Cottage Industry to Factories? The Effects of Electrification on the Macroeconomy

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\textsuperscript{a}Arizona State University, \textsuperscript{b}UCSD and NBER

Econometric Society Winter Meetings
January 4-6, 2019
Electric Generation Capacity Per Capita in 2000

- ETH: 6.4 Megawatts/(million people)
- SSA: 40.1 Megawatts/(million people)
Electric Generation Capacity Per Capita in 2000

<table>
<thead>
<tr>
<th>Country</th>
<th>Megawatts/(million people)</th>
</tr>
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<tbody>
<tr>
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</tr>
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<tr>
<td>USA</td>
<td>2583.8</td>
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Increase in Generation Capacity Per Capita Since 2000

Cottage Industry to Factories?
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Increase in Generation Capacity Per Capita Since 2000

Cottage Industry to Factories?

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Generation Capacity in Ethiopia: 1970-2014

![Graph showing the generation capacity in Ethiopia from 1970 to 2014. The graph indicates a steady increase in generation capacity, particularly after the year 2000.](image-url)
What Are the Macro Effects of Electrification?

1. Intensive margin

- Firms with grid connections get more electricity
- Fewer power outages
What Are the Macro Effects of Electrification?

1 Intensive margin
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2 Extensive margin
   - Entry
   - More firms produce with electricity
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3. Capital accumulation
   - Electricity increases $MP_k \Rightarrow$ HHs accumulate more capital
   - More capital $\Rightarrow$ higher labor productivity
What We Do

• General equilibrium macro model with all three channels
• Calibrate to match the Ethiopian economy in 2000
• Simulate the observed increases in electricity from 2000-2014
Micro Studies of the Effects of Electrification

1 Intensive margin
   - Allcott, Collard-Wexler, O’Connell (2016)
   - Effects of power outages on manufacturing firms in India
   - Eliminating outages increases revenue 5-10 percent
Micro Studies of the Effects of Electrification

1 Intensive margin
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2 Extensive margin
   - Kassem (2018)
   - Effects of grid expansions in Indonesia on firm entry and exit
   - Substantial increases in the number of manufacturing firms
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2. Extensive margin
   - Kassem (2018)
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3. Regional analyses
   - Lipscomb, Mobarak, Barham (2013)
   - County-level effects of increase in hydropower dams in Brazil
   - Large effects on housing prices and HDI
   - Migration $\Rightarrow$ can’t infer aggregate effects
Model: Three Key Features

1 Structural change

- Traditional sector: produce output with capital and labor
- Modern sector: produce output with capital, labor, electricity
Model: Three Key Features

1 Structural change
   - Traditional sector: produce output with capital and labor
   - Modern sector: produce output with capital, labor, electricity

2 Grid electricity is rationed
   - Prices do not adjust to clear markets
   - Demand > supply ⇒ power outage
Model: Three Key Features

1. Structural change
   - Traditional sector: produce output with capital and labor
   - Modern sector: produce output with capital, labor, electricity

2. Grid electricity is rationed
   - Prices do not adjust to clear markets
   - Demand > supply ⇒ power outage

3. Firms can generate their own electricity
   - More expensive
   - Perfect substitute (a kwh is a kwh, regardless of the source)
Agents

1. Measure 1 of identical households
   - Infinitely lived
   - Consume final good and save

2. Measure $N_t$ of heterogeneous entrepreneurs
   - Live for one period
   - Produce final good

3. Government
   - Produces grid electricity
   - Natural monopoly; geopolitical externalities; appropriation risk
Entrepreneur Productivity and Entry

Pay entry cost to operate: $A\Omega$

- Cost scales with TFP (Bollard, Klenow, and Li 2016)
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Pay entry cost to operate: $A\Omega$

- Cost scales with TFP (Bollard, Klenow, and Li 2016)

After entry, draw productivity $z$ from a Pareto distribution

$$G(z) = 1 - \left(\frac{1}{z}\right)^\lambda$$
Entrepreneur Productivity and Entry

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After entry, draw productivity $z$ from a Pareto distribution

$$G(z) = 1 - \left(\frac{1}{z}\right)^\lambda$$

Modern sector entry

- Pay entry cost again to operate in the modern sector
- Otherwise, operate in the traditional sector
Production Technology

Traditional sector

\[ y_t = Az^1_{i \eta} (k_1^{\alpha} l_1^{1-\alpha}) \eta \]

• Hassler, Krusell, and Olovsson (2018)

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Production Technology

Traditional sector

\[ y_i^t = A z_i^{1-\eta} (k_i^{\alpha} l_i^{1-\alpha})^\eta \]

Modern sector:

\[ y_i^m = A^m z_i^{1-\eta} \left[ \min(k_i^{\alpha} l_i^{1-\alpha}, \mu e_i) \right]^\eta \]

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Two Ways an Entrepreneur Can Get Electricity

1. Purchase electricity from the national electric grid, $e_i^g$
   - Limited and un-predictable
   - Grid electricity is available fraction $\nu$ of the period

   \[ \text{electricity supply} = (\text{electricity demand}) \times \nu \]
Two Ways an Entrepreneur Can Get Electricity

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   - Grid electricity is available fraction $\nu$ of the period
     \[\text{electricity supply} = (\text{electricity demand}) \times \nu\]

2. Generate their own electricity: $e_i^s$
   - Generator capital: $k_i^s$
   - Units of final good: $y_i^s$
     \[e_i^s = A^s \min[k_i^s, \chi y_i^s]\]
   - Variable of self-generated electricity $\geq$ price of grid electricity
Profits

