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

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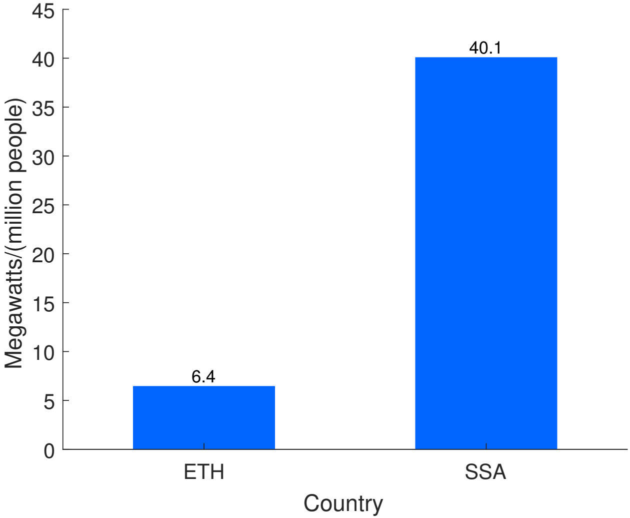
Electric Generation Capacity Per Capita in 2000



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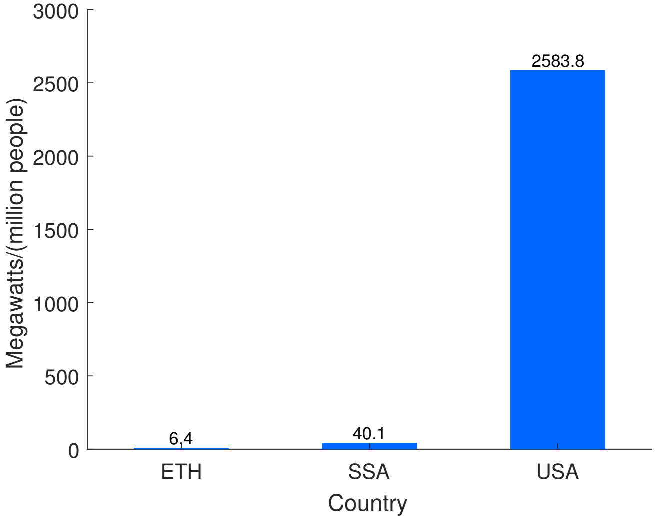
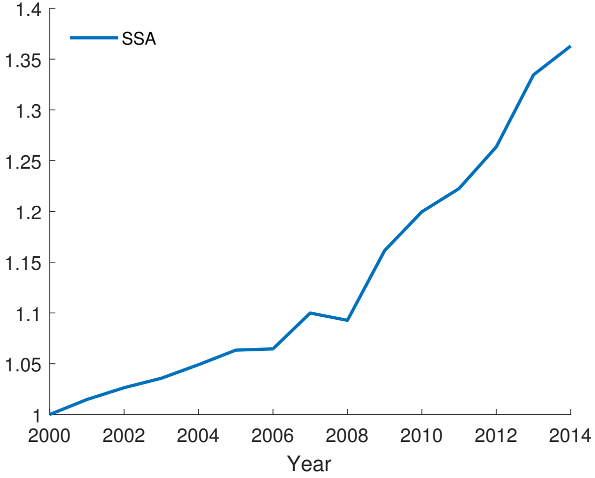


Increase in Generation Capacity Per Capita Since 2000



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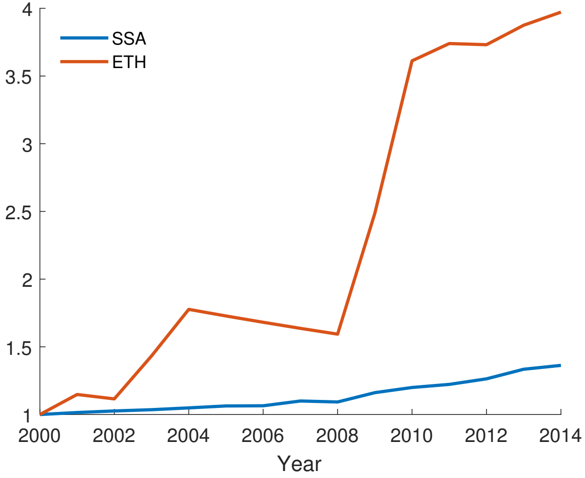
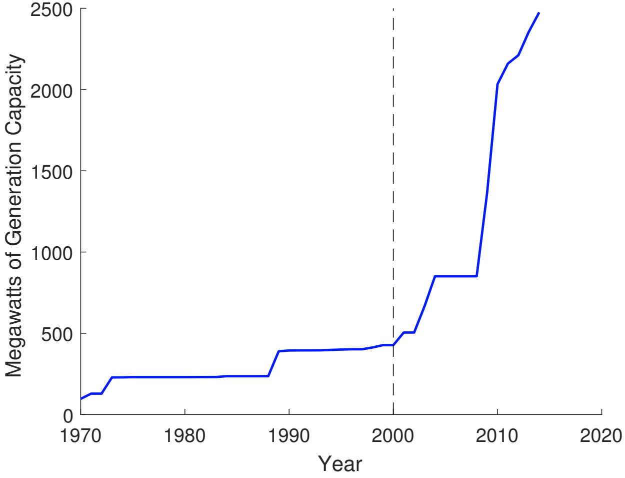


