Climate Change and Economic Development

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Guest lecture:

University of Tampere, 22 March 2011

Climate change and development economics

- Development economics has traditionally focused on large-scale phenomena
  - Structural transformation (agriculture vs. non-agriculture)
  - Physical and human capital accumulation
  - Technical change and economic growth

- Climate change is another large-scale phenomenon
  - Economywide and long-term implications
  - Considerable uncertainty (esp. for large-scale investments)
  - May alter our policy prescriptions and development strategies
  - Stern suggests that CC will herald a "new industrial revolution"

Lecture outline

1. Climate change science

    From uncertainty to risk

2. Mitigation policy

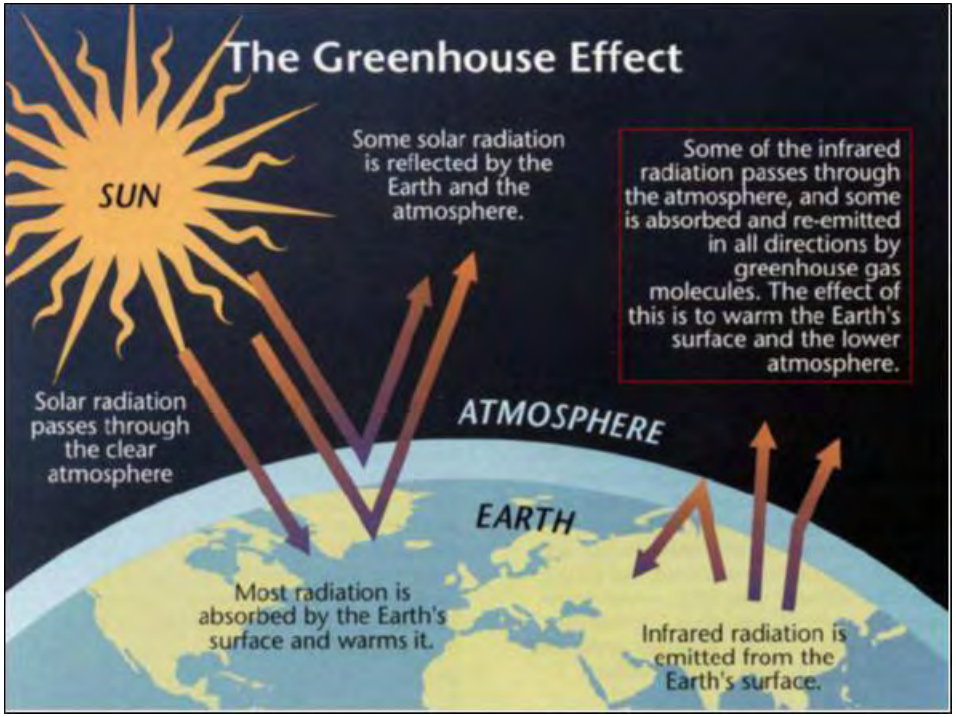
    Switching to low-carbon development

3. Impacts and adaptation strategies

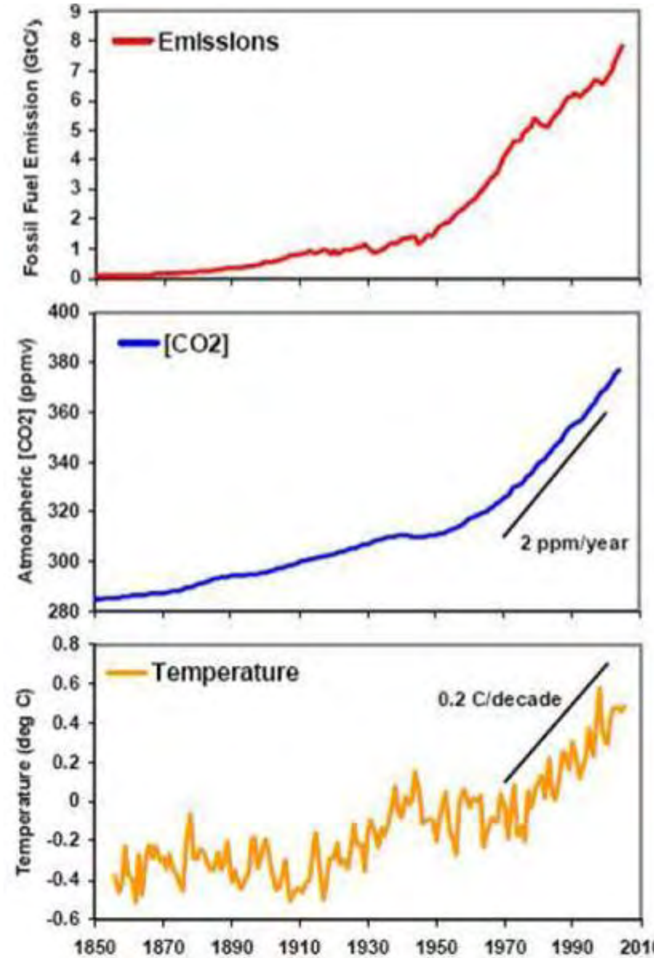
    Building resilience to climate change

PART 1
Climate change science
From uncertainty to risk

What is "climate change"?



There is a >90% chance that at least half of the observed warming is due to human-caused greenhouse gas emissions (IPCC AR4)

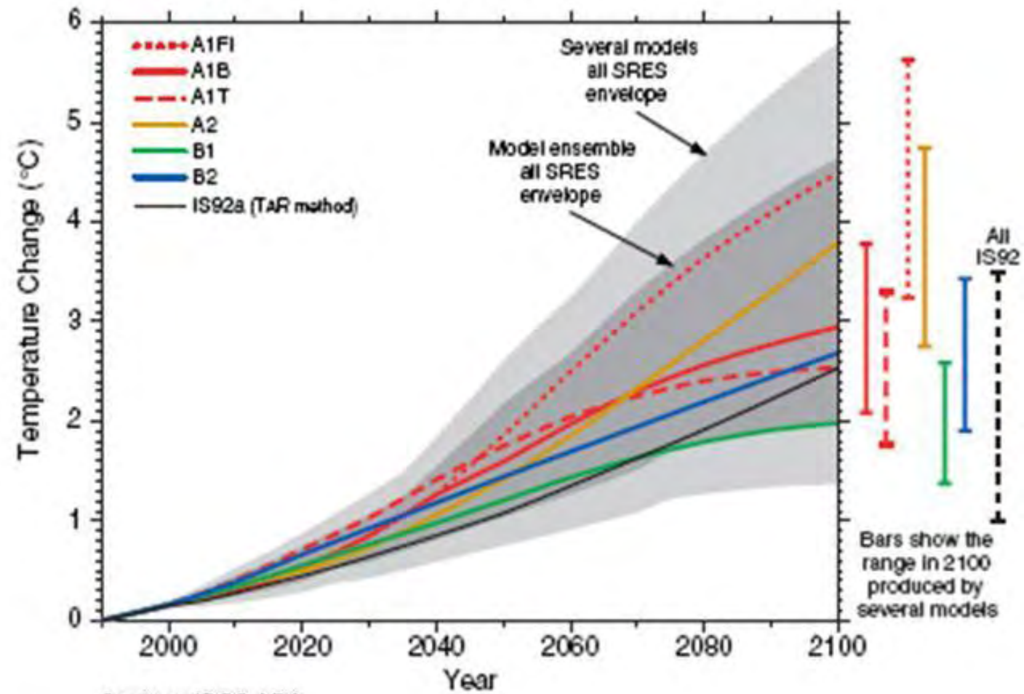


Source: Cited in Midgley (2011)

The “cone of uncertainty”

- Climate projections are produced by General Circulation Models (GCMs)
- There are about two dozen major GCMs
  (reflecting climate uncertainty)
- Models are used to reflect different global economic “emissions scenarios”
  (reflecting economic uncertainty)

