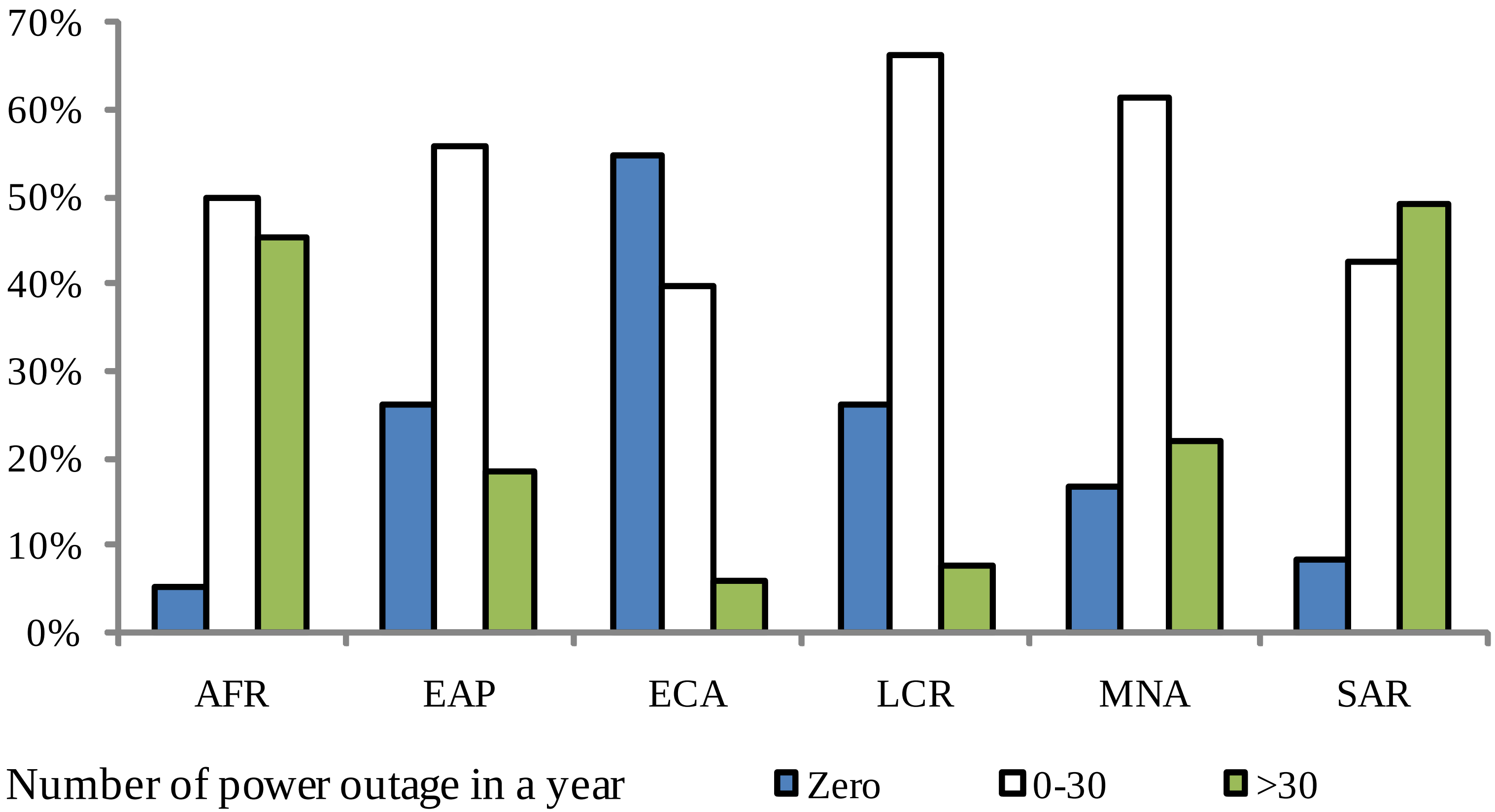
Table 3: Access to Electricity by Firms across Regions and Country Income Groups

