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

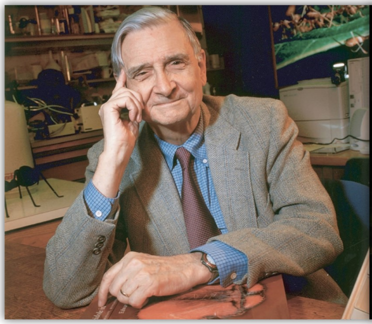
Jisung Park[1]

Harvard University Economics Department

World Bank Climate Change and Poverty Conference 2015

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?

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?

Key Takeaways

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

Key Takeaways

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

Key Takeaways

- **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**
- 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?

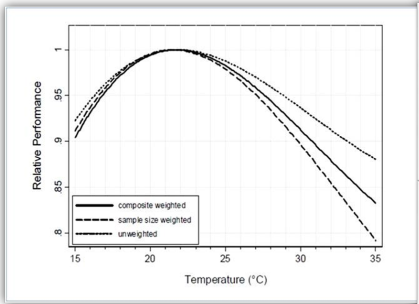
Methodological Issues in estimating labor productivity impacts from climate change

Two stylized facts

Temperature and Task Productivity

Fact # 1:

Task productivity (and health) declines at temperature extremes

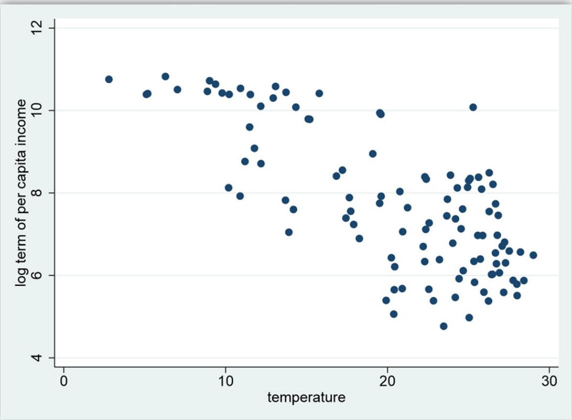


(Seppanen et al, 2007; Kovats and Hajat, 2008; etc)

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***

Labor Productivity Impacts from Climate Change?

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

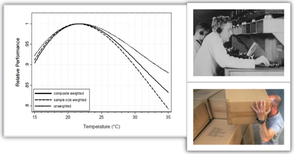
"Already hot and poor countries will get hotter and poorer."

What's wrong with this argument?

Two important methodological issues:

1. ***Context***
2. ***Causality***

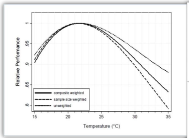
Methodological Issues: Context



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

- Economic impact of temperature stress $\neq$ 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:
  - $Utility = U(Y(\frac{\Delta Y^L}{\Delta T}(T\ldots), T, Health(T), \ldots)$

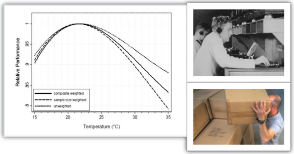
Methodological Issues: Context



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

- Economic impact of temperature stress $\neq$ 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:
  - $Utility = U(Y(\frac{\Delta Y^L}{\Delta T}(T \ldots), T, Health(T), \ldots)$

Methodological Issues: Context



1. Welfare-Relevant Context:

Laboratory settings may not be the right context from a policy perspective

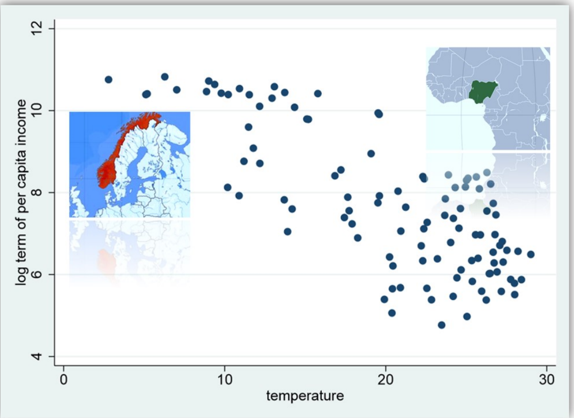
- Economic impact of temperature stress $\neq$ physiological/task productivity impacts:
  - Workers may adjust timing/location of work, level of effort, types of tasks conducted

- There may be important direct disutility or health impacts:
  - $Utility = U(Y(\frac{\Delta Y^L}{\Delta T}(T...), T, Health(T), ...)$