Change in mean global temperature



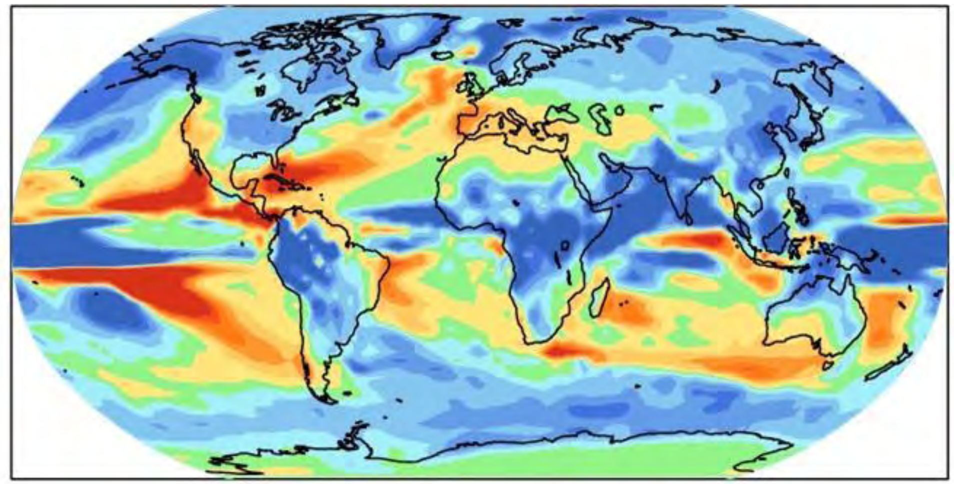
Source: IPCC AR4

- 50/50 split between uncertainty from science and economics

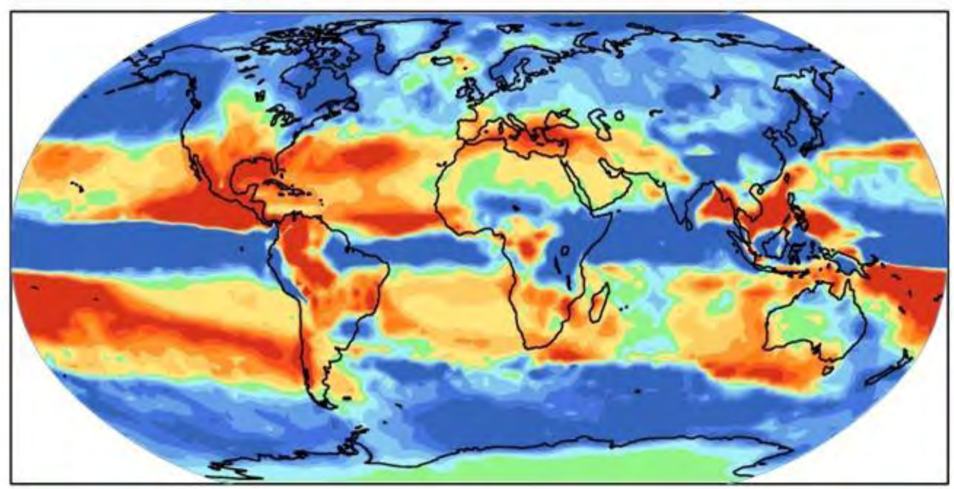
Wide variation at local scale between models

- Different GCMs give different results at the country-level
- Moreover, GCMs are often at too low a resolution for planning purposes (e.g., 2'x2')
- “**Downscaling**” projections to local areas has its own difficulties

Precipitation in 2100

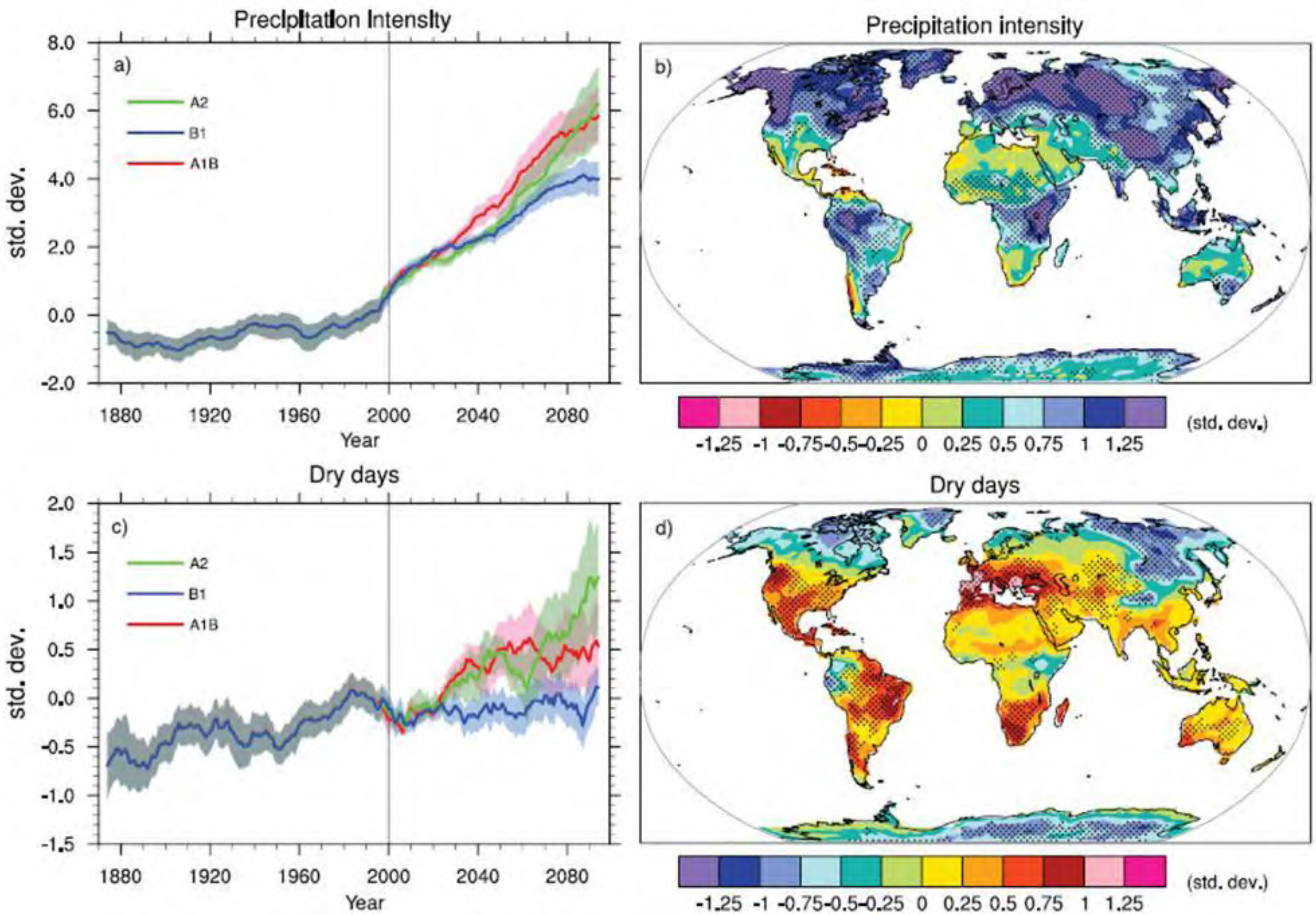


NCAR



MIROC

Change in extreme weather events



Some regularities

- Warmer
  - Higher temperatures will be observed throughout the globe.
- Wetter
  - Precipitation globally is likely to increase due to speeding of the hydrologic cycle. The distribution of this increase is unknown.
  - Indeterminate affect on climate moisture index [CMI =f(P/T)].
- More intense
  - More intense rainfall and higher probability of extreme weather events (flooding, perhaps cyclones…).

Uses of history

- CC heightens the uncertainty under which governments and economists must design/prescribe policies

- Uses of historical experience
  - Future CC impacts are like past impacts with some modifications to the distributions
  - Future CC impacts are out of the historical domain and therefore require a different approach to analysis

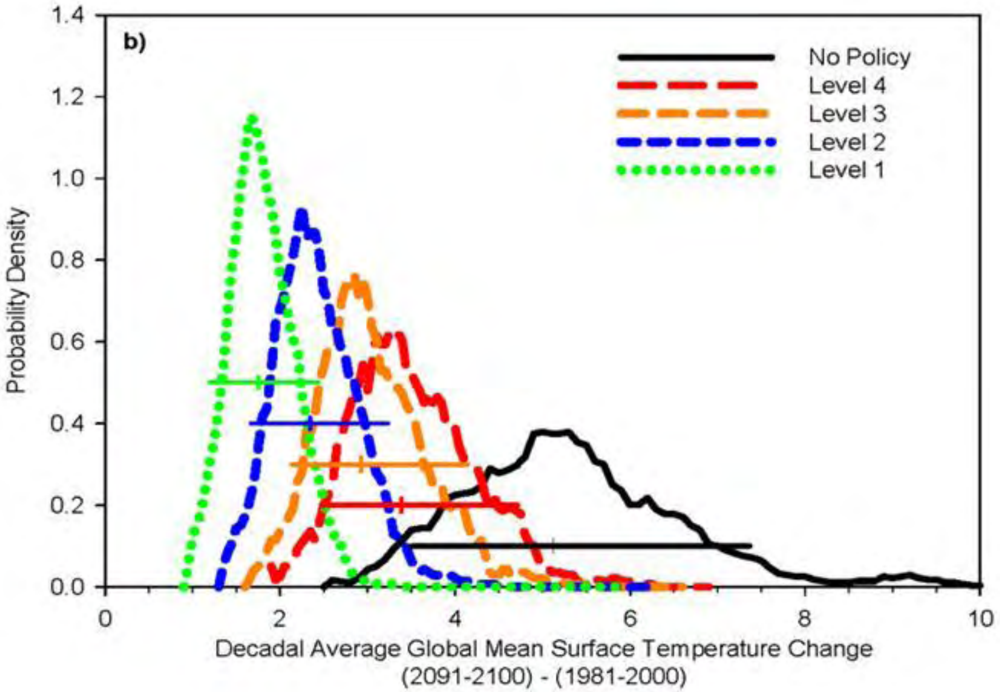
- Models
  - Reduced form models using historical data
  - Deep structural models based on underlying science and knowledge of technology/biology and the economic system

Risk and uncertainty

- Knight (1921):
  - **Risk** refers to situations where the decision-makers can assign mathematical probabilities to the randomness which they face.
  - **Uncertainty** refers to situations when this randomness “cannot” be expressed in terms of specific mathematical probabilities.