Region	*Percent of firms mentioning electricity as major or severe constraint*	*Average number of power outages*	*Percent of firms having more than 30 power outages*
Europe/Central Asia	8,5%	9,72	5,7%
Latin America	9,3%	12,44	7,7%
East Asia & Pacific	25,1%	36,49	18,3%
Mid. East/North Africa	21,5%	41,32	22,1%
SubSah Africa	16,4%	61,12	45,2%
South Asia	43,0%	131,74	49,0%
Country Income Level			
High	4,9%	1,32	0,2%
upper-middle	8,3%	13,02	6,2%
lower-middle	14,3%	13,76	9,1%
Low	26,4%	64,08	34,1%

Motivation

- To offset these negative impacts, firms in LDCs often opt for own generation even though it is widely considered a second best solution.
  - Ex: in Africa, out of 25 countries, own generation > 25% of installed generating capacity in 3 countries, > 10% in 9 others.
  - In Nigeria, 40% of own generation, eating up 20-30% of initial investments.
  - Own generated electricity on avg 313% more expensive than that from grid.
- If strong credit constraints, mitigating investments often not possible. Credit constraints therefore interact with infrastructure deficiencies.

Figure 1: Distribution of firms according to number of power outages (by region)



What we do

- **Question: how do infrastructure and credit constraints affect:**

  1) firms decisions to invest in own electricity generation and,

  2) firms general investment behavior

- We use a sample of 71,789 firms across 102 countries and 28 two-digit (ISIC) industry classifications, covering the period 2002-2006 to answer this question

A moral hazard investment model

- Continuous MH invt model (Holmstrom & Tirole, 97). Entrepreneurs are endowed with assets *A.*
- Entrepreneurs intend to borrow amount $I - A$ to undertake a productive project of variable size I .
- This project yields δrI in case of success, where
  - r is gross return absent any infrastructure constraint,
  - $\delta \in [0, 1]$ is effect of deficient electric supply.
- Note that if $pH\delta r < 1$, unit NPV too low, production does not occur. This defines a threshold $\delta^0 \equiv 1/pHr$, under which credit will not be offered.
- $\delta > \delta^0$: sectors only mildly sensitive to infrastructure deficiencies.

A moral hazard investment model (cont'd)

- Entrepreneurs invest $I = k^{\delta}A$, where:

$$k^{\delta} = 1 / [1 + (p_H B/\Delta p) - p_H \delta r].$$

- Firm may obtain higher return by investing in a generator. This investment has a cost κ, leaving the firm with an initial capital $A - \kappa$, but the firm then ensures a return R^G, such that $\delta r < R^G < r$.

- Firm then invest $I^G = k^G(A - \kappa)$, where:

$$k^G = 1 / [1 + p_H B/\Delta p - p_H R^G].$$

Figure 1 ($\delta < \delta_0$)