Methodological Issues: Causality

2. Causal Attribution:

- Correlation is not causation: classic omitted variables problem



- $Y(T)$ but also $Y(T, A, K, HK, \ldots)$

Recent Literature: Panel-Based Solutions

1. ***Context***
2. ***Causality***

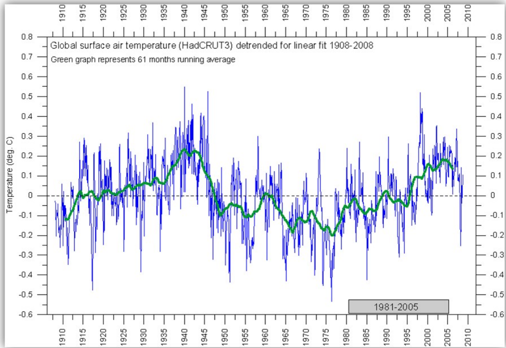
A wave of recent studies address these issues by leveraging panel estimation techniques

Recent Literature: Panel-Based Solutions

Panel Estimation Technique:

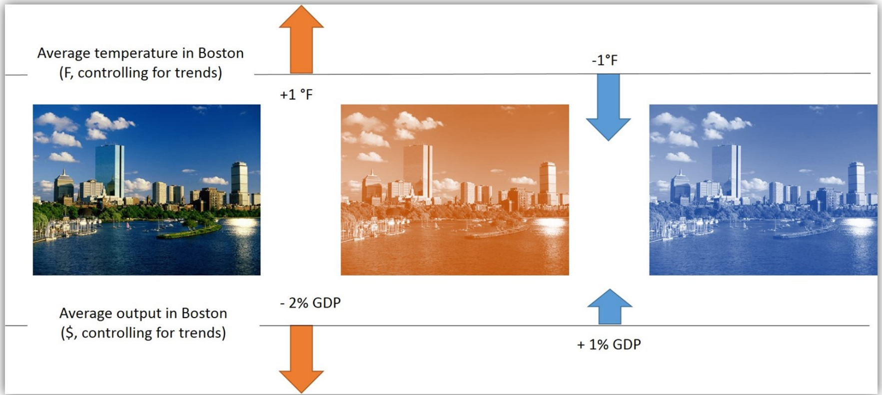
- Exploit high frequency weather fluctuations, which are effectively random, to simulate "natural experiments" in situ:

$$\underbrace{y_{it}}_{output/productivity} = \beta_0 + \underbrace{\beta_1 T_{it}}_{Temperature\, variables} + \underbrace{\beta_2 P_{it}}_{Precip\, variables} + \underbrace{\gamma_i + \theta_t}_{Region,\, Year\, fixed\, effects} + \varepsilon_{it}$$

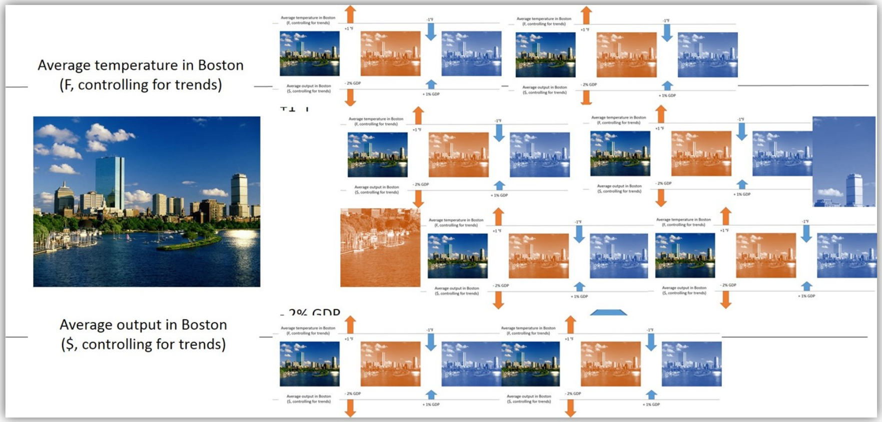


Exploit the fact that short-run weather variation is essentially random...

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)

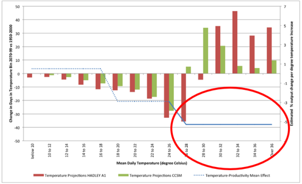


Figure 3: Historical and projected temperatures under a business as usual climate change scenario for India. See Burgess et al. (2011) for climate change projections. Lines denote estimated productivity effects of temperature with solid lines representing statistically significant effects

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)

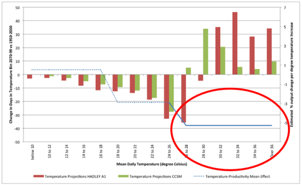
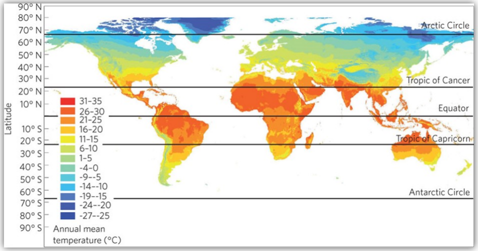


Figure 3: Historical and projected temperatures under a business as usual climate change scenario for India. See Burgess et al. (2011) for climate change projections. Lines denote estimated productivity effects of temperature with solid lines representing statistically significant effects

