Tyndall°Centre
for Climate Change Research

# Doing macroeconomic research on climate-change mitigation for national and international policymakers

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# Outline

- Framing the research question
- Modelling
- Learning from the literature
- Examples
  - Effects of UK energy-efficiency policies
  - Policies for global decarbonisation

# Framing the research question

- For the climate change issue, as in all global system-wide issues, the research has to be
  - general: having an understanding of the whole problem and solutions
  - special: with detailed knowledge of the literature, research methods, and results for a particular area within the general problem
- Detailed modelling of countries and institutions requires multi-disciplinary team work

# Cause-and-effect chain for climate change

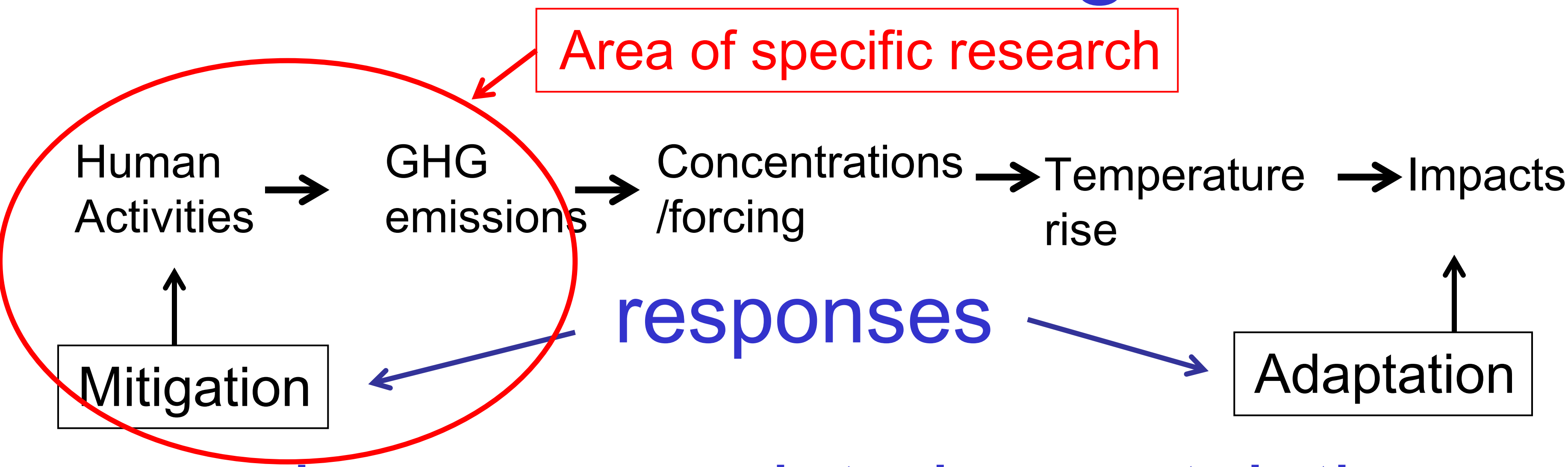

## and some associated uncertainties:

- The rate of economic growth
- The rate of technological change
- The carbon cycle and the mix of GHGs and other atmospheric emissions
- Climate sensitivity and the take up of heat by the oceans
- Local temperatures and population vulnerabilities
- What constitutes “dangerous” climate change?

"The economics of climate change is shaped by the science. That is what dictates the structure of the economic analysis and policies" Stern, 2007, p.1

- The science and the politics ("dangerous") emphasise that the problem is one of uncertainty and risk
- Cost-benefit analysis traditionally used by economists (e.g. Nordhaus, 1994) for the problem is unsuitable
  - It emphasises returns by converting risks to "certainty equivalents"
  - Different risks for different aspects, countries and time periods are treated symmetrically and aggregated
  - Far-future risks are discounted and become insignificant, e.g. catastrophic outcomes such as a sea level rise of several meters over this century (Hanson, 2007)
  - It assumes that assets such as the Amazon rainforest or coral reefs can be substituted by money, when their loss is effectively irreversible
- See Robert S. Pindyck (2013) "Climate change policy: what do the models tell us?", Working Paper 19244, http://www.nber.org/papers/w19244

# Cause-and-effect chain for climate change

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# Framing research on climate change mitigation

- This approach accepts that the uncertainties and risks of unabated climate change justify immediate and strong actions to reduce GHG emissions
- Given the political negotiated targets of global temperature levels and reductions in GHGs, one set of research tasks is to explore effective, efficient and equitable ways of achieving the targets
- Such research involves many disciplines – engineering, economics, computing - and a disaggregated computable model can provide a framework for organising quantitative research
- In particulate a disaggregated macroeconomic model can represent a set of targets and policies and allow simulations country by country of different scenarios to achieve the targets
- The development of structural dynamic economy modelling in Cambridge, starting with the Cambridge Growth Project 1960-1987, continues with Cambridge Econometrics and 4CMR, which support such models

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# Models for climate change mitigation

- All models involve simplification and strong assumptions
- GHG mitigation
  - global problem (atmospheric dispersion of $CO_2$)
  - With long time scales, at least to 2050 for transition to a low-carbon economy
  - Requiring national and international policies
  - With representation of fossil fuels (different $CO_2$ content) and fuel users
  - And detail for critical low-carbon technologies
  - Capable of representing the transformation to a low-GHG economy
- These characteristics suggest that suitable models will
  - Cover countries and/or political groupings of countries
  - Project to 2050 or further
  - Show policies at least by large GHG-emitting countries (if global model)
  - Include a detailed energy system in these countries
  - Allow for the representation of technological change
  - Allow for radical (non-marginal) changes in technology and behaviour