Generation Capacity in Ethiopia: 1970-2014



What Are the Macro Effects of Electrification?

1. Intensive margin
   - Firms with grid connections get more electricity
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3. Capital accumulation
   - Electricity increases $\mathrm{MP}_k \Rightarrow$ 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

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   - Effects of grid expansions in Indonesia on firm entry and exit
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3. Regional analyses
   - Lipscomb, Mobarak, Barham (2013)
   - County-level effects of increase in hyrdopower 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

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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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Modern sector entry

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

Production Technology

Traditional sector

$$y_i^t = Az_i^{1-\eta}(k_i^\alpha l_i^{1-\alpha})^\eta$$

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

Modern sector:

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

- Hassler, Krusell, and Olovsson (2018)

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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 v of the period

$$\text{electricity supply} = (\text{electricity demand}) \times v$$

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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 $>$ price of grid electricity

Profits

Traditional sector

$$\pi_i^t = y_i^t - wl_i - Rk_i$$

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Modern sector

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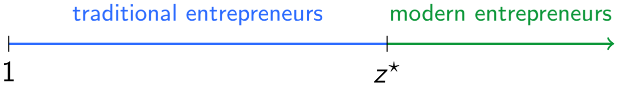
Structural Change: Modern Sector Entry Decision



Entrepreneurs with $z_i > z^\star$ enter the modern sector:

$$\pi^t(z^\star) = \pi^m(z^\star) - A\Omega$$

Government Produces Grid Electricity

Invests in grid capital and produces electricity

$$K^g_{t+1} = (1-\delta)K^g_t + I^g_t \qquad E^g = A^g K^g$$

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

Parameter	Value	Source
Span of control: η	0.85	Midrigan and Xu (2014)
Capital share: α	0.33	Gollin (2002)
Depreciation: δ	0.06	Data
Entry cost: Ω	1	Assumption
Grid productivity: A^g	1	Assumption

Main Data

Quantity and cost of electric power generation

- PLATTS World Power Plants Data Base
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Ethiopia manufacturing surveys: 2001/2002

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

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- Medium and large scale manufacturing $\leftarrow$ Modern
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Ethiopia manufacturing surveys: 2001/2002

- Medium and large scale manufacturing $\leftarrow$ Modern
- Small scale manufacturing $\leftarrow$ Modern
- Cottage/handicraft manufacturing $\leftarrow$ Traditional

Method of Moments

Parameter	Value	Target
Generator efficiency: χ	4.73	(variable self)$/p^g = 1.9$
Generator productivity: A^s	1.05	(AC self)$/p^g = 3.18$
Grid capital: K^g_{2000}	0.09	$K^g/K = 0.0249$
Leontief parameter: μ	0.90	Modern electricity share $= 0.16$
Pareto parameter: λ	2.50	Frac modern labor$= 0.13$
Modern productivity: A^m	1.43	Frac modern firms$= 0.033$
Discount rate: β	0.96	$r = 0.04$

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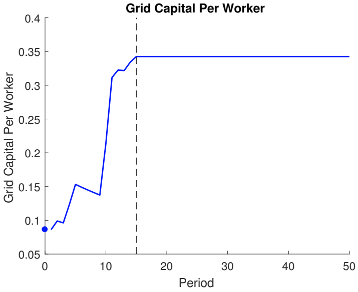
Quantitative Exercise

- 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)



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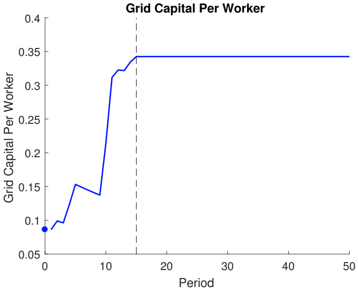