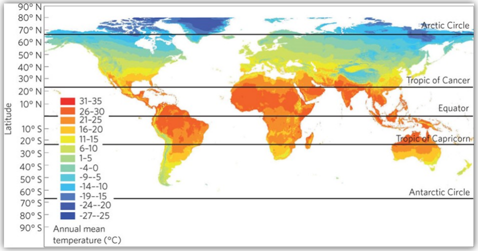
Summary of Recent Literature

- **Macro-level studies: Sectors, Regions, Nations**
  1. **Exports** in poor countries: -2.4% per degre 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)



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)



Summary of Recent Literature

- **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**

Summary of Recent Literature

- **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**

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**

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**

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

What does this mean for poverty rates?

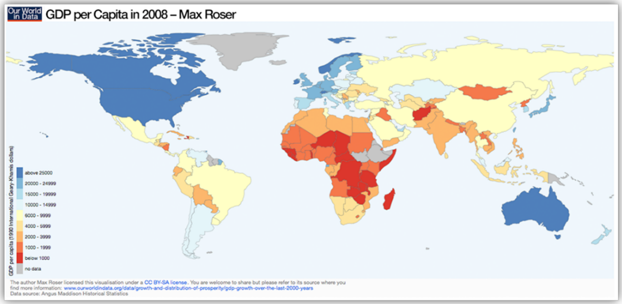
What might the distributional implications of this new climate damage mechanism be?

- 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**

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



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?

Distributional Impacts of Labor Productivity channel

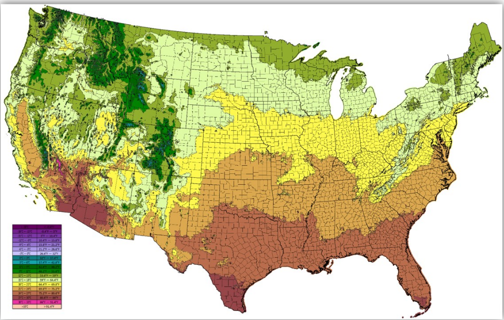
- **Low adaptive capacity + Realistic limits to adaptation**
  - Poor have less access to physical and financial capital buffers in response to environmental shocks
  - Even if they are able to access known adaptive technologies (e.g. air conditioning), are there realistic limits to adaptation?

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?

Preliminary Results: Large impacts even in US

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

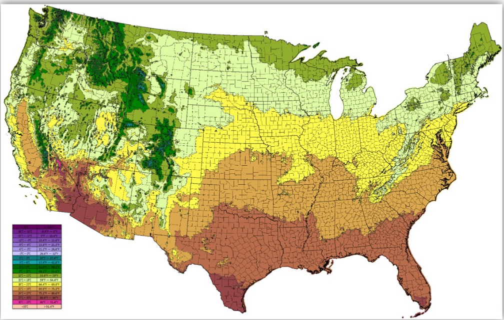
- **+10 days above 32C →-2.02***% annual growth in non-agricultural payroll per capita**



Preliminary Results: Large impacts even in US

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

- **+10 days above 32C →-2.02***% annual growth in non-agricultural payroll per capita**

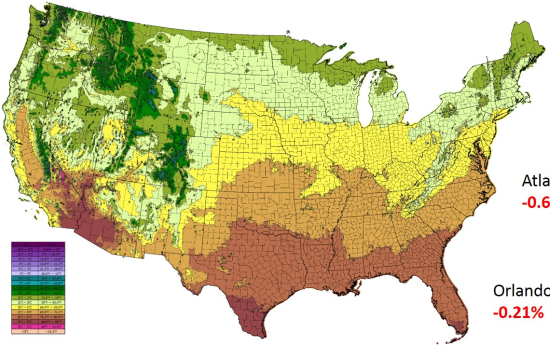


Preliminary Results: Limits to adaptation

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

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

Suggests realistic limits to air conditioning and other adaptations in the face of extreme heat.



Boston (25th percentile):
-3.90%

Atlanta (75th percentile):
-0.62%

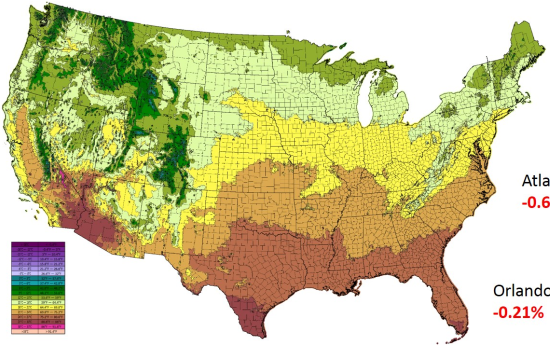
Orlando (95th percentile):
-0.21%

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 32C $\rightarrow$-0.21**% annual growth payroll per capita**

Suggests realistic limits to air conditioning and other adaptations in the face of extreme heat.