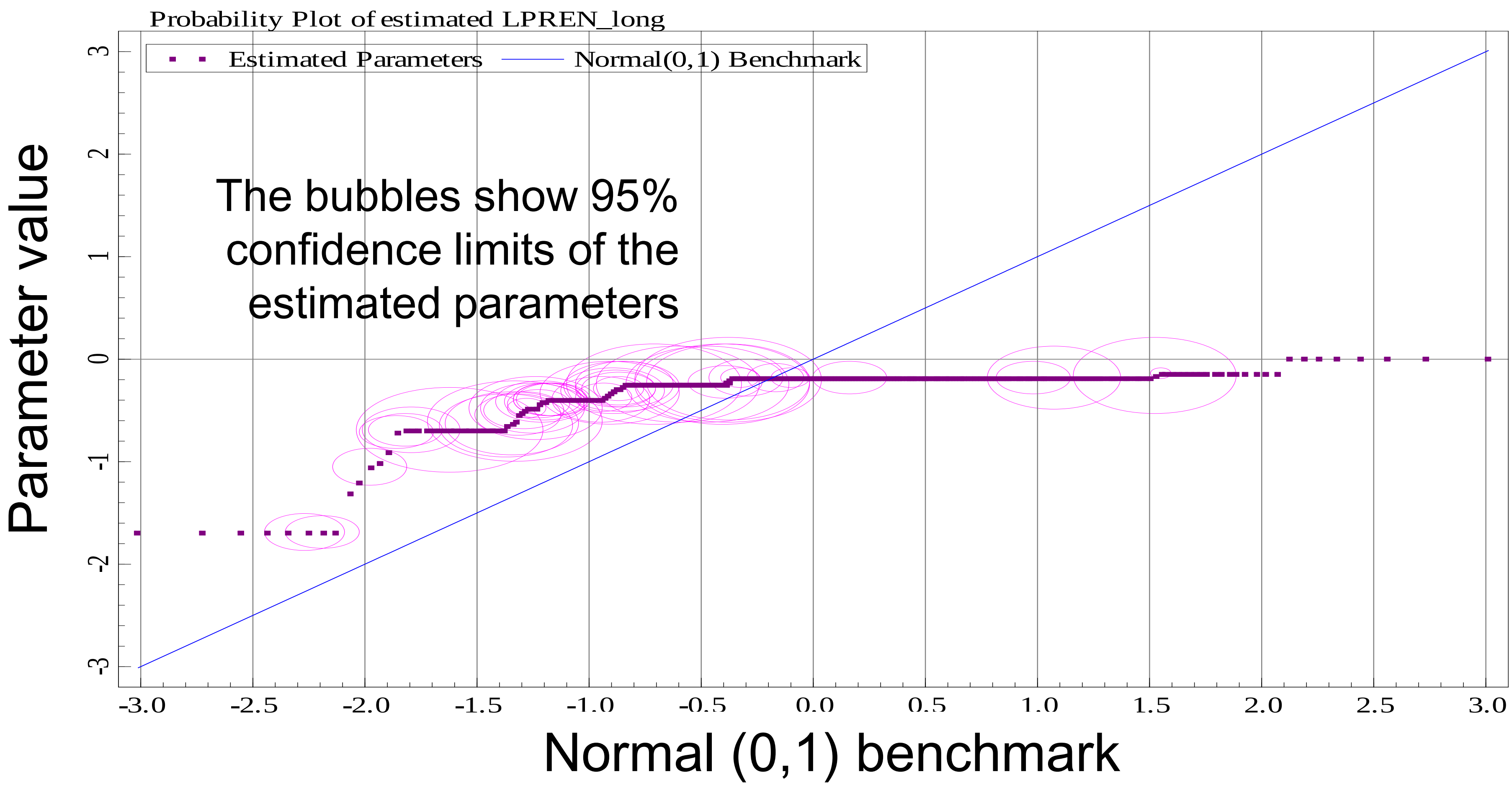
# Features of UK (MDM-E3), EU (E3ME) and world (E3MG) models

- Structural with disaggregation of variables
- Organized around a Social Accounting Matrix
  - i.e. UN's System of National Accounts
- Dynamic
  - behavioural equations with effects from previous outcomes: i.e. history matters
- Estimated on X-section & annual data (e.g. 1970- )
  - identifies current-year responses and long-term trends
  - allows sectoral and regional differences
- Forward-looking
  - projections annually

# Theory and data in the macroeconomic models

- Theory: institutional, demand-led & supply-constrained, dynamic, open as regards policy
- Time-series data of GDP, investment, fossil fuel use, etc, provide the basis for testing theories, estimating causal relationships, and predicting the future
- The approach in the models is to estimate parameters using formal econometric techniques
- In E3MG there are 1000s of equations and many more parameters, each estimated with a standard error
- Standardized normal probability plots, testing for all the parameters in a set being the same, provide a representation of parameters, showing their values and their uncertainties

# Probability plots for long-run responses of fuel use to relative prices in E3ME




Source: Terry Barker and Sebastian A. de-Ramon (2004) 'Testing the Representative Agent Assumption: the distribution of parameters in large-scale models', Working paper, Cambridge Econometrics.

# Interpreting the probability plots

- The estimated parameters cover a wide range and many are significantly different from one another
- The parameters are constrained to be between 0.0 and -1.75 with a clustering about -0.4, i.e. the demand is inelastic to prices
- The assumption that they are all the same, following a normal distribution, appears to be wrong, implying that the “representative agent” assumption is wrong

