Geography and Development

- The temperate drift hypothesis

Carl-Johan Dalgaard

Warwick Summer School in Economic Growth

Background

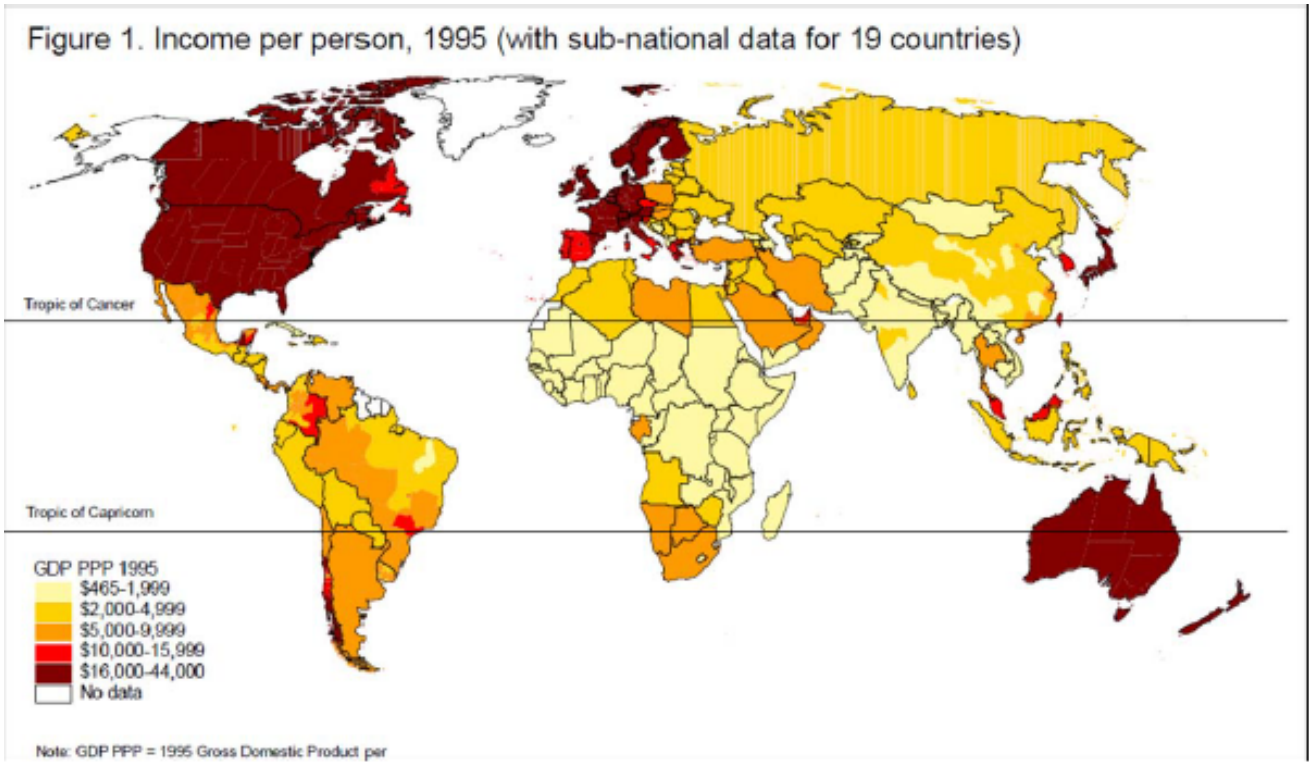
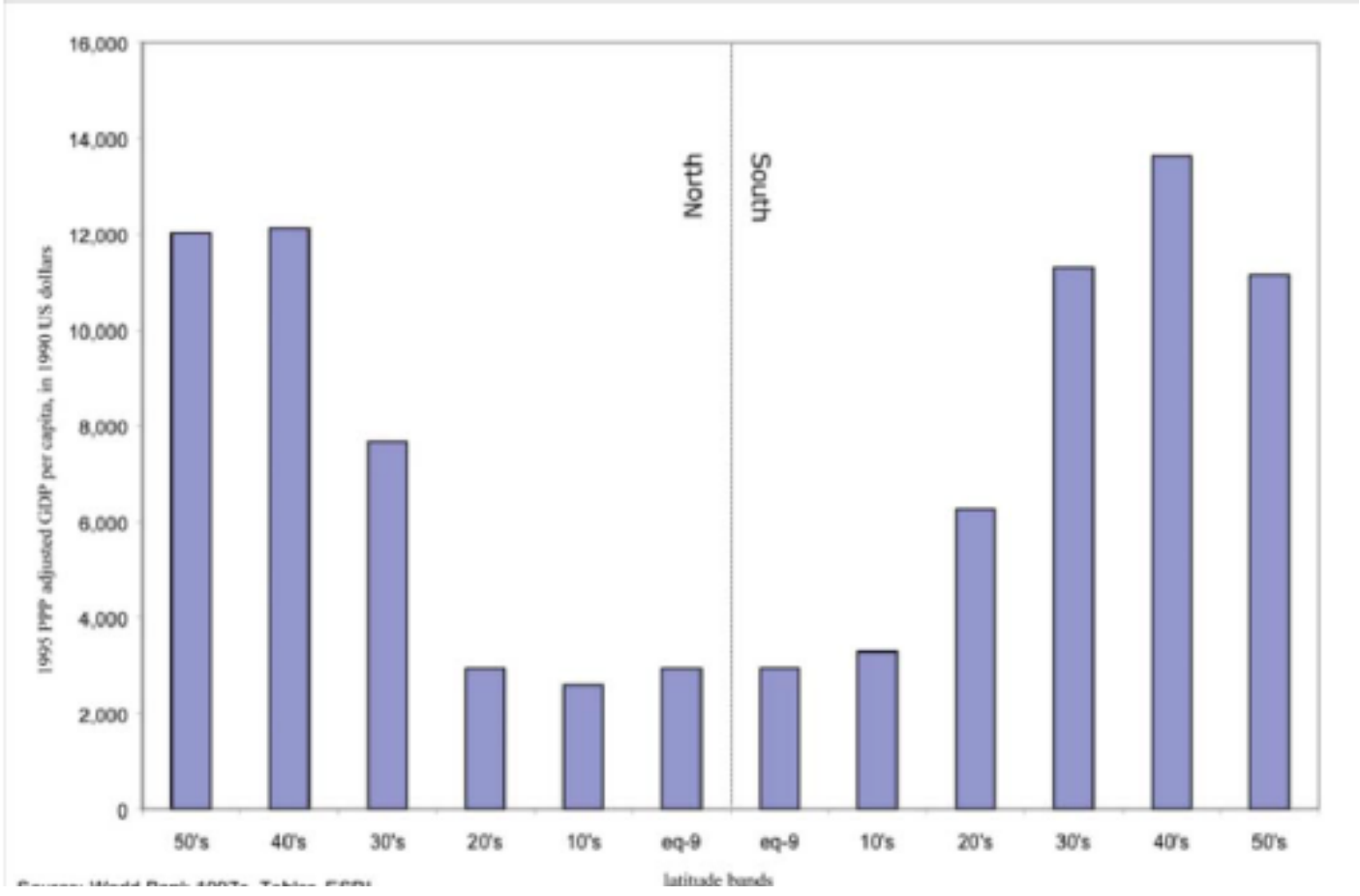