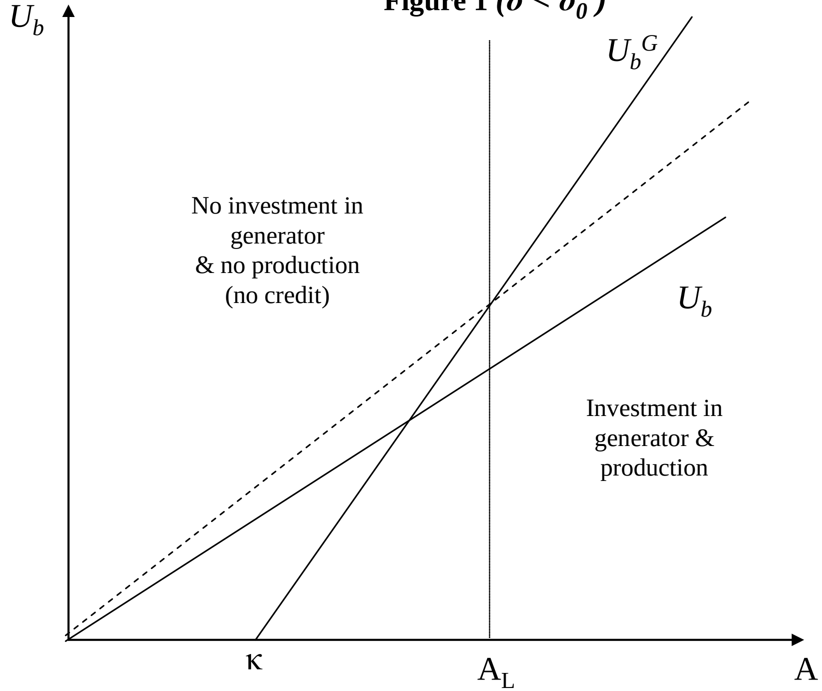
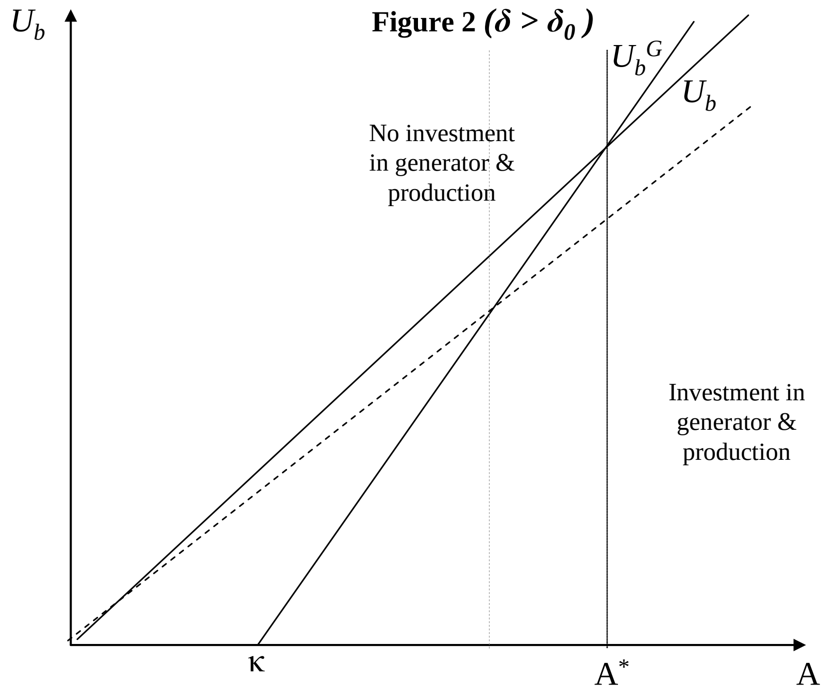


Figure 2 ($\delta > \delta_0$)



Predictions of the model

1. Investment in Generator

- *for* $\delta \geq \delta^0$ (sectors only mildly sensitive to infrastructure deficiencies), $\partial A^*/\partial \delta > 0$
- *for* $\delta < \delta^0$, $\partial A^*/\partial \delta = 0$.
- Corollary: for small firms ($A \leq A_L$), outages have no effect on A^* (asset level above which firm invest in generator). Effect is negative for larger firms ($A \geq A_L$).

Predictions of the model(con't)

2. General investment

- For small firms without generator:

  for $\delta < \delta^0$, $\partial I/\partial \delta = 0$ (they do not invest)

  for $\delta \geq \delta^0$, $\partial I/\partial \delta < 0$.

  – No effect of electricity deficiencies in sectors very sensitive to infrastructure deficiencies; invt decreasing in extent of deficiencies in less sensitive sectors.

- For larger firms with generators: $\partial I/\partial \delta = 0$

  – Large firms with generators are not affected by power outages.

Predictions of the model (con't – 2)

3. Effect of financial constraints

- Minimum level of initial assets *A** above which firms find it profitable to invest in generator is increasing in extent of financial constraints. Effect stronger in sectors very sensitive to infrastructure deficiencies.

$$\partial A^*/\partial B > 0, \text{ and } \partial A^*/\partial B|_{\delta < \delta 0} > \partial A^*/\partial B|_{\delta \geq \delta 0}$$

Econometrics

Construction of parameter δ_0

- We select countries in our sample with smallest number of power outages: Indonesia, Lithuania, Moldova, Poland and Thailand.
- From this subsample, extract average cost of electricity as a percentage of total cost, by industrial sector.
- Classify as "very reliant on electricity" industrial sectors above the median (7%):
  - δ_0 = 1 for sectors for which electricity as share of total costs >7%.
  - δ_0 = 0 for sectors below the median, for which electricity as share of total costs < 7%.

