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Induced Technological Change in the Stabilization of CO_2 Concentrations: scenarios using an econometric model

A presentation to the symposium on "Avoiding dangerous climate change", Met Office, Exeter, 1-3 Feb 2005

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The other contributors to the main paper reporting the results are Jonathan Köhler, Haoran Pan and Sarah Winne.

February 2005

Outline

- The problem
- Effects of technological change on modelling mitigation
- Indication of results
- Why the costs of stabilization are so low
- Conclusions

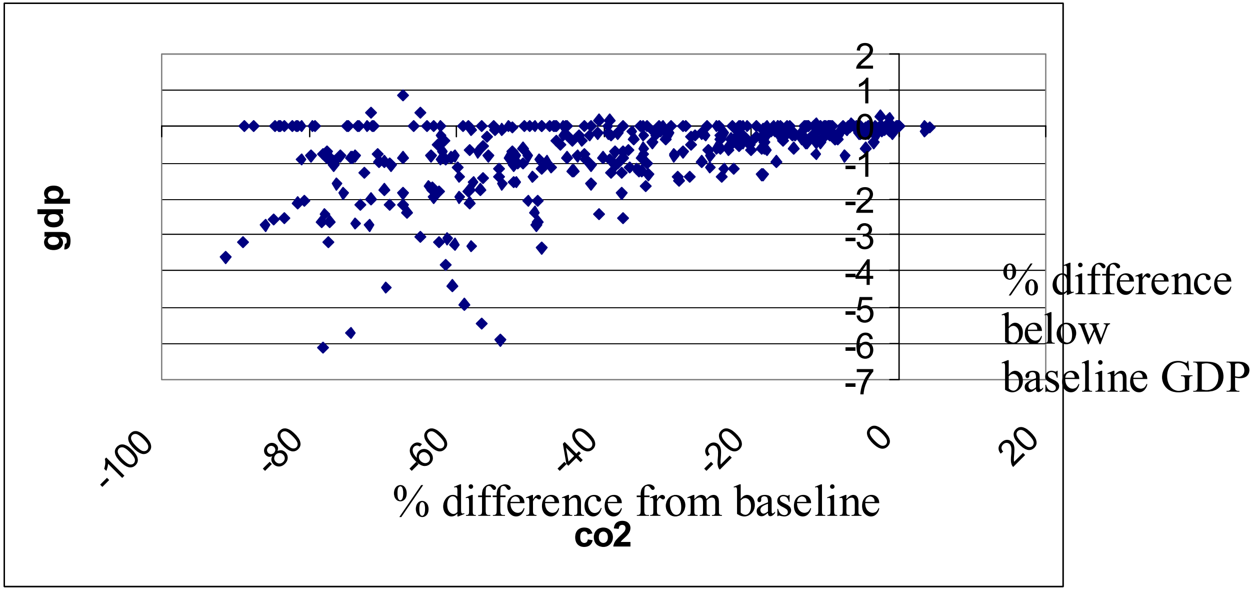
The stabilization problem

- Deep-rooted carbon “addiction”
  - but many plausible low-carbon options
  - and long periods to adjust (now-later debate and signals)
- Hi-carbon is seems the likely baseline
  - at $50/bbl oil price, coal-fired power is economic
  - low oil prices make the problem worse
- Carbon taxes seem unlikely
  - efficient but PR campaigns make taxes off the agenda
  - international equity schemes face opposition
- The research agenda: technology-economy interactions

The treatment of technological change in published results

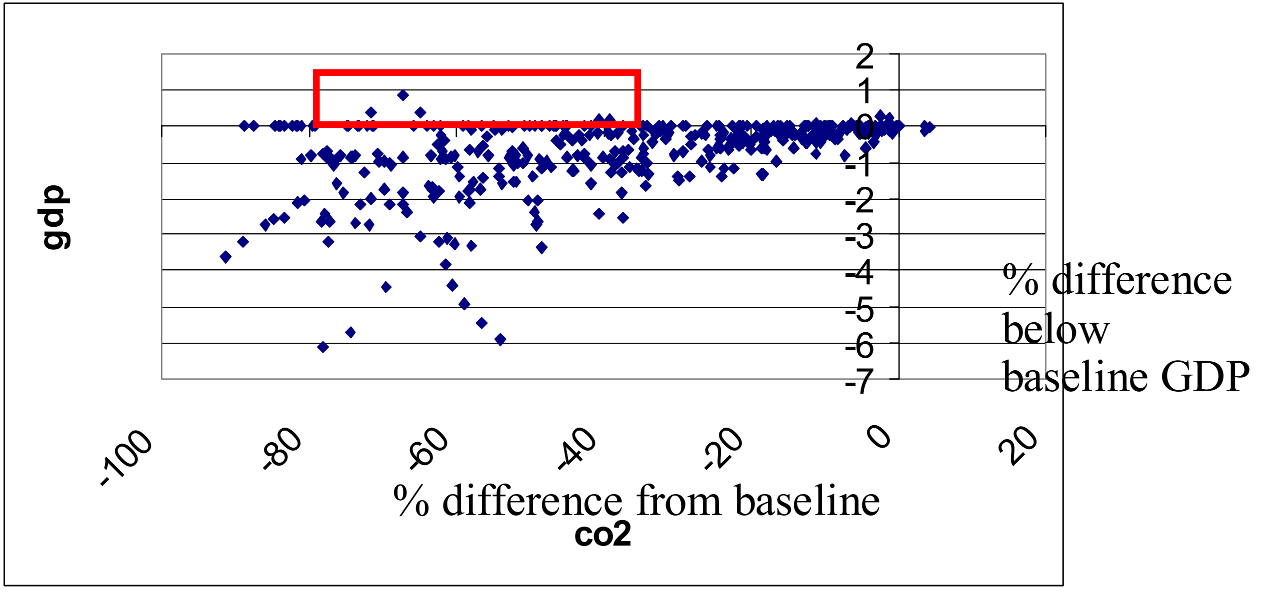
- **Usual assumption has been of autonomous growth in energy efficiency, constant across all economies: therefore no effect on efficiency from stabilisation policies**
- **Good evidence that**
  - **higher relative prices of energy lead to increased efficiencies**
  - **costs of renewable power will fall as markets develop**
- **New research:**
  - **modelling of endogenous technological change (bottom-up and top-down) and implications for policy action**
  - **low-carbon paths may be low-cost, even beneficial, global options**

Cost of emission reductions for stabilization varies widely due to models used and baseline assumptions



Note: The points shown are results from stabilization scenarios based on 6 SRES baseline scenarios, 6 models and many time periods from 2000 to 2100.