Converting uncertainty into risk

- MIT has developed a *probabilistic* model (IGSM)
  - 70 uncertain parameters
  - 400 Monte Carlo simulations
  - Climate + socioeconomic scenarios
- Global policy is powerful:
  - Reduces mean (smaller impacts)
  - Reduces standard deviation (less uncertainty)
- Economists can use risk to identify robust policies



Source: MIT Joint Program
http://globalchange.mit.edu/resources/gamble/

Five positions on global climate change

1. **Denialist**

   Global warming is a myth (the science is wrong)

2. **Skeptical scientist**

   Global warming is real, but humans aren't causing it

3. **Skeptical economist**

   We are causing climate change, but we can't do anything about it

4. **Pragmatist**

   We can and should doing things differently, but we should weigh these against other development objectives

5. **Fundamentalist ("climate crazies")**

   We can and must stop climate change no matter what the cost

Areas of CC linked to development policy

- **Mitigation policy**
  - Steps at the global level to reduce GHG emissions and climate change (uncertainty)
  - Case study: South Africa and carbon pricing
- **Adaptation strategy**
  - Steps at the national level to reduce vulnerability to climate shocks and sustain economic development
  - Case study: Mozambique impact assessment

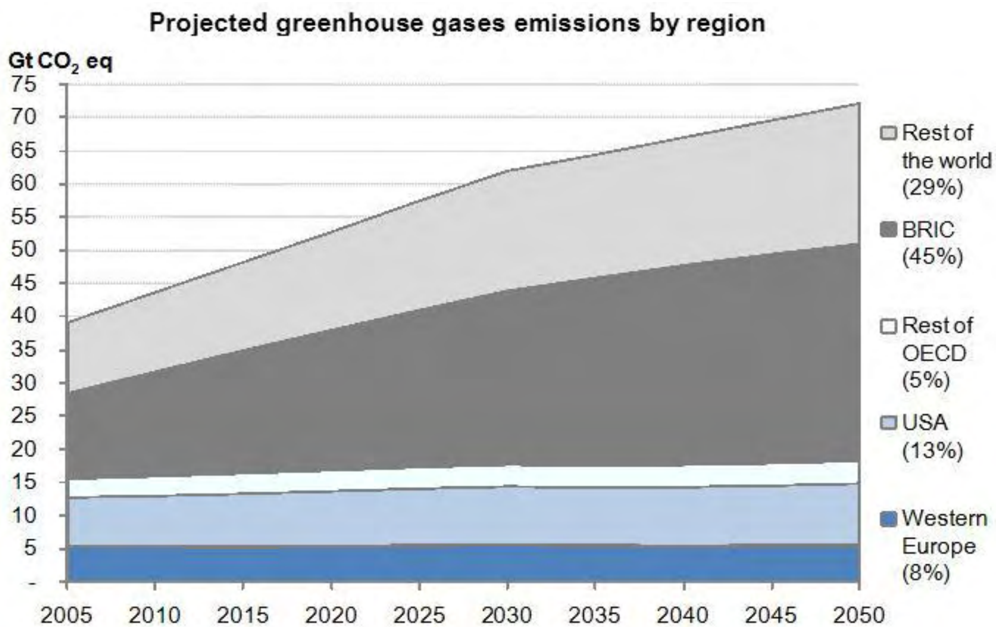
PART 2

Mitigation policy

Switching to low-carbon development

Global GHG emissions

- GHG emissions mainly come from burning fossil fuels and land-use change (i.e., clearing forests, etc.)
- Most historical emissions come from the OECD countries
- But most future emission growth will come from LDCs

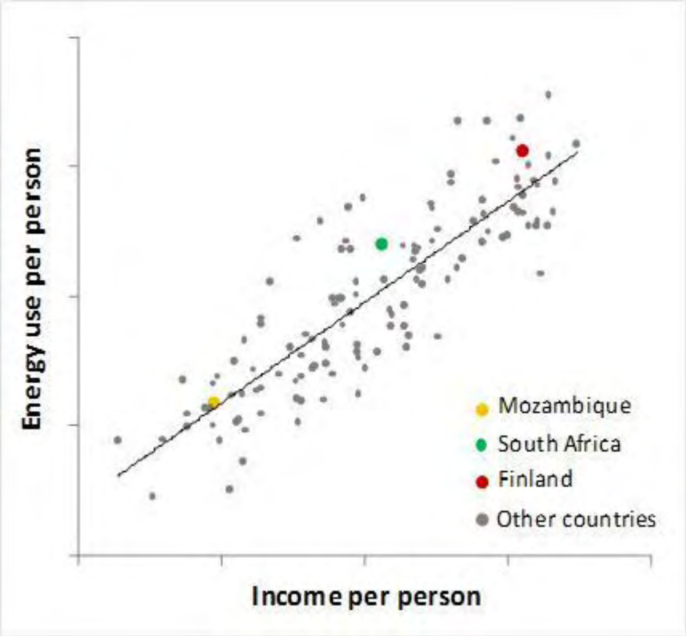


Source: OECD Green Growth Strategy

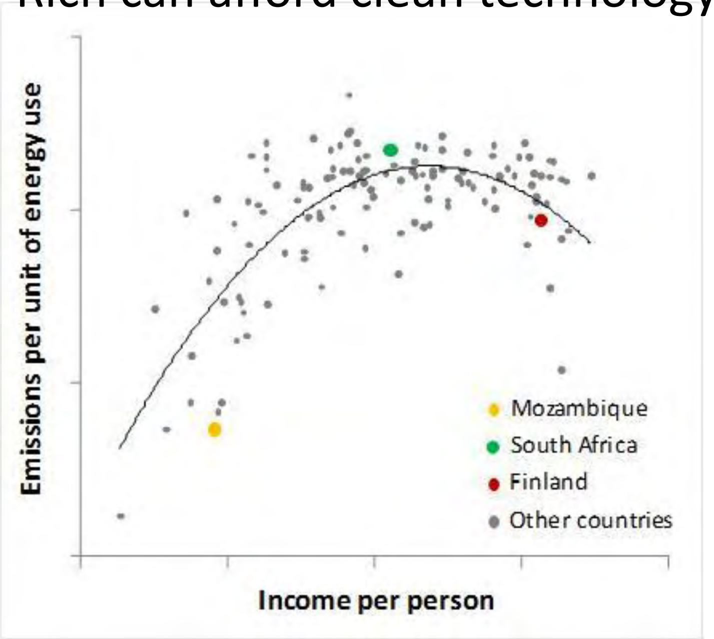
Energy, emissions and development

Emissions = Energy use x Emissions per energy unit

- **Energy use rises with income**
- Reducing energy use in low-income countries means slowing the development process



- **Energy emissions first rise and then fall with income**
- Industrializing countries use cheaper dirtier energy
- Rich can afford clean technology



Source: Davies et al. (2011)
Notes: Energy Use is measured in tons of oil equivalents.

Global emissions and energy use in 2007

	Global CO_2 emissions share (%)	Emissions per person (tons CO_2)	Energy use per person (tons)	CO_2 per ton energy use (tons)
World	**100**	**4.5**	**1.8**	**2.5**
Developed countries	**46.6**	**12.5**	**5.2**	**2.4**
United States	19.7	19.3	7.8	2.5
Euro area	9.0	8.2	3.8	2.2
Russian Federation	5.2	10.8	4.7	2.3
Japan	4.2	9.8	4.0	2.4
Finland	**0.2**	**12.1**	**6.9**	**1.8**
Developing countries	**53.4**	**2.9**	**1.1**	**2.7**
China	22.1	5.0	1.5	3.3
India	5.5	1.4	0.5	2.7
South Africa	**1.5**	**9.0**	**2.8**	**3.2**
Mozambique	**0.01**	**0.1**	**0.4**	**0.3**

US$25 tax per CO_2mt transfers **US$220 billion** from developed to developing countries each year (distributed on p.c. basis)

OR

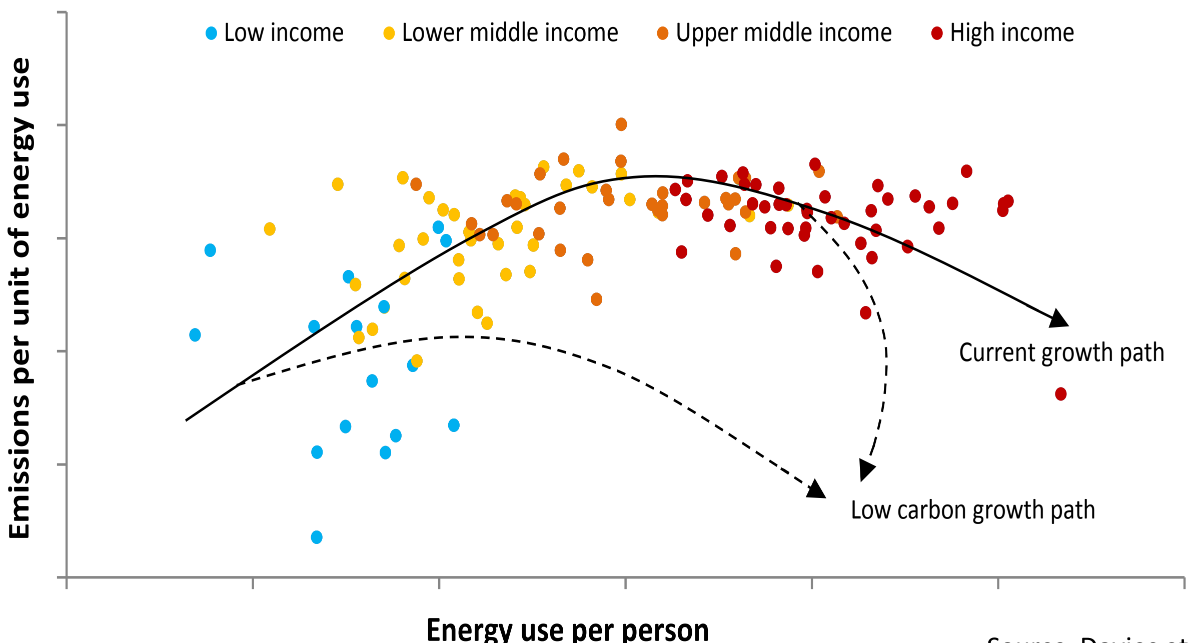
US$240 per person tax in developed countries

Source: Davies et al (2011).
Notes: Energy Use is measured in tons of oil equivalents.

