Event Series: Global Migrations

Climate Action Game Experiment (CAGE)

WEDNESDAY, OCTOBER 23
MAIN LIBRARY, ROOM 106
12-1PM

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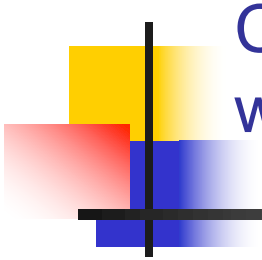
ILLINOIS
Center for Global Studies



Clifford Singer, Chenghao Ding, Lula Chen, and Bei Yang, with input from Li Hui and Ryan Sriver

CAGE extrapolates economic impacts of climate change based on 200 years of country level data on

- Demographics
- GDP
- Greenhouse effects

Without and without policy modifications based on

- Assumed scenarios (earlier work)
- Interactive negotiation exercises (in progress)
- Game theory (under development)

Overall Goal: Data calibrated probability distribution for the actual climate change outcome:

Including how climate change alters anthropogenic effects

Why is this needed: Mirador, Galapagos, as an example

There is now some significant but realistic planning going on, with acute sensitivity to the islands' special culture and needs… by Pedro Quintanilla and Samantha Singer of the London-based Prince (Charles) Foundation (for the Built Environment). The two planners have been living on the islands for a year, having been invited by the Galapagos Regional Government.

https://www.citylab.com/equity/2012/11/balancing-people-and-nature-galapagos/3910/

Galapagos Urban Planning Code Question: How close to the shore should new construction be allowed?

The *IPCC won a Nobel Prize for unprecedented international cooperative work on estimating probability distributions for sea level rise in different greenhouse gas emissions scenarios.

However, the IPCC does not estimate the probability of different future emissions scenarios occurring. So the billions of dollars that have supported IPCC reports does not provide a probability distribution for actual future sea level rise.

*IPCC=Intergovernmental Panel on Climate Change

Why Not?? (This is speculative)

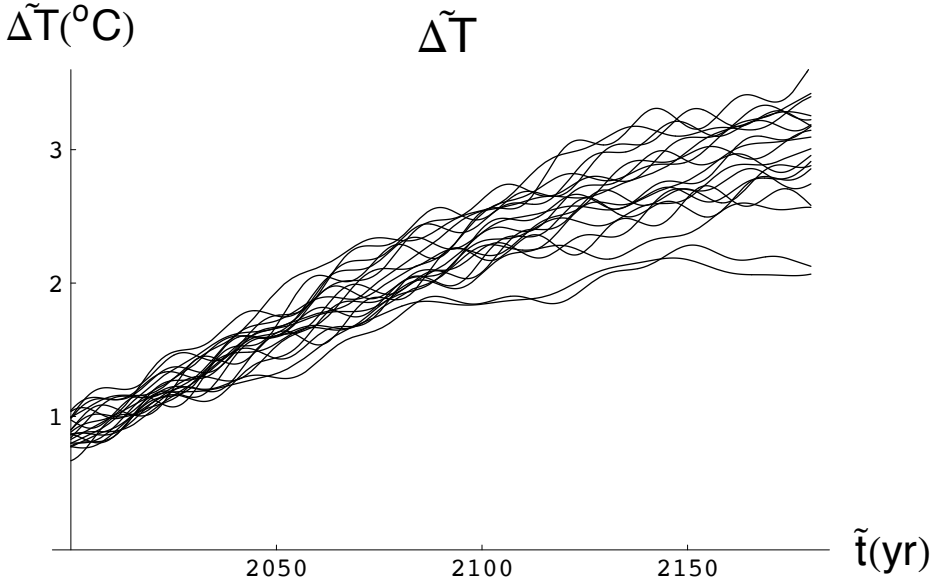
IPCC focusses on “natural” (=hard??) science, albeit also with emphasis on social (=soft???) science.

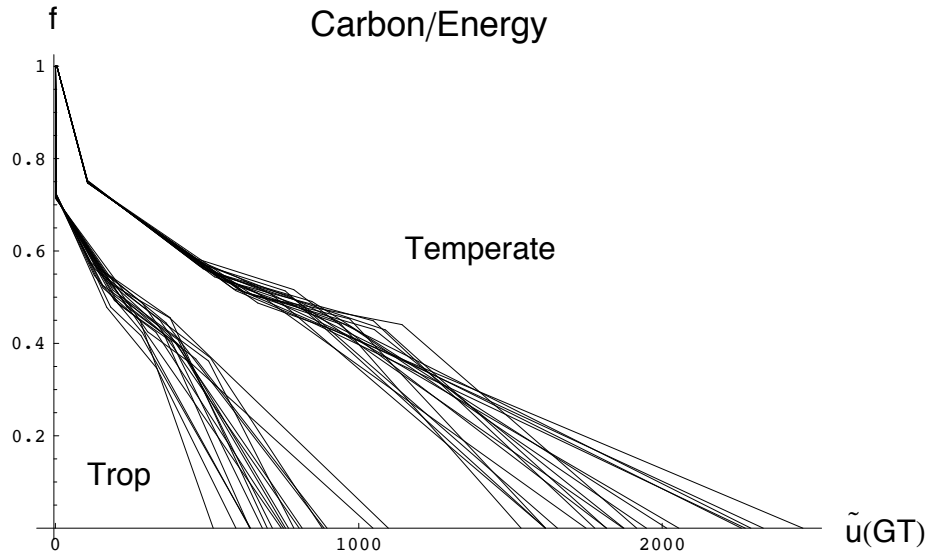
IPCC is an intergovernmental cooperation.
Especially internationally, it can be difficult to get governments to fund critical analysis of how they make their own decisions.

Probability distribution for the actual climate change outcome with an assumed probability distribution for human response

see Singer, Rethinaraj…(2007), at https://acdis.illinois.edu/research/published-research-reports/

20 random samples of industrial era increase in global average temperature





Based assumed extrapolation of carbon intensity of energy production (normalized to all coal=1) vs. cumulative carbon emissions in gigatonnes.