Cost of emission reductions for stabilization varies widely due to models used and baseline assumptions



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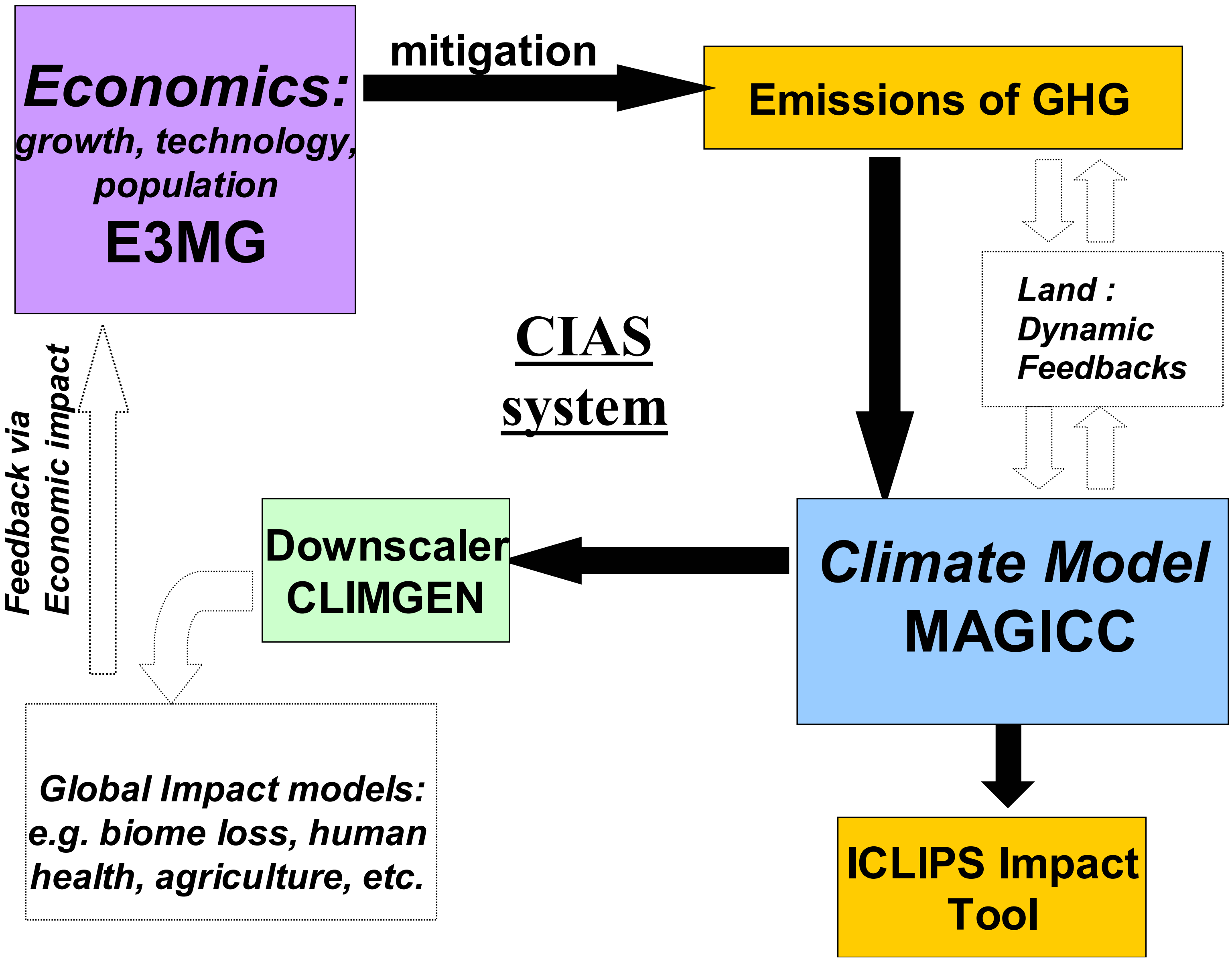
Conclusions from the meta-analysis* of mitigation costs

- Widespread use of equilibrium models based on one year's data for projections to 2100
- Deep CO_2 reductions appear in many studies with negligible costs
- GDP-CO_2 relationship is strongly model-dependent (reliability of results?)
- No induced technological change, with GDP largely assumed

*Terry Barker, Jonathan Koehler and Marcelo Villena, 'The costs of greenhouse gas abatement: a meta-analysis of post- SRES mitigation scenarios', *Environmental Economics and Policy Studies,* Vol.5, 2002, pp. 135-166.

