QUANTIFYING THE ECONOMIC CONSEQUENCES OF CLIMATE CHANGE

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OECD
BETTER POLICIES FOR BETTER LIVES

Outline

I. Early approaches to quantifying global economic impacts of climate change
   - Enumerative approaches
   - Integrated Damage Assessments
   - Integrated Assessment Models (IAMs) via Damage Functions

II. New(er) Approaches
   - Computable General Equilibrium (CGE) models
   - Empirical panel estimation using weather shocks

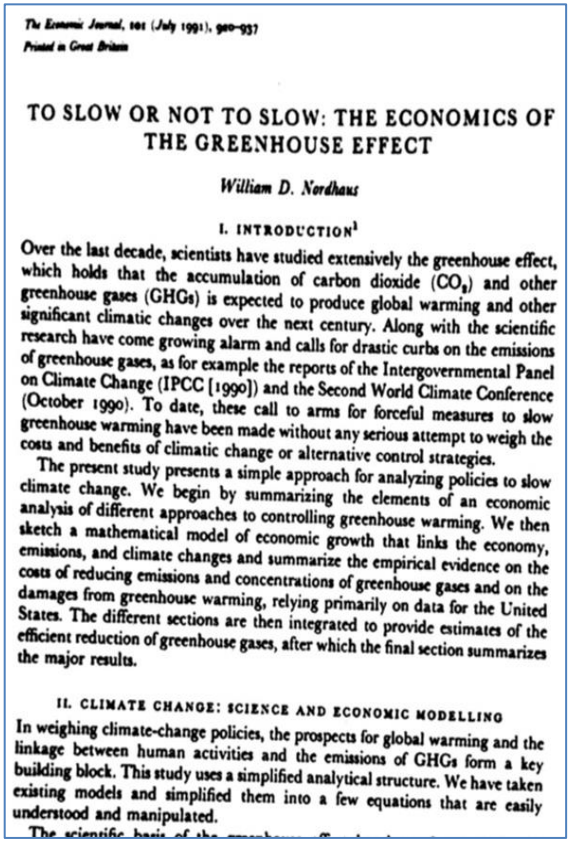
III. Reconciling findings and some thoughts on future directions

I. Early Approaches

We now move from the *terra firma* of climate change to the *terra incognita* of social and economic impacts of climate change

W.D. Nordhaus, The Economic Journal (1991)

I.a Enumerative approaches



The Economic Journal, 101 (July 1991), 920–937
Printed in Great Britain

TO SLOW OR NOT TO SLOW: THE ECONOMICS OF THE GREENHOUSE EFFECT

William D. Nordhaus

I. INTRODUCTION[1]

Over the last decade, scientists have studied extensively the greenhouse effect, which holds that the accumulation of carbon dioxide (CO_2) and other greenhouse gases (GHGs) is expected to produce global warming and other significant climatic changes over the next century. Along with the scientific research have come growing alarm and calls for drastic curbs on the emissions of greenhouse gases, as for example the reports of the Intergovernmental Panel on Climate Change (IPCC [1990]) and the Second World Climate Conference (October 1990). To date, these call to arms for forceful measures to slow greenhouse warming have been made without any serious attempt to weigh the costs and benefits of climatic change or alternative control strategies.

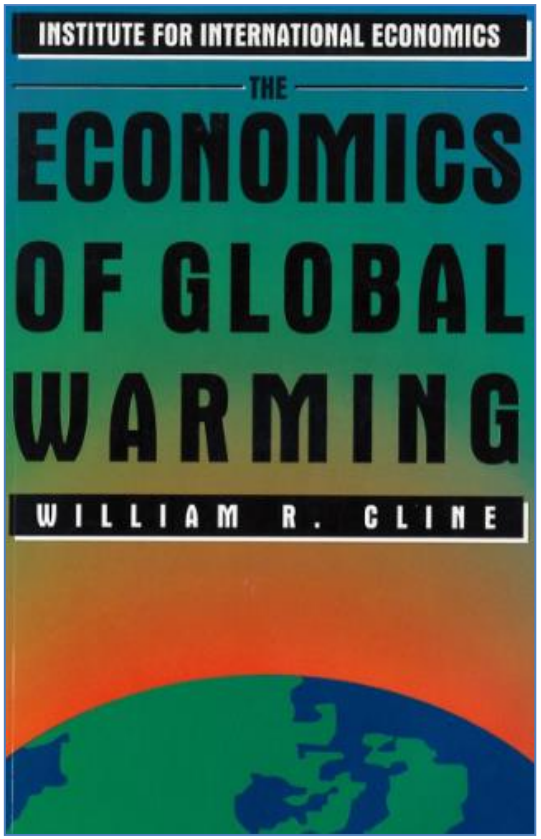
The present study presents a simple approach for analyzing policies to slow climate change. We begin by summarizing the elements of an economic analysis of different approaches to controlling greenhouse warming. We then sketch a mathematical model of economic growth that links the economy, emissions, and climate changes and summarize the empirical evidence on the costs of reducing emissions and concentrations of greenhouse gases and on the damages from greenhouse warming, relying primarily on data for the United States. The different sections are then integrated to provide estimates of the efficient reduction of greenhouse gases, after which the final section summarizes the major results.