Species Included in Feedback Models

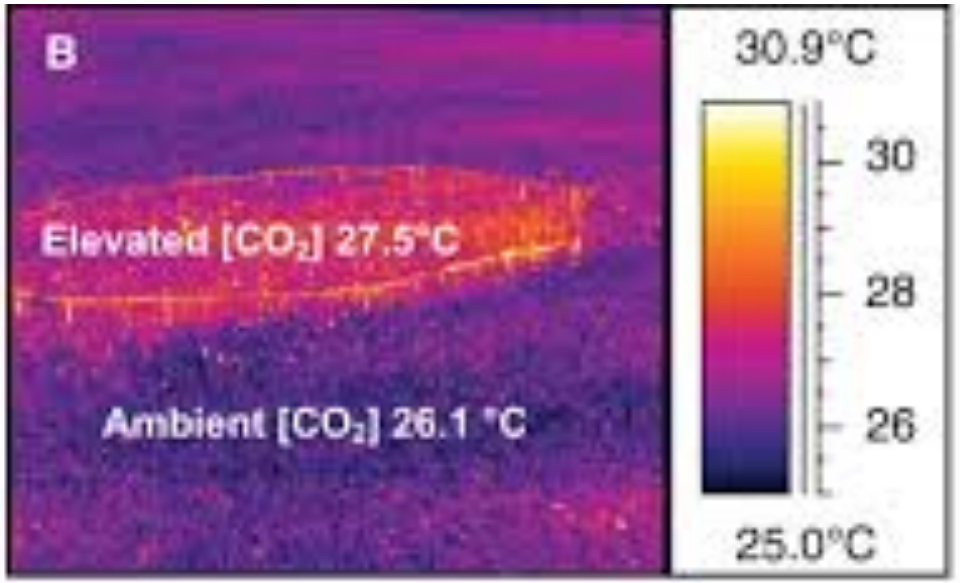
Photosynthetic organisms that fix CO_2, e.g.

- Corn (my son worked on field experiments on exposure to elevated CO_2 levels at UIUC)
- Soybeans (that fix nitrogen and thus reduce use of nitrogen fertilizers used on corn and result in emissions of nitrous oxide (N_2O), which extrapolates to be the second most important anthropogenic greenhouse gas)

Soil organisms that metabolize cellulose

- Fungi (release CO_2); termites (release methane)

UIUC Field Exposure of Crops to Elevated CO_2



Home sapiens: The one species included with scenarios only (i.e. without experimental basis) in papers included in the IPCC reports through the most recent Assessment Report 5 (AR5)

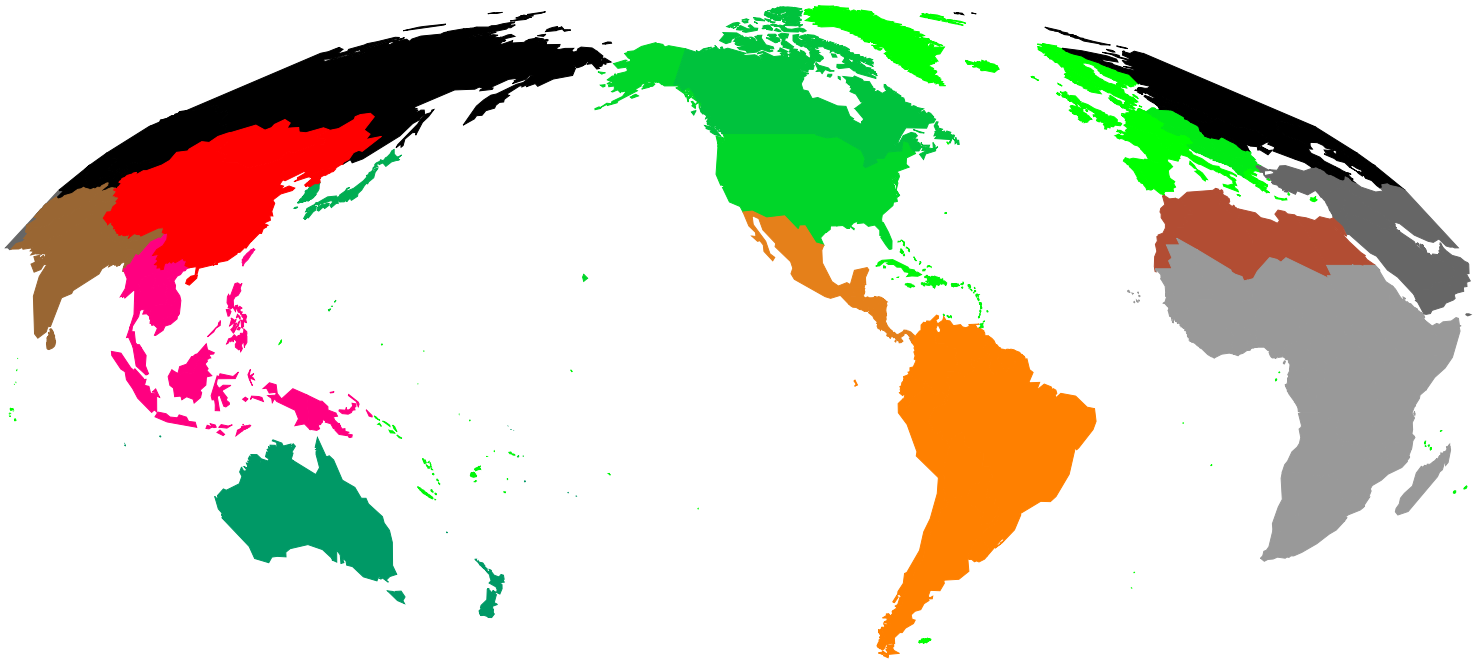
CAGE Concept: Include experimental data on feedback of climate change on anthropogenic effects on the global heat balance:

Divide world into up to 16 countries/region groups

CAGE participants negotiate policies affecting global heat balance. During negotiations:

we give participants real time information on economic and environmental impact of policy choices

Example Division into 16 Groups
(for the work on “Green New Deal” options discussed next)



Shades of Green: Various possible “Green New Deal” Countries
Shades of Grey: Assumed “No New Policy” regions
Shades of Red: China, possibly with Southeast Asia in a negotiation Block with China
Other: Possible “New Policy” countries adversely affected by global warming