UK Tyndall Centre: modelling of induced technological change (ITC)

- Investigations use the newly developing Tyndall Community Integrated Assessment System
  – Linking economic system, physical climate system and impacts of climate change
- E3MG (Economy-Energy-Environment Model of the Globe) is the key economic component of this system enabling study of technological change and mitigation costs
  – Designed and built by teams in
    - Tyndall (Cambridge) and
    - Cambridge Econometrics (thanks to data team led by Rachel Bevan and estimation team led by Sebastian de-Ramon)

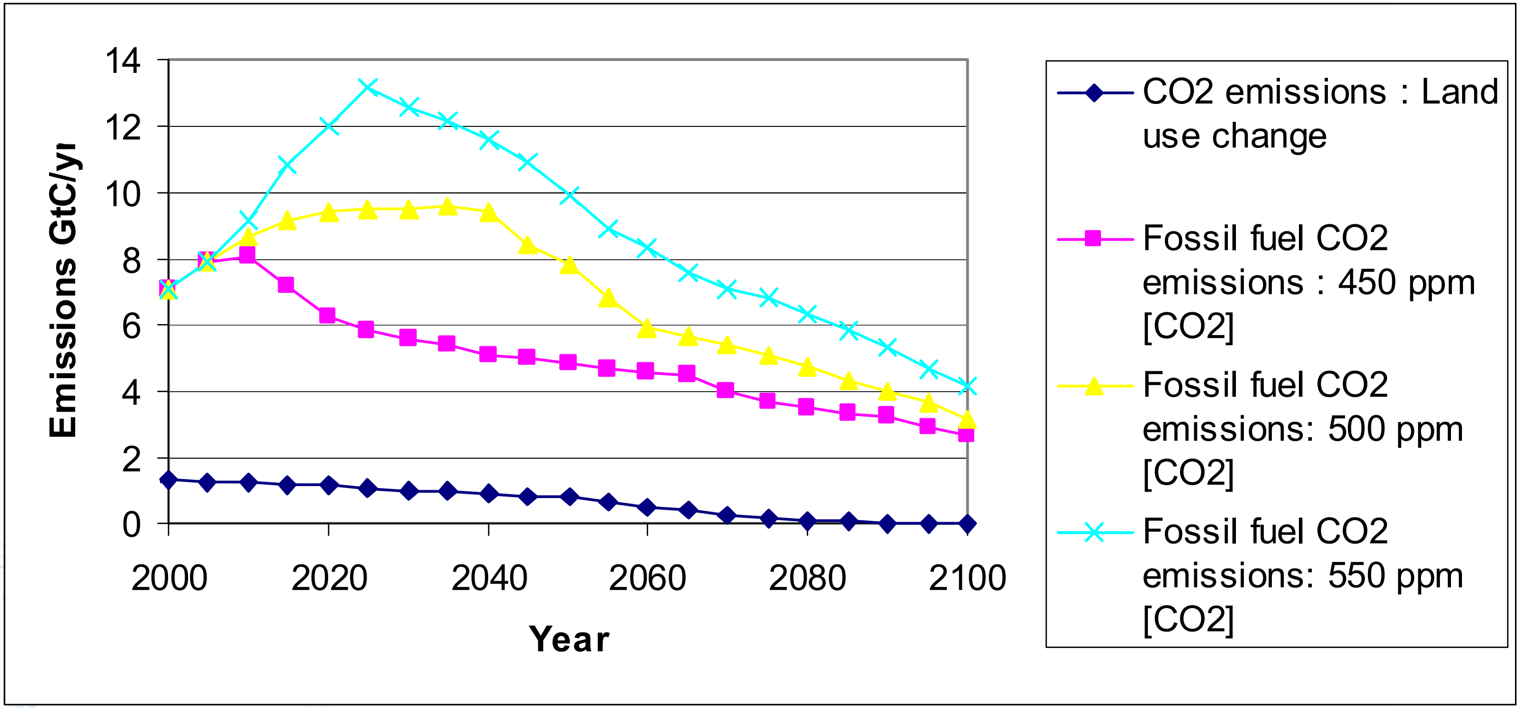


Economics:
growth, technology, population
E3MG
mitigation
Emissions of GHG
CIAS system
Land : Dynamic Feedbacks
Feedback via Economic impact
Downscaler CLIMGEN
Climate Model MAGICC
Global Impact models: e.g. biome loss, human health, agriculture, etc.
ICLIPS Impact Tool

E3MG: a medium- to long-run E3 global model 1970-2100

- Use of cointegration techniques to identify long-run trends from panel data
  - 20 world regions, 21 energy users, 12 energy carriers, 42 industries, 14 atmospheric emissions
- With explicit autonomous & induced TC
  - Anderson & Winne model of induced change with learning
  - technological progress (incl. R&D) in many equations e.g. energy use
  - projections of IO coefficients with new technologies
- Focussed on fiscal instruments for mitigation and diffusion of technology
  - » ETS, carbon taxes, R&D incentives