Table 7: Reliance on electricity in countries with reliable service, by industrial sector

INDUSTRIAL SECTOR	Cost of Electricity (as percent of total cost)	Number of firms having non zero electricity cost
Other services	2,21	1
Metals and machinery	3,51	176
Garments	4,17	377
Agroindustry	5,70	17
Leather	5,73	6
Auto and auto components	5,74	156
Electronics	6,25	197
Non-metallic and plastic materials	6,30	234
Construction	7,58	18
Other unclassified	7,72	8
Food	8,33	385
Wood and furniture	8,79	195
Transport	11,08	11
Textiles	12,02	417
Paper	12,40	28
Retail and wholesale trade	13,31	2
Chemicals and pharmaceutics	17,47	74
Beverages	21,80	26
Other transport equipment	21,86	18
Real estate and rental services	24,49	1
Overall Total	8,02	**2347**

NOTE: The countries with the least number of power outages in our sample are Lithuania, Thailand, Poland, Indonesia and Moldova.

Econometrics (own power generator)

$Gen_{ijc} = 1[Gen^{*} = \theta_j + \theta_c + \theta_t + a_1\delta_{ijc} + a_2 (\delta_{ijc}.\delta_0) + \beta_1 F_{jc} + \beta_2 (F_{jc}.\delta_0) + X_{ijc}\,\gamma + \varepsilon_{ijc} > 0]$

- From model, we expect:

  $a_1 > 0,\ a_2 < 0$ *and* $a_1 + a_2 = 0$

  Probability that firms invest in generator is only significantly affected by outages in sectors not too sensitive to electricity.
- Moreover, we expect

  $\beta_1 < 0,\ \beta_2 < 0$ and $\beta_2 < \beta_1$.

Table 8: Complementary Capital Decision

	(1)	(2)	(3)	(4)	(5)	(6)
Probit	Generator	Generator	Generator	Generator	Generator	Generator
Number of Power Outage (log)	0.104 (6.72)***	0.122 (7.18)***			0.105 (6.66)***	0.121 (6.91)***
Number of Power Outage (log) * Delta0 (Sector)	-0.045 (1.94)*	-0.050 (2.24)**			-0.042 (1.80)*	-0.046 (2.04)**
Access to Credit is Major/Severe			-0.218 (6.19)***	-0.196 (5.30)***	-0.261 (6.52)***	-0.190 (4.36)***
Access to Credit is Major/Severe Constraint (dummy) * Delta0 (Sector)			0.025 (0.46)	0.033 (0.56)	0.039 (0.67)	-0.013 (0.22)
Age (log)		0.140 (8.37)***		0.116 (7.74)***		0.136 (7.72)***
Capital City dummy		0.112 (2.12)**		0.129 (2.69)***		0.121 (2.27)**
Export dummy		0.354 (7.52)***		0.327 (7.88)***		0.352 (7.38)***
Foreign dummy		0.239 (5.53)***		0.203 (4.99)***		0.229 (5.21)***
Constant	-2.453 (12.45)***	-1.551 (5.62)***	0.691 (3.91)***	-0.745 (1.24)	-0.818 (1.61)	-1.825 (6.55)***
Firm Size dummies		Yes		Yes		Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	24,451	18,320	39,197	24,662	23,461	17,551
TEST Alpha1+Alpha2=0	chi2(1)=14.08 Prob>	chi2(1)=21.36 Prob>chi2=0.0000			chi2(1)=14.81 Prob>chi2=0.0001	chi2(1)=21.24 Prob>chi2=0.0000

Absolute value of z statistics in parentheses, clustered at the country-industry level.
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 9: Complementary Capital Decision and Firm Size