Boston (25th percentile): **-3.90%**

Atlanta (75th percentile): **-0.62%**

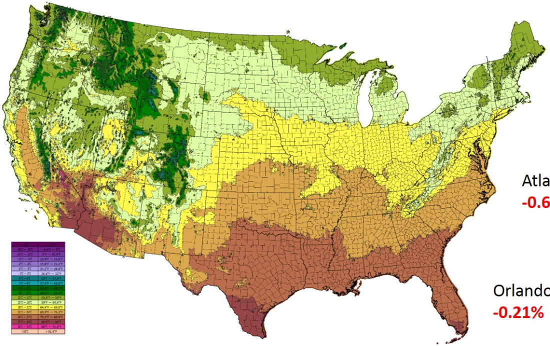
Orlando (95th percentile): **-0.21%**

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 32C $\rightarrow$-0.21**% annual growth payroll per capita**

Suggests realistic limits to air conditioning and other adaptations in the face of extreme heat.



Boston (25th percentile): **-3.90%**

Atlanta (75th percentile): **-0.62%**

Orlando (95th percentile): **-0.21%**

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

	Avg Annual Temp	Income per cap	AC (%)	Implied $\frac{\Delta Y^L}{\Delta T(C)}$
Boston (or colder)	9C (48F)	$33,940	~80%	-3.90***%
Orlando (or hotter)	20C (69F)	$34,211	~95%	-0.21**%
...	...	...	...	...
Mumbai	27C (81F)	$2,026	?? [1]	??

- Poor countries likely cannot "grow" their way out of this problem, at least not in the near future

[1] urban electrification rate: 79%

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

	Avg Annual Temp	Income per cap	AC (%)	Implied $\frac{\Delta Y^L}{\Delta T(C)}$
Boston (or colder)	9C (48F)	$33,940	~80%	-3.90***%
Orlando (or hotter)	20C (69F)	$34,211	~95%	-0.21**%
...	...	...	...	...
Mumbai	27C (81F)	$2,026	?? [1]	??

- Poor countries likely cannot "grow" their way out of this problem, at least not in the near future

[1] urban electrification rate: 79%

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 asses scope for effective adaptation**
- **Likely disproportionate impacts on world's poor**

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 asses scope for effective adaptation
- Likely disproportionate impacts on world's poor

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 asses scope for effective adaptation**
- **Likely disproportionate impacts on world's poor**

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 asses scope for effective adaptation**
- **Likely disproportionate impacts on world's poor**

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 jeapordizing climate mitigation?** Can the world's poor adopt widespread AC within safe emissions budgets?

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 jeapordizing climate mitigation?** Can the world's poor adopt widespread AC within safe emissions budgets?

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 jeapordizing climate mitigation?** Can the world's poor adopt widespread AC within safe emissions budgets?

Thank you

Contact: jisungpark@fas.harvard.edu

All point estimates are preliminary.

Please do not cite without authors' permission.

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

This Presentation

- 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 quantifiied 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"

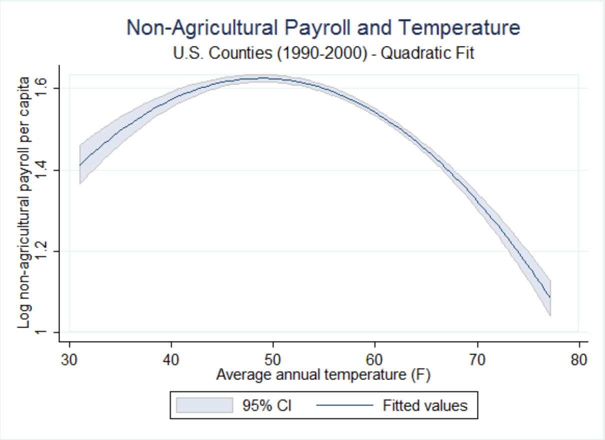
This Presentation

- 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 quantifiied 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"

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 22C**
- Sudarshan et al, (2014): Indian garment manufacturing plants
  - **-2.8% per degree C on hot days (above 25C)**

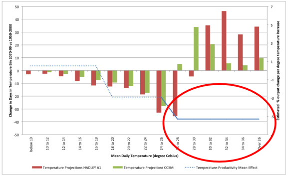


Figure 3: Historical and projected temperatures under a business as usual climate change scenario for India. See Burgess et al. (2011) for climate change projections. Lines denote estimated productivity effects of temperature with solid lines representing statistically significant effects

Micro Panel Estimates: Automobile Assembly in US

- Cachone et al (2013): Automobile manufacturing plants in US (1994-2004)
  - "A week with six or more days of **heat exceeding 90 F reduces production that week by 8% on average**."

