The Labor Productivity Impacts of Climate Change: Implications for Global Poverty

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Core Intuition

“Humanity is a biological species, living in a biological environment, because like all species, we are exquisitely adapted in everything: from our behavior, to our physiology, to that particular environment in which we evolved.”
Specific Research Questions

• Whether and to what extent future climate change and associated heat stress may lead to declines in labor productivity...

• What might this mean for global poverty rates, and the research agenda in this field moving forward?
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Key Takeaways

- Significant causal impacts of temperature shocks on labor productivity and related economic outcomes, with short-run damage estimates clustered around \(-2\% \text{ per degree C above room temperature}\).

- While evidence on distributional impacts is thin, possible that this climate damage channel will likely have \textit{disproportionately large effect on the world’s poor.}
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- Significant causal impacts of temperature shocks on labor productivity and related economic outcomes, with short-run damage estimates clustered around -2% per degree C above room temperature.

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- While evidence on distributional impacts is thin, possible that this climate damage channel will likely have **disproportionately large effect on the world’s poor**.
Agenda

1. Key methodological challenges; panel-based solutions
2. Review of the recent literature, focusing on panel estimates
3. What are the likely long-term impacts for the world’s poor?
Methodological Issues in estimating labor productivity impacts from climate change

Two stylized facts
Temperature and Task Productivity

Fact # 1:

Task productivity (and health) declines at temperature extremes

(Seppanen et al, 2007; Kovats and Hajat, 2008; etc)
Temperature and the Wealth of Nations

Fact # 2:

Hotter countries tend to be poorer on average

(Sala-i-Martin, 1997; Acemoglu, Johnson, Robinson, 2001; Sachs, Gallup, Mellinger, 2000; etc)
Labor Productivity Impacts from Climate Change?

#1 + #2 + Global warming = Reduced labor productivity due to climate change?

“Already hot and poor countries will get hotter and poorer.”

What’s wrong with this argument?

Two important methodological issues:

1. Context
2. Causality
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1. Welfare-Relevant Context:
Laboratory settings may not be the right context from a policy perspective

- Economic impact of temperature stress ≠ physiological/task productivity impacts:
  - Workers may adjust timing/location of work, level of effort, types of tasks conducted

- There may be important direct disutility or health impacts:
  - \( Utility = U(Y \left( \frac{\Delta Y}{\Delta T} \right)(T...), T, Health(T),...) \)
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Methodological Issues: Causality

2. Causal Attribution:
   - Correlation is not causation: classic omitted variables problem

   \[ Y(T) \] but also \( Y(T, A, K, HK, ... \) \)
Recent Literature: Panel-Based Solutions

1. **Context**

2. **Causality**

A wave of recent studies address these issues by leveraging panel estimation techniques.
Recent Literature: Panel-Based Solutions

Panel Estimation Technique:

- Exploit high frequency weather fluctuations, which are effectively random, to simulate “natural experiments” in situ:

\[ y_{it} = \beta_0 + \beta_1 T_{it} + \beta_2 P_{it} + \gamma_i + \theta_t + \varepsilon_{it} \]

- Output/productivity
- Temperature variables
- Precip variables
- Region, Year fixed effects
Exploit the fact that short-run weather variation is essentially random...

Are hotter-than-average periods associated with lower output/productivity?
...to run a series of quasi-experiments in situ
Summary of Recent Literature: Panel estimates

- **Micro-level studies: Individuals, Plants, Firms**

  1. Call center workers in India: -1.8% per degree C above 22C hot days (Niemala et al, 2002)
  2. Garment manufacturing, diamond picking in India: -2.8% per degree C above 25C hot days (Sudarshan et al, 2014)
  3. Automobile manufacturing in US: -8% during weeks with 6 or more days above 32C (Cachone et al, 2013)

Figure 3: Historical and projected temperatures under a business as usual climate change scenario for India. See Burgess et al. (2011) for climate change projections. Lines denote estimated productivity effects of temperature with solid lines representing statistically significant effects.
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Summary of Recent Literature

