Green Growth, Climate Change and India

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Green Growth

- A bit like sustainability – difficult to define
- What is it?
  - Toman (2012): Is it simply a reminder to move toward intertemporal efficiency, a la literature of 1970s?
  - Hallegatte et al (2011): Growth that ensures that natural assets continue to provide services to us
  - UNEP (2011): economy which provides enhanced well-being, social equity and reduced env risks
- Two basic economic interpretations (Toman, 2012)
  - Fix externalities and market failures, nothing more
  - Exploit synergies between growth policies and environmental policies (eg, reducing subsidies to fossil fuels addresses both issues)

Green Ramsey Model

Toman (2012), Smulders and Withagen (2012)

- Two states: Env (Z) and capital (K)
- Two controls: Extraction of env (E), investment (I)
- Max NPV of aggregate per period utility, u(C,Z), such that
  - Y=f(A,K,L,E,Z), with A as technology, L labour
  - $Y=C+I+\pi E$
  - $dK/dt = -\delta K + I$
  - $dZ/dt = -H(E) + R(Z)$
  - Where H is how E depletes Z and R is regeneration of Z
- Implications
  - Higher initial K ➔allows reduced depletion of Z
  - If H(E) can be reduced through innovation and policies, get more growth with less depletion of environment
- Empicial implementation difficult

Today's talk

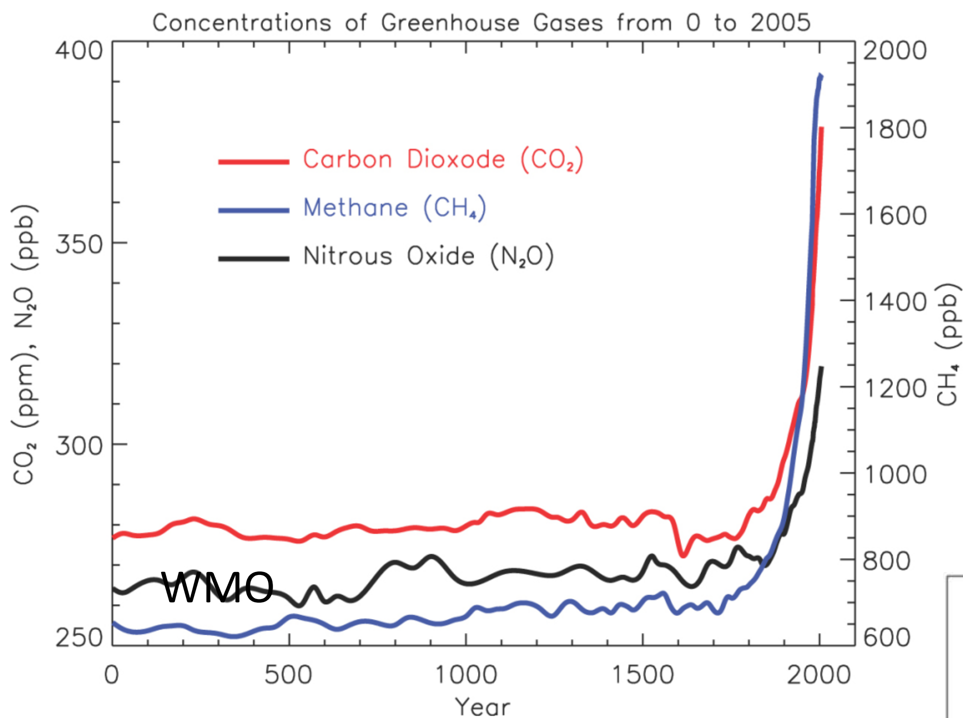
- Main goal: confront question of empirical implementation of Ramsey green growth model for climate
- Ultimate questions: How much mitigation, when, by whom?
- Identify economics research questions along the way
- At the end: address implications for India

1. Brief facts on climate change
2. Identify issues in empirically implementing Ramsey
3. Walk through these issues, identifying some of what is known and some of what is not known
4. Remarks as an outsider on India's perspective

CC Primer: in one slide

- How does it work?
  - Earth's temperature is an equilibrium balance between incoming radiation from the sun, which warms the earth, and outgoing infrared radiation (heat) from the warmed earth, which cools us
  - Greenhouse gases make the atmosphere more opaque to outgoing infrared ➔ with more GHG, earth gets warmer in order to re-establish equilibrium balance
- CO2 main greenhouse gas (but others too)
- Most greenhouse gases have same global effect, no matter where emitted—mitigation is pure public good.
- Greenhouse gases in the atmosphere (mostly CO2) have fluctuated throughout history but have risen dramatically in last century
- Current atmospheric load from past emissions, primarily from developed economics (eg, USA, EU and SU)
- China currently top emitter in aggregate; US top emitter per capita