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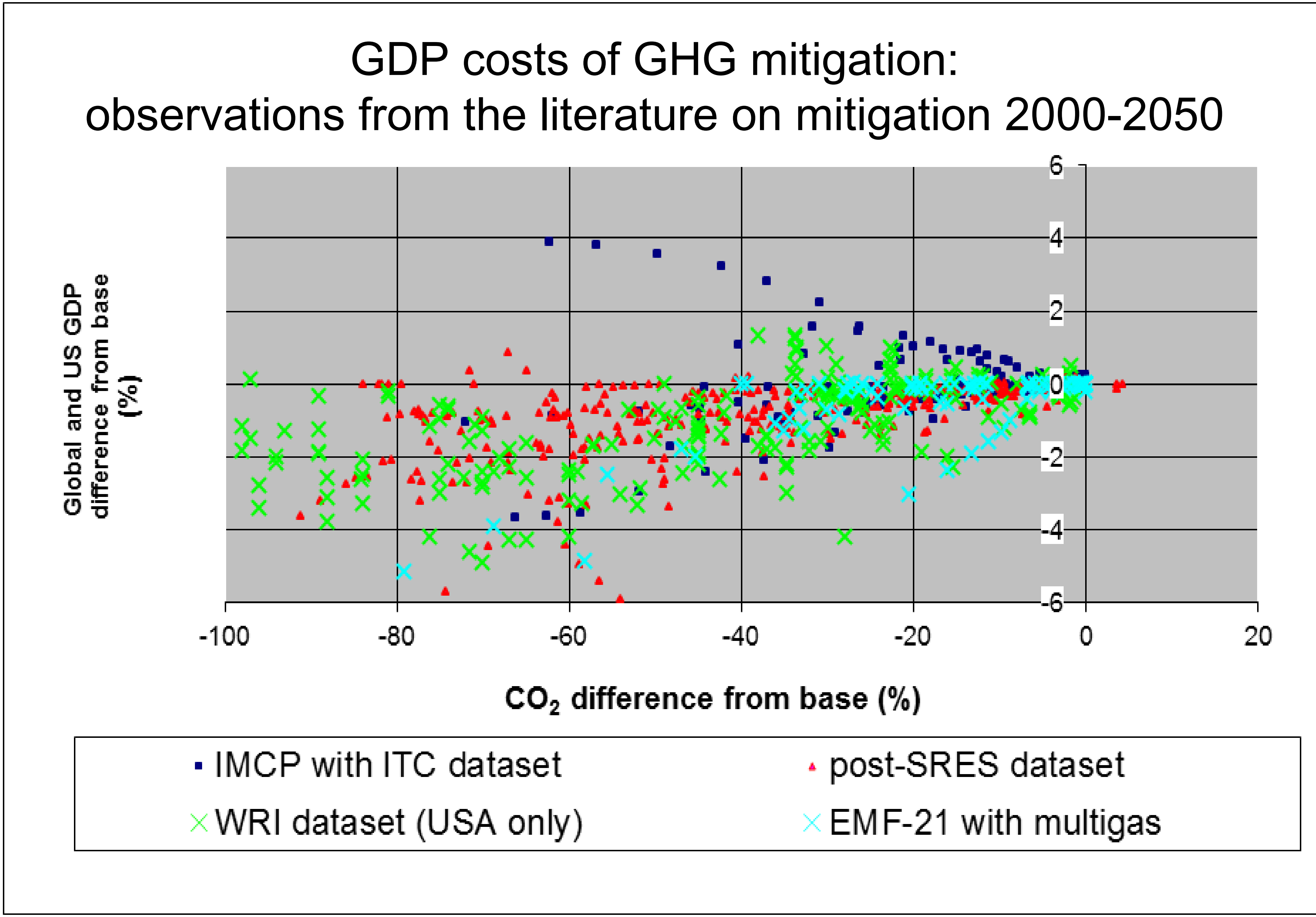
# Learning from the literature

- Policy meta-analysis allows for a quantitative identification of the contributions of different assumptions to the results
- Regression equations are estimated to explain GDP difference from baseline in any year in terms of the $CO_2$ differences and a set of dummy variables indicating the approach and assumptions
- Results allow the imputation of GDP effects from combinations of assumptions




Source: Terry Barker 'The Macroeconomic Effects of the Transition to a Low-Carbon Economy', The Climate Group, "Breaking the Climate Deadlock", July 2008, p. 7.

# Policy meta-analysis: effects on GDP by 2030 of stabilisation policy

(difference from reference case in 2030 as %)