Table 8: Ranking of average productivity reduction due to weather by location

Rank	*City*	*State*	*Total productivity loss (%)*	*Snow loss (%)*	*Rain loss (%)*	*Temp. loss (%)*	*Wind loss (%)*
1	Montgomery	AL	2.88%	0.00%	0.34%	2.45%	0.10%
2	Arlington	TX	2.41%	0.01%	0.52%	1.71%	0.17%
3	Shreveport	LA	2.18%	0.02%	0.48%	1.56%	0.12%
4	Canton	MS	1.93%	0.00%	0.53%	1.40%	0.00%
5	Avon Lake	OH	1.83%	0.74%	0.54%	0.22%	0.33%
6	St Paul	MN	1.81%	1.03%	0.23%	0.41%	0.14%
7	Oklahoma City	OK	1.81%	0.10%	0.17%	1.23%	0.30%
8	Lorain	OH	1.80%	0.78%	0.45%	0.25%	0.33%
9	Warren	OH	1.78%	1.00%	0.44%	0.21%	0.13%
10	Roanoke	IN	1.77%	0.79%	0.43%	0.29%	0.25%
11	Hazelwood	MI	1.70%	0.35%	0.50%	0.70%	0.16%
12	Lansing	MI	1.66%	0.93%	0.38%	0.27%	0.08%
13	Toledo	OH	1.65%	0.70%	0.42%	0.35%	0.18%
14	Vance	AL	1.63%	0.03%	0.35%	1.10%	0.16%
15	Wayne	MI	1.63%	0.76%	0.35%	0.26%	0.26%
16	Edison	NJ	1.61%	0.28%	0.70%	0.42%	0.21%
17	Linden	NJ	1.59%	0.28%	0.67%	0.38%	0.26%
18	Fenton	MO	1.58%	0.36%	0.32%	0.73%	0.17%
19	Smyrna	TN	1.57%	0.19%	0.54%	0.74%	0.10%
20	Flint	MI	1.55%	0.92%	0.26%	0.28%	0.09%
21	Spring Hill	TN	1.52%	0.17%	0.54%	0.73%	0.08%
22	Lake Orion	MI	1.50%	0.87%	0.26%	0.28%	0.10%
23	Baltimore	MD	1.50%	0.17%	0.67%	0.49%	0.18%
24	Wentzville	MO	1.48%	0.37%	0.27%	0.65%	0.19%
25	Sterling Heights	MI	1.45%	0.98%	0.20%	0.27%	0.00%

Temp. loss (%)
2.45%
1.71%
1.56%
1.40%

Macro Panel Estimates: By sector in Caribbean countries

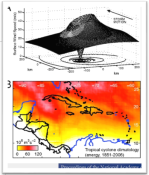
- Hsiang, (2010): 28 Caribbean countries (1970 - 2006)
  - **-2.5% per degree C hotter summers**

PNAS
Proceedings of the National Academy of Sciences of the United States of America www.pnas.org

Table 1. Effect of annual average surface temperature on production (1970–2006)

Industry	%Δ/+1 °C	SE	% output
Total production	−2.5%**	[1.0]	—
Wholesale, retail, restaurants and hotels	−6.1%***	[1.7]	20.4
Other services	−2.2%**	[1.1]	35.0
Transport and communications	−2.2%	[1.7]	10.7
Construction	−0.6%	[3.1]	7.4
Manufacturing	+1.4%	[2.6]	12.0
Agriculture, hunting and fishing	−0.8%	[2.5]	10.5
Mining and utilities	−4.2%*	[2.4]	4.2

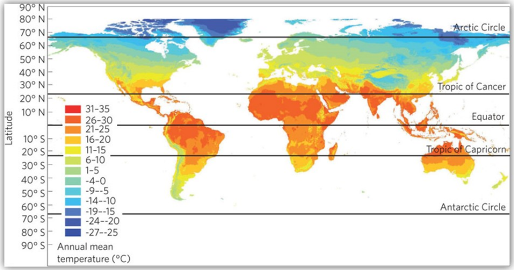
***P < 0.01, **P < 0.05, *P < 0.1.



Macro Panel Estimates: GDP impacts by Country

Dell et al (2013):

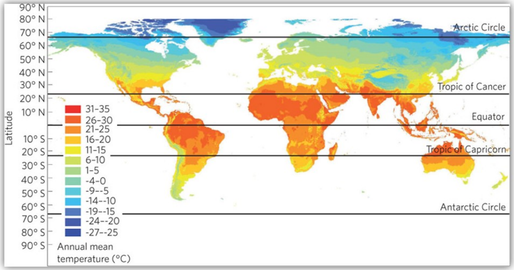
- Industrial value-added in "poor" countries:
  - **-2% per degree C hotter than average year**
- Exports in "poor" countries::
  - **-2.4% per degree C hotter than average year**



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***

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***

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***

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***

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***

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)

~~Two~~ Three Methodological Issues

1. ***Context***
2. ***Causality***
3. ***Adaptation***

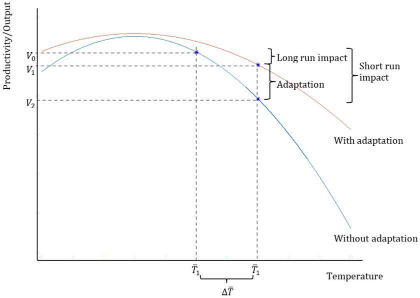
Adaptation

3. Adaptive responses:

Climate change will occur gradually. Human beings are adaptive creatures.