Figure 1. Income per person, 1995 (with sub-national data for 19 countries)
Tropic of Cancer
Tropic of Capricorn
GDP PPP 1995
$465-1,999
$2,000-4,999
$5,000-9,999
$10,000-15,999
$16,000-44,000
No data
Note: GDP PPP = 1995 Gross Domestic Product per


16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1995 PPP adjusted GDP per capita, in 1990 US dollars
North
South
50's
40's
30's
20's
10's
eq-9
eq-9
10's
20's
30's
40's
50's
latitude bands

- **Stylized fact:** Strong positive (absolute) latitude gradient in the data; "north is rich, south is poor"
- Also holds within regions (e.g. Northern vs Southern Europe) as well as countries (e.g., Northern vs Southern USA, Northern vs Southern Italy etc)
- More formally, we can look at the OLS correlation across pixel's (1 degree lat/long), which allows us to prune the data for country fixed effects (pixel area is also controlled below)

	logGDPpc, 2005		logLights, 2004	
Abslat	0.032^{***}	0.017^{***}	0.012^{***}	0.014^{**}
	(0.0002)	(0.0004)	(0.0009)	(0.05)
Country FE	No	Yes	No	Yes
N	17,108	17,108	18,433	18,433

- The plot thickens. Absolute latitude and population density (1 CE, 1000 CE or 1500 CE) is - if anything - *negatively* correlated (conditional on continental fixed effects); cf Ashraf and Galor (2001, AER); Wacziarg and Spolaore (2013, JEL). **The "positive" latitude gradient is comparatively recent**.

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- Latitude hardly matters *per se* ... so why do we see the latitude gradient? Why is it changing over time?
- Channeling via fundamental determinants. Institutions? (e.g., Acemoglu et al, 2001, QJE; Hall and Jones, 1999, QJE) Culture? (e.g., Tabellini, 2010, JEEA). Probably not the full story in light of the modest difference in the between and within-country latitude gradient.

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- Leaves us with Geography itself. But time invariant, and therefore indicating persistence, it would seem?

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    - Example 1 speaks to how geography have influenced the diffusion of the *industrial revolution*;
    - Example 2 concerns the link between geography and the (ongoing) diffusion of the *IT revolution*. (time permitting)

EYE DISEASE AND DEVELOPMENT

Joint with Thomas Barnebeck Andersen and Pablo Selaya

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- This project: Morbidity and Development. Novel focus: **Eye** disease

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- **Issue 2: Identification.** Confounders is a problem. E.g., Other diseases? (e.g., skin cancer); institutions; culture etc. *Need to dispel other plausible mechanisms linking UV til current development*

Plan of attack

1. Why would eye disease matter to current income differences?
2. Empirics
    a. Reduced form evidence (cross country data; cc data)
    b. Exploring the "take-off explanation" (cc data)
    c. Exploring alternative channels: Skin cancer; other (tropical) diseases (cc data)
    d. Institutions and culture (pixel level data; 1×1 lat/lon)
3. Bottom line

WHY WOULD IT MATTER?

A B

Fig. 1. A: Ka-aper´s statue *(Egyptian Museum, Cairo, Egypt)*. B: Detail of the white pupillary reflex in the left eye indicating a mature cataract *(taken from J Cataract Refract Surg 2001;27(11):1714-5)*

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- The code of Hammurabi: "'If a doctor operates ... on the eye of a patrician who loses his eye in consequence, his hands shall be cut-off." (Ascaso, Singh and Dua, 2011, Br J Opht.).

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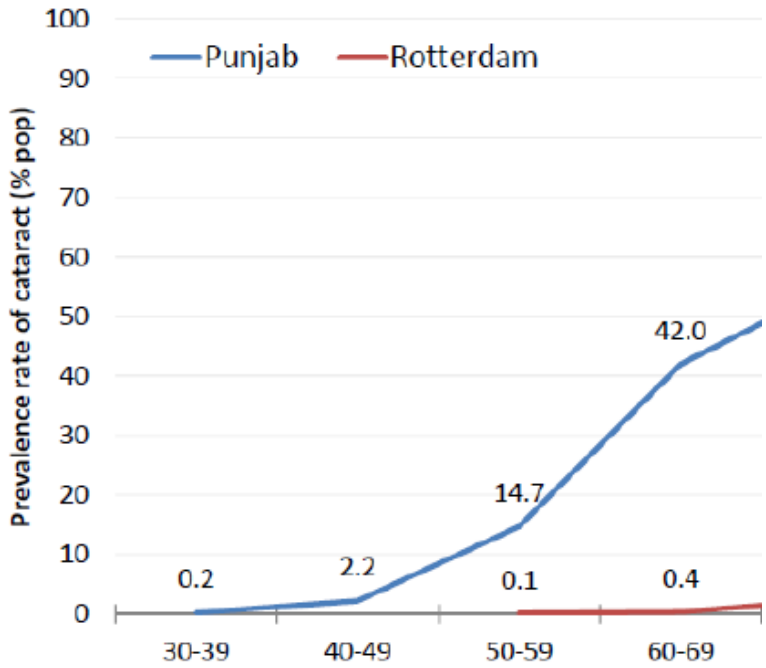
- Reduced vision is likely to be a *particular problem* in human capital intensive occupations; might reduce work-life in skilled occupations (the return of skill formation). But by how much?

