The Light and the Heat
Productivity Co-benefits of Energy-saving Technology

Ach Adhvaryu
Namrata Kala
Anant Nyshadham

Michigan, Harvard/J-PAL, and BC

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Technology adoption, energy efficiency, and India

- India 4th largest energy consumer globally (International Energy Agency); Indian industry second largest consumer of primary commercial energy (Bhattacharya and Cropper, 2010)
  - Lighting represents almost 20% of global electricity consumption (Int'l Energy Agency)
- Global energy supply gap increasing (WEO 2014); energy efficiency *could* close the projected energy gap (Bureau of Energy Efficiency)
- But very difficult to get firms to adopt "green" technologies (Knittel & Sandler, 2011), analogous general "puzzles" in technology adoption

Climate change and mitigation

- The IPCC estimates that end-century warming will exceed 1.5°C ("..since the 1950s, many of the observed changes are unprecedented over decades to millennia. ") (IPCC 2014)
  - Impacts disproportionately located in developing countries (Mendelsohn et al., 2006)
- Great interest in identifying
  - impact of temperature on economic outcomes (Deschenes & Greenstone 2007, 2011; Guiteras 2009; Burgess et al. 2013; Hsiang et al. 2013; Barreca, Clay, Deschenes, Greenstone, & Shapiro 2014, Dell & Olken 2014; Somanathan et al. 2015)
  - effective mitigation strategies – not easy to convince individual/firms to adopt, given wedge between public and private returns (Bollen et al. 2009; Knittel & Sandler 2011; Deschenes et al. 2013)

Research questions

- **What are the impacts of temperature on the productivity (and other workplace outcomes) of factory workers?**
- **Can mitigation strategies have private "co-benefits" that promote adoption?**

This Study

1. Estimate temperature-productivity gradient using line-level, daily production data for 30 garment factories and mean daily outdoor temperatures in Bangalore, India
2. Estimate extent to which installation of LED lighting on factory floors reduces the negative effects of outdoor temperature
3. Using actual firm costing data, generate cost-benefit calculations for LED lighting adoption with / without estimated productivity gains

Data

Time span: May 2010 - June 2013

Workplace outcomes

- 30 factory units, 523 production lines
- Daily line-level data on efficiency (produced/target q), budgeted efficiency
- Daily worker-level data on attendance

Temperature and Humidity

- Daily outdoor temperature, relative humidity and precipitation: Climate Forecast System Reanalysis (CFSR) from NOAA's National Centers for Environmental Prediction (NCEP)