II. CLIMATE CHANGE: SCIENCE AND ECONOMIC MODELLING

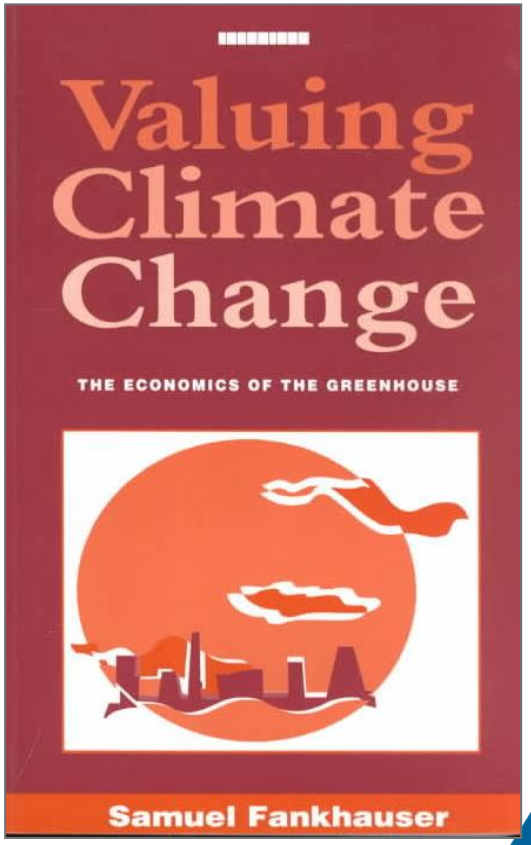
In weighing climate-change policies, the prospects for global warming and the linkage between human activities and the emissions of GHGs form a key building block. This study uses a simplified analytical structure. We have taken existing models and simplified them into a few equations that are easily understood and manipulated.

The scientific basis of the

1991



1992



1995

I.a Enumerative approaches

- Total damage is the sum of individual categories (no higher order adjustments)
- Benchmarked for 2xCO2
- Underlying information initially dominated by US studies, certain impacts (agriculture, sea level rise)
- Incorporate both market and non-market damages

Table 3.15 Total damage due to $2xCO_2$ (bn$)