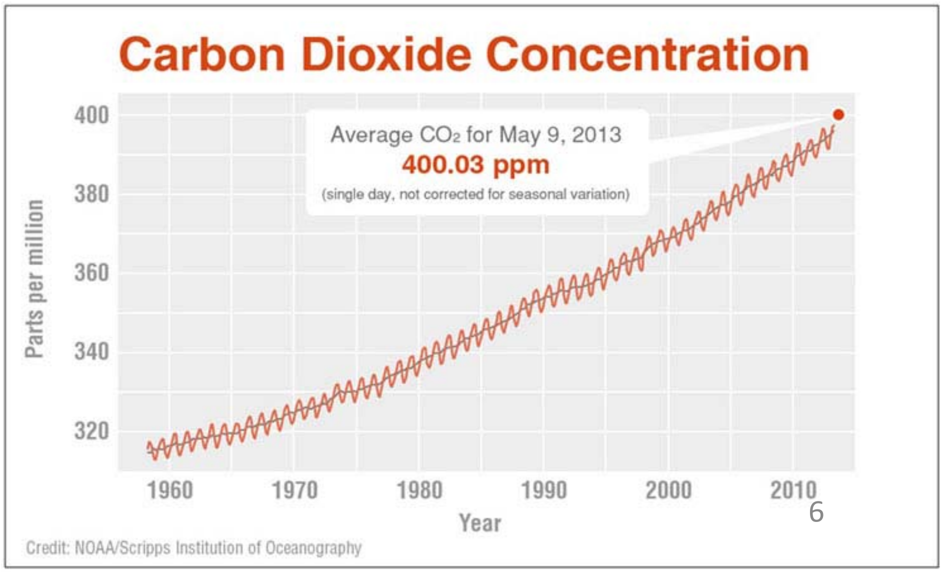
GHG Atmospheric Concentrations



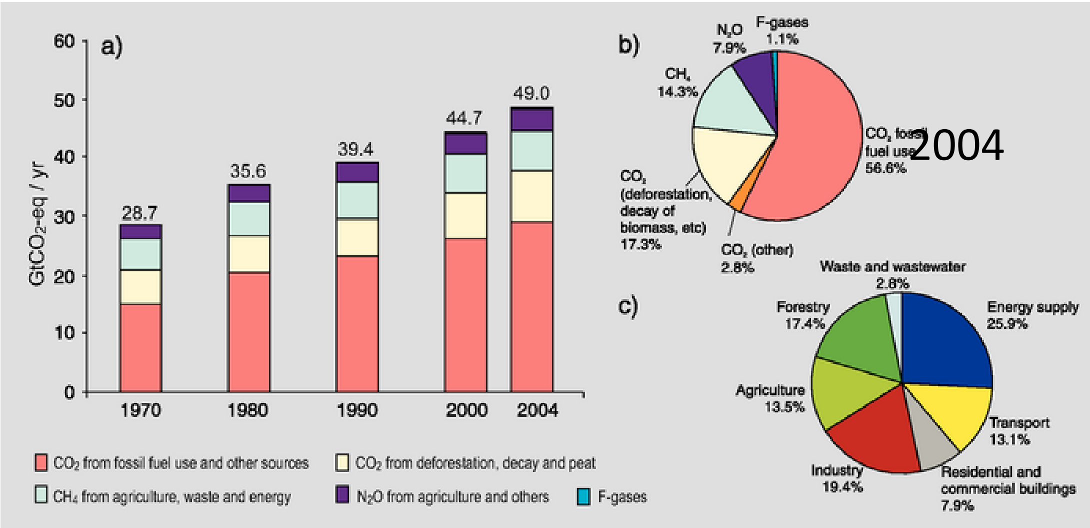
2000 years ago

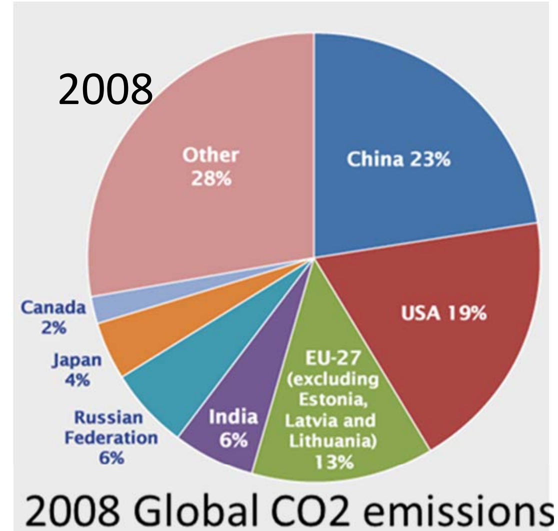
Today

Measured at Mauna Loa, Hawaii



Emissions





Source: IPCC; units: CO2 Equiv

Per Capita →

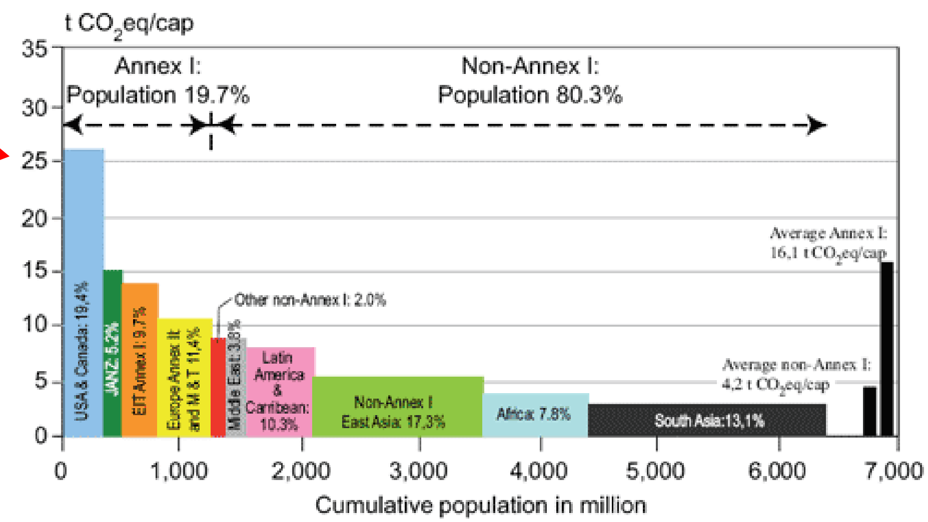
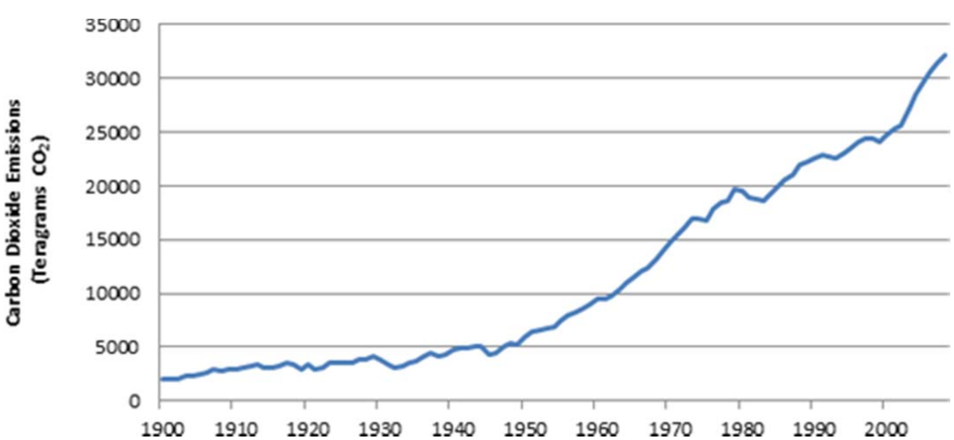


Figure SPM.3a: *Year 2004 distribution of regional per capita GHG emissions (all Kyoto gases, including those from land-use) over the population of different country groupings. The percentages in the bars indicate a regions share in global GHG emissions [Figure 1.4a].*



Issues facing societies

- What amount of mitigation (reduction in GHG) should be pursued by whom, when at whose expense?
  - Mitigation (or GHG emissions) a pure public good
  - Mechanisms needed to avoid free riding
  - Regulations needed to implement societal goals
  - International agreements may be needed -- difficult
- Same question for adaptation
  - Adaptation more of a private good
  - Market failures (eg, incomplete capital markets) generate insufficient adaptation
- Is geoengineering a viable/desirable way of coping with problem?