Examples of emission pathways used to derive the stabilisation scenarios



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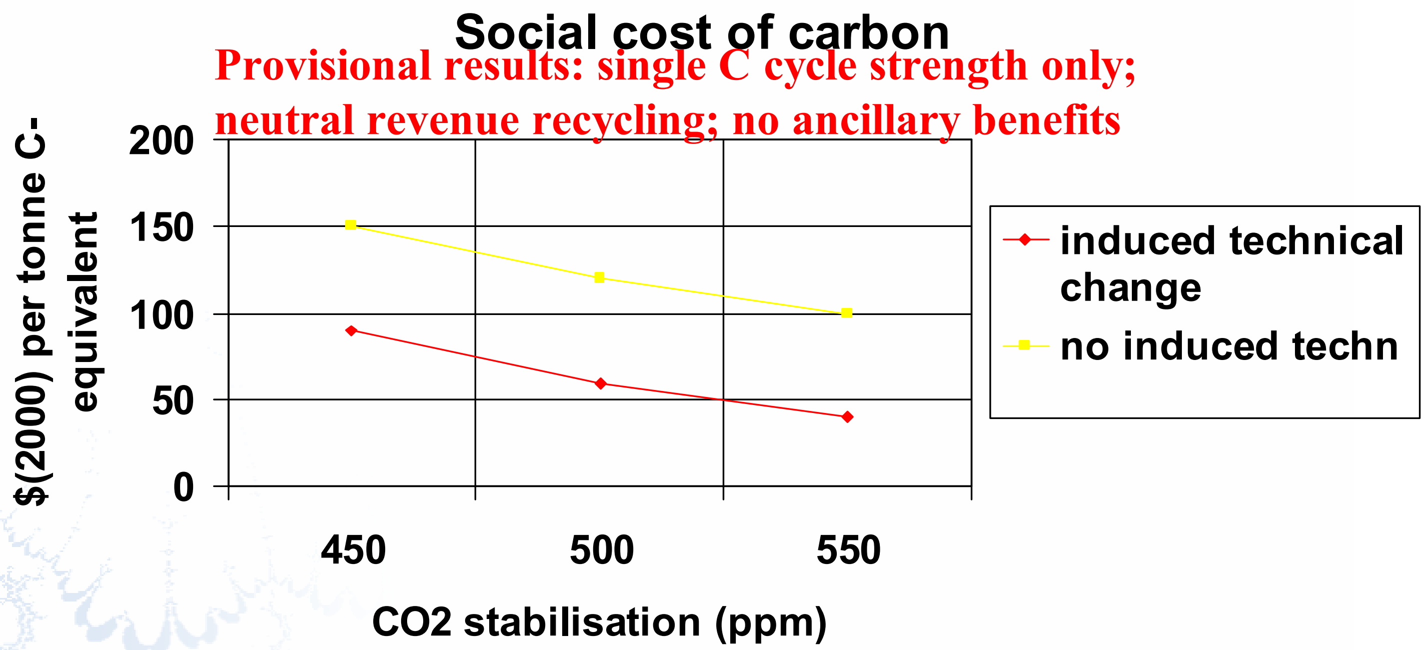
Estimating effects of ITC

- Costs are estimated by comparing baseline and stabilization scenarios
- Technological change is induced by learning-by-doing, reducing costs and accelerating adoption of new technologies
- Carbon tax rates are computed to meet stabilisation targets using a single estimate of the carbon cycle
- The costs (GDP, loss of fossil fuel output, etc) are associated with these tax rates
- The effects of ITC are calculated by comparing model results with and without the ITC learning curves

Results

- Understanding the global E3 system
  - 1970-2002
  - Baseline projections to 2100 with and without technological change
- The social cost of carbon
  - At 450, 500, 550 ppm CO_2 concentrations
  - With and without technological change
- Costs of mitigation
  - in terms of GDP effect

The global social cost of carbon: E3MG solutions 2000-2100



Source: E3MG2.0sp1r1, 6 scenarios, escalating tax rates with year 2020 tax rates shown.

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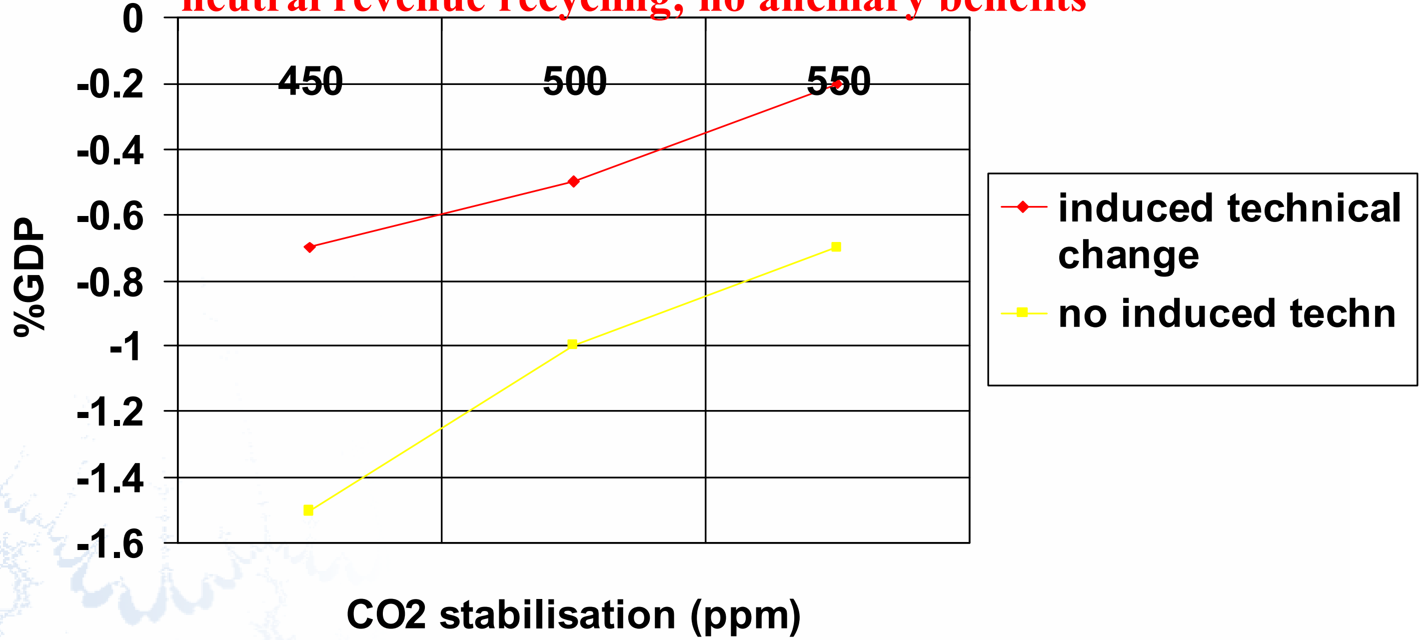
The effects of stabilization on global GDP by 2100: E3MG solutions

Provisional results: single C cycle strength only; neutral revenue recycling; no ancillary benefits



Source: E3MG2.0sp1r1, 6 scenarios, % difference from base in year 2100.