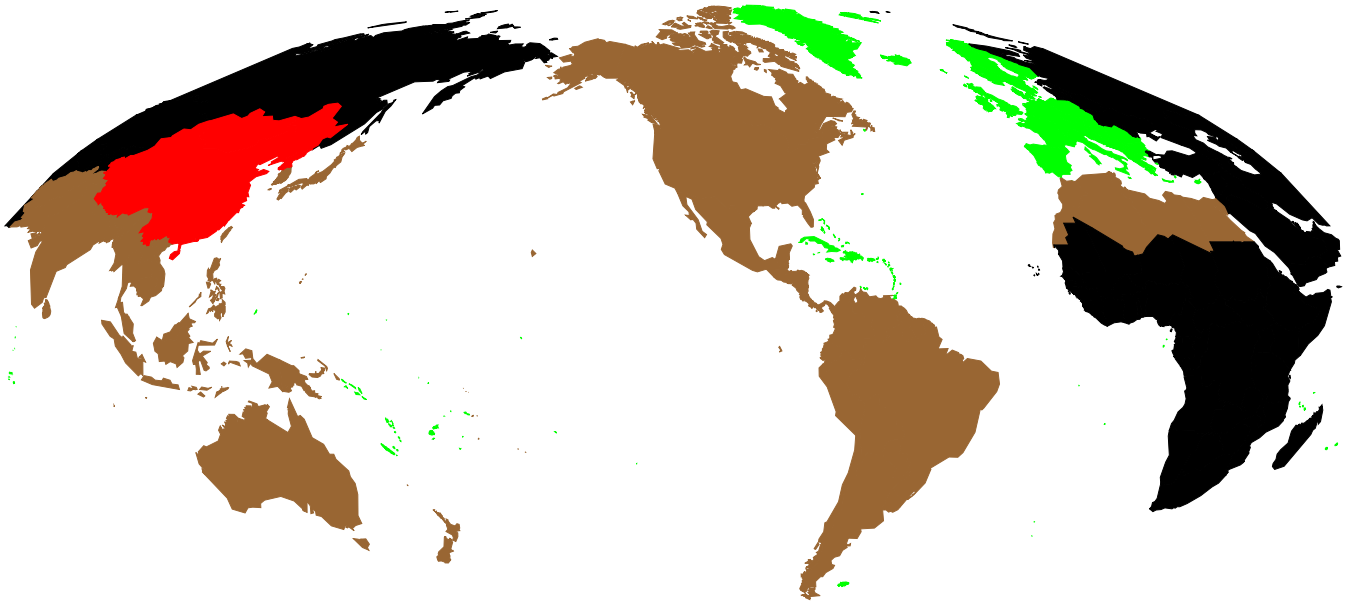
Reworking the http://www.fund-model.org/ Tol and Antoff integrated assessment model

Assignment of Countries to Negotiating Blocks:

Start with the 58 countries stating intent to achieve Zero Equivalent CO2 Emissions by 2050 at the 23 Sept. 2019 UN Climate Summit

Minimum Green Block=EU and Small Island States
Might future U.S. government “go green”? (and Central America follow suit ??)
Chile = Nov. 2019 Climate Meeting host; Are Ukraine & 6 in Africa serious?

UN Summit Outcome Motivated Example Blocks



Green: EU + Small Island States

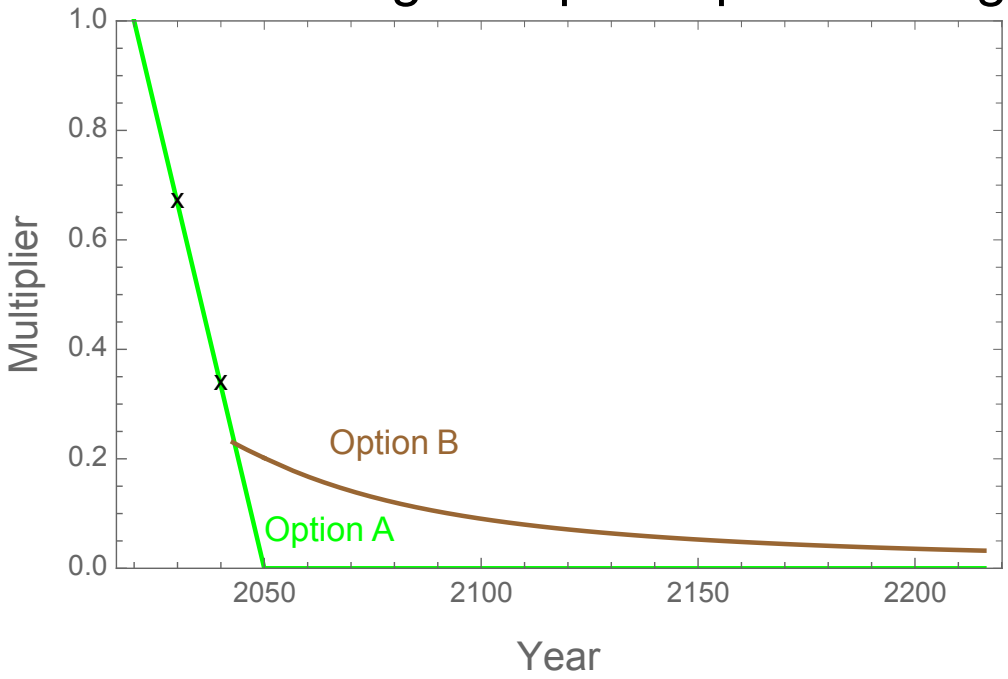
Red and Brown: China and Other's reactions to Greens

Black: Major fossil fuel producers and poorest countries

Green New Deal Options Analysis (a "warm-up" exercise)

Option A: Multiply "no new policy" emissions by ramp down to zero net emissions by 2050 (sometimes expressed as CO_2 equivalent emissions)

Option B: Ramp down to meet global per capita average emissions (e.g. sometime between 2040 and 2050). Then match global per capital average emissions.