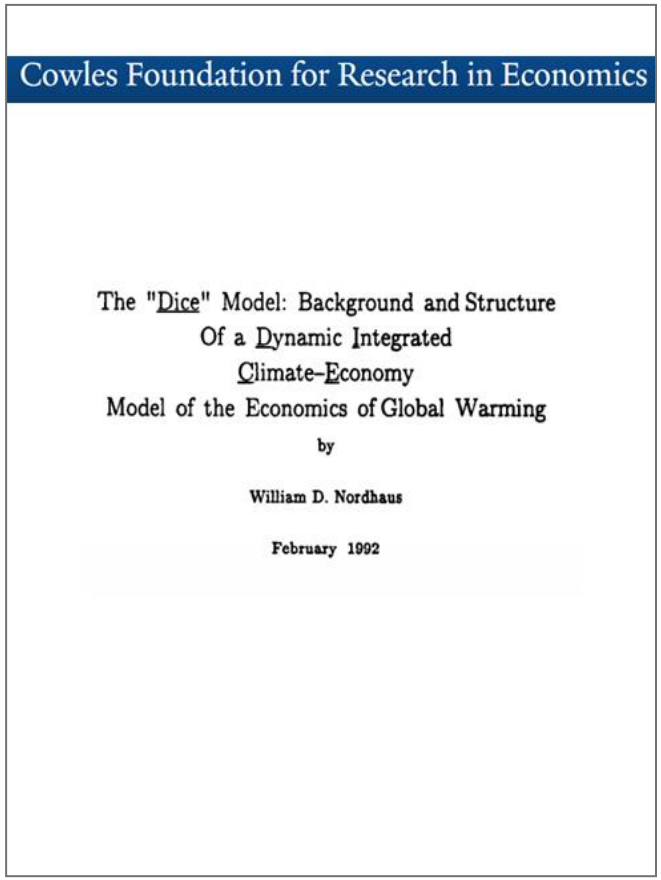
	EU	USA	Ex-USSR	China	OECD	World
coastal defence	0.1	0.2	0.0	0.0	0.4	0.9
dryland loss	0.3	2.1	1.2	0.0	8.1	14.0
wetland loss	4.9	5.6	1.2	0.6	16.9	31.6
ecosystems loss	9.8	7.4	2.3	2.2	25.5	40.5
agriculture	9.7	7.4	6.2	7.8	23.1	39.1
forestry	0.1	0.6	0.4	0.0	1.8	2.0
fishery[a]	–	–	–	–	–	–
energy	7.0	6.9	–0.7	0.7	20.5	23.1
water	14.0	13.7	3.0	1.6	34.8	46.7
other sectors	–	–	–	–	–	–
amenity	–	–	–	–	–	–
life/morbidity[b]	13.2	10.0	2.3	2.9	34.4	49.2
air pollution	3.5	6.4	2.1	0.2	11.9	15.4
migration	1.0	0.5	0.2	0.6	2.0	4.3
nat. hazards[c]	0.0	0.2	0.0	0.1	1.0	2.7
TOTAL (bn$)	63.6	61.0	18.2	16.7	180.4	269.5
(% GNP)	(1.4)	(1.3)	(0.7)	(4.7)	(1.3)	(1.4)

Fankhauser 1995

I.b Integrated Damage Assessments

- More comprehensive than enumerative studies with regard to treatment of market effects (e.g. via changes in relative prices)
- … But ignore non-market damages
- Early assessments include:
  - *MINK (Rosenberg et al. 1993)* using the 1930s "dust bowl" as an analogue. Adaptation explicitly considered. 1C warming would reduce regional incomes by not more than 1 per cent.
  - *Scheraga et al. (1993)* General equilibrium modelling of impacts of climate change in the US (agriculture, change in energy demand, and sea level rise). 5.1 C warming assumed by 2060: impact of 0.8% GNP.

I.c Integrated Assessment Models (IAMs)


Cowles Foundation for Research in Economics

The "Dice" Model: Background and Structure
Of a Dynamic Integrated
Climate-Economy
Model of the Economics of Global Warming

by

William D. Nordhaus

February 1992

- Climate damage function pioneered by the DICE model (Nordhaus 1991; 1993)
- Current examples include DICE/RICE (Nordhaus 2017, Nordhaus and Sztorc 2013), PAGE (Hope 2011), and FUND (Tol 2013)
- DICE/RICE and PAGE specify an aggregate non-linear climate damage function. FUND aggregates up from region and sector level.
- Progress on explicit treatment of adaptation and related costs in IAMs (e.g. de Bruin et al. 2009)

IAM Estimates of the Economic Impact of Climate Change

Study	Warming	Impact (% GDP)	Worst-off region		Best-off region	
			(% GDP)	Name	(% GDP)	Name
Nordhaus (1994)	3.0 °C	-1.3				
Tol (1995)	2.5 °C	-1.9	-8.7	Africa	-0.3	Eastern Europe and the former Soviet Union
Plambeck and Hope (1996)	2.5 °C	-2.5	-8.6	Asia (w/o China)	0.0	Eastern Europe and the former Soviet Union
Nordhaus and Boyer (2000)	2.5 °C	-1.5	-3.9	Africa	0.7	Russia
Hope (2006)	2.5 °C	-0.9	-2.6	Asia (w/o China)	0.3	Eastern Europe and the former Soviet Union
Nordhaus (2008)	3.0 °C	-2.5				
Nordhaus (2017)	3.0 °C 6.0 °C	-2.1 -8.5				

Table adapted from Tol (2014)

Taking stock of IAM damage functions

- "Plug and play" ease for integrated climate-economy analysis, over long time-horizons
- Relative simplicity and flexibility

But ....