Switching to low-carbon development

For lower-income countries… this means increasing energy use by adopting a more expensive package of investments that could slow economic growth.

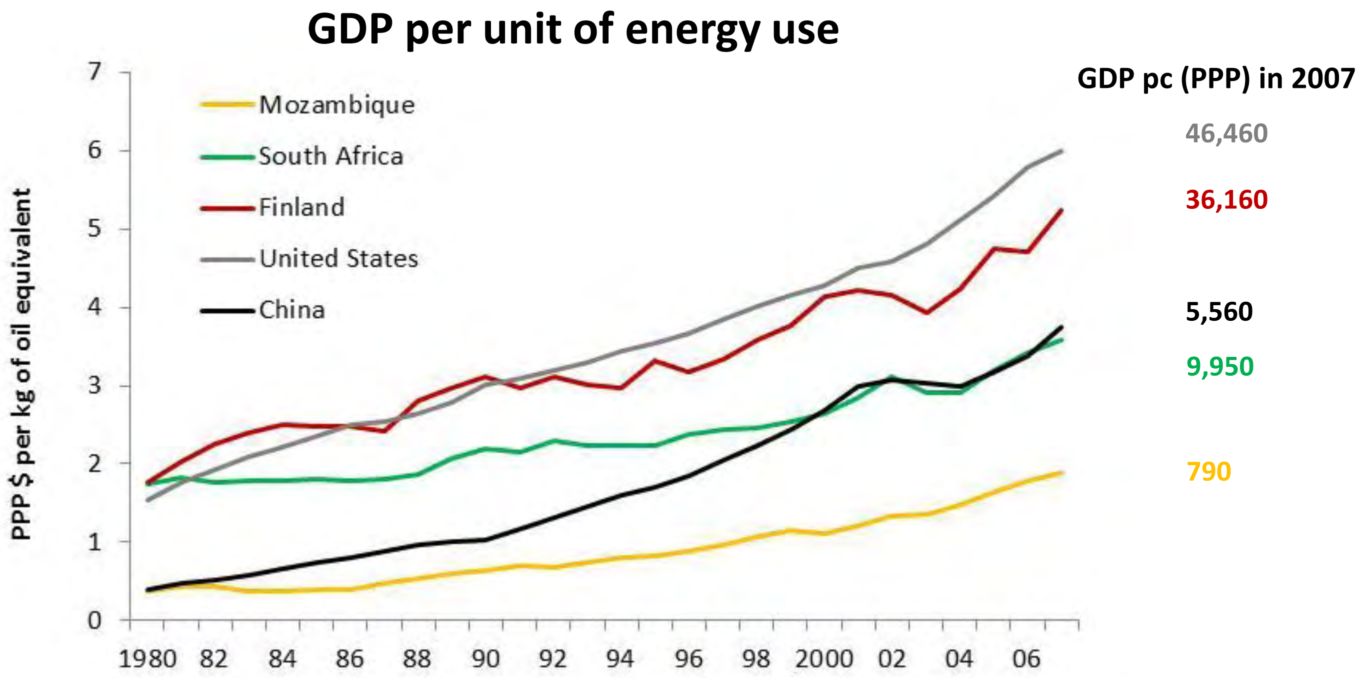
For middle-income countries… this also means improving energy efficiency and possibly abandoning existing "dirty" investments.



Source: Davies et al. (2011)

Becoming more energy efficient

…means generating your income in less energy-intensive ways



Source: World Development Indicators (2010).
Notes: Energy Use is measured in tons of oil equivalents.

Policies to reduce GHG emissions

- Need to promote low-carbon energy use:
  - Invest in cleaner and renewable energy resources (R&D)
  - Promote energy awareness and efficiency
- But ultimately you have to correct the market failure (negative externality) by pricing carbon
  - Cap-and-trade scheme and/or carbon tax
- Carbon tax choices (multilateral vs. unilateral mitigation):
  - Production-side: Only tax fossil fuel use (leads to leakage)
  - Consumption-side: Border tax adjustments (avoid loss of competitiveness when you're the only country mitigating)

Case study: South Africa

- Middle-income country (US$ 5,930 p.c. | US$ 9,950 p.c. PPP)
- Mineral-rich (over 100 years of remaining coal resources)
  - Cheap coal-fired electricity (and coal-to-liquid petroleum)
  - Economic development historically based on mining and heavy industry
- Dirtiest non-oil producing developing country (excl. island states)
- Persistent poverty, inequality and underdevelopment
  - 25% unemployment rate
  - One of the highest Gini coefficients (SA = 0.58 | Finland = 0.27)
- Currently debating introducing a carbon tax

Political economy of taxing carbon

- Business/Industry (esp. mining and metals)
  - Afraid of losing competitiveness in global and local markets
- Labor unions
  - Afraid of job losses and higher unemployment
- Civil society
  - Environmentalists want green economy
  - Developmentalists want low-cost electricity for poor households
- Government
  - Wants to meet global commitments and maintain international relations
  - Wants to be re-elected (by the poor and labor unions)
  - Needs growth to reduce unemployment

Measuring carbon intensity

Methods and data

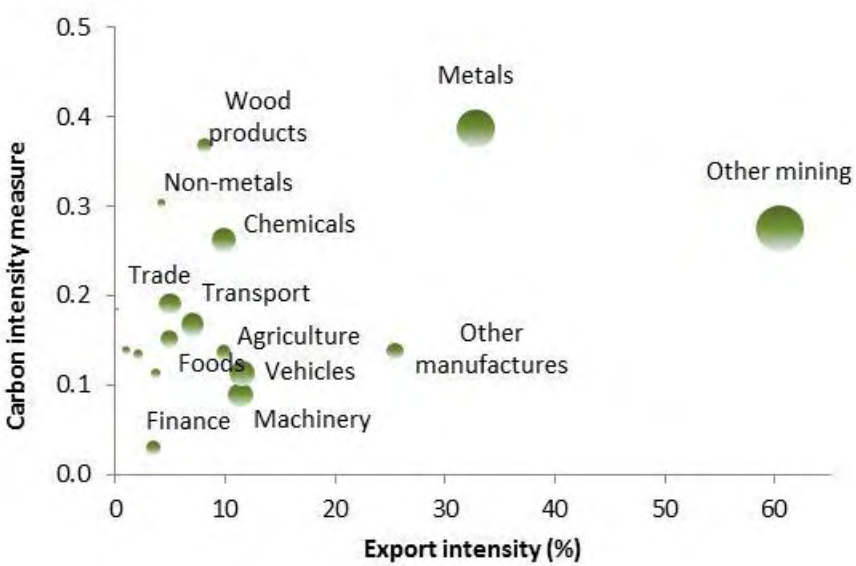
- Need to consider direct and indirect carbon use
  - Direct use of fossil fuels and transformed energy (e.g., electricity and petroleum)
  - Plus indirect use of carbon embodied in other inputs (e.g., plastics)
- Multiplier analysis using supply-use tables
  - Carbon enters the system as fossil fuels (oil, gas and coal)
  - We track all upstream and downstream product flows to determine total (net) carbon use per unit of output or final demand
- Limitation: Implicitly assumes no demand response
  - Carbon tax would change prices and influence consumer demand
  - So this is a "situation analysis" rather than a "policy simulation"

Measuring carbon intensity

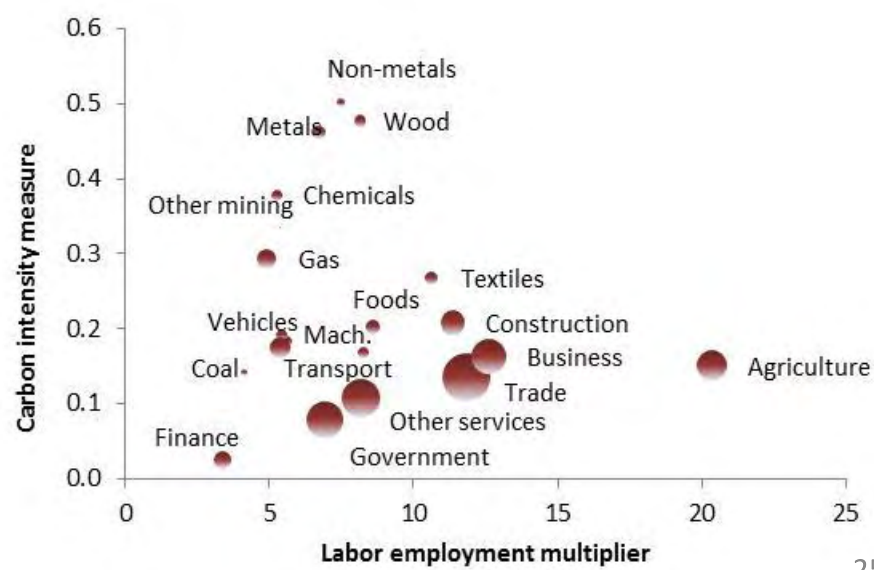
Results: Exports and employment

- South Africa is a large net exporter of carbon (2.5x imports)
  - Metals and mining exports would be affected most by a carbon tax
- Carbon-intensive sectors are less labor-intensive
  - So unlikely to be big employment effect (but transition costs for unions)