LED Rollout

- Month and year of replacement of florescent lighting with LEDs

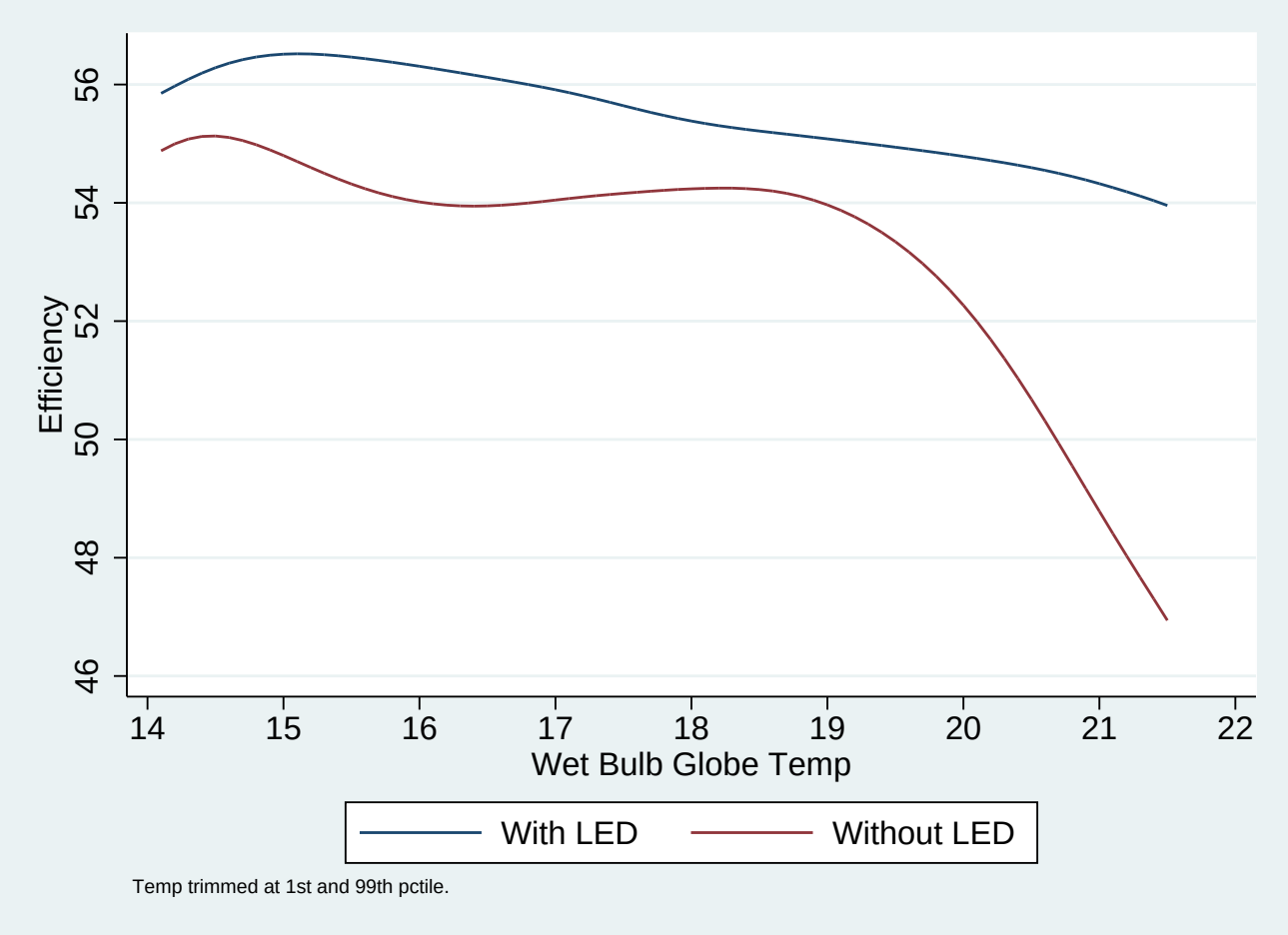
▸ IndoorOutdoorTemp

Production Context

LED Rollout

- LEDs rolled out across 26 of 30 factories from Oct 2009 to Feb 2013
- Buyer pressure to "go green"
- On average, each unit replaced about 1000 7W florescent bulbs with same number of 1W machine-mounted LEDs