Robert Mendelsohn, *Climate Change Economics* (2010):

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



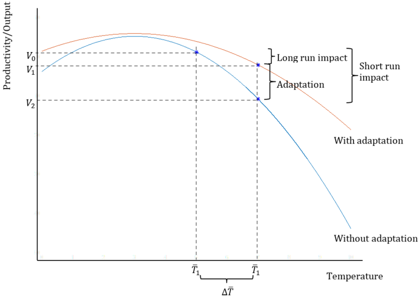
Adaptation

3. Adaptive responses:

Climate change will occur gradually. Human beings are adaptive creatures.

Robert Mendelsohn, *Climate Change Economics* (2010):

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



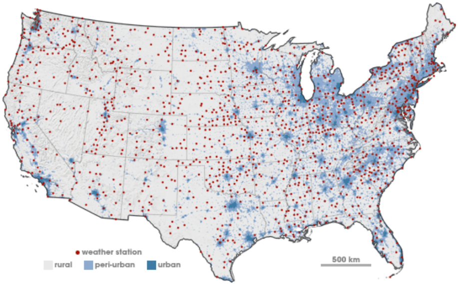
We don't yet know: Extent of adaptive responses

- **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

We don't yet know: Extent of adaptive responses

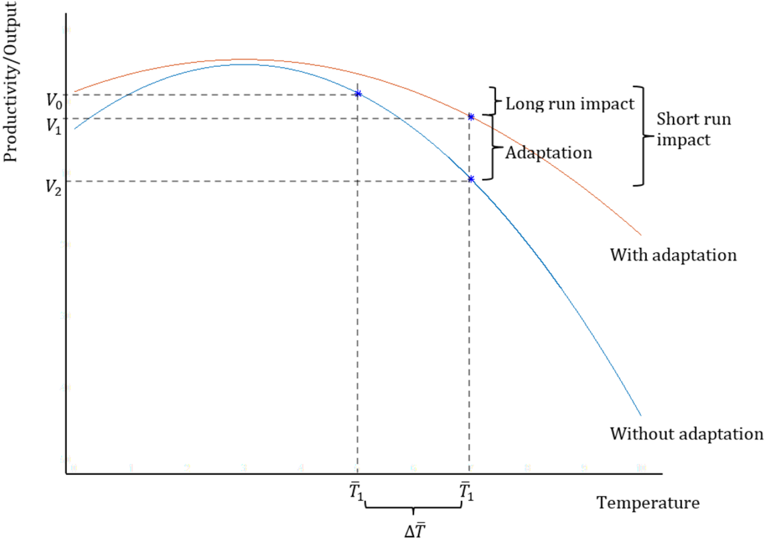
- **Case A:** Labor productivity impacts may be reduced, even eliminated, by appropriate adaptive responses over the long run
- **Case B:** Even with high levels of development or adaptation, labor productivity impacts may be large / adaptation may be costly or untenable for other reasons

Data and Methods



- US county-level weather and economic data (1986-2012)
  - 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



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): +1ºC $\Longrightarrow$ *-1.2~1.9%* per capita income across municipalities within countries (North, Central and South America)
- Park (forthcoming): +1ºC $\Longrightarrow$ *-1.5-2.5%* per capita payroll across counties within US (extreme cold hurts as well)

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): +1ºC $\Longrightarrow$ *-1.2~1.9%* per capita income across municipalities within countries (North, Central and South America)
- Park (forthcoming): +1ºC $\Longrightarrow$ *-1.5-2.5%* per capita payroll across counties within US (extreme cold hurts as well)

II. Demography: Occupation

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

II. Demography: Occupation

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

II. Demography: Occupation

Outdoor, manual labor occupations are likely more susceptible to heat-related losses.

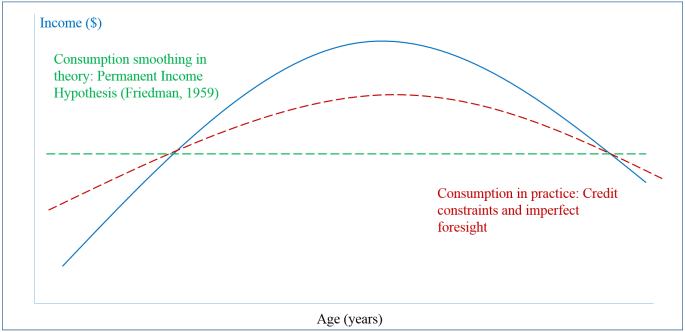
At the same time, outdoor, manual occupations tend to pay lower-wages in most countries.