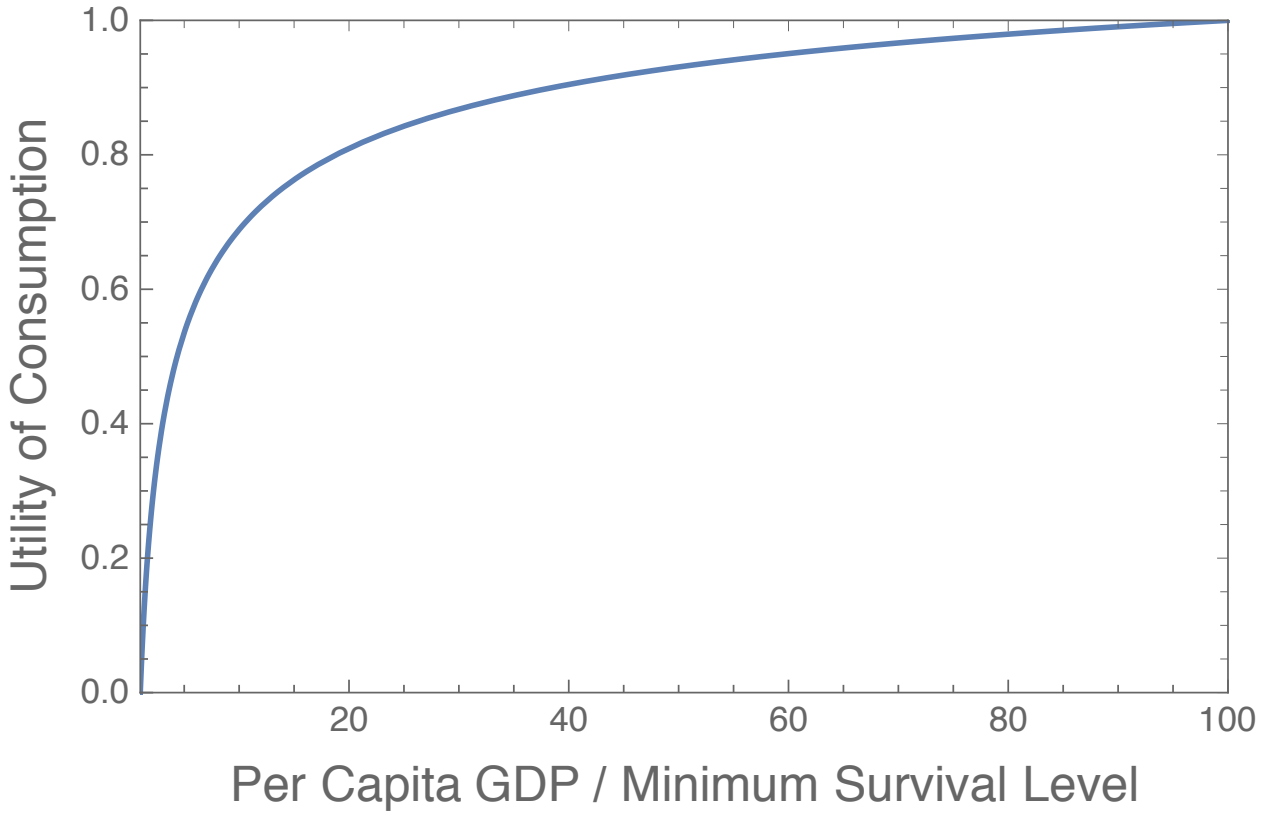
To reach 1st x
Mostly coal->natural gas

To reach 2nd x
Renewables with
natural gas backup

Below 2nd x
Increasingly more expensive

Analyzing Effect of Climate Change on Welfare

Step 1: How does utility depend on per capita consumption?



Analyzing Effect of Climate Change on Welfare

Step 2: How much more is near term consumption valued?

Real Interest Rate = (Social) Discount Rate, ρ
+ Rate of growth of Real GDP/Person

Result $\rho = 0.023 = 2.3\%$

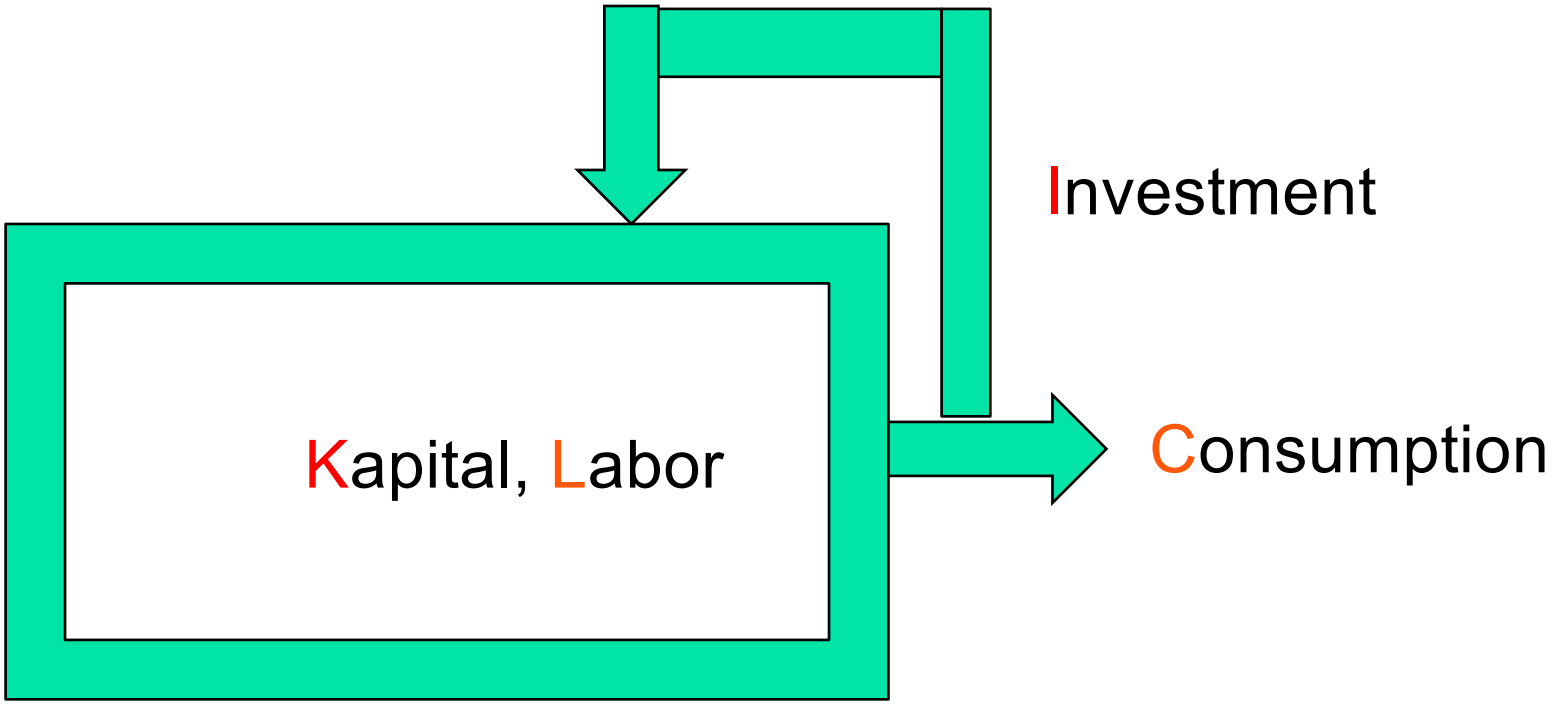
Analyzing Effect of Climate Change on Welfare

Step 3: Note tendency to forgo some current consumption for benefit of offspring with growing population P.

Add up population times utility, discounted over time:

Welfare=Time integral of: $P\ U\ e^{-\rho\ t}$

Step 4: Use historical data to calibrate an extrapolatable model of Per Capita Consumption as a function of time.
Assume Labor is proportional to Population and adjust Investment(t) to maximize Welfare
Assume climate change is a (mostly future) perturbation.



Investment = r K + dK/dt; r = Depreciation Rate = 0.107/yr

$C+I = \text{Production} = a\, K^{0.325}\, P^{1-0.325}$

Efficiency growth $a = 1/(1+e^{-(t-h)/b})$; h is a=1/2 time; b is growth time

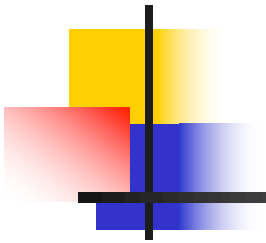
Step 5: Include estimates of the effect of climate change on economic productivity for each of 16 “country” groups

Productivity replace a by $b = a(1 - \varepsilon D)$

D is damage to productivity due to changes in
regional average temperature and
atmospheric CO2 concentration

With D measured in fractions of to a few %
only terms to first order in $\varepsilon = 0.01$ are included.