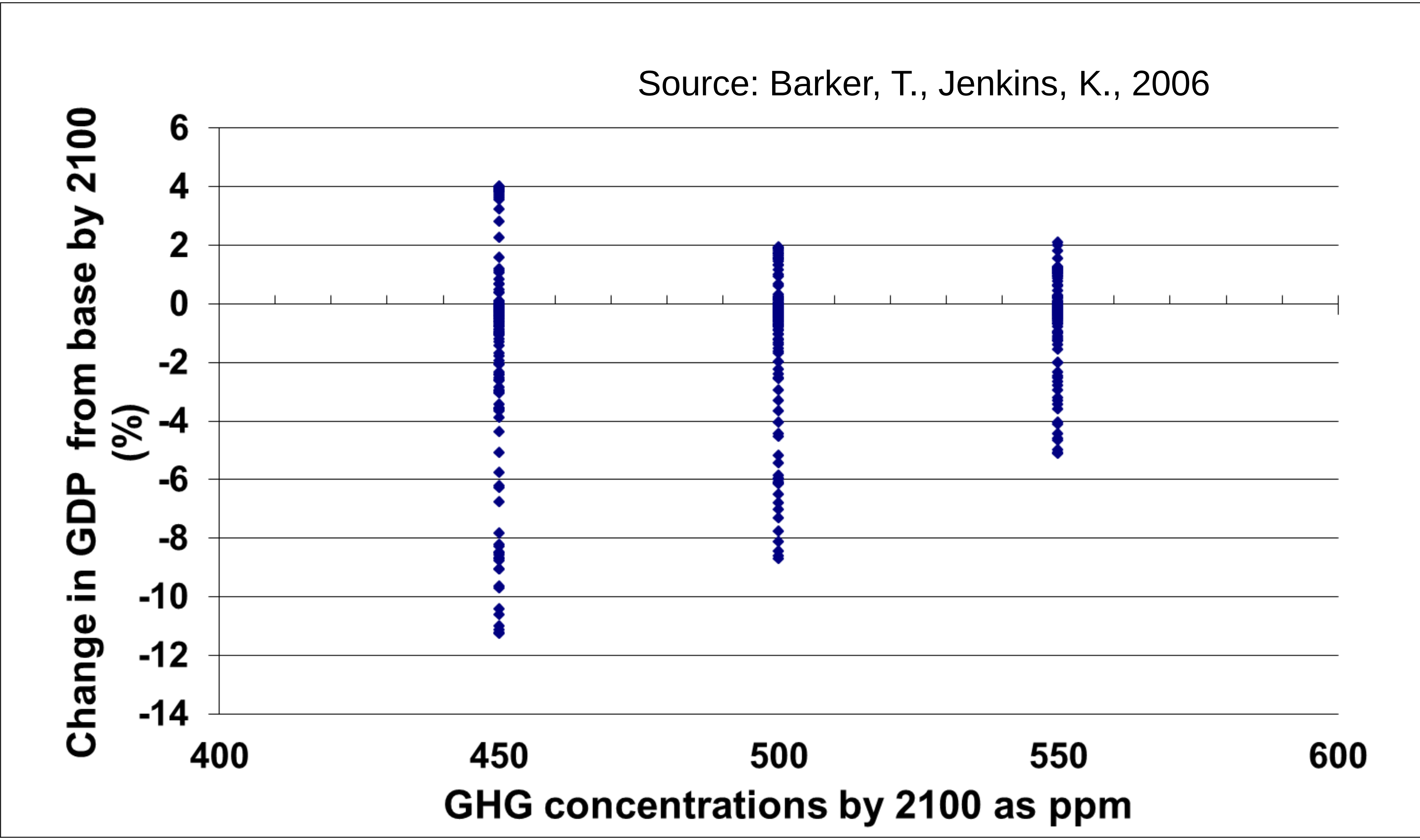
| | 550ppmv | effect | 450ppmv | effect |
|---|---|---|---|---|
| Worst-case assumptions | -3.3 | | -4.4 | |
| assumption: CGE model | | 0.8 | | 1.0 |
| :Kyoto mechanisms | | 0.9 | | 1.1 |
| :'Backstop' technology | | 0.5 | | 0.6 |
| :Climate benefit | | 0.5 | | 0.6 |
| :Non-climate benefit | | 1.0 | | 1.3 |
| :Induced technological change (ITC) | | 2.0 | | 2.6 |
| :Active revenue recycling | | 3.3 | | 4.3 |
| Total extra assumptions | | 9.0 | | 11.5 |
| Best-case assumptions | 5.7 | | 7.1 | |

Source: Barker, T., Jenkins, K., 2006

# Comments on technological change in macroeconomic modelling of mitigation

- Inclusion of induced technological change
  - significantly reduces the costs, especially for stringent mitigation
- General technological change alone insufficient
  - one break-through solution unlikely
  - improvements in energy efficiency are offset in their effects on $CO_2$ emissions by the effects of higher growth on energy demand
- Emission trading schemes/carbon taxes/innovation subsidies are required to provide the price incentives to induce new technologies
- A wide range of technology and system changes may be induced by higher real costs of carbon
  - substantial mitigation options are feasible at relatively low rates of permits/taxes
  - Permit/tax revenues recycled via innovation subsidies give the greatest GHG reductions for a given carbon price

# Effects of mitigation policy on world GDP from models with ITC



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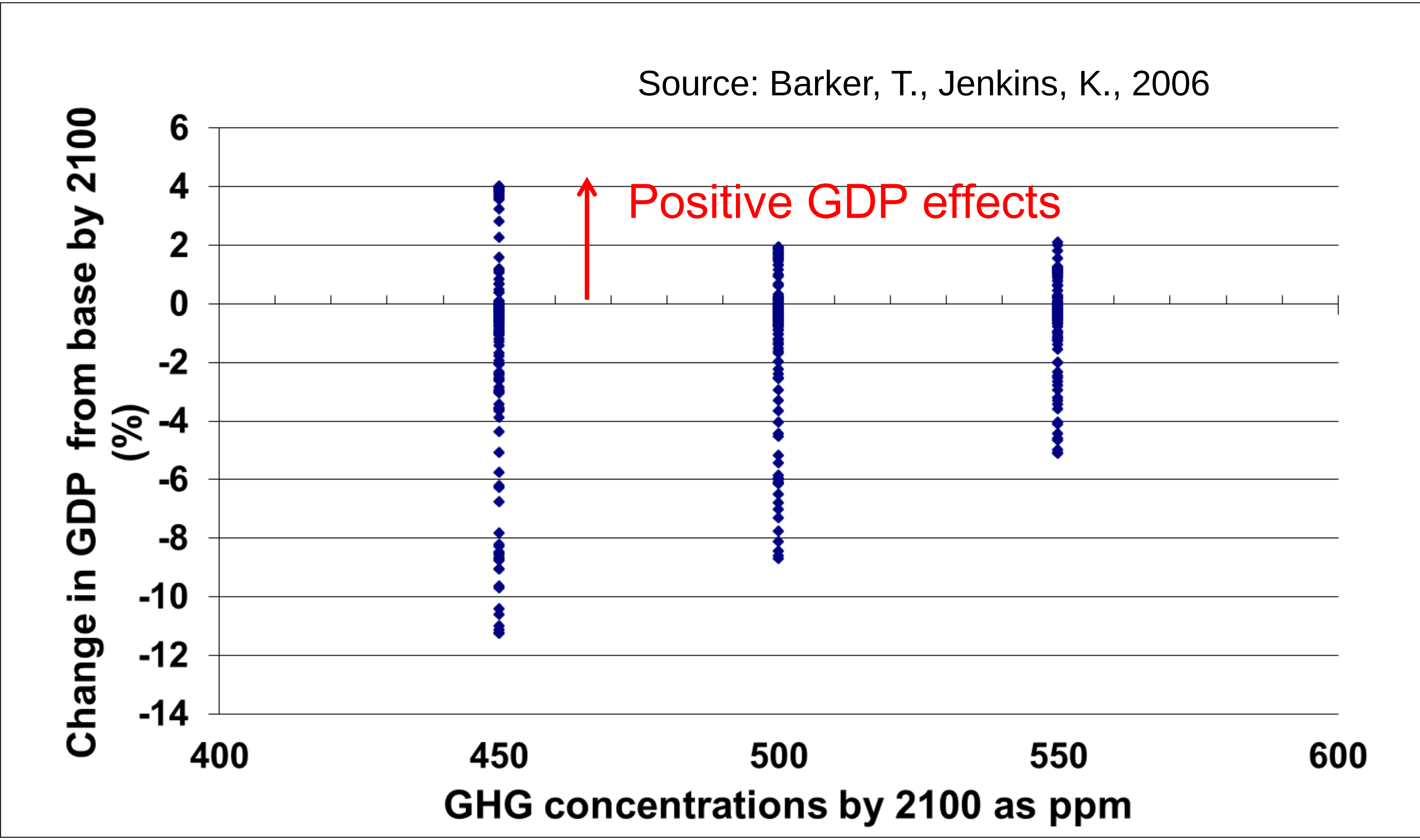