Relation to exports



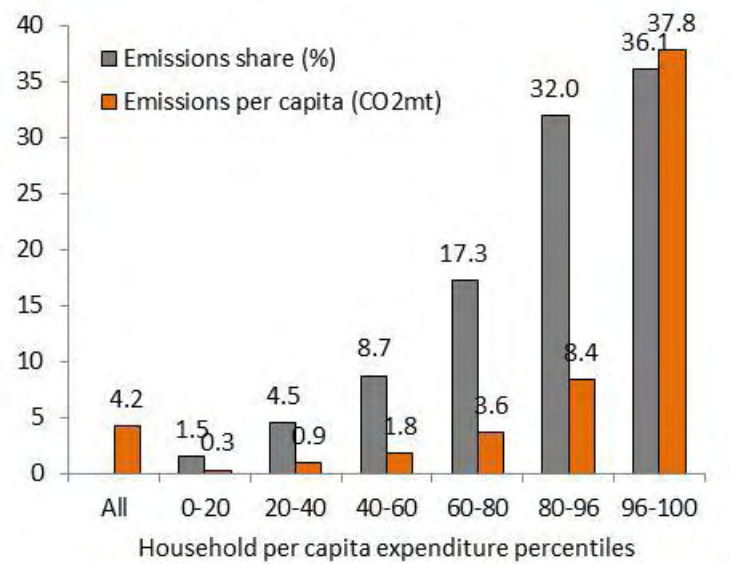
Relation to employment

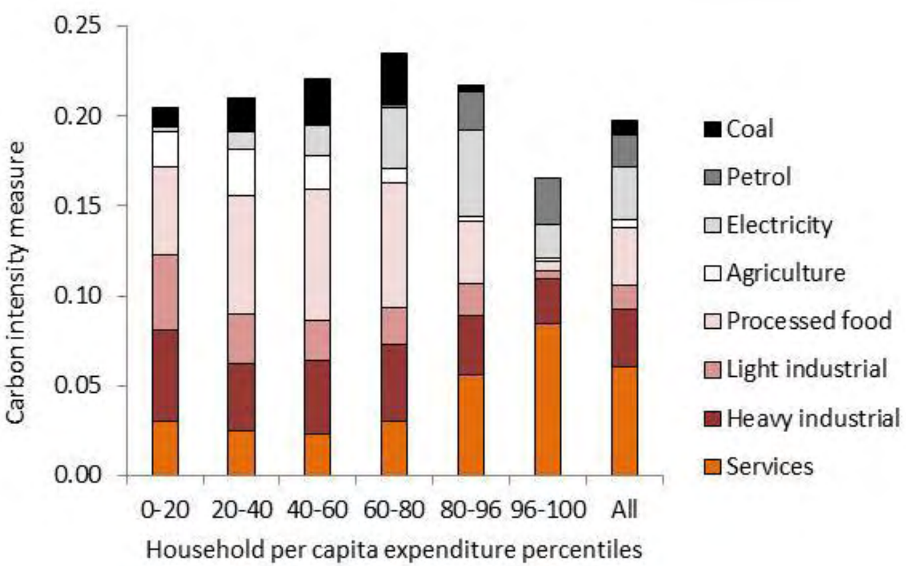


Measuring carbon intensity

Results: Household carbon use

- Household emissions are below national average but unevenly distributed across income groups
  - Poorest 20% of population (0.3 tons of CO_2 pc ≈ Benin)
  - Richest 4% of population (37.8 tons of CO_2 pc ≈ Kuwait)
- But middle-income households are the dirtiest (just like countries)





Economic impact of a carbon tax

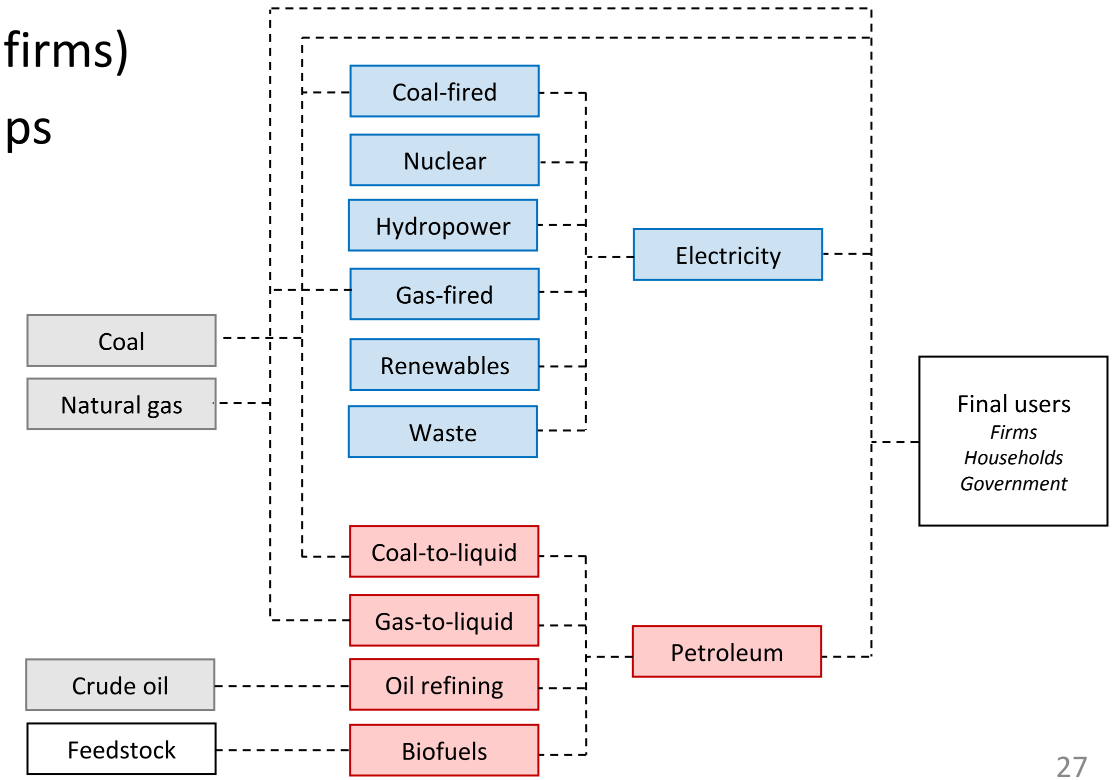
Methods and data

- Recursive dynamic CGE model
- Detailed energy sector (primary fuels and transformation)

- Final users
  - 46 sectors (representative firms)
  - 14 household income groups

- R200 carbon tax (US$28)

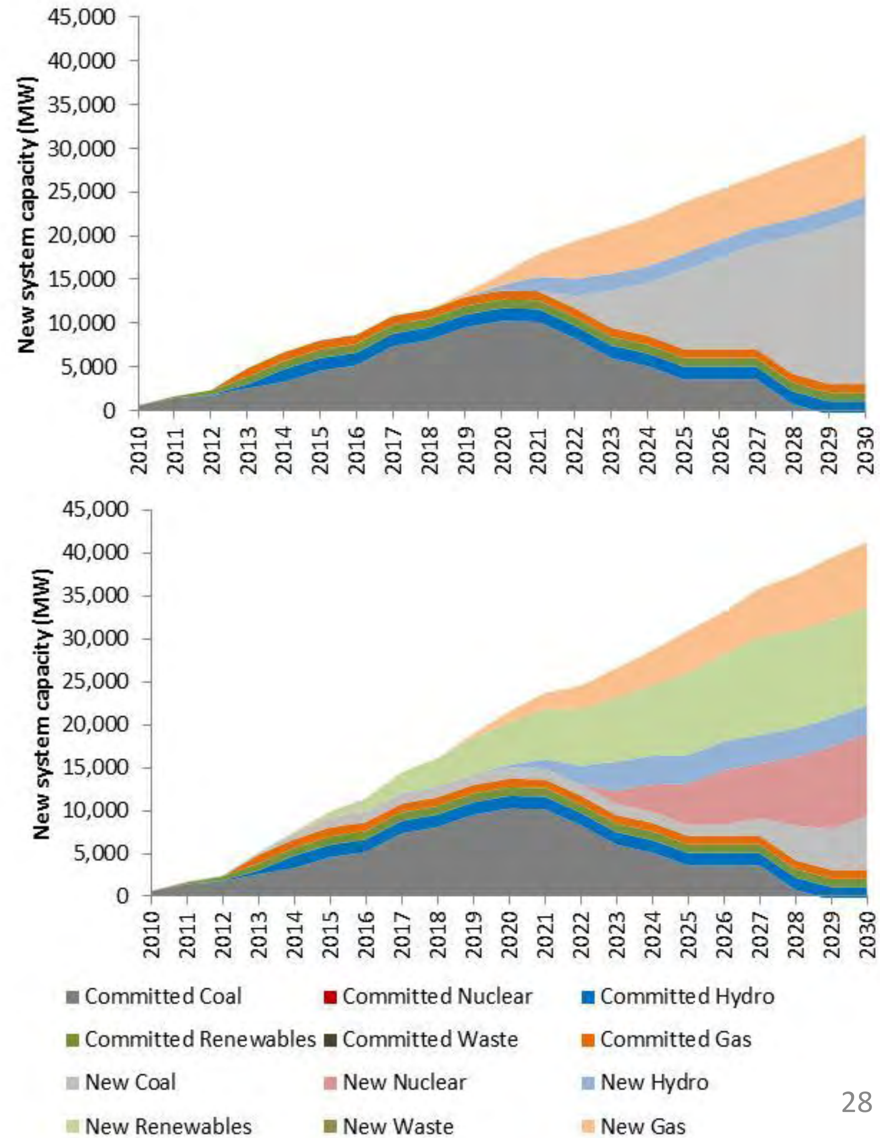
- Government sector
  - CT generates public resources
  - Assume revenue neutral (reduce VAT)