- Two extremes: Prevalence of cataract with at most 20/60 visual acuity (contingent on best possible correction) in Punjab (1970s) and Rotterdam.



- Assume: cataract→exit. What is your expected years of work (EYWL) life in Punjab *as skilled*? (Method: Reimers, 1976, J. Am. Stat. Assoc)
- EYWL(20) = 40; LE(20) of 49.8. Hence, an expected loss of roughly **a decade.**

- "Static effects" from loss of work life. Unlikely to be large.
- "Dynamic effects" might be more substantial; propagated via *the timing of the take-off* (cf Unified Growth Theory)
    - Growth take-off intimately linked to the onset of the fertility transition
    - Trigger (Galor and Weil, 2000, AER): Rising return to skill accumulation.
    - If so: timing of the take-off would be influenced by the *inherrent* return to skill accumlation (e.g., Galor, 2010, IER). Arguably, places with more cataract had an inherrently lower return $\longrightarrow$ delayed fertility transition $\longrightarrow$ delayed take-off to growth, and thus poorer today.
- Formal model, where "health" is key in triggering the take-off: Hasan and Zoabi (2006, JoEG). See also Cervalleti and Sunde (2013) (5 years differences in worklife translates into delay of 140 years).

- To fix ideas: consider the following stylized representation of the process
- Suppose GDP per capita evolves in the following way

$$y_{it} = \begin{cases} \bar{y} & \text{if } t < s \\ \bar{y} + g\left(t - s_i\right) & \text{otherwise} \end{cases}$$

Suppose further $s_i = \tau x_i + \tilde{s}$, with x being uncorrelated with $\bar{y}$.

- Run:

$$y_i = a + bx_i + \epsilon_i$$

Then:

$$b^{OLS} = \frac{cov\left(y_i, x_i\right)}{var\left(x_i\right)} = -g\tau\frac{\tilde{N}var\left(\tilde{x}_i\right)}{Nvar\left(x_i\right)}$$

With $\tilde{N}$ the number of countries that have taken off; $var\left(\tilde{x}_i\right)$ is on x among $\tilde{N}$. Bottom line: *Rising coefficient (absv) over time.*

Summing up

- **Hypothesis**: Historical eye disease served to delay the onset of sustained growth thereby motivating comparative development
- **Temperate drift**. Only as formal human capital rises in importance does eye disease gain importance; the rising return to skill accumulation is what elevates the importance of eye disease, and its geographic determinants.
- **Prediction 1**: Historical eye disease should impact on contemporary income per capita and income per worker
- **Prediction 2**: Historical eye disease should impact on the timing of the fertility transition (take-off)
- **Consistency check 1**: The estimated "delay" should plausibly be enough to account for reduced form impact on "y" today
- **Consistency check 2**: The estimated link between eye disease an income should emerge over time.