- **Macro-level studies: Sectors, Regions, Nations**
  1. **Exports** in poor countries: -2.4% per degree C hotter than average years (Dell et al, 2012)
  2. **Industrial Value-added** in poor countries: -2% per degree C hotter than average years (Dell et al, 2012)
  3. **Services output** in Caribbean countries: -6.1% per degree C hotter than average summers (Hsiang, 2011)
  4. **GDP per capita** in poor, hot countries: -2~3% per degree C hotter than average years (Park & Heal, 2013; Dell et al, 2013)
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- **Causal Impact** of temperature stress on labor productivity and related (non-agricultural) output metrics, documented at the level of individual workers, plants, and even entire regions in welfare-relevant contexts.

- Remarkable consistency in point estimates: (at least) $-2\%$ per degree C above room temperature.
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What does this mean for poverty rates?

What might the distributional implications of this new climate damage mechanism be?

- Research on distributional impacts of labor productivity channel remains thin...
- ...but there are ex ante reasons suggesting significant impacts on the world’s poor:
  1. High geographic exposure
  2. High occupational vulnerability
  3. Low adaptive capacity / Realistic limits to adaptation
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Distributional Impacts of Labor Productivity channel

- **Geographic Exposure:**
  - Poorer households are located in more heat-prone areas, across countries and within countries.
  - To the extent that an additional degree increase in average temperatures leads to a disproportionately higher incidence of extreme heat days in already heat-stressed regions...poor may suffer larger share of the global burden.

![Map of GDP per Capita in 2008 by Max Roser](image-url)
Distributional Impacts of Labor Productivity channel

- **Occupational Exposure:**
  - Poorer households also tend to work in occupations with greater exposure (outdoors, manual labor)
  - These occupations generally pay lower wages (e.g. construction workers in US: 25% below median wages)
Distributional Impacts of Labor Productivity channel

- **Low adaptive capacity + Realistic limits to adaptation**
  - Poor have less access to physical and financial capital buffers in response to environmental shocks
  - Even if they are able to access known adaptive technologies (e.g. air conditioning), are there realistic limits to adaptation?

Hypothesis: If LDC’s are able to reach US-levels of income and AC penetration within the next several decades, would they be immune to labor productivity impacts from climate change?
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Preliminary Results: Large impacts even in US

Large growth rate impacts of hot days/years on local economic growth (Park, forthcoming):

- +10 days above 32°C → -2.02***% annual growth in non-agricultural payroll per capita
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Preliminary Results: Limits to adaptation

Even in the hottest places (95th percentile) of one of the world’s wealthiest and technologically advanced countries (Park, forthcoming):

- +10 days above 32°C $\rightarrow$ -0.21**% annual growth payroll per capita

Suggests realistic limits to air conditioning and other adaptations in the face of extreme heat.
Preliminary Results: Limits to adaptation

Even in the hottest places (95th percentile) of one of the world’s wealthiest and technologically advanced countries (Park, forthcoming):

- 10 days above 32°C → -0.21**% annual growth payroll per capita

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More research needed, but evidence suggests realistic limits to adaptation in medium term

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<tr>
<th>City</th>
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<th>AC (%)</th>
<th>Implied $\frac{\Delta Y_L}{\Delta T(\text{C})}$</th>
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<tbody>
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<td>Boston (or colder)</td>
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\(^1\) urban electrification rate: 79%
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Summary

Summary of recent findings:

- **Existence of causal effect** of temperature stress on labor productivity **in economically meaningful contexts**

- Magnitudes of short run impacts on the order of -2% per degree C above 20C

- More research needed to assess scope for effective adaptation

- Likely disproportionate impacts on world’s poor
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Parting thoughts

Policy implications:

- **Social cost of carbon estimates may be systematically understated** inasmuch as they miss this important damage channel.