Empirical Green Ramsey Model: Standard Neoclassical Approach

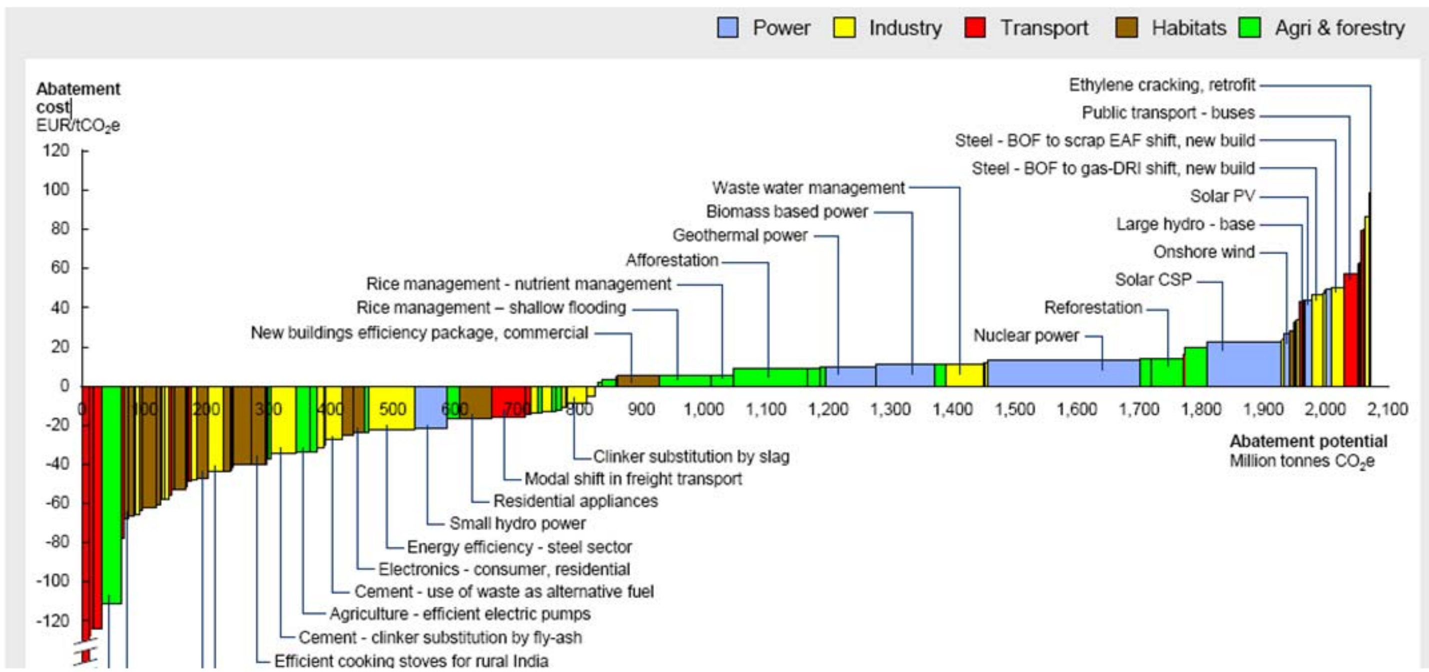
1. Production function--Estimate cost of mitigation curve by industry, country and internationally: mitigation as a function of carbon price; include co-benefits of mitigation, if any [ie, how E enters f]
   - Rebound effect dilutes mitigation potential
   - Co-benefits of mitigation may or may not change mitigation costs
2. Estimate connection between emissions and impacts;
3. Determine individual WTP for avoided impacts around world
   - Enters production function and utility function
4. Aggregate WTP to avoid impacts, generating aggregate damage function (will of course depend on income distribution; may need to be weighted)
5. Integrate induced technical change into costs at different points in time
6. Use discounting to aggregate benefits and costs intertemporally
7. SOLVE:
   - Determine trajectory of emissions which balances marginal mitigation costs with marginal damage intertemporally
   - Determine regulations which can support trajectory

- This is the approach of Bill Nordhaus, using DICE
- Problems are largely big issues for non-economists

Problems: Cost of Mitigation

- Estimating micro-level costs controversial
  - Existence of negative cost mitigation opportunities?
  - Co-benefits reduce effective cost of mitigation
  - Innovation—how will it proceed?