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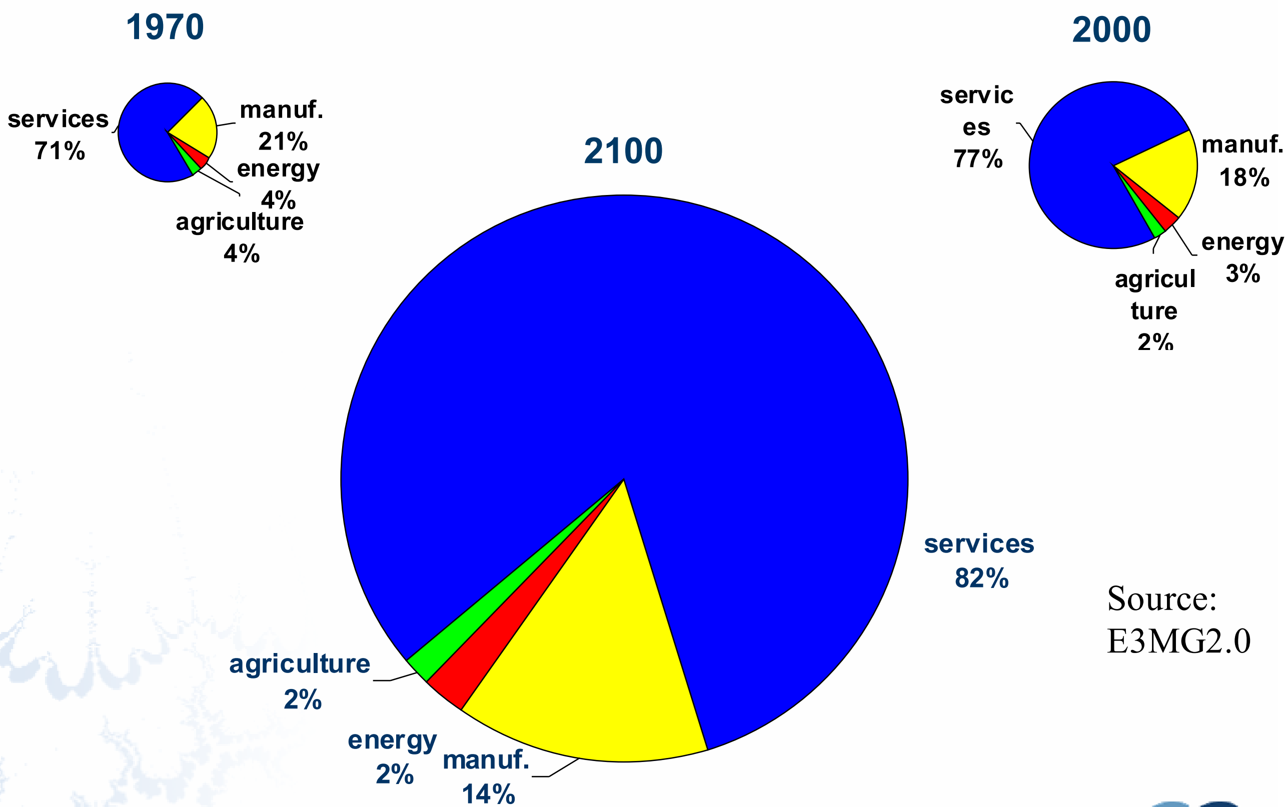
Why are the long-run costs so low?

1) The small shares of fossil-fuel energy in global GDP (3 to 5%)
2) Many of the IPCC post-SRES mitigation scenarios are high-cost scenarios because they assume 100 years of high CO_2 emissions in the baseline
   - these imply substantial future funding of investment in coal and unconventional oil
   - this funding has an alternative use: technology-driven energy-saving & renewables
3) The ease of substitution to low-GHG-emission energy products and processes in the long-run when new technologies can be developed

Global GHG mitigation in context: energy in world GDP



Source: E3MG2.0

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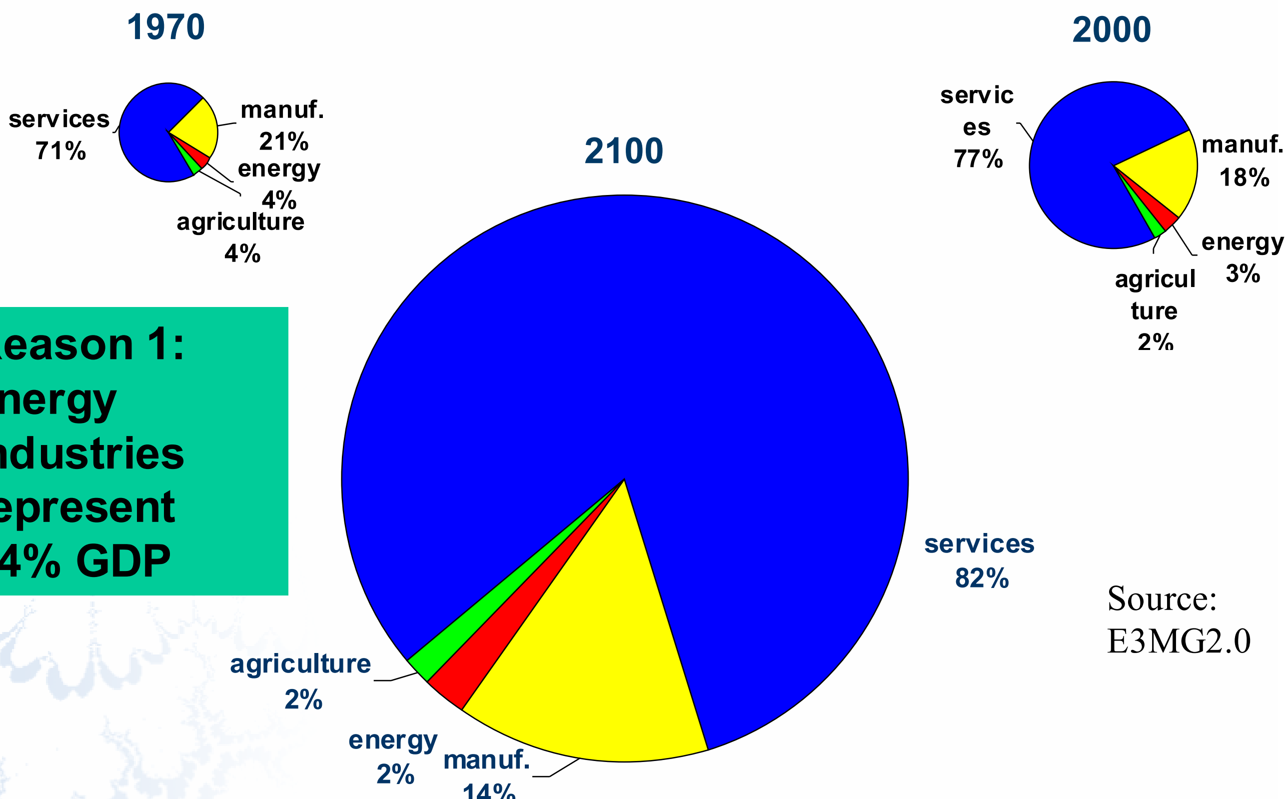