EMPIRICAL ANALYSIS
- Part I: Reduced form, and consistency checks

- We can measure eye disease incidence today, but we cannot measure **historical** eye disease incidence
- **Proxy: UV radiation.** Well established environmental determinant of *cataract*. Also *suspected* to cause *pterygium* and possibly macular degeneration (loss of vision in the center of the visual field).
- Measurement: Data constructed by NASA. The UV index factors in solar irradiance, earth-sun distance, column ozone amount, and cloud conditions. **But not** aborbing aerosols (e.g., smoke plumes)

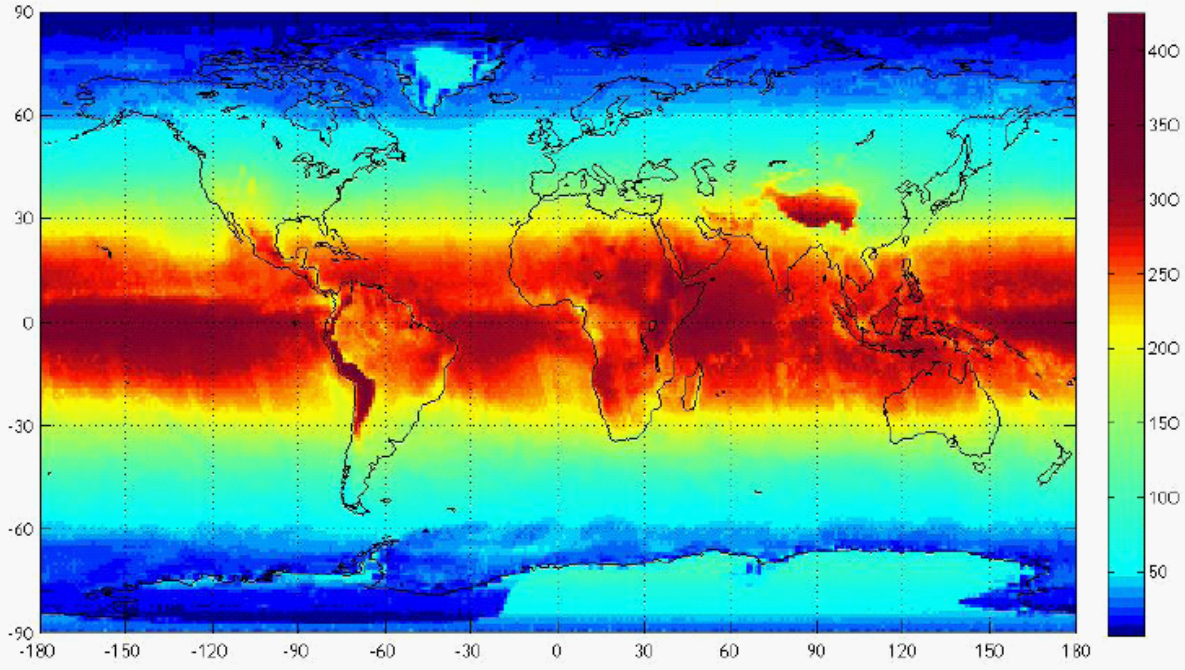


Figure 1. Daily average of biological damage potential per sq km due to solar irradiance (average 1990 and 2000).

- Basic specification

$$\log(y_i) = a + b\log(\text{uv}_i) + \mathbf{X}_i'\gamma + \epsilon_i$$

- i : Cross-section of countries, and (later) pixel's.
- $\mathbf{X}_i$: Follow literature on "fundamental determinants of productivity" (e.g., Acemoglu, 2009, Ch. 4): Geography, Institutions, Culture (and luck)
- Geography. UV determined by 3 factors: Latitude, Elevation, Cloud cover. We control for latitude and elevation. **Identification from variation in cloud conditions.** *Clouds play other roles*: Control for temperature and percipitation. *Elevation plays other roles*: Timing of the Neolithic, Distance of coast or river; country area. Full set of continental fixed effects. **Collectively our (13) controls span 93% of the cross-country variation in UV-R.**
- Institutions and culture. Maybe indirectly controlled? More later.