Include in the Damage Function, D, impacts of



Red=Cost; Blue=Benefit; Purple=Mixed

Temperature and associated precipitation changes on agriculture

Temperature change on heating and cooling costs

Sea level change impacts on land loss

CO2 fertilization of agriculture

CO2 effects on human productivity

Ocean acidification impacts on coral reef loss

Also include costs of energy decarbonization

Not directly included in Damage Function for this talk (but need more future attention)

Storm damage (damage is visible but cumulatively modest)

Effects on human health (which can be mitigated by adaptation)

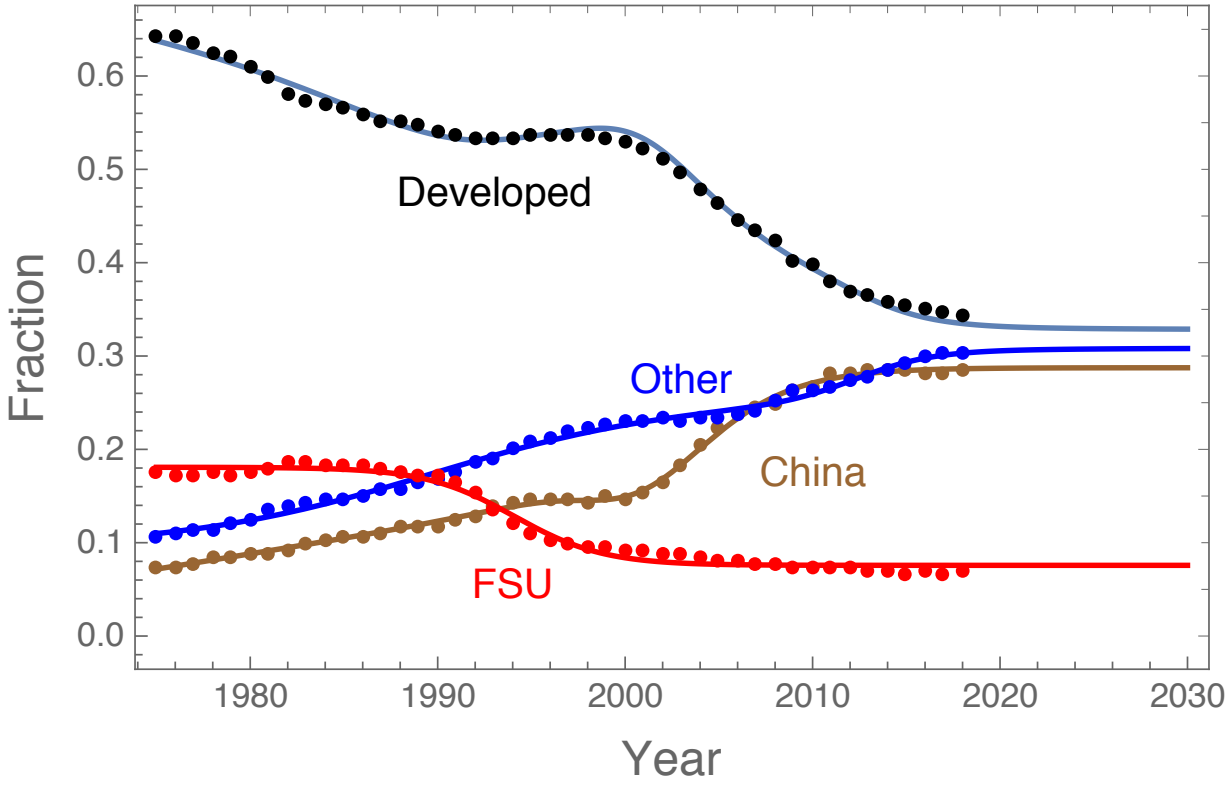
Biodiversity impacts (hard to assign regionally)

Human migration (assumed contained in agriculture and and land loss impacts)

Step 6: Fit historical data and extrapolate ”no new policy” CO2 fractions of global emissions for the 16 groups.

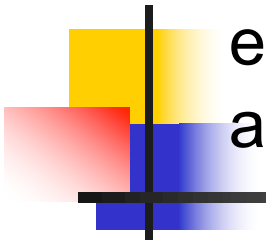
“No new policy is not “no policy.” Impacts of previous policy are captured in the historical data fits.

“Developed” and ”Other” are similarly broken down into constituent groups to fit all 16 groups



Developed includes G7 countries and EU S. Korea, Australia and New Zealand

FSU=Former Soviet Union



Step 7: Fit and extrapolate historical data relevant radiative forcing, and solve for “no new policy” extrapolated global average temperature, atmospheric greenhouse gas concentrations, and sea level

In addition to CO2 effects, include

- Nitrous oxide
- Methane
- Other well mixed greenhouse gases
- Contrails
- Tropospheric aerosols and black carbon on snow
- Tropospheric Ozone
- Albedo changes related to land use
- Solar irradiance oscillations
- Volcanoes (Our model of this cumulatively small but complicated effect is being improved by Chenghao Ding.)