Reason 1: energy industries represent <4% GDP

Source: E3MG2.0

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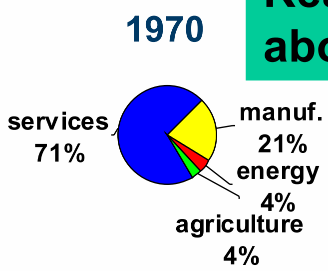
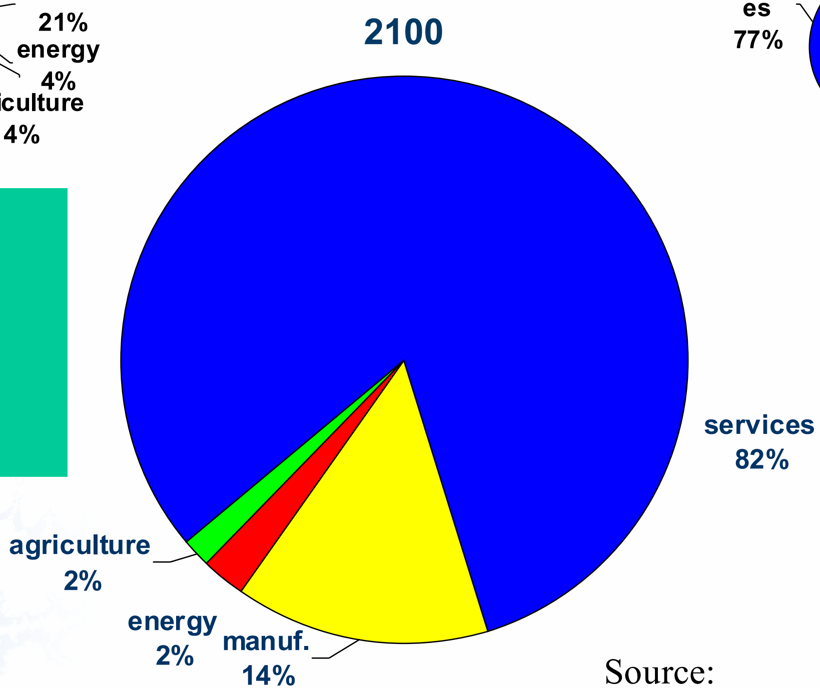
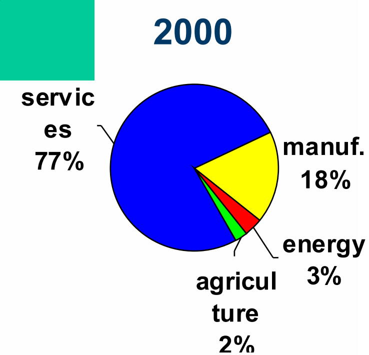
Global GHG mitigation in context: energy in world GDP

Reason 2: future energy use is about growth & investment







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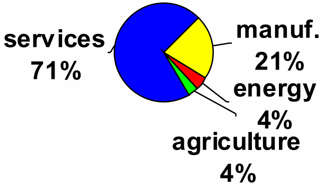

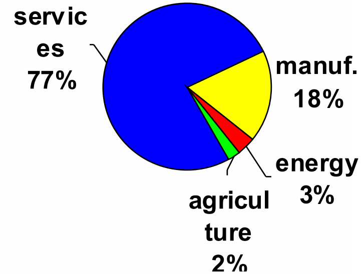

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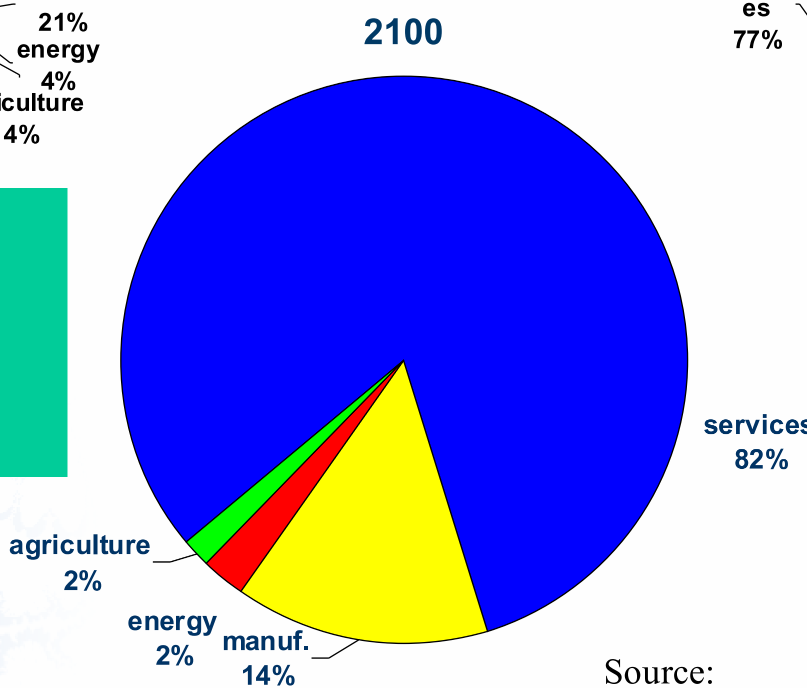