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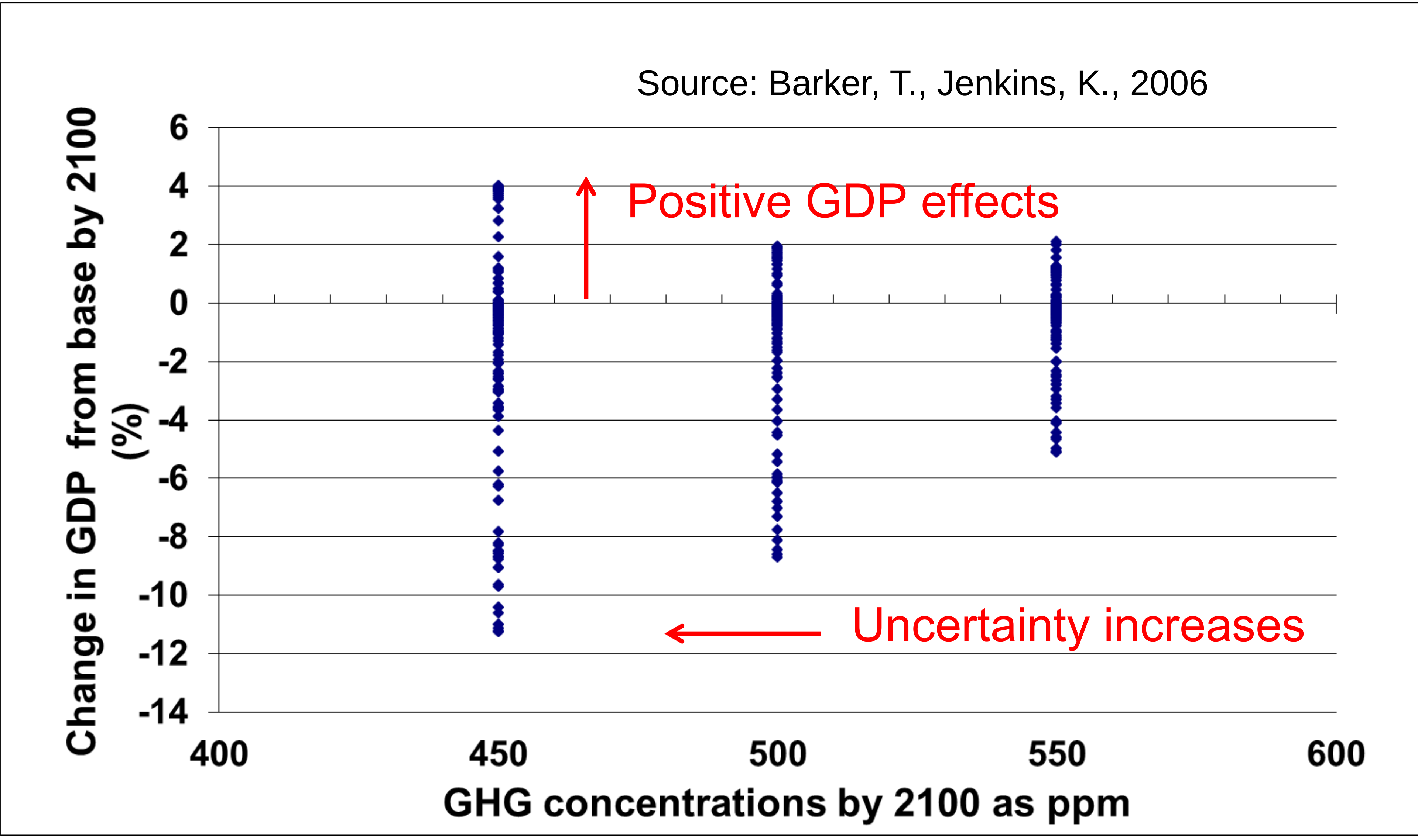

# Comments on active revenue recycling

- Here, revenues from carbon taxes or auctioned emission permits are used to reduce other taxes or raise subsidies
- Depending on the model, the effects can be to increase GDP above baseline
- The revenues allow for compensation to reduce effects of higher fuel prices on vulnerable groups

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# Modelling macroeconomic effects of energy efficiency policies

- Consider energy-efficiency policies (e.g. UK's 2000 policies)
  - prospective reductions in energy consumption & $CO_2$
  - investments for such policies
  - the direct rebound effect (treated as exogenous)
- Estimate macroeconomic (incl. rebound effect), and effects on emissions and the macro economy using scenarios for
  - reference case (no extra policies, efficiency on trend)
  - energy-efficiency policies added to reference case
  - using the MDM-E3 "new economics" model