Economic impact of a carbon tax

Results: electricity sector investment

- Investments are only partly an economic decision
  - Capital lasts a long time (so limited flexibility)
  - Reducing emissions beyond threshold levels means abandoning working capital
- New build plan is expensive (US$30bil. = 11% of 2005 GDP)
- It also misses emission targets
  - 2020 = -4% (target is -34%)
  - 2025 = -18% (target is -42%)
- So carbon tax must do the rest

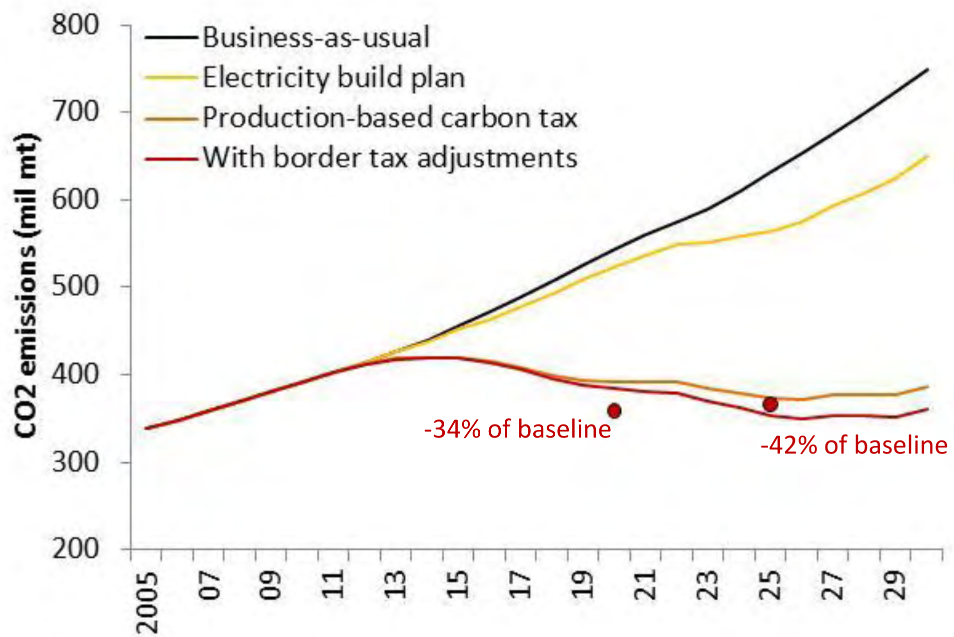


Economic impact of a carbon tax

Results: Total emissions

- Gradually introduce a carbon tax from R20 in 2012 to R200 in 2022 (initial collections for R200 tax = 5% of GDP in 2005)
- Meets emissions reduction targets

Total emissions, 2005-2030

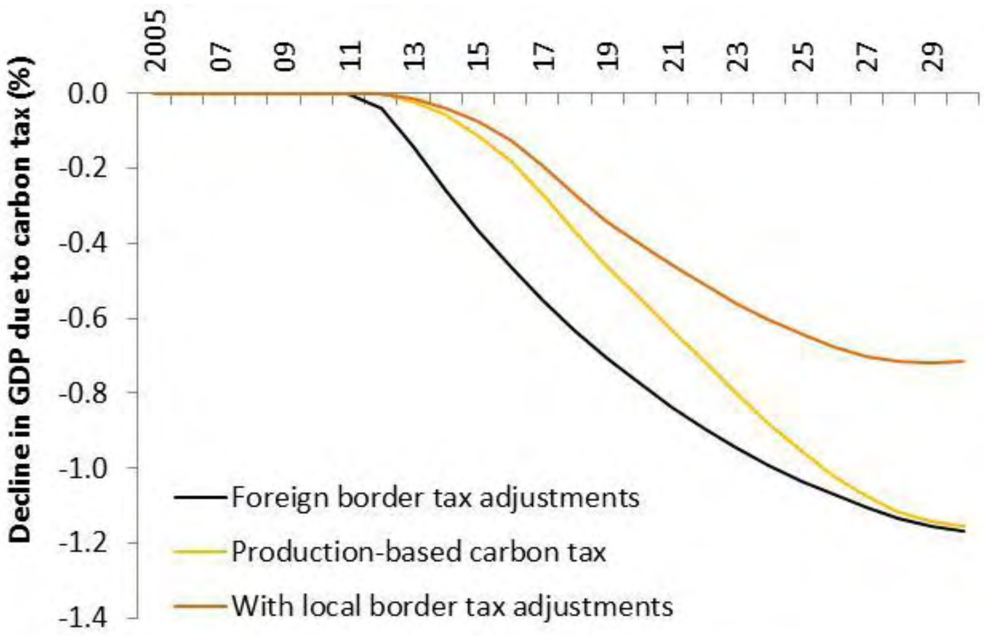


Economic impact of a carbon tax

Results: Economic growth

- Carbon tax reduces economic growth, but only slightly
  - Returns on fixed capital declines
  - Takes time/resources to shift into less carbon-intensive sectors
  - Lower profits and savings (and hence reduced investment)

Total GDP losses from carbon tax, 2005-2030



Economic impact of a carbon tax

Other key findings

- Foreign (retaliatory) border taxes are as negative as the carbon tax
- Domestic border taxes reduce negative impacts
  - Avoids loss of competitiveness against imported goods
  - Maintains export competitiveness of carbon-intensive goods
- Net impact depends on how tax revenues are recycled
  - Using funds to raise public/private investment is growth-enhancing
- Gradual introduction of CT is as effective as a big-bang approach
  - Gives local economy time to adjust their capital allocations
- Impacts on employment and households are small
  - But tax is slightly regressive
  - Structural transformation means short-term job losses

Challenges for economic development (1)

- Mitigation is necessary but it requires countries to…
  - use cleaner energy early in industrialization
    - BUT this has expensive start-up and opportunity costs
      - May have to abandon working capital (e.g., coal plants)
      - Must borrow abroad to finance new investments (e.g., nuclear)
      - Using imported technology raises operations/maintenance cost (e.g., solar)
      - Most LDCs still need massive social and infrastructure investments
  - not use their natural resources
    - BUT this can slow economic growth by not using cheap energy options
    - AND this involves politically difficult policies (e.g., South Africa's carbon tax)
      - Higher electricity prices
      - Job losses during the transition period

Challenges for economic development (2)

- Financing global mitigation and “high-cost” development
  - Who should pay for developing countries to reduce GHGs?
  - How should global carbon tax funds be distributed?
    - Locally, within the country where they were collected
    - Globally, based on existing emissions shares
    - Globally, based on per capita emissions
    - Some efficiency-based measure (GDP per energy unit)
- What if there is no global agreement to cut emissions?
  - Should countries be allowed to introduce border-tax adjustments?
    - On the carbon embedded in imports (might lead to trade war)
    - With rebates on the carbon within exported goods (“passing the buck”)