India’s CO2 Abatement Curve, 2030



Are negative abatement costs plausible?

- Aggregate social costs may well be negative
  - Market failures, externalities and existing distortions
- Private abatement costs tougher to argue as negative
- Firms/consumers have insufficient info on mitigation opportunites ➔ misoptimize
  - Information asymmetric or split incentives – eg landlord/tenant
  - Credit markets imperfect in financing such investments
- Empirical evidence (eg, Allcott and Greenstone, 2011, JEP)
  - Engineering estimates—overestimate opportunities
    - Typically omit costs; also only examine adopters – selection bias
    - Anderson and Newell (2004)—examined audit program and found extra costs not uncovered by engineering analysis of conservation
  - Actual energy conservation programs show returns simliar to market returns (Joskow and Marron, 1992; Arimura et al, 2011)
  - Actual consumer behavior (eg, Hausman, 1979; Allcott & Wozny, 2013) show high discount rates and evidence of misoptimization
- Conclusion: even estimating private mitigation costs difficult. Ripe area for further empirical research.

Co-benefits: What are they? Valid?

- Assume welfare, V, affected by multiple social objectives, $z_1,\ldots z_m$ (1^{st} n climate rest other)
- Assume one climate policy, p_1
- Welfare change: $dV = \Sigma_i\{(dV/dz_i)\ (dz_i/dp_1)\}\ dp_1$
- Components co-benefits (dz_i/dp_1)
- Note: Envelope theorem tells us if some components at optimum, $(dV/dz_i = 0)$ → social value of cobenefits zero
- Eg, climate and sulfur emissions