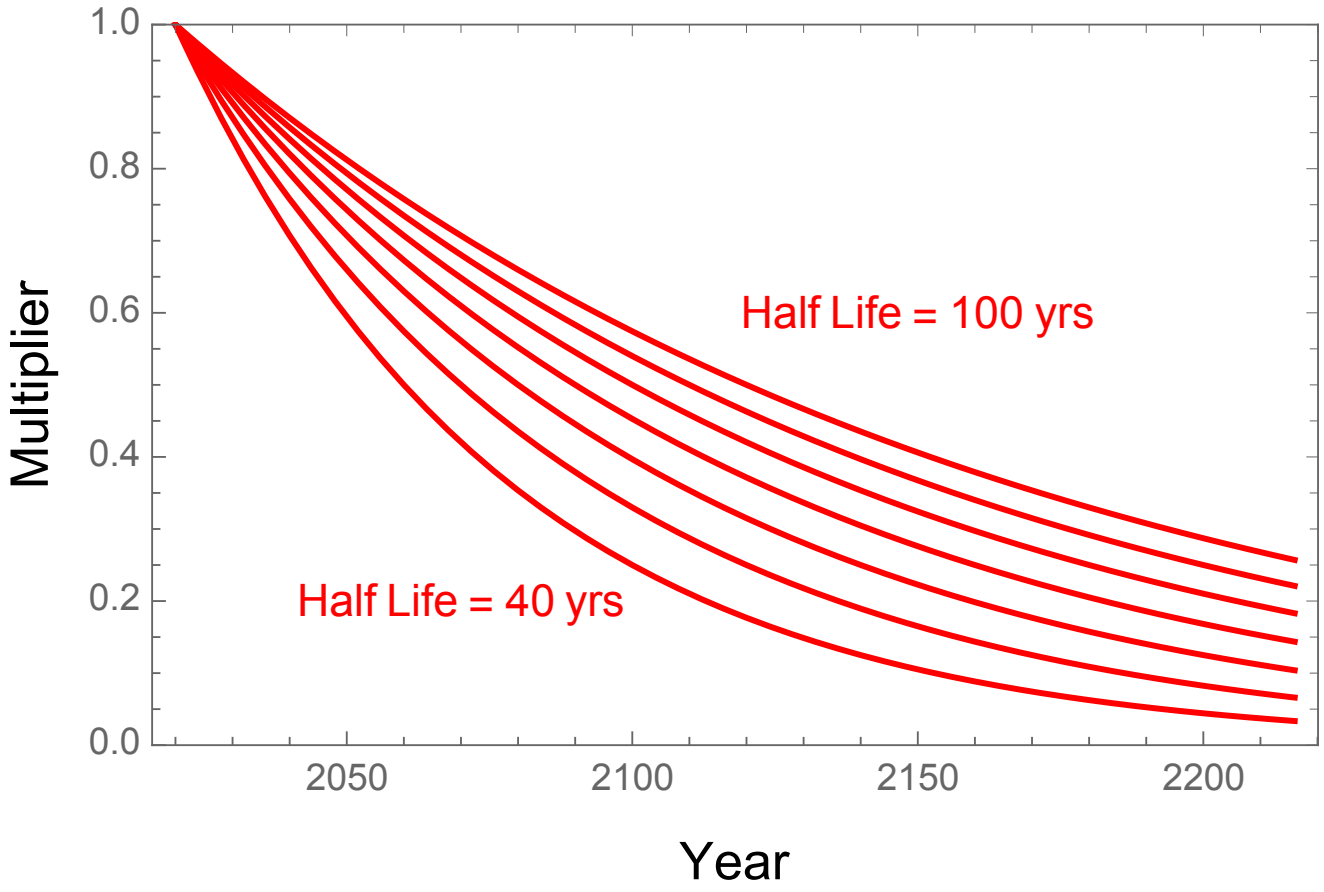
Step 8: Examine policy option combinations.

7x2=18 options for the Block containing China and the Block containing Others than the Green New Deal and No New Policy Blocks.

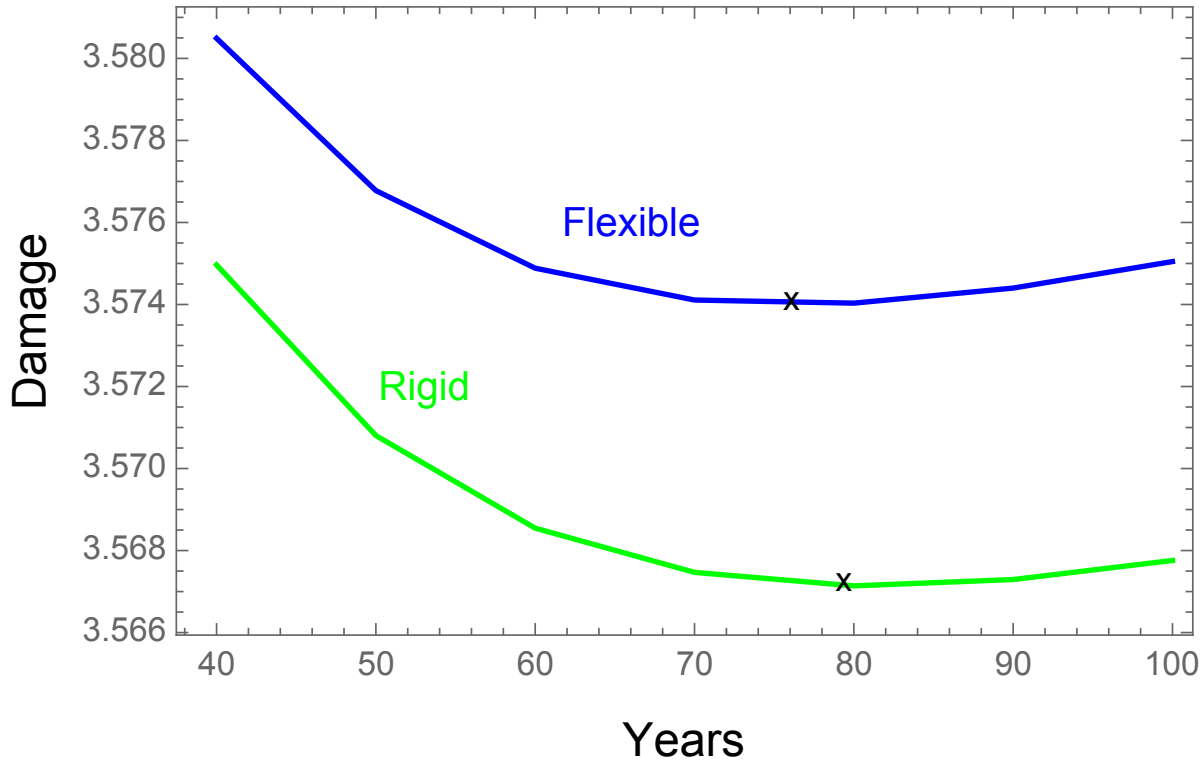
Compare the combinations that minimize the climate change damage to C + O for
Green New Deal Block Option A (to 0 by 2050)
vs.
Option B (draw down to and then match global per capita average CO2 emissions)

Step 8: Examine policy option combinations.

China Block No New Policy CO2 Emissions Multiplier
cuts in half every 40, 50, 60… or 100 years



China + Other Welfare Damage Impact vs. China CO2 Emissions Multiplier Half Life



China Block Optimum Half Lives:

79 years with Green Block Option A (Rigid: to 0 in 2050)

76 years with Green Option B (i.e. lower CO2 emissions)

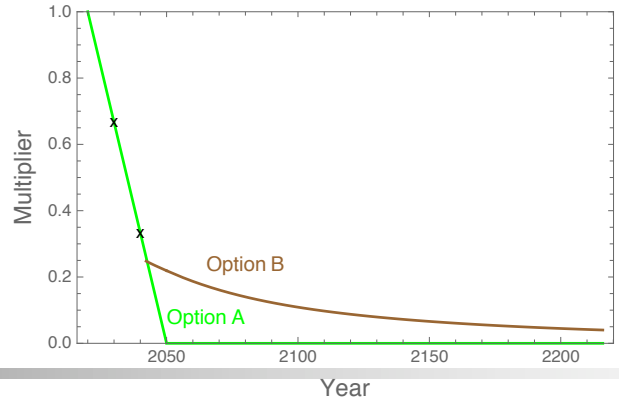
Compare Welfare Damage from Climate Change & CO2 Emissions Reduction Cost for Rigid vs. Flexible Green Block New Deal