- Labor productivity channel highlights overlap between policy objectives of climate mitigation and poverty alleviation.

- Raises the question: Can we design effective adaptation (AC adoption) policies without jeopardizing climate mitigation? Can the world’s poor adopt widespread AC within safe emissions budgets?
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Thank you

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All point estimates are preliminary.

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Outline

- Review of recent literature: What we now know about temperature and labor productivity
  - Focus on methodological issues
- What we don’t yet know: Preliminary Evidence using U.S. Data
  - Focus on potential for adaptation
- Implications
Recurring themes (Skoufias, 2012; Hallegatte, 2014): exposure, vulnerability, adaptive capacity

Labor productivity is relatively new to the game:

- Richard Tol, *Journal of Economic Perspectives* (2009): “The effects of climate change that have been quantified and monetized include the impacts on agriculture and forestry, water resources, coastal property...the direct impact of climate change on labor productivity has never featured on any list of missing effects”
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Temperature and the Wealth of Nations

Fact # 2:

Hotter countries and regions tend to be poorer

(Park and Heal, forthcoming)
Micro Panel Estimates: Worker productivity in Poor countries

- Niemelä et al. (2002): Call center workers in India
  - -1.8% per degree C above 22°C

- Sudarshan et al, (2014): Indian garment manufacturing plants
  - -2.8% per degree C on hot days (above 25°C)

Figure 3: Historical and projected temperatures under a business as usual climate change scenario for India. See Burgess et al. (2011) for climate change projections. Lines denote estimated productivity effects of temperature with solid lines representing statistically significant effects.

“A week with six or more days of heat exceeding 90 F reduces production that week by 8% on average.”
Macro Panel Estimates: By sector in Caribbean countries

  -2.5% per degree C hotter summers

<table>
<thead>
<tr>
<th>Industry</th>
<th>%Δ/+1 ºC</th>
<th>SE</th>
<th>% output</th>
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<tbody>
<tr>
<td>Total production</td>
<td>-2.5%**</td>
<td>[1.0]</td>
<td>—</td>
</tr>
<tr>
<td>Wholesale, retail, restaurants and hotels</td>
<td>-6.1%***</td>
<td>[1.7]</td>
<td>20.4</td>
</tr>
<tr>
<td>Other services</td>
<td>-2.2%**</td>
<td>[1.1]</td>
<td>35.0</td>
</tr>
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<td>Transport and communications</td>
<td>-2.2%</td>
<td>[1.7]</td>
<td>10.7</td>
</tr>
<tr>
<td>Construction</td>
<td>-0.6%</td>
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</tr>
<tr>
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***P < 0.01, **P < 0.05, *P < 0.1.
Macro Panel Estimates: GDP impacts by Country

Dell et al (2013):

- Industrial value-added in “poor” countries:
  - -2% per degree C hotter than average year

- Exports in “poor” countries:
  - -2.4% per degree C hotter than average year
Macro Panel Estimates: GDP impacts by Country

Dell, Jones, Olken (2012); Park & Heal (2013):
- GDP growth in “poor” countries:
  - -1.1% growth per degree C hotter than average year
- GDP per capita in “hot” countries, low AC:
  - -2~3% income per capita per degree C hotter than average year
Adaptation is a central issue

A key unresolved methodological issue:

1. (Lack of) Welfare-relevant Context
2. (Lack of) Causal Attribution
3. Adaptive Responses

Weather versus Climate impacts: Adaptation dynamics are key

- What we have:
  - Short-run, retrospective weather-productivity relationship

- What we want:
  - Long-run, prospective climate-productivity relationship
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Evidence

Adaptive Responses:
- Time-use changes in response to heat stress (Zivin and Neidell, 2013)
- Reduction in mortality driven by AC adoption (Greenstone et al, 2012)
Three Methodological Issues

1. Context
2. Causality
3. Adaptation
Adaptation

3. Adaptive responses:
Climate change will occur gradually. Human beings are adaptive creatures.


“The damages from climate change can be reduced by appropriate responses. Adaptation is...the important link.”
Adaptation

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![Graph](image-url)
We don’t yet know: Extent of adaptive responses

- **Case A:** Labor productivity impacts may be reduced, even eliminated, by appropriate adaptive responses over the long run.