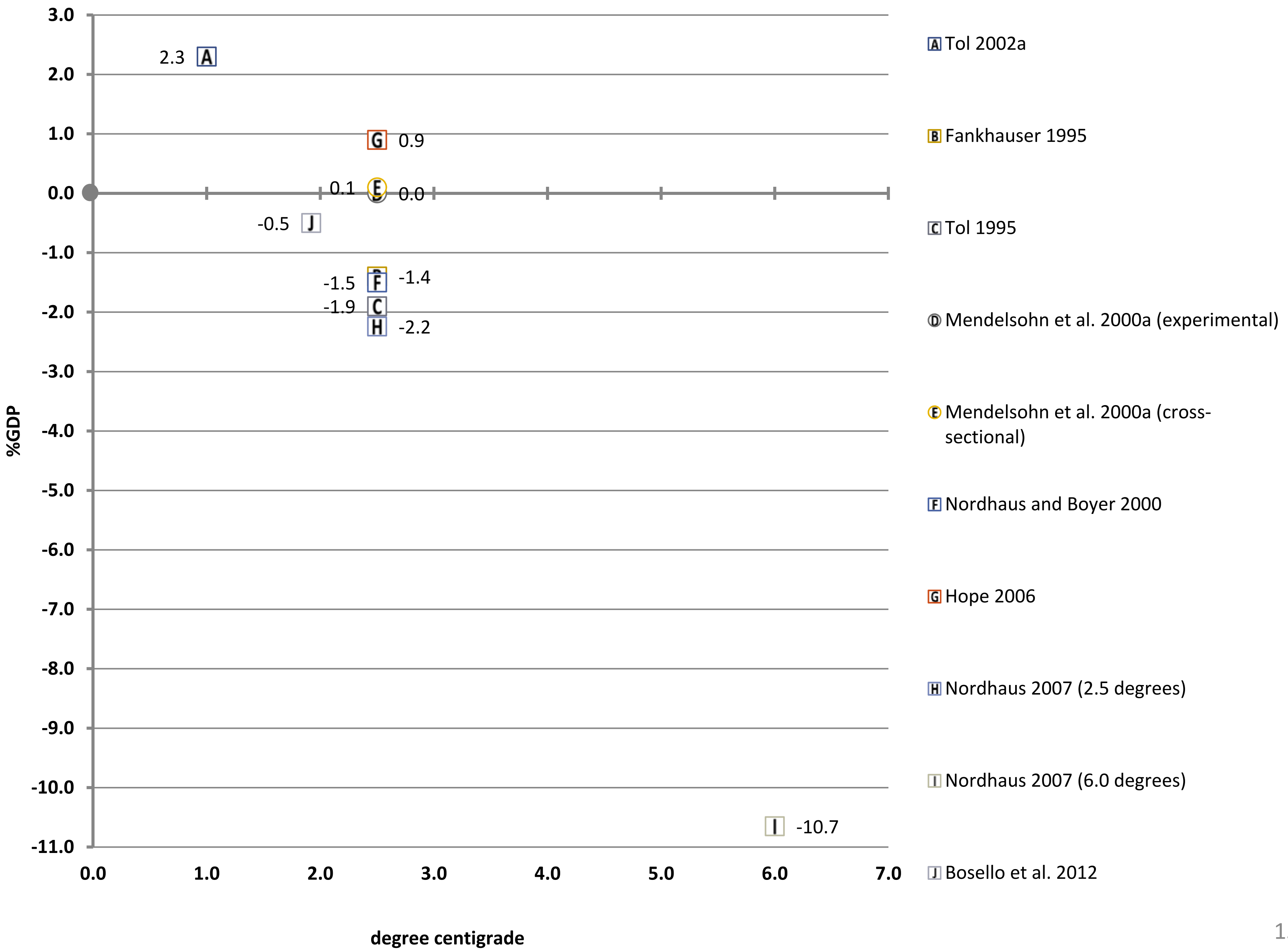
Induced Technical Change & Rebound

- Technical change expected to play an important role in reducing mitigation costs
  - How to represent induced technical change? Autonomous technical change?
- Rebound dilutes impact of technical change
  - Innovation: more energy efficient car
  - Rebound
    - Direct – price of use drops
    - Indirect—effective income increases
    - Economy-wide rebound—price of energy may drop
- Intellectual property regimes impede the transfer of new technology to developing countries

Damage—WTP to avoid change

- Damage is WTP to avoid impact from a change in the climate
- First step: convert temperature change into physical impacts
- Second step: convert physical impacts into WTP to avoid impacts
- Third step: aggregate impacts over time and individuals

Estimates of Aggregate Damage



Aggregation of Damage across space

- Problem: aggregating across individuals/countries with vastly different income levels (David Pearce)
- Illustrate: Dreze (1998)
  - Problem: invest fixed amount in pollution control in Delhi area
  - How to aggregate benefits across income levels
- Welfare weights reflect prioritarian ethics
- What weights?
  - No unequivocal positive answer
  - How about 1/VSL?

Aggregating Across Time: Positive discounting

	Government Bills (maturity <1 year)		Government Bonds (maturity =10 years)		Equity	
	1900-2006	1971-2006	1900-2006	1971-2006	1900-2006	1971-2006
Australia	0.6%	2.5%	1.3%	2.8%	7.8%	6.3%
France	-2.9%	1.2%	-0.3%	6.6%	3.7%	7.8%
Japan	-2.0%	0.4%	-1.3%	3.9%	4.5%	5.0%
United Kingdom	1.0%	1.9%	1.3%	3.9%	5.6%	7.1%
USA	1.0%	1.3%	1.9%	4.0%	6.6%	6.6%

Source: Gollier, 2012

- Appropriate for climate investments which displace capital
- Markets may give poor signals for some climate investments
  - Term of investments; incompleteness of market

Aggregating Across Time: Normative

- Ramsey rule:

  $\rho_t = \delta + \eta g_t$

- Extended Ramsey Rule (Gollier):

  $\rho_t = \delta + \eta g_t - 0.5\, \eta(\eta+1) s_t^2$

Calibration of Ramsey Rule

Author	Rate of pure preference for present	Inequality aversion	Growth rate	Implied social discount rate
Cline (1992)	0%	1.5	1%	1.5%
IPCC AR2 WGIII	0%	1.5-2	1.6% - 8%	2.4% - 16%
Arrow (1996)	0%	2	2%	4%
UK: Green Book (HM Treasury, 2003)	1.5%	1	2%	3.5%*
US OMB (2003)**				3% - 7%
France: Rapport Lebègue (2005)	0%	2	2%	4%*
Stern (2007)	0.1%	1	1.3%	1.4%
Arrow (2007)		2-3		
Dasgupta (2007)	0.1%	2-4		
Weitzman (2007b)(2007)(2007a)	2%	2	2%	6%
Nordhaus (2008)	1%	2	2%	5%