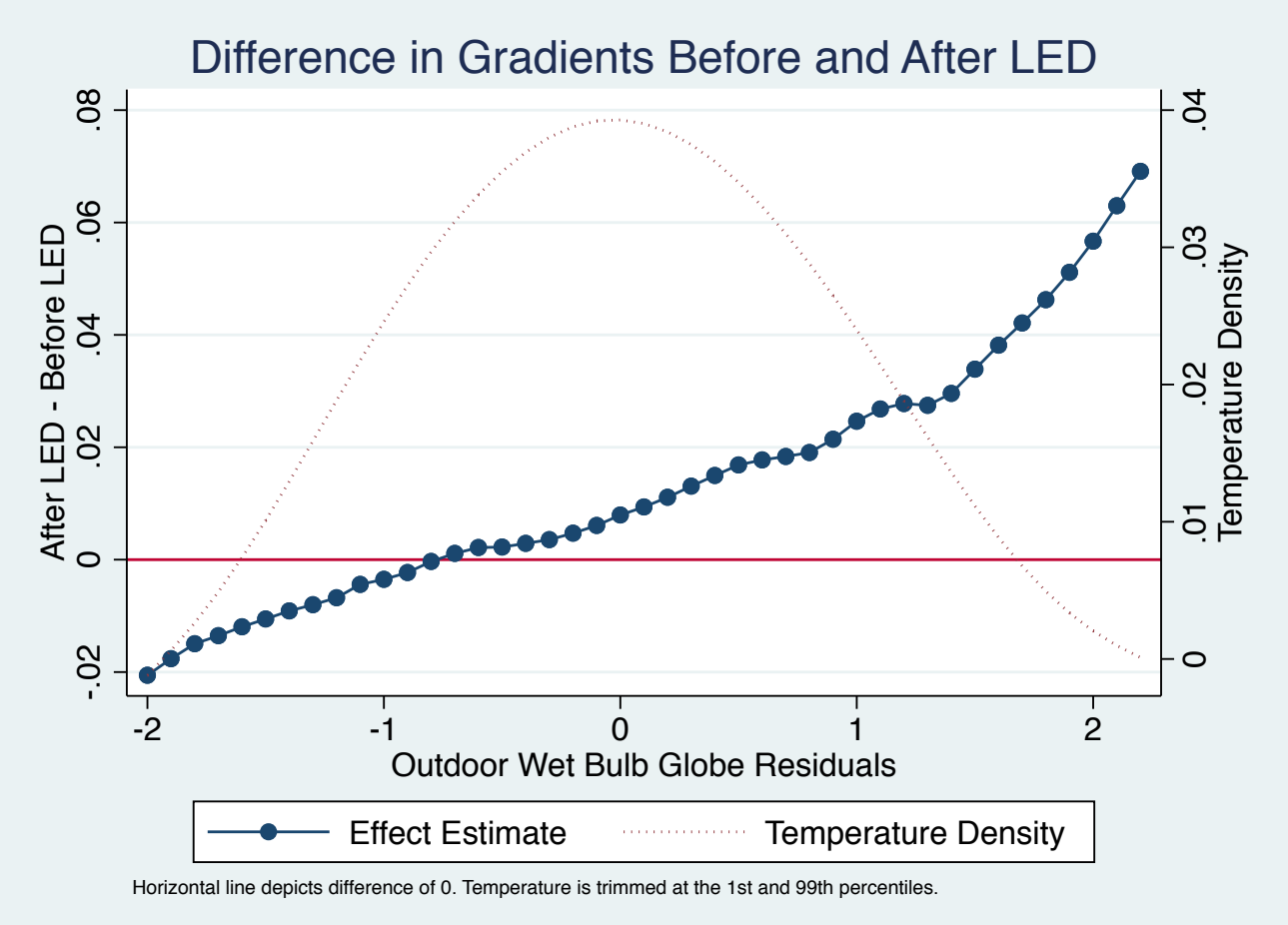
Temperature and Efficiency before/after LED installation