- 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

II. Demography: Age

Very old and very young are most susceptible to heat stress.

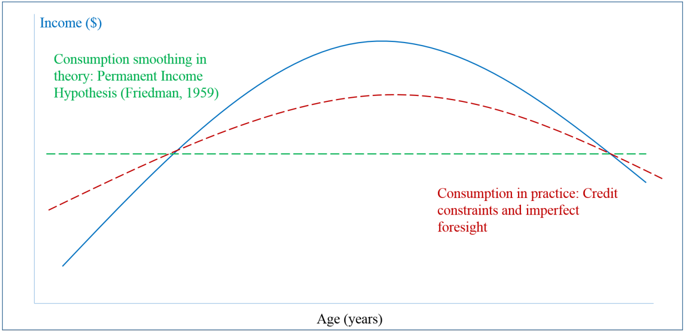
- In theory: income-smoothing over lifetime (Modigliani, 1963; Friedman, 1959)
- In practice: credit constraints and inherent volatility
- Result: correlation between age and income, implies correlation between incidence of heat stress and lower income/consumption.



II. Demography: Age

Very old and very young are most susceptible to heat stress.

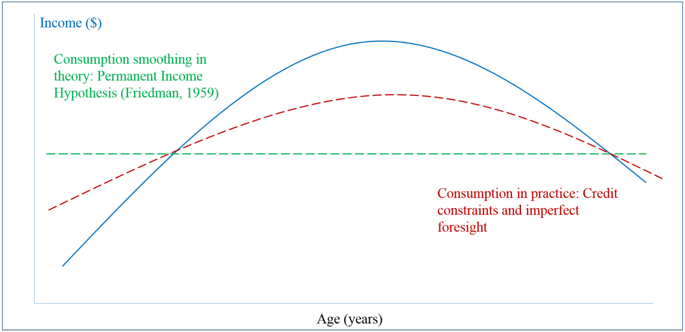
- In theory: income-smoothing over lifetime (Modigliani, 1963; Friedman, 1959)
- In practice: credit constraints and inherent volatility
- Result: correlation between age and income, implies correlation between incidence of heat stress and lower income/consumption.



II. Demography: Age

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.



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)

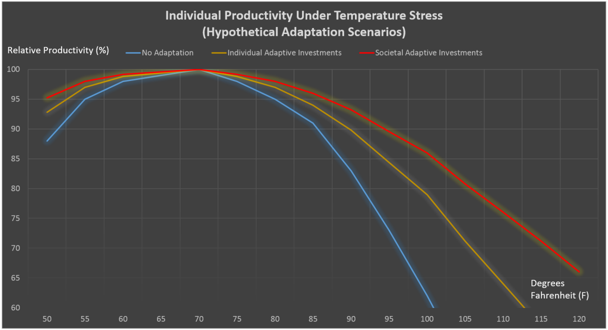
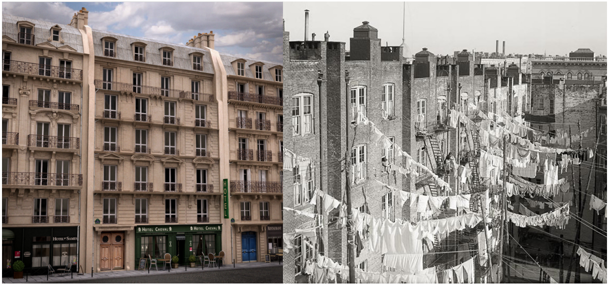


Figure : Hypothetical dose-response relationships between thermal stress and productivity, with and without adaptive investments

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



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**

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**

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**

Social Cost of Carbon Estimates

Table 2
The Social Cost of Carbon
(measured in \$/tC)

	Sample (unweighted)				Fitted distribution (weighted)			
		Pure rate of time preference				Pure rate of time preference		
	All	0%	1%	3%	All	0%	1%	3%
Mean	105	232	85	18	151	147	120	50
Standard Deviation	243	434	142	20	271	155	148	61
Mode	13	—	—	—	41	81	49	25
33rd percentile	16	58	24	8	38	67	45	20
Median	29	85	46	14	87	116	91	36
67th percentile	67	170	69	21	148	173	142	55
90th percentile	243	500	145	40	345	339	272	112
95th percentile	360	590	268	45	536	487	410	205
99th percentile	1500	—	—	—	1687	667	675	270
N	232	38	50	66	—	—	—	

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.