- Little insight on channels of transmission of economic impacts
- Questions about underlying theoretical/empirical basis

" (this) damage function is made out of thin air. It isn't based on any economic (or other) theory or any data. Even if this function were somehow the true damage function, there is no theory or data that can tell us the value of the parameters..."

Pindyck (2017)

“New(er)” approaches 1

CGE modelling

CGE Modelling of climate damages

- Combine economic models with sectoral detail, with information from climate models and empirical literature on climate damages.
- Climate damages modelled with a production function. Can explain how composition of GDP is affected over time.
- Better capture the heterogeneity of climate impacts, and how they translate into shocks. Also include effect on growth rates.
- But … capture smaller subset of impacts, cannot handle non-market damages, more complex, suitable for shorter terms than IAMs

Recent Evolution of CGE Studies

« Hybrid » approach in OECD (2016)

Included in the modelling

- Agriculture: yield changes for 8 crop sectors, and fisheries
- Coastal zones: capital and land losses due to sea level rise
- Health: diseases and labour productivity losses from heat stress
- Energy demand
- Tourism demand
- Capital damages from hurricanes

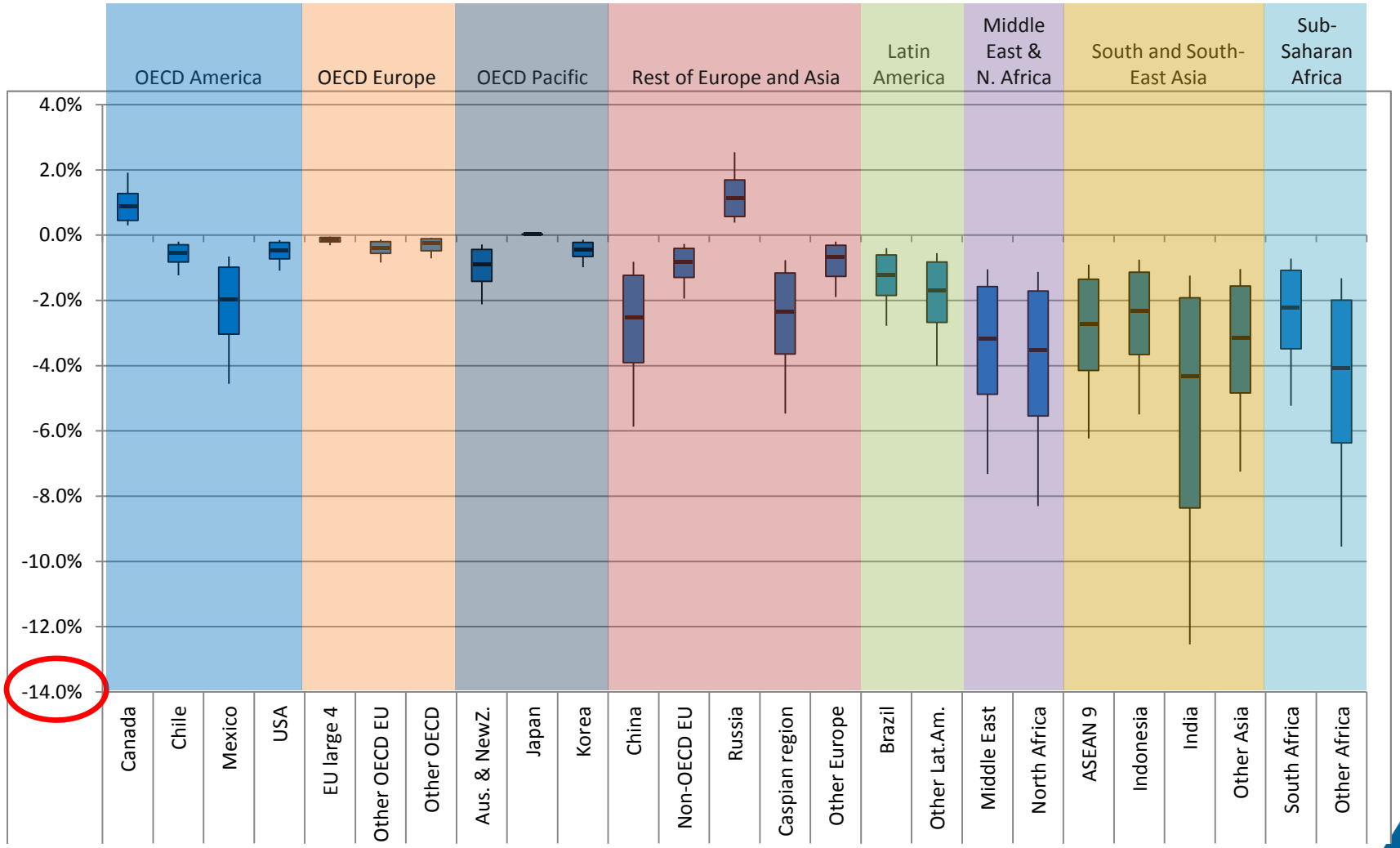
Stand-alone analysis

- Fatalities from heatwaves
- Urban damages from river floods
- Ecosystems: biodiversity (crude approximation)

Still not quantified

- Large-scale disruptive events

Regional Results and Uncertainty from Climate Sensitivity – year 2060



“New(er)” approaches

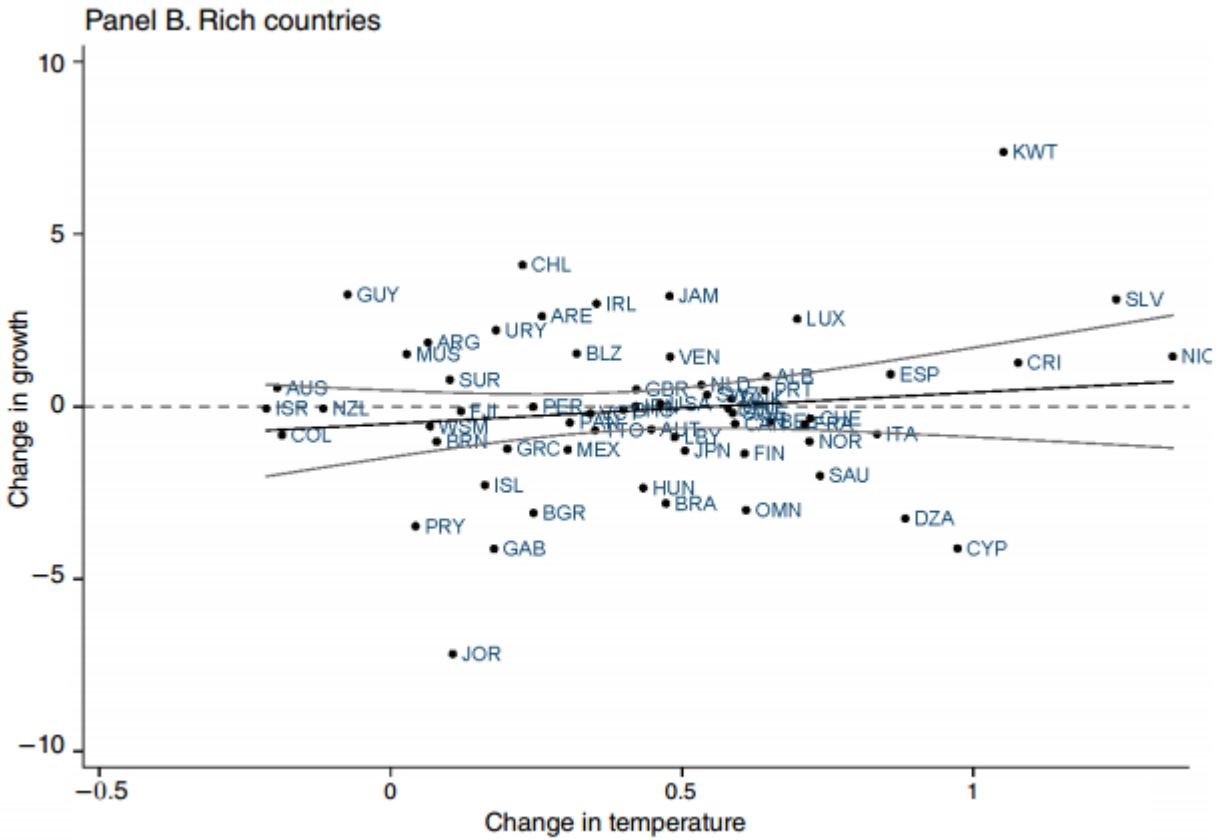
Empirical Studies 2.0

New Empirical Climate-Economy Studies

- Past empirical work using cross-sectional data has shown strong negative relationship between hot climates and incomes per capita, with less clear evidence on precipitation.