PART 3

Impacts and adaptation strategies

Building resilience to climate change

“Climate proofing” development strategies

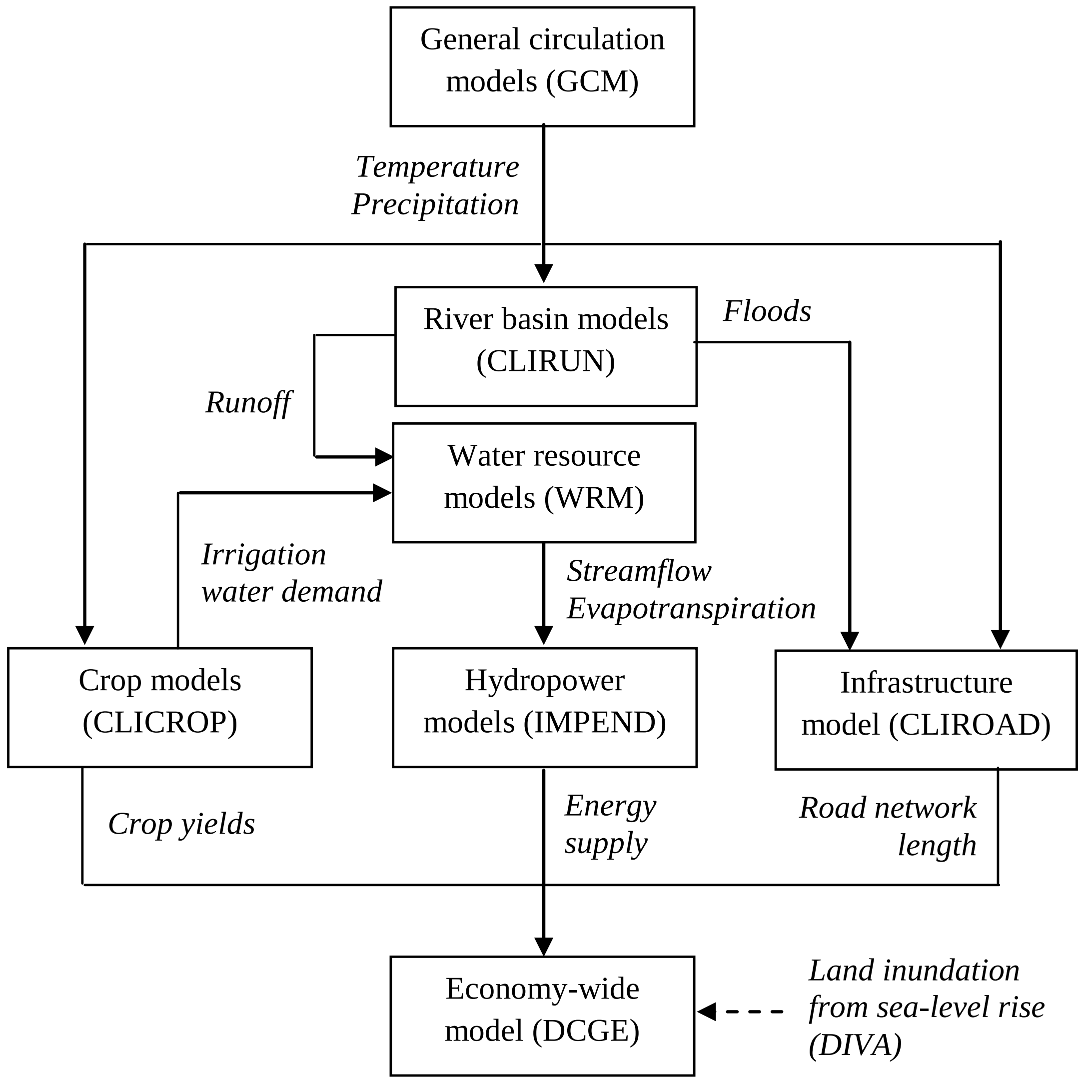
- Most developing countries are “climate-takers”
  - Domestic mitigation will not stop global climate change (i.e., like a small-country assumption)

- Low-income countries will have to adapt to climate change, even though they have not contributed much to global emissions
  - They may benefit from new and/or “late-mover” technologies (e.g., cell phones and solar energy)
  - But adapting to climate change is likely to require a more *expensive*, *skill-intensive* development strategy

Mozambique

- Low-income country (US$ 370 p.c. | US$ 790 p.c. PPP)
  - Very little infrastructure and low productivity after years of civil war
- Extremely favorable agro-ecological conditions
  - Large country with lots of uncultivated land (but would need clearing)
  - Most of the population are small-scale subsistence farmers
- Supposedly one of the five most vulnerable countries to climate change (based on donor assessments)
  - Long coast-line and at the end of the Zambeze river delta
- Widespread and severe poverty
  - 75% of the population live on less than US$ 1.25 per day

Integrated modeling framework



Four climate change scenarios

- Global wettest and driest scenarios
- Local wettest and driest (i.e., for Mozambique)

- Selected using “Climate Moisture Index” (CMI)
  - Global wet/dry are actually dry/wet scenarios for Mozambique
  - Global dry scenario is very wet scenario for Zambezi River Basin and Southern Africa

- Must use multiple GCMs

- Must take regional approach

Scenario	CMI
Global wet	-0.6
Global dry	+9.3
Local wet	+33.0
Local dry	-58.6

Biophysical impacts

Agriculture and crop yields

- CLICROP models: 14 crops in 3 sub-national regions
- Captures daily T and P effects, water-logging and irrigation water demand (exclude CO_2 fertilization)

Average change in yield from baseline, 2041-2050 (%)

	Global Wet	Global Dry	Local Wet	Local Dry
Cassava				
North region	2.01	-3.44	-0.09	-6.51
Center region	-4.75	-6.24	-3.10	-6.21
South region	-9.36	-3.27	0.36	-3.20
Maize				
North region	1.27	-1.32	-2.92	-1.87
Center region	0.34	0.64	-3.04	-5.59
South region	3.49	6.37	-4.36	-3.95

Biophysical impacts

Flooding and road infrastructure

- CLIRUN: River basin models predict change in flood RPs
- CLIROAD: Captures P, T and flood damages on roads

- Global Dry has most flooding (regional basin effect)
- This damages roads more than in other scenarios

	Change in national road network length relative to baseline, 2050 (%)
Global Wet	-16.1
Global Dry	-22.4
Local Wet	-11.9
Local Dry	-2.1

Biophysical impacts

Hydropower generation

- IMPEND model determines hydropower generation based on streamflow and installed/planned investments
- Hydropower declines in all scenarios, but Mozambique remains a net energy exporter regardless

Average annual production (Giga watt hours per year)

	Baseline	Change from baseline (%)			
		Global Wet	Global Dry	Local Wet	Local Dry
2003-2010	13,533	1.09	0.26	-3.07	-5.31
2011-2020	17,391	-2.35	-0.55	-7.36	-6.62
2021-2030	26,991	-1.82	0.40	-5.30	-6.75
2031-2040	26,087	-3.94	-0.62	-8.08	-7.26
2041-2050	25,479	-3.37	-0.98	-4.15	-12.04

Economic impacts

Dynamic CGE model

Detailed economic structure:

- 4 regions (3*x* rural, urban)
- 33 sectors (17 in agriculture)
- 7 factors (3*x* land, 3*x* labor, capital)
- 20 households (rural/urban quintiles)

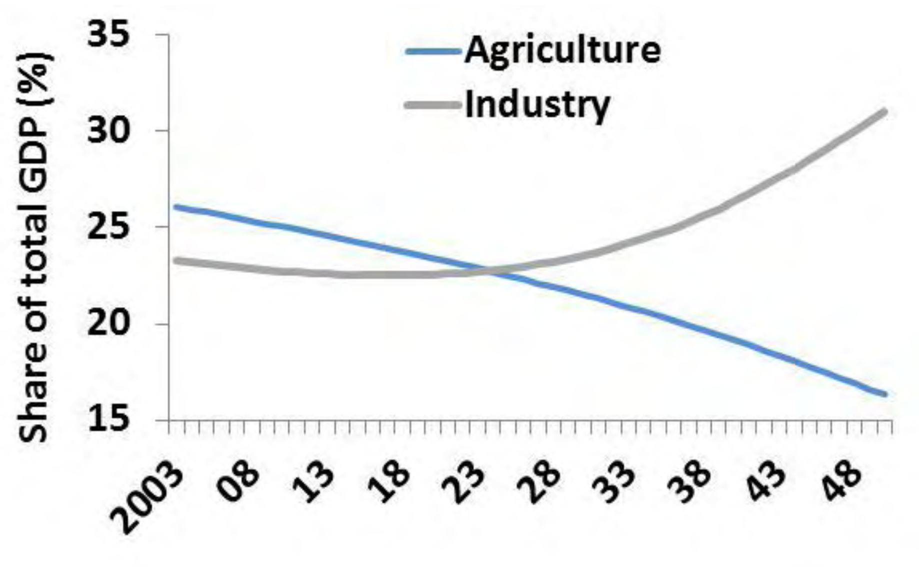
Recursive dynamic:

- Capital accumulation on past investment
- Exogenous TFP (linked to sector models)
- Autonomous adaptation ("typical farmer")

Economic impacts

Baseline "no climate change" scenario

- Baseline specifies a future scenario reflecting development trends, policies, and priorities without climate change.
- Assumes a reasonable trajectory for growth and structural change until 2050 (e.g., falling agricultural GDP share).
- Consistent with sector models' baselines (i.e., CGE captures individual baselines and their interactions within a market economy)