Reason 3: substantial substitution in the long run

Source: E3MG2.0

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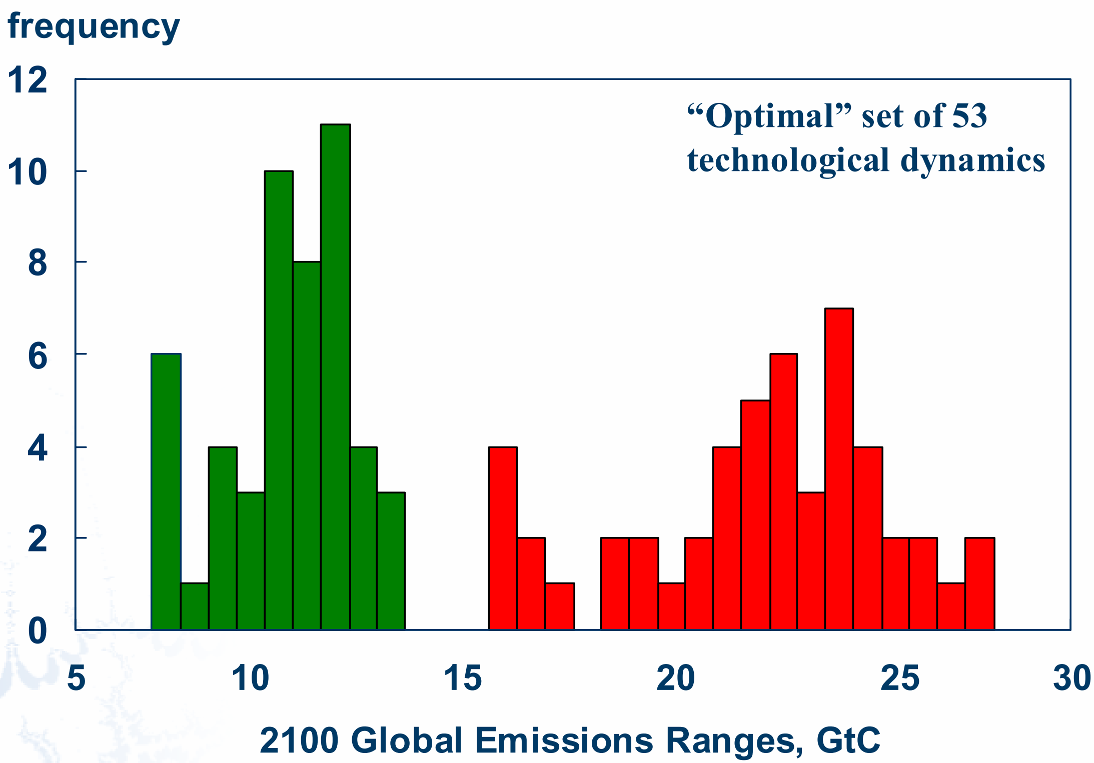
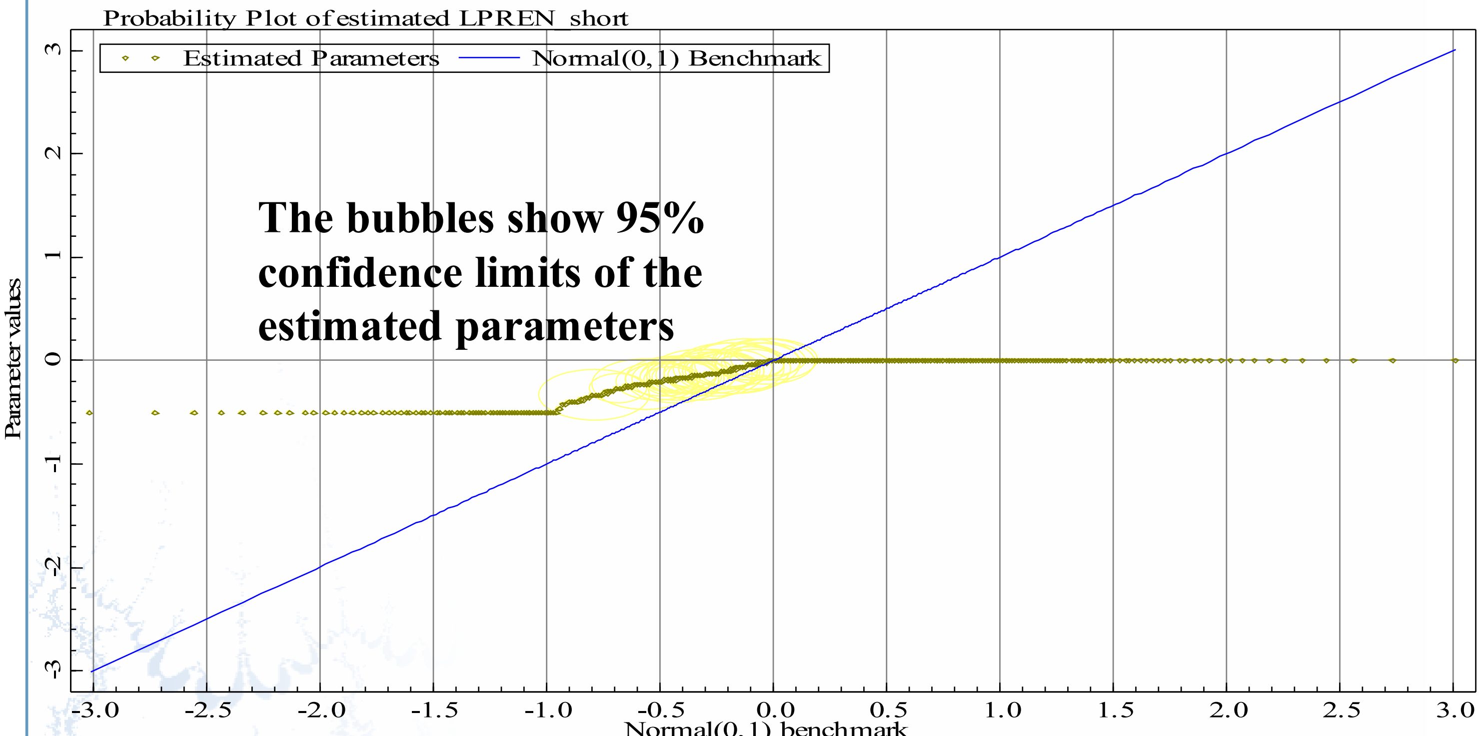
Future technological clusters: a global choice