Table 1
Real GDP per worker, cataract incidence, and biological damage due to exposure to UV radiation

	1	2	3	4	5	6	7
Dependent variable:	(log) Real GDP per worker, 2004						
(log) UV damage	-1.11*** [0.11]	-0.72*** [0.19]	-0.88*** [0.15]	-1.19*** [0.20]	-1.24*** [0.11]	-0.80** [0.37]	
(log) Cataract prevalence							-0.28*** [0.064]

- **Economic significance (reduced form)**: 1 std reduction in UVR increases GDP per worker by ca. 49%.

Table 5
Year of the fertility decline and biological damage due to exposure to UV radiation

	1	2	3	4	5	6	7	8
Dependent variable:	Year of the fertility decline						(log) Real GDP per worker, 2004	(log) Real GDP per capita, 2004
(log) UV damage	48.8*** [3.70]	28.8*** [5.17]	46.9*** [4.71]	53.4*** [6.60]	49.3*** [3.93]	23.9** [11.7]		
Year of the fertility decline							-0.018*** [0.0057]	-0.020*** [0.0060]

- **Consistency check 1:** 1 std increase in UV delays transition by ca. 12 year, if each year "costs" 2-3 percent ("g"; see also Dalgaard-Strulik, 2013, EER forthc) that means an income reduction of 30-45%.

- **Consistency check 2**: Time-varying correlation with economic activity

Table 4
Historical real GDP per capita (Maddison data) and biological damage due to exposure to UV radiation

	1	2	3	4	5
Dependent variable:	Real GDP per capita in:				
	1700	1820	1900	1950	1950[a]
(log) UV damage	-0.31 [0.22]	-0.27 [0.23]	-0.52 [0.44]	-1.16*** [0.38]	-0.89* [0.46]
Observations (countries)	21	40	40	110	40
R-squared	0.89	0.84	0.71	0.62	0.77
Number of controls	11	13	13	13	13

- No link to population density in 1 CE, 1000 CE or 1500 CE.

EMPIRICAL ANALYSIS
- Part II: Confounders

- **Confounders 1**: Skin cancer? Other (tropical) diseases?

Table 6
Placebo regressions

	1	2	3	4	5	6	7	8	9	10	11
		Other eye diseases				Other diseases			Infectious, parasitic, tropical-clustered diseases		
Dependent variable: (log)	Cataract	Trachoma	Onchocer-chiasis	Glaucoma	Referactive errors	Hear loss	All sense organ diseases	Skin cancer	HIV/AIDS	Malaria	Hookworm
(log) UV damage	0.80* [0.43]	0.09 [0.64]	-0.40 [0.43]	0.23 [0.14]	-0.20 [0.13]	-0.17 [0.10]	-0.06 [0.12]	0.10 [0.32]	0.41 [0.74]	-0.11 [0.52]	0.60 [0.40]
Observations (countries)	146	146	146	146	146	146	146	146	146	146	146
R-squared	0.80	0.52	0.45	0.84	0.57	0.74	0.79	0.63	0.70	0.80	0.84
Number of controls	13	13	13	13	13	13	13	13	13	13	13

- Skin cancer: no surprice. Evolutionary adaptations (Diamond, 2005 Nature).

- **Confounders 2: Institutions and Culture.** Go to pixel-level analysis; take out country fixed effects. Specification unaltered except for timing of neolithic (not present)

Table 7
Real product per capita (2005) and biological damage due to exposure to UV radiation

	1	2	3	4	5
Dependent variable:	(log) Real product per capita by geographic cell (1x1 degrees), 2005				
(log) UV damage	-0.39***	-0.30**	-0.35***	-0.38***	-0.15**
	[0.14	[0.15]	[0.09]	[0.14]	[0.07]

Lights at night and biological damague die to exposure to UV radiation

	1	2	3	4	5
Dependent variable	(log) Lights at night (1x1 degrees), 2004				
(log) UV damage	-0.35***	-0.34***	-0.34***	-0.35***	-0.24**
	[0.098]	[0.11]	[0.10]	[0.079]	[0.11]