- Panel estimations are more recent, better isolate contemporaneous impacts of weather. Stronger causative interpretation.
  - Studies focussing on average weather
  - Studies focussing on extreme events
  - Most focus on specific impact categories (agriculture, labour productivity, industrial output…) and/or regions (US, Caribbean, Sub-Saharan Africa..). Very few (two?) global assessments.

Two recent global studies: retrospective



Dell et al. 2012

Two recent global studies: retrospective

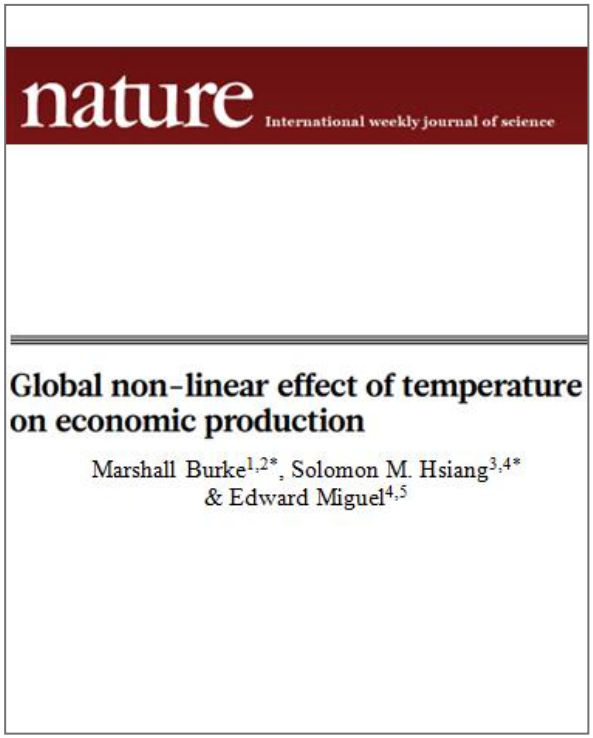
- Higher temperatures substantially reduce economic growth in poor countries
- Higher temperatures may reduce growth rates, not just level of output
- Wide ranging impacts(reduced agricultural and industrial output, instability..)

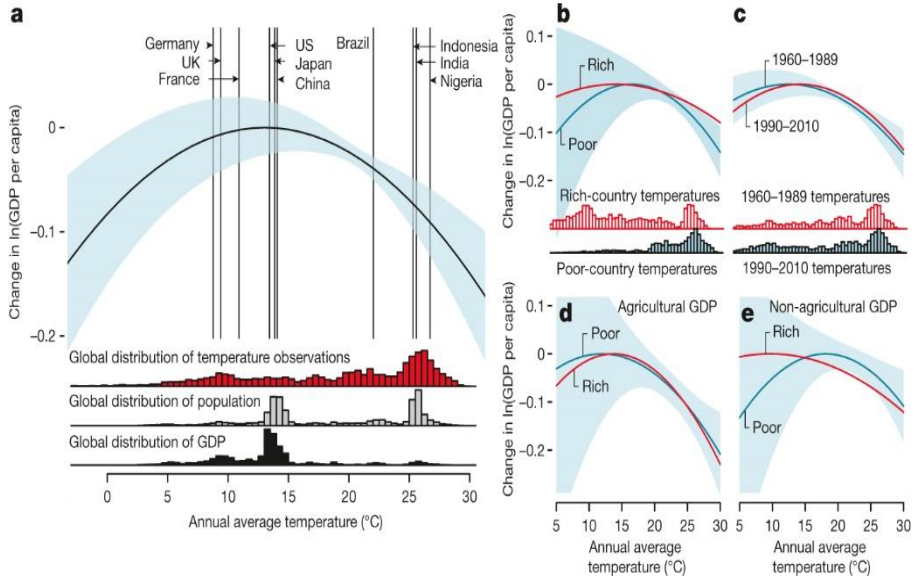
But ….