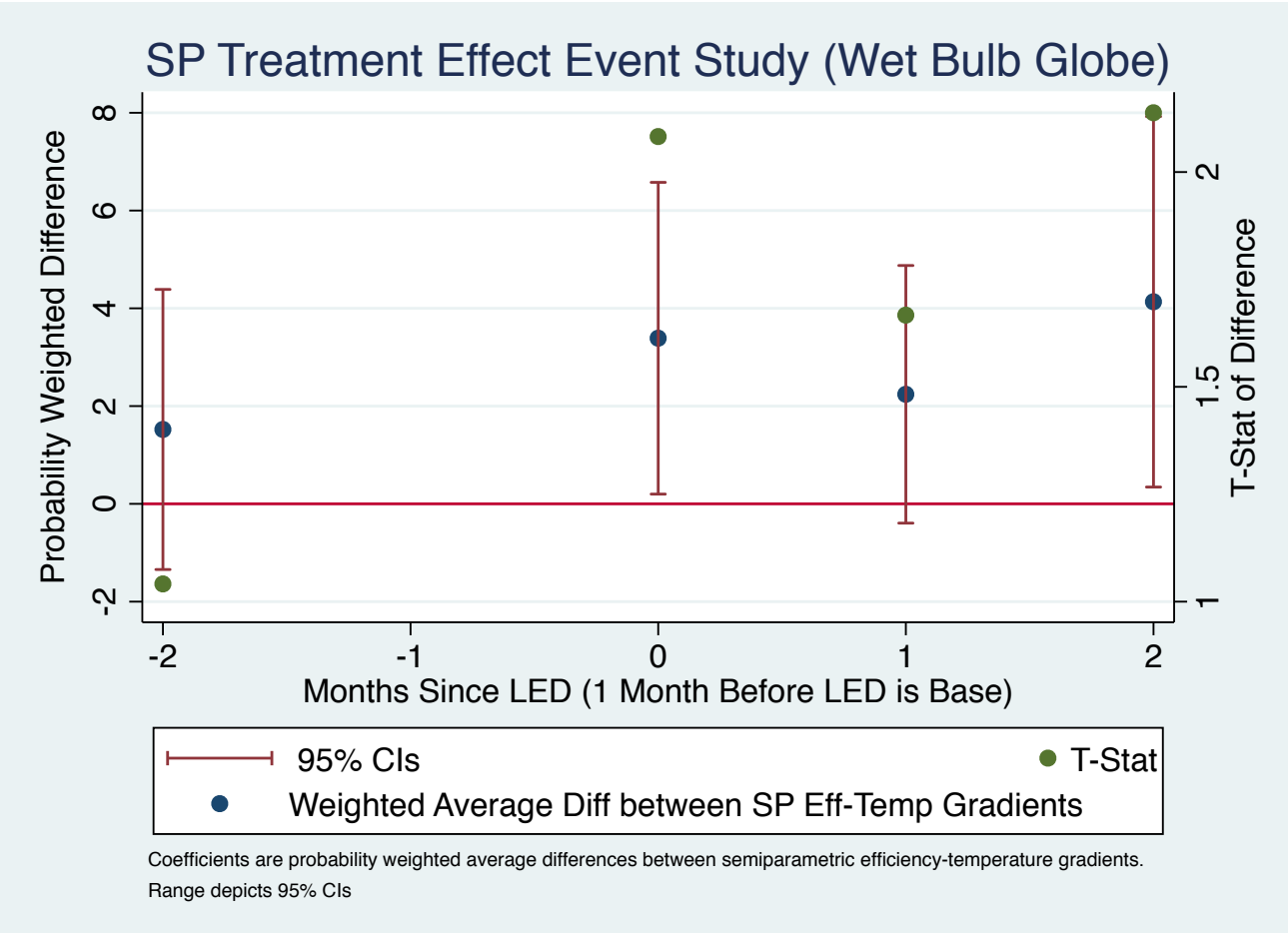
WBT $<$ 19^o C: $\uparrow$ 1^o C $\Rightarrow \downarrow$ 0.11 (no LED), $\downarrow$ 0.21 (LED)

WBT $\geq$ 19^o C: $\uparrow$ 1^o C $\Rightarrow \downarrow$ 1.98 (no LED), $\downarrow$ 0.30 (LED)

Impacts across the temperature distribution (semiparametric estimates)



Event analysis: LED impact



Cost-benefit Analysis

- Calculate difference in the productivity-temperature residual gradients with and without LED
- Calculate probability of each value from temperature residual
- Incidence weighted area between the gradients with and without LED
- Yields average percentage point efficiency gain per line per day (unit of observation) (we got 0.71). 20% translates into firm returns (0.14).
- Using firm's profitability estimates, we get productivity gains of $14088 per factory per year)
- Cost of bulb replacement per factory = $6300; energy savings = $3000 per factory per year
- Break-even using energy savings alone 2.1 years; break-even accounting for efficiency gains 5 months