Bottom line

- **Question**: Has historical eye disease incidence (cataract in particular) been a detriment to development?
- Proposed proxy for historical eye disease: UV radiation. Sensible science foundation.
- Proposed mechanism: Variation in eye disease incidence $\longrightarrow$ Differential timing of take-off $\longrightarrow$ global income inequality today
- Results: UV has a detrimental impact on income per capita (and worker)
- Consistent with take-off: UV gradually emerges as a determinant of income post take-off (temperate drift); it predicts the timing of the fertility decline and delay sufficient to motivate reduced form estimates. UV predicts cataract, but not other diseases like skin cancer, malaria etc. Robust to: Country fixed effects and extensive set of climate/geo controls

LIGHTNING, IT DIFFUSION AND ECONOMIC GROWTH ACROSS THE US

Review of Economics and Statistics (2012)

Joint with Thomas Barnebeck Andersen, Jeanet Bentzen and Pablo Selaya

Introduction

- Geography almost surely influenced the historical growth record.
- But what about today? In highly developed countries?
- We argue the answer is in the *affirmative.*
- A particular geographic feature – lightning density – has influenced the speed of IT diffusion and thereby economic growth across the contignous US states
- Suggests that "geography" will matter to the dynamics of the global distribution of income going forward.
- Also first macro-level evidence documenting a substantial causal impact of IT on the growth revival during the 1990s

The basic story

The argument:

- Whereas the (2nd) industrial revolution required power quantity, the digital revolution requires very high power *quality:*

"For the average computer or network, the only thing worse than the electricity going out completely is power going out for a second. [...]For more than a century, the reliability of the electricity grid has rested at 99.9% [...] But microprocessor - based controls and computer networks demand at least 99.9999% reliability [...] amounting to only seconds of allowable outages a year." -The Economist, "The power industry's quest for the high nines", 22-3-01

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- Places with better power quality will be able to attain IT capital at lower user cost $\Rightarrow$ faster diffusion
- In the US, 1/3 of annual power disturbances are generated by *lightning strikes.* External source of variation in power quality

The basic story

- Well known problem among electrical engineers, who have entire handbooks on the topic
- Well known in the business world:

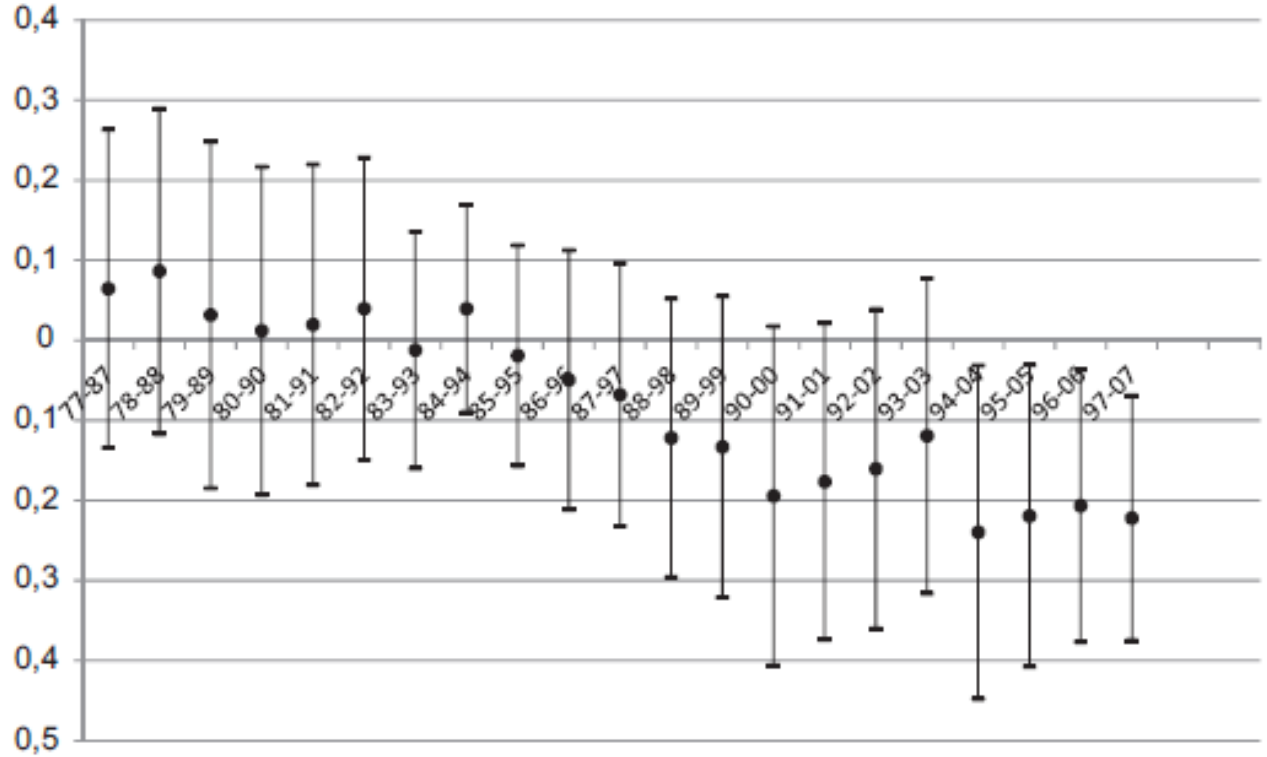
Even if electricity lines are shielded, lightning can cause power surges through unprotected phone, cable and Internet lines—or even through a building's walls. [...] During the summer, Vertical [Tampa information-technology consulting firm] gets as many as 10 calls a week from clients with what look to Mr. Cohen like lightning related problems. Computer memory cards get corrupted, servers shut down or firewalls cut out. Wall Street Journal, August 25, 2009.