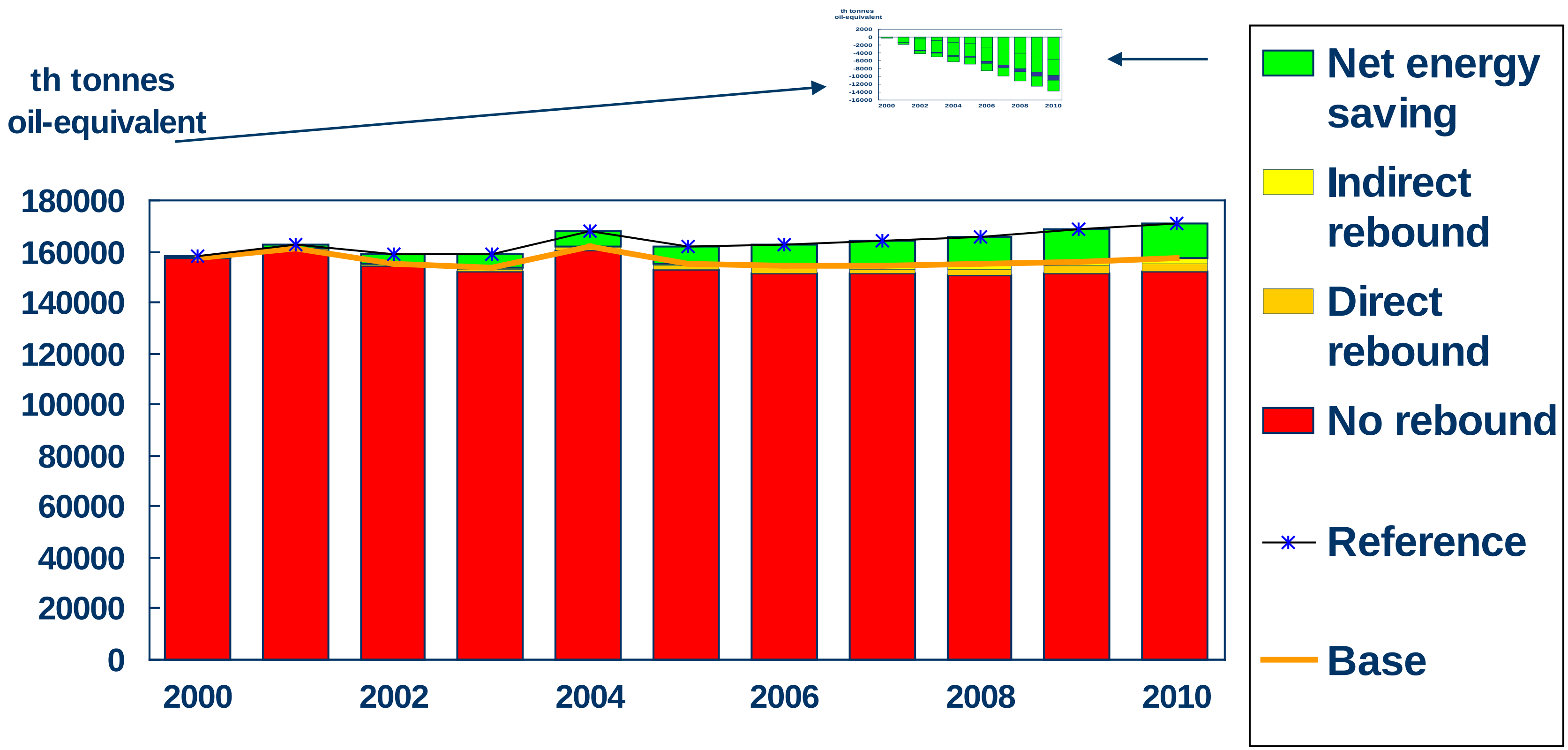
# UK's year 2000 energy-efficiency policies included in projections

| Target sector | Policy/measure | DEFRA's estimated $CO_2$ savings in 2010 (MtC) |
|---|---|---|
| Domestic | Building Regulations | 1.3 |
| | Energy Efficiency Commitment | 1.4 |
| | Warm Front | 0.4 |
| | Appliance Standards and Labelling | 0.2 |
| Business | UK Emission Trading Scheme | 0.3 |
| | Climate Change Levy package | 1.1 |
| | Climate Change Agreements | 2.9 |
| | Building Regulations | 0.5 |
| Public Sector | Public Sector measures | 0.3 |
| Transport | Voluntary Agreement Package | 2.3 |
| | 10-Year Transport Plan | 0.8 |
| Total | | 11.5 |

# Example: effects of energy-efficiency policies on UK final energy demand 2000-2010 (with EU ETS from 2005) using MDM-E3