- **Case B:** Even with high levels of development or adaptation, labor productivity impacts may be large / adaptation may be costly or untenable for other reasons.
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Data and Methods

  - 3,000+ counties, 12 sectors, 27 years, (weather data: 365 days per year)
- Non-agricultural payroll
- Panel estimation:
  - controls for precipitation, county-specific characteristics, year fixed effects, differential productivity trends
What we don’t yet know: Extent of adaptive responses

![Graph showing productivity/output vs. temperature changes](image)

- **Long run impact**
- **Short run impact**
- **Adaptation**
- **With adaptation**
- **Without adaptation**

- Productivity/Output
- Temperature
- Long run impact
- Short run impact
- Adaptation
- With adaptation
- Without adaptation

- $V_0, V_1, V_2$
- $T_1$
- $\Delta T$

---

*Note: The graph illustrates the impact of temperature changes on productivity/output, highlighting the extent of adaptive responses. The adaptive responses are shown as a shift from $V_0$ to $V_2$ with adaptation, compared to $V_1$ without adaptation.*
I. Geography: Extent of exposure

Poorer people tend to live in hotter places (across countries)

Poorer people tend to live in hotter places (within countries)

- Dell et al (2009): $+1^\circ C \rightarrow -1.2\sim1.9\%$ per capita income across municipalities within countries (North, Central and South America)

- Park (forthcoming): $+1^\circ C \rightarrow -1.5\sim2.5\%$ per capita payroll across counties within US (extreme cold hurts as well)
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Outdoor, manual labor occupations are likely more susceptible to heat-related losses.

At the same time, outdoor, manual occupations tend to pay lower-wages in most countries.

- USA (BLS, 2013): Median annual wage: $46,440
  - Farming, Fishing, Forestry occupations: $24,330
  - Laborers and Freight, Stock, and Material Movers: $26,690
  - Transportation Occupations: $33,860
  - Construction laborers: $35,020
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Very old and very young are most susceptible to heat stress.

- In theory: income-smoothing over lifetime (Modigliani, 1963; Friedman, 1959)
- In practice: credit constraints and inherent volatility
- Result: correlation between age and income, implies correlation between incidence of heat stress and lower income/consumption.

![Graph showing income and age relationship]

- Consumption smoothing in theory: Permanent Income Hypothesis (Friedman, 1959)
- Consumption in practice: Credit constraints and imperfect foresight
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![Graph showing income and consumption over age](image-url)
III. Adaptive Capacity: Access to capital

- Poorer individuals tend to have reduced access to adaptive capital which can protect against temperature stress:
  - Stock of climate control equipment (e.g. air conditioning)
  - Flow of climate control services (e.g. electricity)

**Figure:** Hypothetical dose-response relationships between thermal stress and productivity, with and without adaptive investments
III. Adaptive Capacity: Housing amenities

- **Housing quality in urban contexts (AMM spatial equilibrium)**
  - Correlation between income and housing quality
  - Poorer individuals tend to live on top floors in buildings without elevators

![Image showing housing quality in urban contexts](image_url)
IV. Temporal Persistence: Levels vs Growth Effects

Evidence for shock persistence, possibly even growth rate effects

- Growth rate effects:
  - Dell, Jones, Olken (2013): \(-1.1\%\) growth rate effect (per +1 C) for poor countries
  - If sustained, 50 years of +1 C could lead to a 170% wider income gap between rich and poor countries
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# Social Cost of Carbon Estimates