Application of Ramsey Rule

	Country	g	σ	*Discount rate*	
				Ramsey rule **Error! Reference source not found.**	*Extended Ramsey rule* **Error! Reference source not found.**
Developed countries	United States	1.74%	2.11%	3.48%	3.35%
	United Kingdom	1.86%	2.18%	3.72%	3.58%
	Japan	2.34%	2.61%	4.68%	4.48%
Emerging countries	China	7.60%	3.53%	15.20%	14.83%
	India	3.34%	3.03%	6.68%	6.40%
	Russia	1.54%	5.59%	3.08%	2.14%
Africa	Gabon	1.29%	9.63%	2.58%	-0.20%
	Zaire (RDC)	-2.76%	5.31%	-5.52%	-6.37%
	Zambia	-0.69%	4.01%	-1.38%	-1.86%
	Zimbabwe	-0.26%	6.50%	-0.52%	-1.79%

How much mitigation?

- Issues leave many unanswered questions
- Some argue for aggressive mitigation (eg, Stern), mostly relying on very low discount rates
- Others argue for modest (but non-zero) mitigation (eg, Nordhaus)

Who Mitigates? Who Pays?

- Who mitigates is an economic question
  - Cost minimization calls for mitigation to equalize marginal costs
- Who pays?
  - Largely ethical/normative question
  - Is there historic responsibility?
  - What role for current income?
- Coordination/Cooperation
  - Is cooperation needed – yes, for first best
  - Cooperation generally among countries, not individuals

Economics of Cooperation

- International Environmental Agreements
  - N-person two stage games: cooperate then mitigate
  - Literature somewhat pessimistic
    - Large agreements only form when gains are low
    - Typically very small agreements (few countries)
  - Experiments yield more cooperation than Nash
- Role of Fairness
  - Fairness seems to promote cooperation among countries
  - Fairness and cooperation in economics mostly experimental
  - Fairness concerns promote cooperation among individuals

Example: Self-interest vs Efficiency

Prisoner's Dilemma: Defection Individually Rational

	B Cooperates	B Defects
A Cooperates	(x,x)	(1,7)
A Defects	(7,1)	(2,2)

Note: With payoff (a,b), a is payoff to player A and b is payoff to player B; $2<x<7$; from Charness et al, 2008

Example: Self-interest vs Efficiency

Cooperation rates: x=4, 15%; x=5, 45%; x=6, 70%

	B Cooperates	B Defects
A Cooperates	(x,x)	(1,7)
A Defects	(7,1)	(2,2)

Note: With payoff (a,b), a is payoff to player A and b is payoff to player B; 2<x<7; from Charness et al, 2008