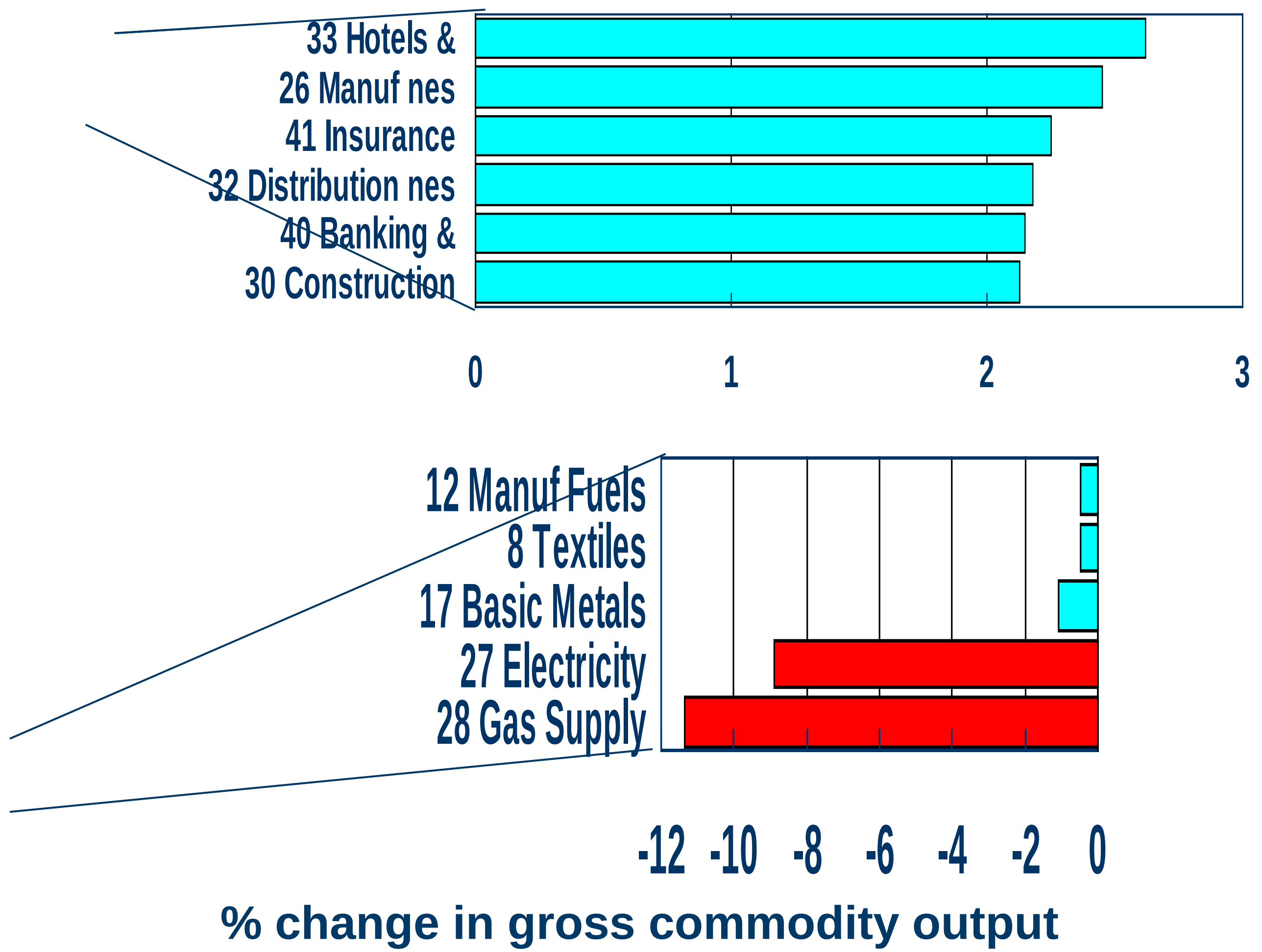
Total rebound by 2010 is 25%

**Net energy saving shown as reductions in demand**




Source: Barker, T., Ekins, P. and Foxon, T. (2007) ‘The macroeconomic rebound effect and the UK economy’, *Energy Policy* 35: 4935–4946.

# Effect of energy-efficiency policies on UK gross output by 2010 using MDM-E3

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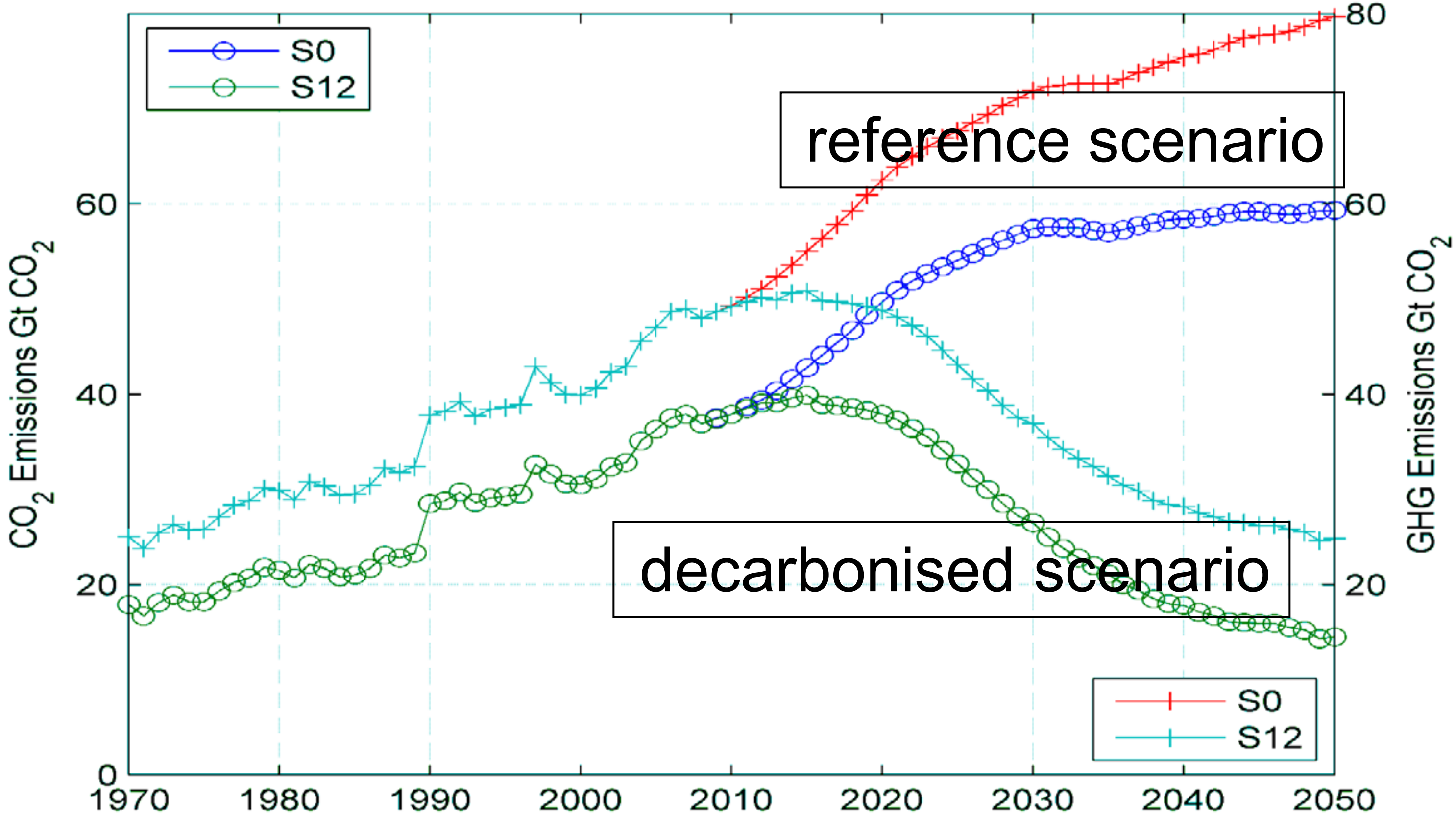
# Modelling policies for global decarbonisation