Social Cost of Carbon Estimates

Table 2

The Social Cost of Carbon

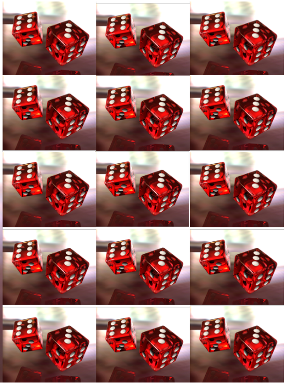
(measured in \$/tC)

	Sample (unweighted)				Fitted distribution (weighted)			
		Pure rate of time preference				Pure rate of time preference		
	All	0%	1%	3%	All	0%	1%	3%
Mean	105	232	85	18	151	147	120	50
Standard Deviation	243	434	142	20	271	155	148	61
Mode	13	—	—	—	41	81	49	25
33^{rd} percentile	16	58	24	8	38	67	45	20
Median	29	85	46	14	87	116	91	36
67^{th} percentile	67	170	69	21	148	173	142	55
90th percentile	243	500	145	40	345	339	272	112
95^{th} percentile	360	590	268	45	536	487	410	205
99th percentile	1500	—	—	—	1687	667	675	270
N	232	38	50	66	—	—	—	

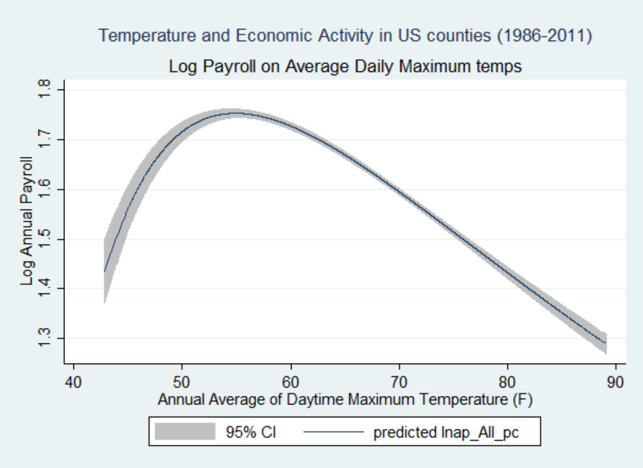
Note: Numbers in the table show the social cost of carbon measured in 1995 dollars per metric ton of carbon (\$/tC). Estimates are based on sample statistics and characteristics of the Fisher–Tippett distribution fitted to 232 published estimates and to three subsets of these estimates based on the pure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

Social Cost of Carbon Estimates May be misleading

Social Cost of Carbon Estimates May be misleading



Optimal Temperature Zone?



Optimal Temperature Zone?

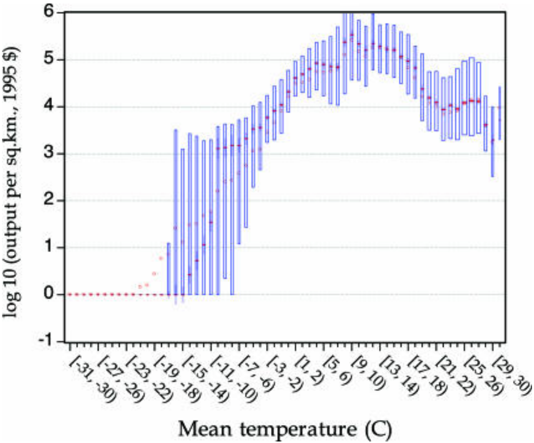
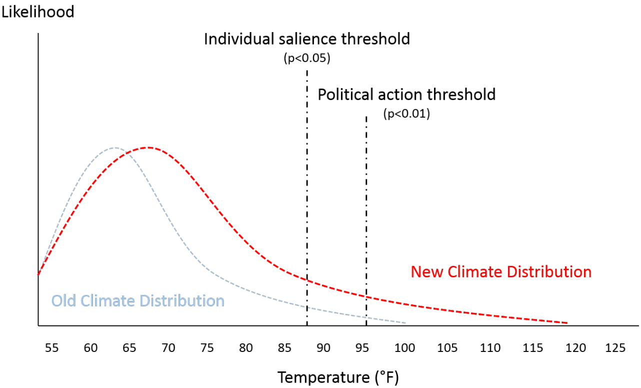


Figure : Nordhaus (PNAS, 2007)

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

	Population without electricity (million)	Electrification rate (%)	Urban (%)	Rural (%)
Africa	587	41.8	68.8	25.0
North Africa	2	99.0	99.6	98.4
Sub-Saharan Africa	585	30.5	59.9	14.2
Developing Asia	675	81.0	94.0	73.2
China & East Asia	182	90.8	96.4	86.4
South Asia	493	68.5	89.5	59.9
Latin America	31	93.2	98.8	73.6
Middle East	21	89.0	98.5	71.8
Developing countries	1,314	74.7	90.6	63.2
World*	1,317	80.5	93.7	68.0