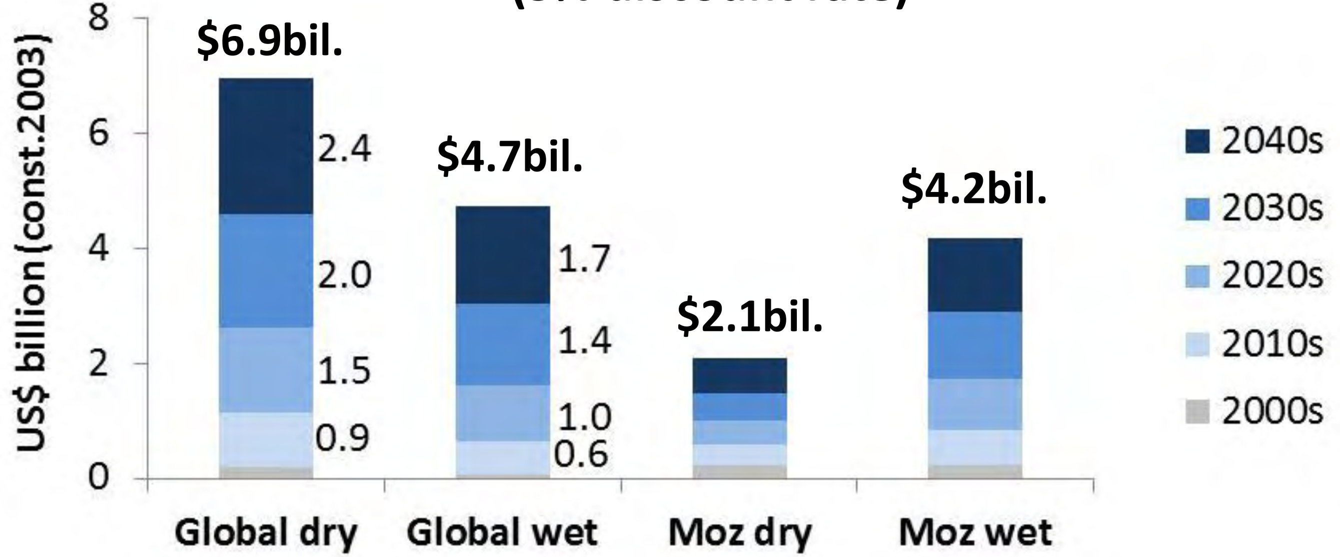
3.7% average annual GDP growth

Economic impacts

Economywide damages

- Effects of climate change are negative and grow with time
- Large declines in national welfare by 2050 (-18.2% in Global Dry)
- Wide variation in impacts across CC scenarios
- In worst scenario adaptation cost is US$7 billion ($390 mil. p.a.)

Cumulative deviation in total absorption, 2003-2050 (5% discount rate)

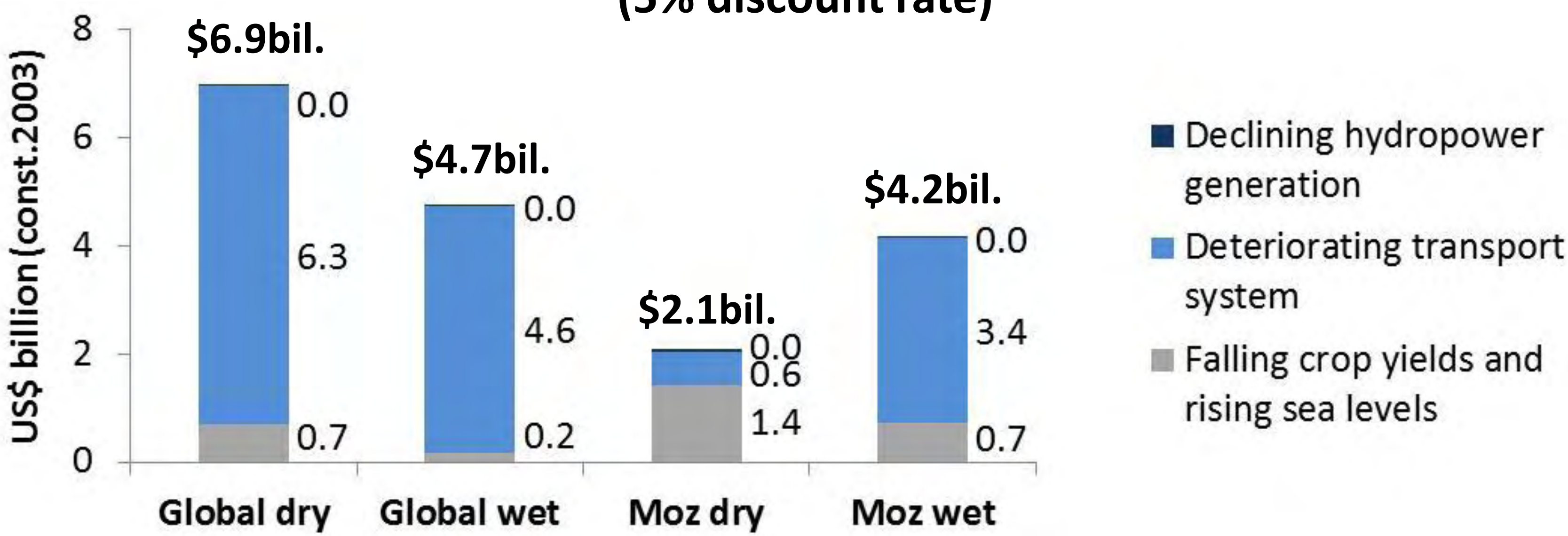


Economic impacts

Decomposition of impact channels

- Road network is the main impact channel due to major flooding within the trans-boundary river basin.
- Crop yield damages are most severe in Local Dry scenario.
- Hydropower reduces surplus energy exports but not welfare.

Cumulative deviation in total absorption, 2003-2050 (5% discount rate)



Adaptation investments

Step 1: Transport system investments

- Sealing unpaved roads reduces worst case CC damages by 1/3 with little or no additional costs (i.e., advisable even without CC).

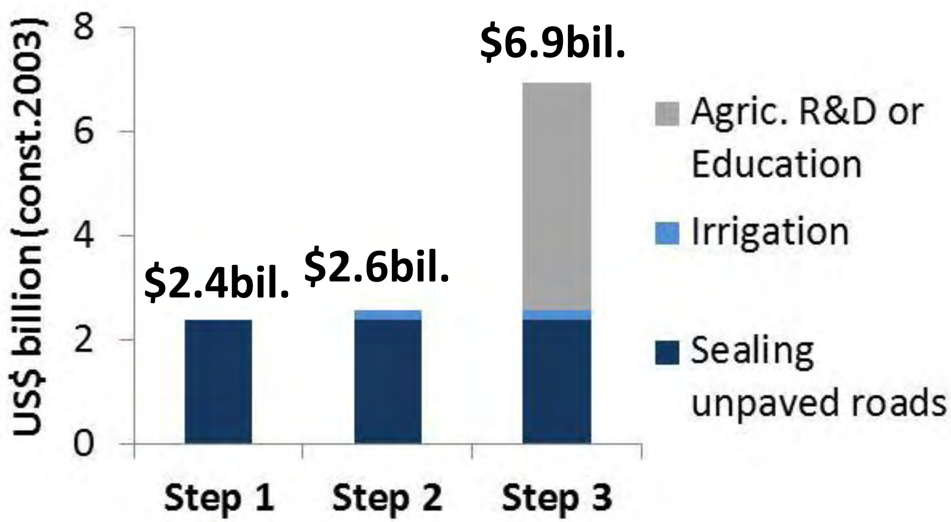
Step 2: Irrigation investments

- 1 million hectares of new irrig. land only slightly reduces CC damages.

Step 3: Agricultural R&D or education investments

- Raising agricultural productivity by 1% each year offsets remaining damages (e.g., further 50% maize yield increase by 2050).
- Providing primary educ. to 10% of the 2050 workforce also offsets damages.

Reduction in CC damages, 2003-2050 (5% discount rate)



Exactly offsets worst CC scenario (Global dry)

Key results from the case study

- Without public policy changes, the worst scenario results in a net present value of damages of nearly US$7 billion.
  - Equal to an annual payment of US$390 million (5% discount rate).
- Hardening rural roads reduces worst case impacts substantially, restoring approximately 1/3 of lost absorption.
- Remaining welfare losses could be regained with improved agricultural productivity or human capital accumulation.
- Investments costs required to restore welfare losses are subject to debate, but are reasonably less than US$390 million per year over 40 years.

General recommendations

- Best adaptation to CC may be more rapid economic development leading to more flexible and resilient society.
  - Adaptation strategies should reinforce development objectives
- But climate-specific interventions include:
  - Regional adaptation strategies (e.g., river basin management)
  - Agricultural research & extension ("no regret" option)
  - Seal unpaved roads (makes sense even if no CC)
  - Soft adaptation where possible (e.g., land use planning: most capital in low-income countries has not yet been invested)
  - Hard adaptation should be scrutinized (e.g., dykes may reduce risk but increase exposure)

Lecture summary (1)

- **Climate change science**
  - Heightens uncertainty for policy makers and researchers
  - We should focus on extreme events (i.e., droughts, floods, etc.)
  - Science is advancing its projections (from uncertainty to risk assessments)

- **Mitigation policy**
  - LDCs should search for cleaner sources of energy (less emphasis on them reducing energy use)
  - Reducing carbon use often means a new form of structural transformation
  - Low carbon development may mean not using your natural resources, and hence adopting a more expensive development strategy
  - Carbon pricing is necessary and effective, but it’s also politically difficult (esp. if a country acts alone)

Lecture summary (2)

- **Adaptation strategies**
  - Faster economic development is a form of adaptation
    - Building a better-educated, more flexible and resilient society
  - But there are policies/investments specifically needed to reduce climate vulnerability
    - Sometimes its "doing things differently", rather than "doing different things"

Way forward for dev. economics

- Development economics must address the challenges posed by climate change
  - Climate science is progressing, and so must our development toolkit

- Three areas where more research is needed:

  - Work across disciplines (the devil is in the details)
    - Engineers, agronomists and scientists
    - Very important for large-scale lumpy investments (e.g., energy, infrastructure)

  - Incorporate risk into our policy prescriptions
    - Qualify our prescriptions with probabilities on returns

  - Model autonomous adaptation at firm/farm/household level
    - No more “dumb” or “genius” farmers in our models