Source: A. Gritsevskyi, N. Nakicenovic (2000), Modeling uncertainty of induced technological change. ***Energy Policy*** **28 (2000) 907-921 (IIASA, Laxenburg, Austria)**

Probability plots for short- and long-run response of fuel use to relative prices



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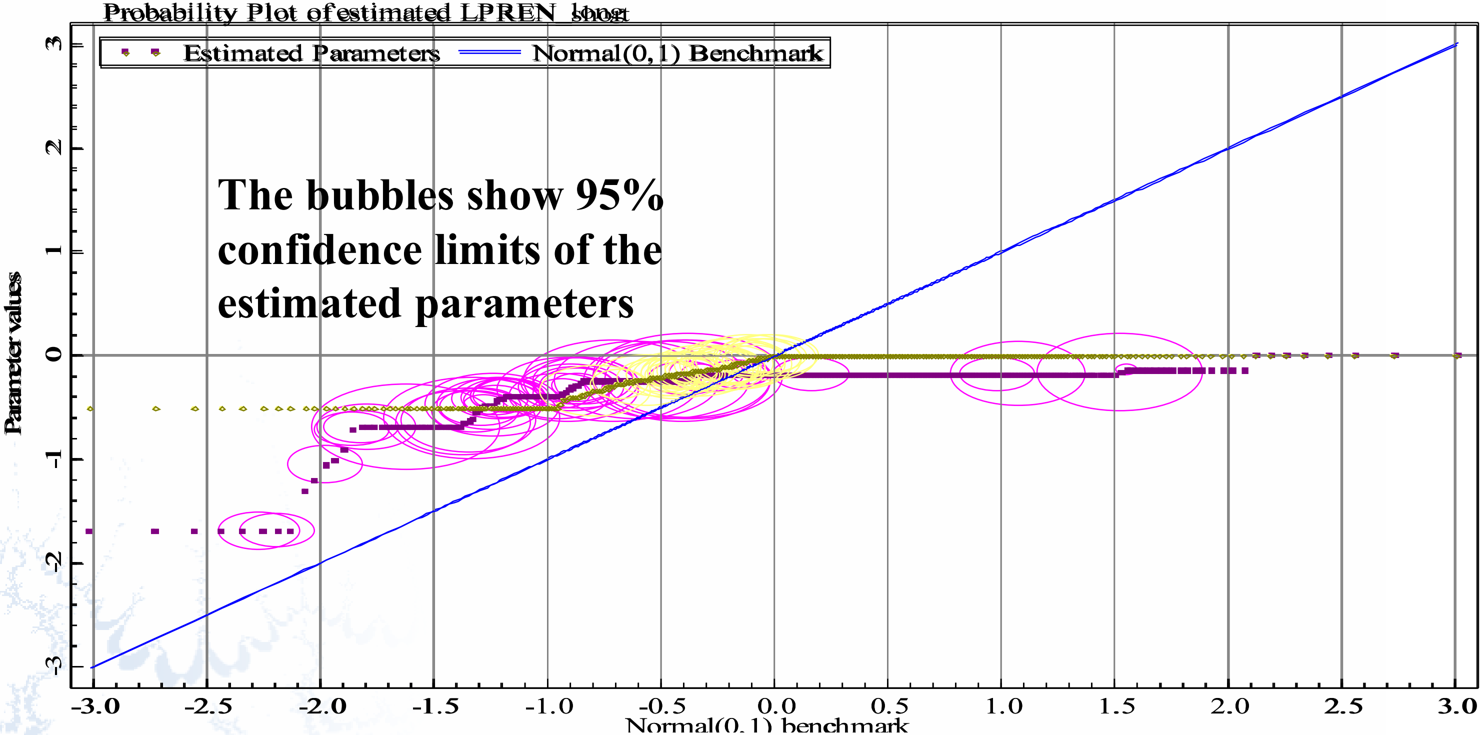

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Conclusions

- Inclusion of induced technological change within integrated assessment models significantly reduces the costs of stabilisation
- The dynamics (short- and long-run responses to real energy prices) change the problem to one of investment as well as allocation
- Cost-effective policies include rising real carbon prices and technologies focused on
  - low-carbon energy sources and carbon capture OR
  - existing fossil-fuel use