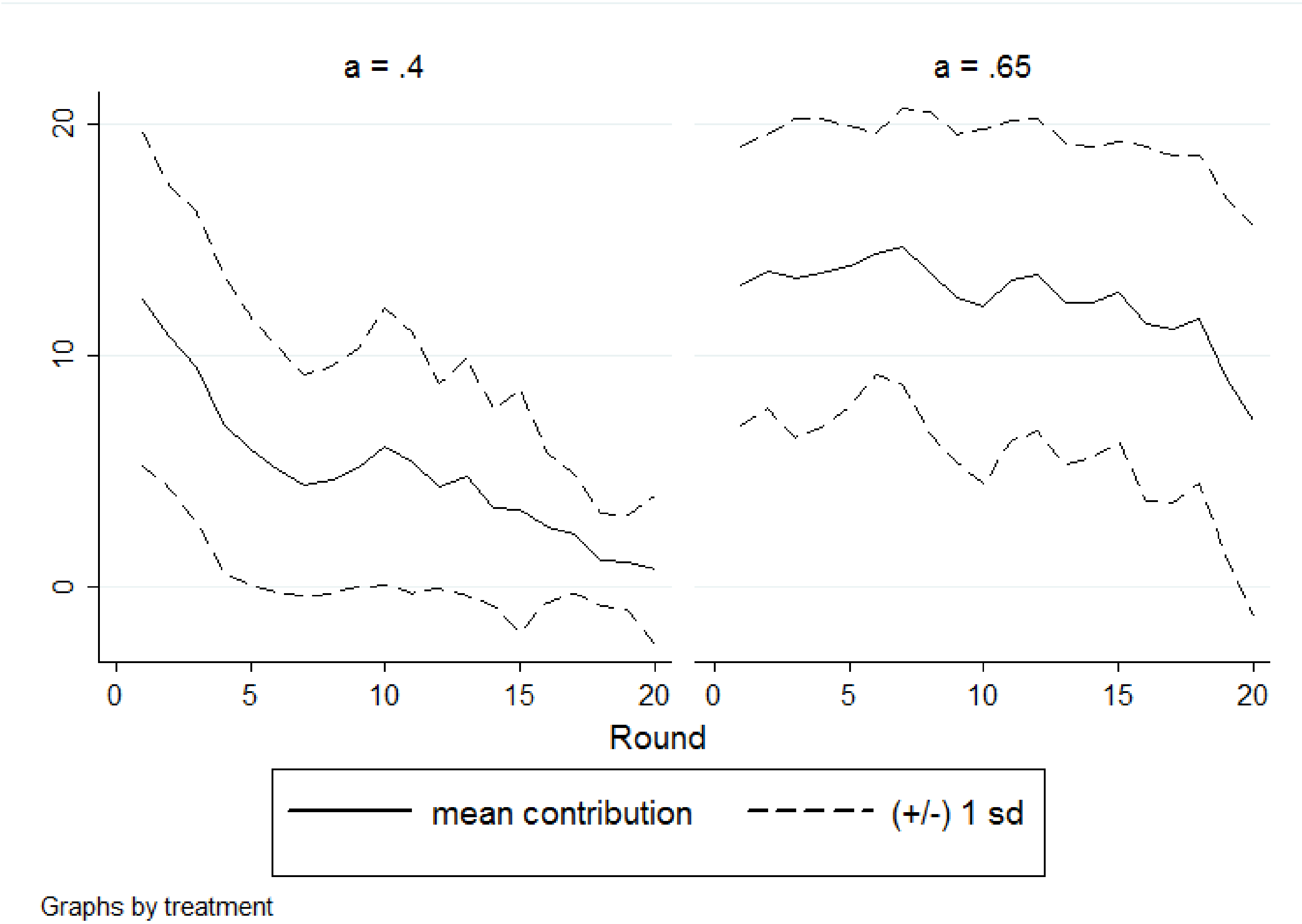
Cooperation in Public Goods Games

- Theory – Bergstrom et al (1986)
  - Max $U(x_i,G)$ s.t. $x_i + g_i = w_i$.
  - Identical preferences but but different wealth levels
  - Some but not much p.g. provision in Nash equilibrium: mostly free riding
  - Andreoni: as size of economy grows, aggregate contributions to public good approach non-zero limit and fraction contributing go to zero – inconsistent with US data on contributions.
- Experiments
  - Kim and Walker (1984), Isaac and Walker (1988) and others
  - Test of free-rider hypothesis
  - Experiments find much less free-riding than theory suggests
- Attempts to explain differences
  - Heterogeneous preferences
    - Fischbacher and Gachter (2010) – 23% pure free riders
    - Fehr and Schmidt (1999) – 73% pure free riders
  - Conditional cooperators
  - Social preferences
    - Fehr and Schmidt (1999)
    - Andreoni (1989)
    - Charness and Rabin (2003)

Anomalous Experimental Behaviour

PG games: Kosfeld et al (2009)

- Two MPCR
- 76 subjects
- 4 subjects per group (N=4)
- 20 repetitions per group
- Endowment: 20 points per round
- Contribute 0 to 20 to PG
- 40 points = 1€
- After each round, subjects told total contributions
- Subjects have no knowledge of distribution of payoffs



Indian Context
(observations from an outsider)

- Short-term issues
  - Indian mitigation only marginally significant to change in climate
  - India has (I would think) significantly higher social priorities
  - Problem so far mostly due to emissions by others (such as EU, US, FSU)
- Longer-term issues
  - Damage from CC may become significant
  - India could gain from a global agreement
- Any action should be in India's self interest (individual rationality argument)

Is there a self-interest argument for Indian Mitigation?

- Help foster an international agreement – helps with long-term climate change moderation
- Green growth MAY have some applicability – try to remove distortions that are exacerbating depletion of natural resources in India
- Learning about decarbonizing Indian economy
  - Green growth is all about decarbonizing and growing. Possible?
  - Small steps can be a low cost way of learning
  - If successful, other countries will follow which will benefit India
  - Primary goal behind California's policies
- Stimulating low carbon innovation, perhaps as an export industry (Porter hypothesis)

Conclusions

- Green growth is a nice concept but practical implications are limited
- Empirically implementing green growth model difficult
  - Motivates a host of research questions
- Climate change is a classic economic problem with tradeoffs and limited resources
- Finding solution to climate change problem pushes economic paradigm to its limits