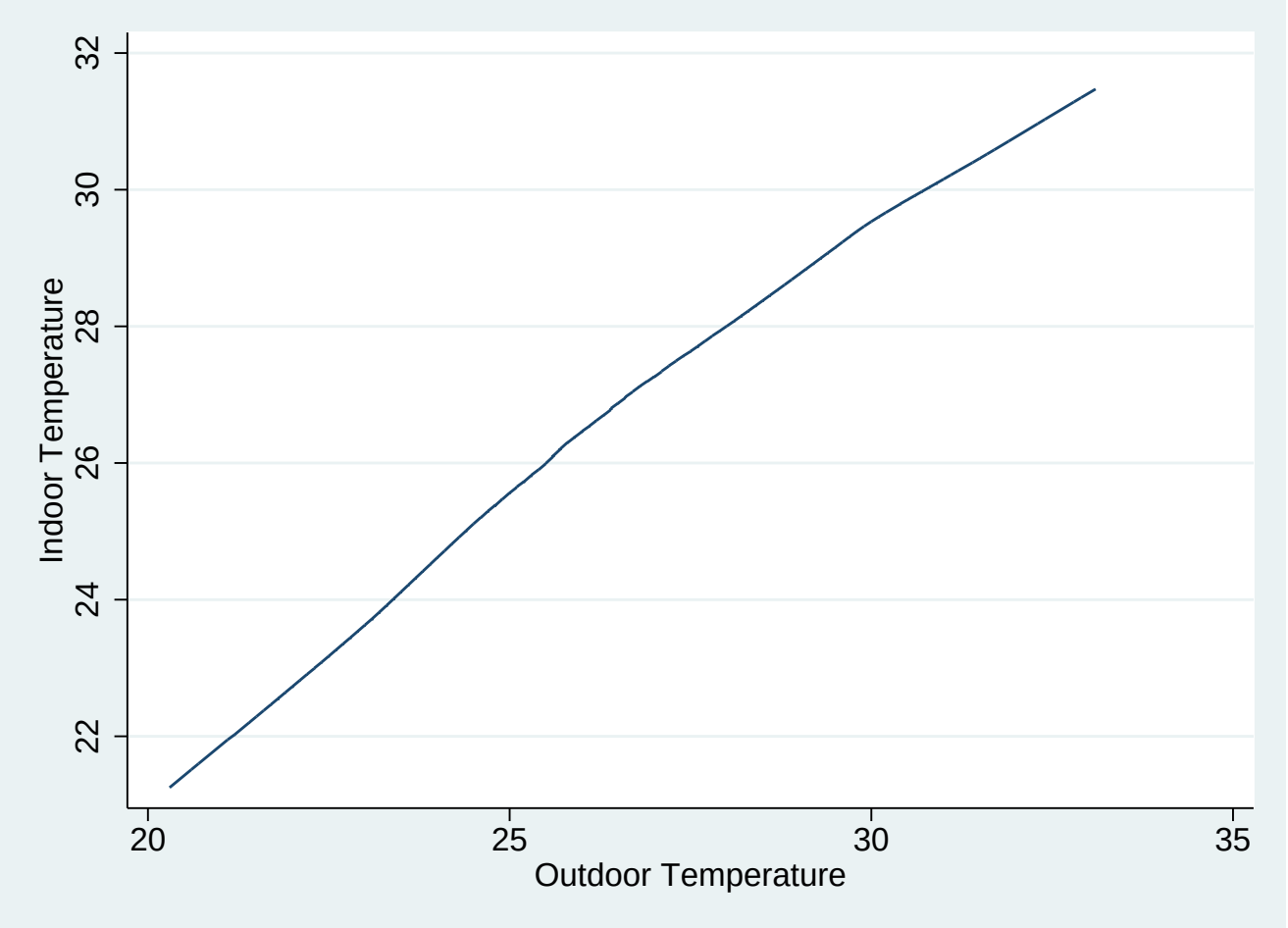
Conclusions

- Temperature has significant impacts on labor productivity in Indian garment factories
- Reducing this elasticity is good for both workers and firms
- Energy-saving LED lighting has an additional productivity benefit via temperature reduction
- Accounting for this "hidden" return drastically changes the cost-benefit calculations of LED adoption (break-even: 5 months v. 2 years)

Thanks

- Ach Adhvaryu: adhvaryu@umich.edu
- Namrata Kala: namrata.kala@yale.edu
- Anant Nyshadham: nyshadha@bc.edu

Indoor-Outdoor Temperature: Sep 2014-Aug 2015



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