	(1)	(2)	(3)	(4)	(5)	(6)
Probit	Generator	Generator	Generator	Generator	Generator	Generator
	Small Firms Sample		Medium Firms Sample		Large Firms Sample	
Number of Power Outages (log)	0.052 (2.16)**	0.070 (2.71)***	0.070 (3.96)***	0.093 (4.23)***	0.065 (2.82)***	0.058 (2.19)**
Number of Power Outages (log) * Delta0 (Sector)	0.039 (1.21)	0.043 (1.11)	-0.012 (0.52)	-0.024 (0.91)	-0.045 (1.36)	-0.050 (1.40)
Access to Credit is Major/Severe Constraint	-0.082 (1.30)	-0.107 (1.40)	-0.134 (2.41)**	-0.128 (1.80)*	-0.231 (3.59)***	-0.218 (3.01)***
Access to Credit is Major/Severe Constraint (dummy) * Delta0 (Sector)	-0.029 (0.26)	-0.091 (0.82)	0.020 (0.23)	-0.049 (0.50)	0.133 (1.40)	0.042 (0.41)
Age (log)		0.114 (2.92)***		0.114 (3.68)***		0.125 (4.12)***
Capital City dummy		0.011 (0.15)		0.193 (2.43)**		0.133 (1.30)
Export dummy		0.229 (2.41)**		0.271 (4.30)***		0.231 (3.84)***
Foreign dummy		0.454 (4.44)***		0.165 (2.30)**		0.260 (3.97)***
Constant	-1.747 (5.74)***	-0.872 (1.55)	0.256 (0.81)	-1.450 (3.40)***	0.317 (0.30)	-0.152 (0.13)
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5913	4239	7142	5010	5147	3917
TEST Alpha1+Alpha2=0	chi2(1)=10.34 Prob>chi2= 0.0013	chi2(1)=8.79 Prob>chi2= 0.0030	chi2(1)=9.31 Prob>chi2=0.0023	chi2(1)=8.49 Prob>chi2= 0.0036	chi2(1)= 0.59 Prob>chi2= 0.4439	chi2(1)=0.07 Prob>chi2= 0.7945

Absolute value of z statistics in parentheses, clustered at the country-industry level.
* significant at 10%; ** significant at 5%; *** significant at 1%

Econometrics (own power generator - 2)

- Alternatively, looking at firm size yields the following specification:

$$Gen_{ijc} = 1[Gen^{*} = \theta_j + \theta_c + \theta_t + a_1\delta_{ijc} + a_2\, small + a_3\,(\delta_{ijc}.small) + a_4\, medium + a_5\,(\delta ijc^{*}\, medium) + X_{ijc}\,\gamma + \varepsilon_{ijc} > 0]$$

- From the model, we expect $a_3 = 0$, $a_5 > 0$.

Table 10: Complementary Capital Decision and Firm Size (Entire Sample)

	(1)	(2)	(3)
Probit	Generator	Generator	Generator
Small (<20) Dummy	-0.500 (6.72)***	-0.461 (5.55)***	-0.471 (5.59)***
Small (<20) Dummy * Number of Power Outage (log)	0.016 (0.78)	0.021 (0.88)	0.019 (0.77)
Medium (0-99) Dummy	-0.198 (4.41)***	-0.207 (3.88)***	-0.204 (3.84)***
Medium (0-99) Dummy * Number of Power Outage (log)	0.034 (2.38)**	0.038 (2.10)**	0.036 (1.95)*
Employment (log)	0.309 (14.14)***	0.318 (12.50)***	0.280 (10.14)***
Age (log)		0.053 (2.09)**	0.065 (2.61)***
Capital City dummy		0.089 (1.47)	0.105 (1.76)*
Export dummy			0.209 (4.38)***
Foreign dummy			0.137 (2.97)***
Constant	-1.376 (5.97)***	-1.808 (7.29)***	-1.746 (7.09)***
Country dummies	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes
Observations	19,583	14,696	14,371

Absolute value of z statistics in parentheses, clustered at the country-industry level.
* significant at 10%; ** significant at 5%; *** significant at 1%

Econometrics (investment)

$$I_{ijc} = \theta_j + \theta_c + \theta_t + \lambda_1\delta_{ijc} + \lambda_2(\delta_{ijc}.\delta_0) + \sigma_1 F_{jc} + \sigma_2 (F_{jc}.\delta_0) + X_{ijc}\gamma + v_{ijc}$$

- If *Gen=1*, we expect $\lambda_1=0$, $\sigma_1<0$ and $\lambda_1+\lambda_2 = 0$, $\sigma1+\sigma2 < 0$.
- If *Gen=0*, we expect $\lambda_1 < 0$, $\sigma_1<0$ and $\lambda_1+\lambda_2 = 0$, $\sigma_1+\sigma_2 = 0$.