With Flexible Instead of Rigid Green Block New Deal

Green Block gains	0.025
China + Other Blocks	-0.007
No New Policy Block	-0.016
Global Total	+0.002

The Green Block has higher Welfare
The Total Global Welfare is higher (albeit only slightly)

Qualitative Insights



An immediate commitment to zero equivalent CO2 emissions by 2050:

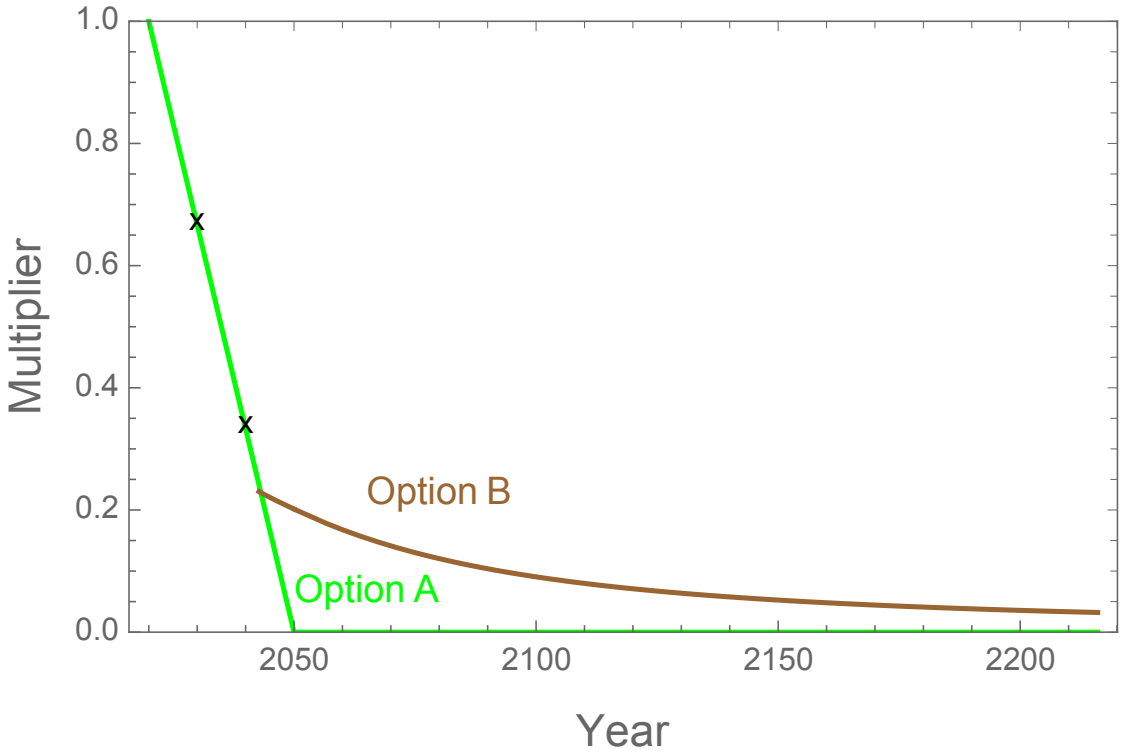
1. Is unlikely to be completed from an economic self interest viewpoint without some other economic benefit to the Block (e.g. the EU) that declares it.

2. From an altruistic viewpoint, rigidity is both deferred and inefficient compared to allocating resources sooner to help reduce the vulnerability of other regions to problems that are *already* acute and may be aggravated by the climate change that is going to happen in any case.

So, why has the EU declared for zero equivalent carbon emissions by 2050??

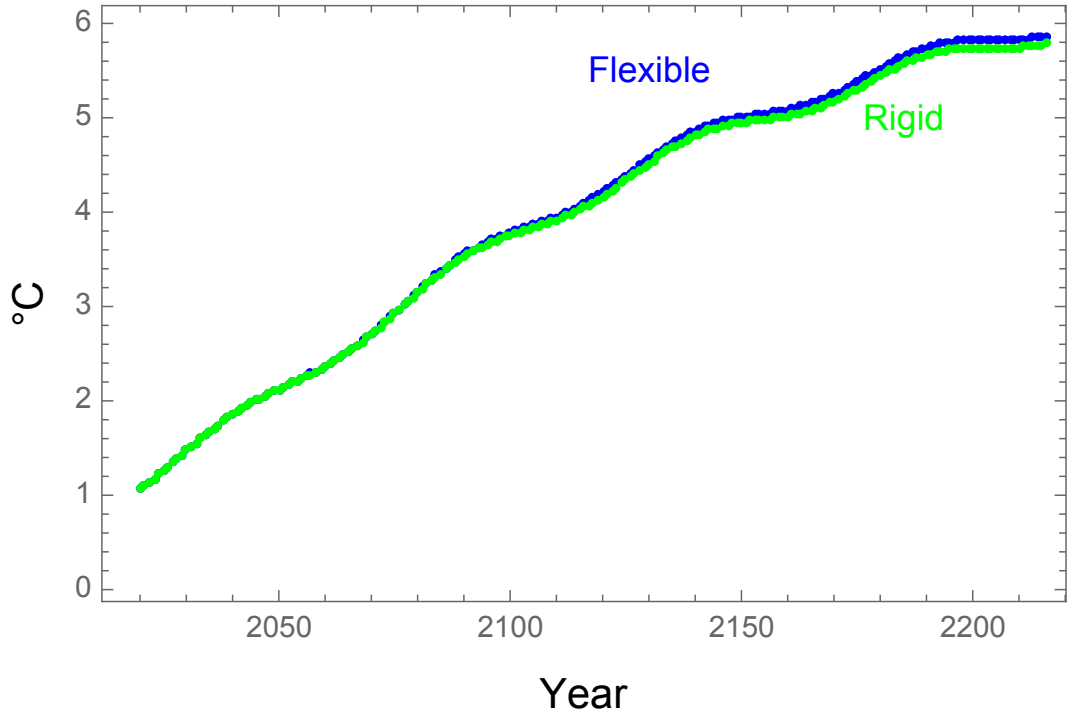
Could there be another long term economic benefit to the EU starting on this path?

What about:
Leverage on Russia and/or possible escape from military interventions in the Middle East??



What if the EU situation is unique amongst developed countries?

Outcome with only the EU doing Green New Deal Option A or B.



This has implications for (a) migration &
(b) solar radiation management

Migration

Two approaches to global climate change adaptation

(a) For low income politically stable areas:

Improve public health to reduce impacts

Improve water management and food production and distribution

(b) For politically unstable areas:

Establish humane procedures for dealing with an increase in displaced persons from ~65 million to twice or more* as many!