Traditional sector

\[ \pi_i^t = y_i^t - wl_i - Rk_i \]
Profits

Traditional sector

\[ \pi_t^i = y_t^i - w_l^i - Rk_i \]

Modern sector

\[ \pi_m^i = y_m^i - w_l^i - Rk_i - Rk_s^i - y_s^i - p^g e_i^g \]
Profits

Traditional sector

\[ \pi^t_i = y^t_i - w_l i - Rk_i \]

Modern sector

\[ \pi^m_i = y^m_i - w_l i - Rk_i - Rk^s_i - y^s_i - p^g e_i^g \]
Entrepreneurs with $z_i > z^*$ enter the modern sector:

$$\pi^t(z^*) = \pi^m(z^*) - A\Omega$$
Government Produces Grid Electricity

Invests in grid capital and produces electricity

\[ K_{t+1}^g = (1 - \delta) K_t^g + I_t^g \quad E^g = A^g K^g \]

Fixed grid electricity price

\[ p^g = MC \]

Government finances investment with lump-sum taxes on HHs

\[ I^g = p^g E^g + T \]
Household Optimization

\[
\max_{c_t, k_{t+1}} \sum_{t=0}^{\infty} \beta^t \left( \frac{c_t^{1-\sigma}}{1-\sigma} \right)
\]

subject to

\[
c_t = w_t + (R_t + 1 - \delta)k_t - k_{t+1} + \pi^t + \pi^m - A\Omega(N_t + N_t^m) - T_t
\]
Calibration

Goal

• Match the Ethiopian economy in 2000

Two steps

1. Take some parameters directly from data/literature

2. Choose other parameters to match a set of targets
## Direct Calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Source</th>
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<tbody>
<tr>
<td>Span of control: $\eta$</td>
<td>0.85</td>
<td>Midrigan and Xu (2014)</td>
</tr>
<tr>
<td>Capital share: $\alpha$</td>
<td>0.33</td>
<td>Gollin (2002)</td>
</tr>
<tr>
<td>Depreciation: $\delta$</td>
<td>0.06</td>
<td>Data</td>
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<tr>
<td>Entry cost: $\Omega$</td>
<td>1</td>
<td>Assumption</td>
</tr>
<tr>
<td>Grid productivity: $A^g$</td>
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Main Data

Quantity and cost of electric power generation

- PLATTS World Power Plants Data Base
Main Data

Quantity and cost of electric power generation

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Ethiopia manufacturing surveys: 2001/2002

- Medium and large scale manufacturing
- Small scale manufacturing
- Cottage/handicraft manufacturing
Main Data

Quantity and cost of electric power generation

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Ethiopia manufacturing surveys: 2001/2002

- Medium and large scale manufacturing ← Modern
- Small scale manufacturing ← Modern
- Cottage/handicraft manufacturing
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Quantity and cost of electric power generation

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Ethiopia manufacturing surveys: 2001/2002

- Medium and large scale manufacturing ← Modern
- Small scale manufacturing ← Modern
- Cottage/handicraft manufacturing ← Traditional
## Method of Moments

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<td>(variable self)/$p^g = 1.9$</td>
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<td>Leontief parameter: $\mu$</td>
<td>0.90</td>
<td>Modern electricity share $= 0.16$</td>
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<td>Pareto parameter: $\lambda$</td>
<td>2.50</td>
<td>Frac modern labor$= 0.13$</td>
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Quantitative Exercise

- Begin in year 2000 steady state
- Shock economy each year from 2000-2014 with observed per capita increase in grid electricity capital
- Transition to new SS with 2014 levels of electricity per capita
Aggregate Effects of Electrification (1)
Aggregate Effects of Electrification (1)

Grid Capital Per Worker

Intensive Margin: Power Outages

Percent Modern Entrepreneurs

Capital Accumulation

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Aggregate Effects of Electrification (1)

Grid Capital Per Worker

Intensive Margin: Power Outages

Extensive Margin: Structural Change

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Aggregate Effects of Electrification (2)

Output Per Worker

Consumption Per Worker

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Welfare Effects of Electrification

Consumption Equivalent Variation

<table>
<thead>
<tr>
<th>Steady State</th>
<th>Transition</th>
</tr>
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<tbody>
<tr>
<td>4.20</td>
<td>0.89</td>
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### Steady State Effects

<table>
<thead>
<tr>
<th></th>
<th>% $\Delta Y^t$</th>
<th>% $\Delta Y^m$</th>
<th>% $\Delta Y$</th>
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<tr>
<td><strong>Benchmark</strong></td>
<td>-19.8</td>
<td>135.0</td>
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## Decomposition

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- **Intensive margin:** $v = v_{2014}, \ N^t = N^t_{2000}, \ N^m = N^m_{2000}$
Decomposition

Steady State Effects

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• Intensive margin: $\nu = \nu_{2014}$, $N^t = N^t_{2000}$, $N^m = N^m_{2000}$

• Extensive margin: $\nu = \nu_{2000}$, $N^t = N^t_{2014}$, $N^m = N^m_{2014}$
Comparison to Micro Studies

Allcott, Collard-Wexler, O’Connell (2016) experiment

- Reduce power outages by 7.2 percentage points
- Partial equilibrium: hold prices and entry constant
- Modern firms only

Increase in modern firm output (percent)

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<th></th>
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The Effects of Electrification on the Macroeconomy

- Substantial increases in output per worker

- Intensive margin: existing modern firms get more electricity
  - Explains $\approx 1/4$ of increase in output per worker

- Extensive margin: entry into modern production
  - Explains $\approx 1/2$ of increase in output per worker
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Thank you!