- To address potential selection issue related to choice of investing in a generator, we perform a two-step Heckman procedure, using selection equations above, in which the variable excluded from the second stage is cost of the generator.

Table 11: Investment

Generator=1

	(1)	(2)	(3)	(4)	(5)	(6)
OLS	Investment (Log)	Investment (Log)	Investment (Log)	Investment (Log)	Investment (Log)	Investment (Log)
Number of Power Outage (log)	-0.006 (0.55)	-0.008 (0.56)			-0.006 (0.55)	-0.008 (0.56)
Number of Power Outage (log) * Delta0 (Sector)	0.002 (0.20)	0.010 (1.11)			0.003 (0.28)	0.011 (1.16)
Access to Credit is Major/Severe Constraint (dummy)			-0.013 (0.75)	-0.005 (0.28)	-0.017 (0.65)	-0.007 (0.27)
Access to Credit is Major/Severe Constraint (dummy) * Delta0 (Sector)			0.001 (0.05)	-0.003 (0.12)	-0.013 (0.40)	-0.008 (0.23)
Age (log)		0.003 (0.19)		0.003 (0.34)		0.002 (0.17)
Capital City dummy		0.020 (0.59)		0.031 (1.66)*		0.024 (0.65)
Export dummy		0.024 (0.96)		0.011 (0.58)		0.023 (0.88)
Foreign dummy		0.000 (0.01)		0.022 (1.12)		0.003 (0.10)
Constant	18.472 (488.55)***	18.591 (166.31)***	18.472 (628.73)***	18.589 (214.15)***	18.471 (474.88)***	18.533 (159.60)***
Firm Size dummies		Yes		Yes		Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3050	2221	4769	3755	2960	2148
R-squared	0.19	0.23	0.20	0.25	0.19	0.23
TEST Lambda1+Lamda2=0	F(1,256)=0.37 Prob>F= 0.5453	F(1,220)=0.06 Prob>F= 0.8110			F(1,255)=0.23 Prob>F= 0.6336	F(1,219)=0.07 Prob>F= 0.7904

Absolute value of z statistics in parentheses, clustered at the country-industry level.
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 12. Heckman correction for non-randomly selected cost of generator sample

	(1)	(2)
Heckman Selection Equation	Investment Without Cost of Generator (Log)	Generator
Number of Power Outage (log)	0.013 (2.66)***	0.073 (1.08)
Number of Power Outage (log) * Delta0 (Sector)	-0.017 (2.97)***	-0.088 (1.13)
Access to Credit is Major/Severe Constraint (dummy)	0.089 (2.04)**	-0.176 (1.90)*
Access to Credit is Major/Severe Constraint (dummy) * Delta0.1 (Sector)	-0.021 (0.43)	0.193 (1.47)
Cost of Running Generator (Log)	- -	4.632 (62.35)***
Age (log)	-0.044 (1.46)	0.214 (4.48)***
Capital City dummy	0.037 (1.25)	-0.302 (2.02)**
Export dummy	-0.026 (0.53)	0.310 (2.26)**
Foreign dummy	0.049 (1.06)	0.568 (3.58)***
Constant	18.381 (536.92)***	-2.845 (14.14)***
Firm Size dummies	Yes	-
Country dummies	Yes	-
Industry dummies	Yes	-
Year dummies	Yes	-
Observations	10,556	10,556

Conclusion

- For sectors reliant on electricity, high number of outages affect returns to investment so badly that small firms lacking initial assets to invest in generator end up squeezed out of financial market.
- Probability that firms invest in generator only depends on level of assets: not affected by prevalence of outages but strongly limited by financial constraints.
- Conditionally on investing in generator, overall investment not affected by the quality of electric supply but negatively affected by credit constraints.
- In these sectors, we see a number of large firms with investments in complementary capital (power generator) and no (or few) small formal firms.

Policy implications

- *For sectors reliant on electricity*: financial constraints are priority (ability to invest in generator depends on credit availability). Marginal reduction in outages have no effect.
- *For sectors less reliant*: there is a range of small firms that manage to produce without generator. These benefit from a reduction in outages, while large firms care about credit constraints.
- *Policy mix*: target credit constraints for large firms (ex: guarantees for buying generator) while allowing private electricity resale to small ones.
- Electricity price discrimination by firm size.