## Table 2

**The Social Cost of Carbon**  
(*measured in $/tC*)

<table>
<thead>
<tr>
<th></th>
<th>Sample (unweighted)</th>
<th></th>
<th>Fitted distribution (weighted)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All</td>
<td>0%</td>
<td>1%</td>
<td>3%</td>
</tr>
<tr>
<td>Mean</td>
<td>105</td>
<td>232</td>
<td>85</td>
<td>18</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>243</td>
<td>434</td>
<td>142</td>
<td>20</td>
</tr>
<tr>
<td>Mode</td>
<td>13</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>33rd percentile</td>
<td>16</td>
<td>58</td>
<td>24</td>
<td>8</td>
</tr>
<tr>
<td>Median</td>
<td>29</td>
<td>85</td>
<td>46</td>
<td>14</td>
</tr>
<tr>
<td>67th percentile</td>
<td>67</td>
<td>170</td>
<td>69</td>
<td>21</td>
</tr>
<tr>
<td>90th percentile</td>
<td>243</td>
<td>500</td>
<td>145</td>
<td>40</td>
</tr>
<tr>
<td>95th percentile</td>
<td>350</td>
<td>500</td>
<td>268</td>
<td>45</td>
</tr>
<tr>
<td>99th percentile</td>
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<td>—</td>
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<tr>
<td>N</td>
<td>232</td>
<td>38</td>
<td>50</td>
<td>66</td>
</tr>
</tbody>
</table>

*Note:* Numbers in the table show the social cost of carbon measured in 1995 dollars per metric ton of carbon ($/tC$). Estimates are based on sample statistics and characteristics of the Fisher–Tippett distribution fitted to 232 published estimates and to three subsets of these estimates based on the pure rate of time preference.
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(measured in $/tC)

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<th>Fitted distribution (weighted)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Pure rate of time preference</td>
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<tr>
<td>99th percentile</td>
<td>1500</td>
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<tr>
<td><strong>N</strong></td>
<td>232</td>
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Social Cost of Carbon Estimates May be misleading
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Optimal Temperature Zone?

Temperature and Economic Activity in US counties (1986-2011)

Log Payroll on Average Daily Maximum temps

Log Annual Payroll

Annual Average of Daytime Maximum Temperature (F)

95% CI  predicted lnap_All_pc
Optimal Temperature Zone?

Figure: Nordhaus (PNAS, 2007)
Option 3: Political Economy of Public Good Provision

**Political Economy Model + Estimation:**

- Use panel variation in extreme events + additional data on public infrastructure (or other related proxy) spending
Access to Electricity

Table 1: Electricity access in 2009 - Regional aggregates

<table>
<thead>
<tr>
<th>Region</th>
<th>Population without electricity (million)</th>
<th>Electrification rate (%)</th>
<th>Urban (%)</th>
<th>Rural (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>587</td>
<td>41.8</td>
<td>68.8</td>
<td>25.0</td>
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<tr>
<td>North Africa</td>
<td>2</td>
<td>99.0</td>
<td>99.6</td>
<td>98.4</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>585</td>
<td>30.5</td>
<td>59.9</td>
<td>14.2</td>
</tr>
<tr>
<td>Developing Asia</td>
<td>675</td>
<td>81.0</td>
<td>94.0</td>
<td>73.2</td>
</tr>
<tr>
<td>China &amp; East Asia</td>
<td>182</td>
<td>90.8</td>
<td>96.4</td>
<td>86.4</td>
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<tr>
<td>South Asia</td>
<td>493</td>
<td>68.5</td>
<td>89.5</td>
<td>59.9</td>
</tr>
<tr>
<td>Latin America</td>
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<td>93.2</td>
<td>98.8</td>
<td>73.6</td>
</tr>
<tr>
<td>Middle East</td>
<td>21</td>
<td>89.0</td>
<td>98.5</td>
<td>71.8</td>
</tr>
<tr>
<td>Developing countries</td>
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<td>74.7</td>
<td>90.6</td>
<td>63.2</td>
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<td>World*</td>
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<td>80.5</td>
<td>93.7</td>
<td>68.0</td>
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</tbody>
</table>