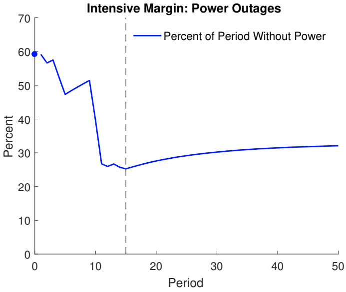

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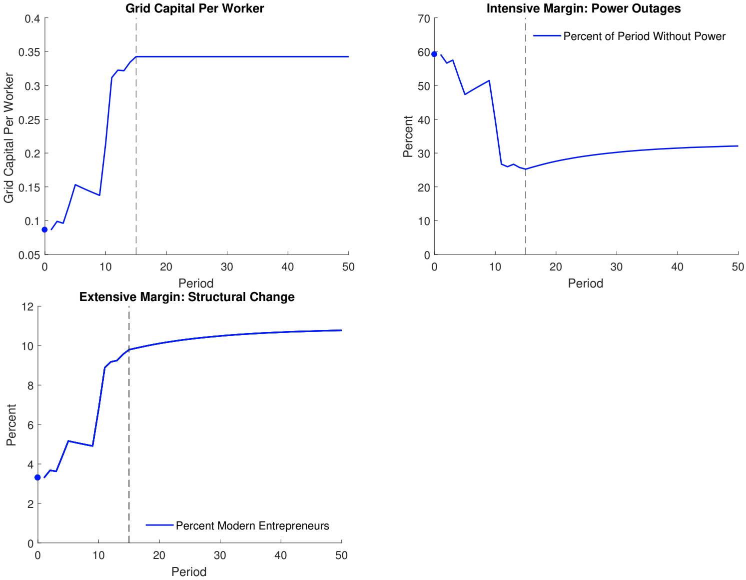

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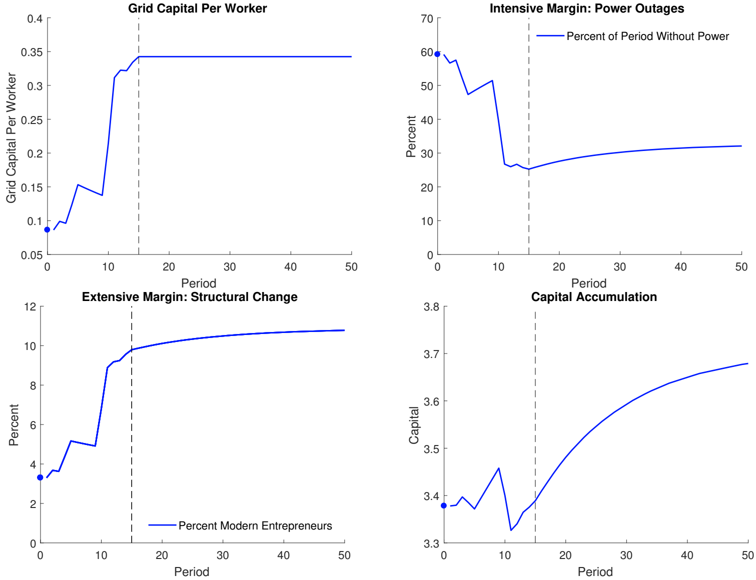
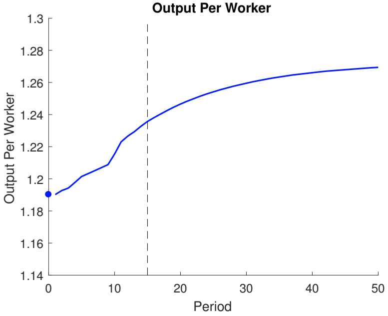


Aggregate Effects of Electrification (2)



Welfare Effects of Electrification

Consumption Equivalent Variation

Steady State	Transition
4.20	0.89

Decomposition

Steady State Effects

	% ΔY^t	% ΔY^m	% ΔY
Benchmark	-19.8	135.0	6.9

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Intensive margin	-2.4	17.3	1.8

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

Decomposition

Steady State Effects

	% ΔY^t	% ΔY^m	% ΔY
Benchmark	-19.8	135.0	6.9
Intensive margin	-2.4	17.3	1.8
Extensive margin	-15.5	104.3	3.4

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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)

Ethiopia	Allcott et al. (2016)
4.9	5-10

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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