"*Given uncertainty over adaptation, technical change, and other issues, the estimates here – driven primarily from short-run fluctuations in temperature – alone cannot provide predictions about the estimated impacts of future climate change*"

Dell et al. 2012

Two recent global studies: retrospective & prospective

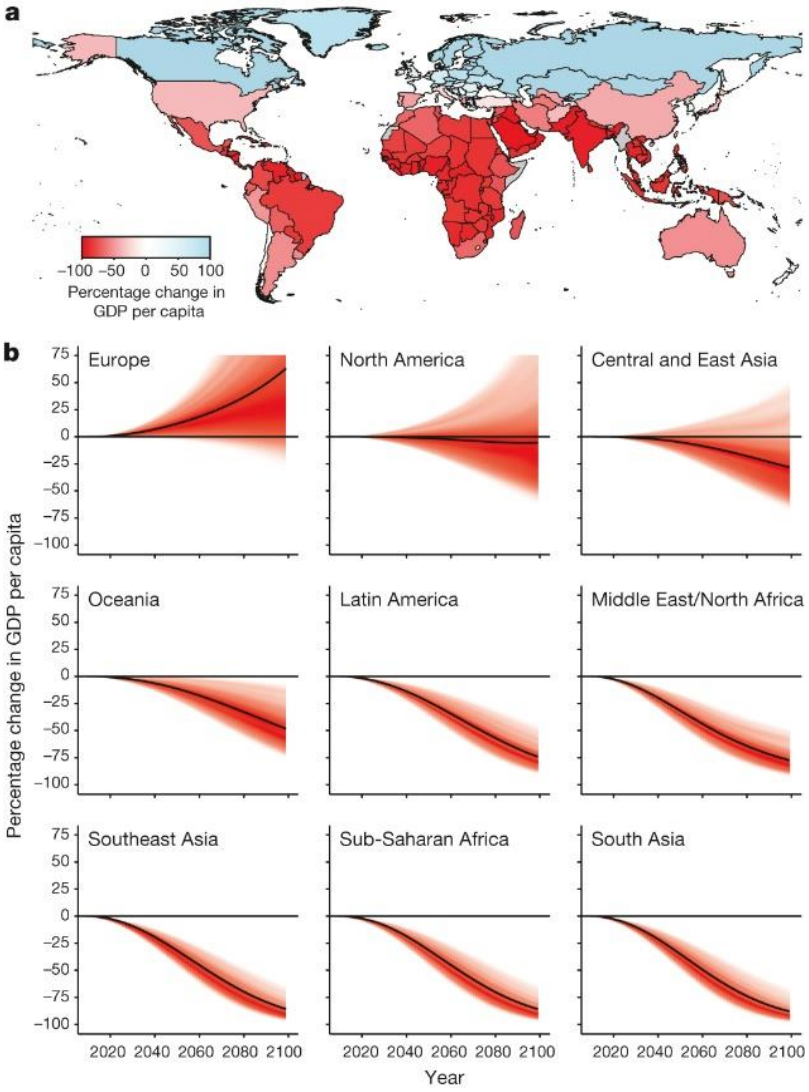




(Using data from 1960-2010) "*We show that overall economic productivity is non-linear in temperature for all countries, with productivity peaking at an annual average temperature of 13 °C and declining strongly at higher temperatures…. These results provide the first evidence that economic activity in all regions is coupled to the global climate and establish a new empirical foundation for modelling economic loss in response to climate change*"

Burke et. al 2015

Two recent global studies: retrospective & prospective



"unmitigated warming is expected to reshape the global economy ***by reducing average global incomes roughly 23% by 2100 .. Average incomes in poorest 40% of countries declines by 75% in 2100***"

Burke et. al 2015

WRAP-UP

Reconciling findings (can we?)

1. "Bottom line" messages over the past quarter century from enumerative approaches, IAMs, and CGEs on global economic damages are surprisingly sticky (a couple of %GDP for 2-3 C).

2. Recent longitudinal studies of weather shocks on economic growth, particularly their use in a global projection for end-century, points to dramatically higher damages.

3. There is a long-standing concern about the basis of IAM damage functions. Current models also exclude large scale disruptive events. Is there also premature anchoring around early results?

4. But projections using panel data on past weather are still nascent. Is there enough variation in the empirical record? Can one extrapolate global economic consequences of climate change from the impacts of country data on unanticipated year to year weather shocks ?

Some thoughts on the road ahead

- **Greater scrutiny and benchmarking**, not just of IAM damage functions, but also CGE *and empirical approaches*.

- **Greater cross-fertilisation** (e.g. use panel studies to add more impacts, calibrate damage functions, impacts on growth rates in IAMs).

- **Greater emphasis on distributional consequences and well-being impacts, not just on aggregate GDP**

- **Recognise the limits of these tools, particularly in their ability to shed light on the true game-changers**
  - Need other approaches (expert elicitation, foresight analysis)

Thank you for your attention

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