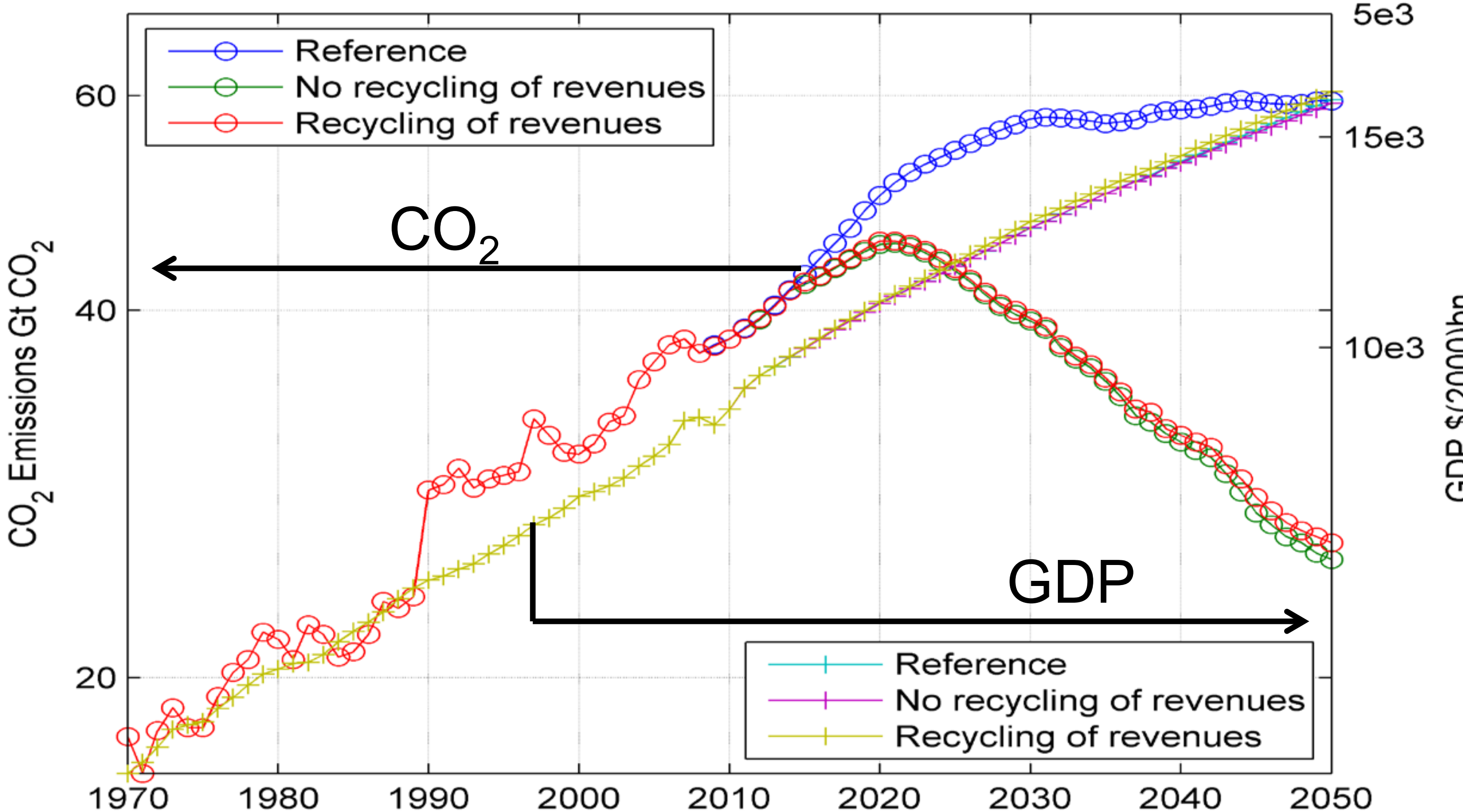
- Use of E3MG, a global 20-region model
- Policies based on those used or proposed by governments (IEA WEO scenarios)
- Use of scenarios for reference case and policy mixes
- Tests of the operational model for effects of carbon prices on achievement of targets
- Being developed for a book on decarbonisation

# GHG and $CO_2$ in the scenarios




Source: E3MG modelling, Barker and Anger, 2013 – work in progress

# Effects of recycling of revenues on $CO_2$ and GDP

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# Conclusions

- Traditional economics has been discredited as useful in climate research
  - Useful research involves institutional detail
  - And a balance of theory and observation
- Renewable industries (wind, solar) have developed rapidly over the last 20 years
  - Showing potential for research into induced technological change
- Effective and low-cost regulations complement market-based policies
  - Regulation very under-researched in economics of mitigation
- “Green growth” is possible, but national policies have to be focused on environmental protection
  - A major challenge for all macroeconomic policy research

Thank you