- Implication: *lightning* should *become* correlated with growth from midt 90s onwards. 1) IT matters more to growth 95-; 2) WWW emerges early 90s; 3) Transistor miniaturization.

The basic story

The point in one figure

FIGURE 6.—LIGHTNING-GROWTH NEXUS, 1977–2007



The figure shows estimates for b_2 (and the associated 95% confidence interval) from regressions of the form: $G = b_0 + b_1 \log(y_{t-10}) + b_2 \log(\text{lightning}) + e$, where y is gross state product per worker and $t = 1987, \ldots, 2007$. For 48 states; estimated by OLS.

What we do in addition

- Formal tests employing interaction with time dummies; control for human capital and regional fixed effects
- Show that lightning indeed predicts diffusion of IT, both at the household level and in terms of firm IT investments
- Show that IT (whichever way measured) eliminates the link between lightning and growth
- Show that *other* climatic variables (Temperature, percipitation, tornado intensity, hail, wind speed, humidity, cloudiness, sunshine, elevation and latitude) neither exhibits a similar time-varying association with growth, nor eliminates the significance of lightning
- Show that other slow moving structural charactaristics (e.g., Workforce in mining, settler mortality rates etc etc) neither exhibits a similar time-varying association with growth, nor eliminates the significance of lightning
- Lightning accounts for nearly 50% of the 5/95% growth gap across US states; IV confirms causal influence from IT.

Last Bottom Line

- The impact of geography can be time-varying, contingent on technological developments: **Temperate drift**.
- **In the past**: The rise of education, and the emerging take-off to modern growth, can have made human societies more sensitive to diseases that exhibits geographic variations and that lowers the return to formal skills. The impact of UV radiation on growth, via the timing of the take-off, can be part of the reason for the emergence of a latitude gradient.
- **In the present**: Once again, fundamental technological innovations makes us sensitive to geographic circumstances that hitherto were thought to be relatively unimportant.
- External validity on lightning:
  - The importance of power quality to IT diffusion is also found around the world (Andersen et al, 2011, WBER).
  - Likewise, within Africa, power quality appears to be a strong determinant of growth differences since 1990s onwards (Andersen-Dalgaard, 2013, Energy Ec).