*Oli Brown, *Migration and Climate Change*
International Organization for Migration Report #31 (2008)

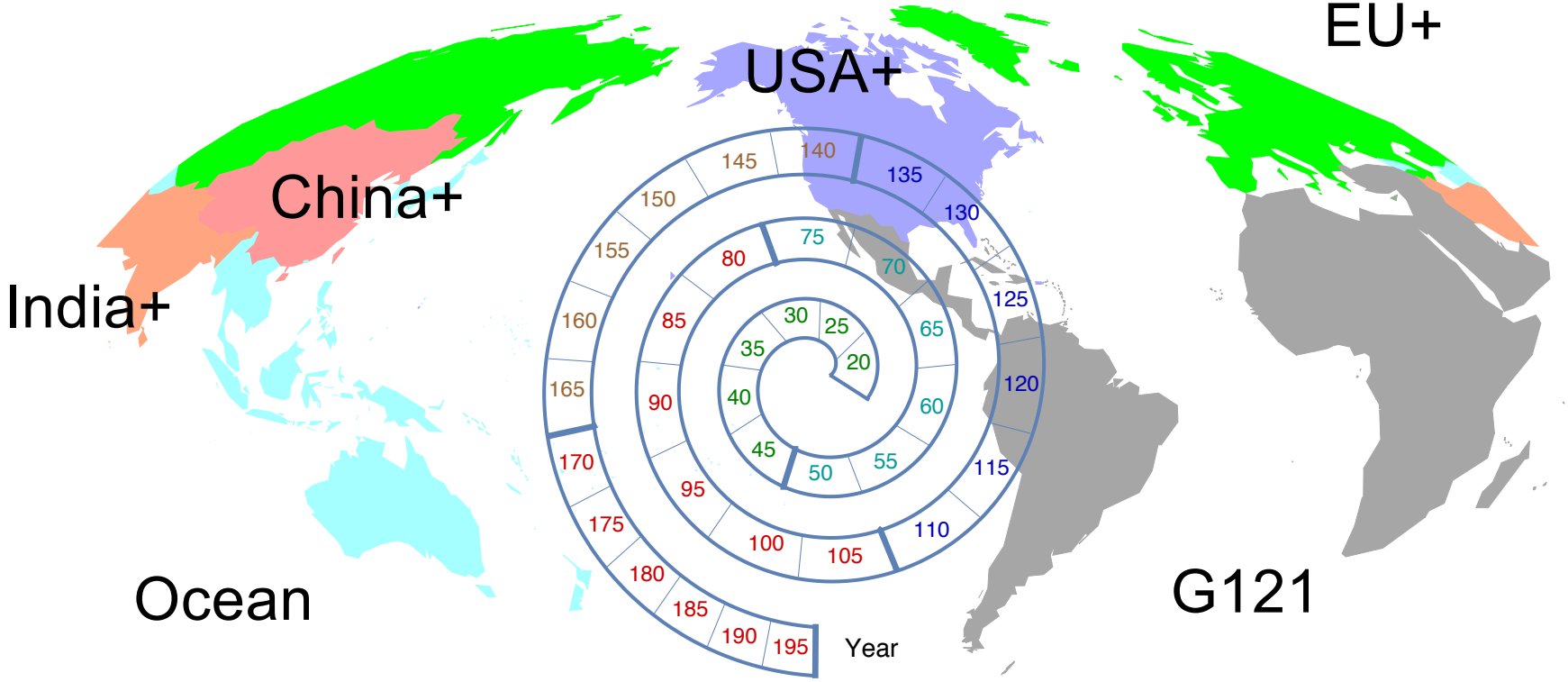
Solar Radiation Management: Observation

Global anthropogenic carbon emissions are
~ 10 Gtonne Carbon/year

From the 1991 Mount Pinatubo and other eruptions,
we know that about 2.5^{o}C of global cooling
can be producied by injecting into the stratosphere
~0.1 Gtonne Sulfur/year

It follows that global radiation management by
stratospheric sulfur injection is over an order
of magnitude less expensive than the expected level of
carbon emissions reductions that would be required
To limit global average temperature to les than
2^{o} to 3^{o} over the preindustrial level.

CAGE Experimental Modeling of Policy Decisions on Solar Radiation Management



c.f. Singer and Matchett (2015): *Challenges* open source journal

Example Experimental Negotiation Simulation Result

Example CAGE Implementation % Reductions from No New Policy CO_2 Emissions

& % of Enough Stratospheric Sulfur Injection for τ =0 with high CO_2 Concentration

Year	China+	USA+	EU+	Ocean	India+	G121	% S	τ (^{o}C)	ppm CO_2
2020	5	5	5	1	1	1	9	0.74	437
2030	8	8	15	1	2	2	18	0.65	540
2040	10	10	17	0	3	3	30	0.51	678
2050	10	13	20	0	4	3	43	0.30	846
2060	10	10	21	0	4	3	50	0.09	1037
2070	17	18	30	0	3	3	54	-0.03	1237
2080	22	22	32	0	2	0	56	-0.05	1437
2090	26	15	30	8	1	0	90	-0.36	1638
2100	37	25	40	1	0	0	78	-0.75	1831
2110	38	33	40	13	10	10	76	-0.81	2007
2120	55	50	55	20	20	30	80	-0.80	2158
2220	*70*	*60*	*55*	*20*	*20*	*30*	*60*	*0.50*	*3444*

τ = Global average temperature change from pre-industrial level

Distribution of CAGE Results (without Cap and Trade)

Results vary from one set of participants to another.

However, CAGE exercises have had a strong tendency to result in substantial increases in atmospheric CO2 concentrations triggering some compensating solar radiation management from tropical/subtropical regions.

Implications of International Cap and Trade

International Cap and Trade between Temperate and Tropical/subtropical regions provides an additional potential mechanism for inducing regions with rapidly growing populations to reduce CO2 equivalent radiative forcing below levels that would otherwise result.

If the recipient regions are willing to resort to a solar radiation management management to induce more cap and trade financial assistance from Temperate region countries, then the existence of prospective climate change damage could actually increase overall global economic welfare!

Summary of Green New Deal Suggested Insights

1. A flexible approach can be more credible and more beneficial to a Green New Deal region, without necessarily reducing overall global economic welfare.

2. Nearer term and continuing poverty impact alleviation and more systematic and humane approaches to displaced persons can be more cost effective than promising to go all of the way to zero net CO2 equivalent emissions between 2040 and 2050.

A More Comprehensive Approach to Probability Distributions for Climate Change Actual Outcome

1. One example (Galapagos Urban Planning) illustrates the importance of an approach to developing probability distributions for actual outcomes that includes more systematic analysis of feedback of climate change effects on impacts of *Homo sapiens* on climate.

2. Included needs to be the very uncertain impact on precipitation patterns of the possibility of solar radiation management that appears to be an order of magnitude less expensive than nearly zeroing CO2 equivalent radiative forcing by 2050.

3. Include analysis of chances for Cap and Trade or other increased wealth transfers between developed and developing countries also needs inclusion.