



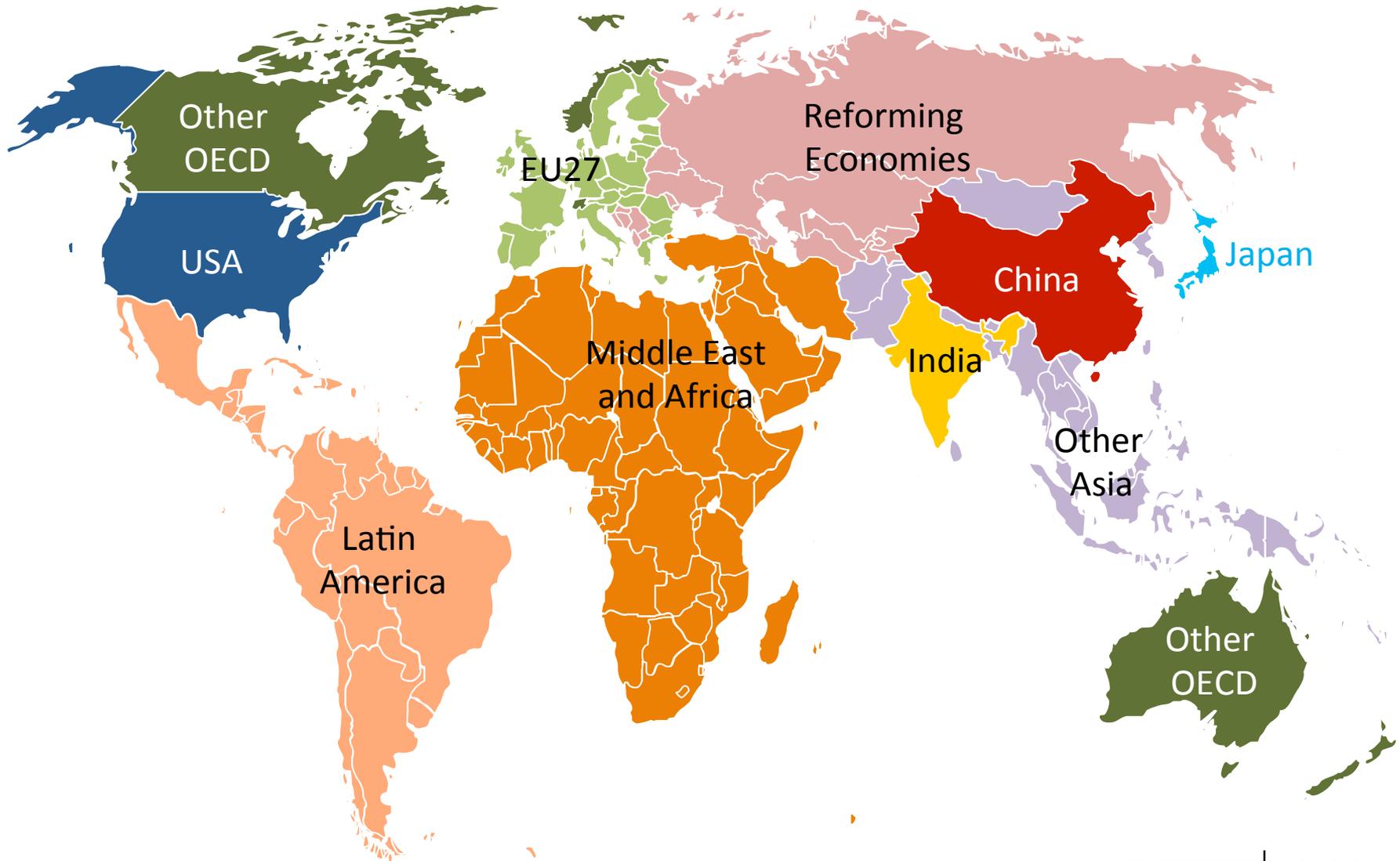
MUG Round 1 Scenarios in MERGE

Geoff Blanford
Snowmass Workshop
July 30, 2012

MERGE Model

- Multi-regional intertemporal optimization
 - GE Ramsey model describing economic growth
 - Process model describing energy technologies
- Reduced-form climate model
 - 5-box ocean-atmosphere carbon cycle
 - No land use, no terrestrial carbon: “neutral biosphere”
 - RF equations cover gas and non-gas agents
 - 1-box lagged temperature function of RF
- Simple formulation of market and non-market damages where willingness-to-pay is a function of income and temperature

MERGE Regions for AMPERE and MUG



MERGE Regions for EMF27



Implementation of Pulse Scenarios

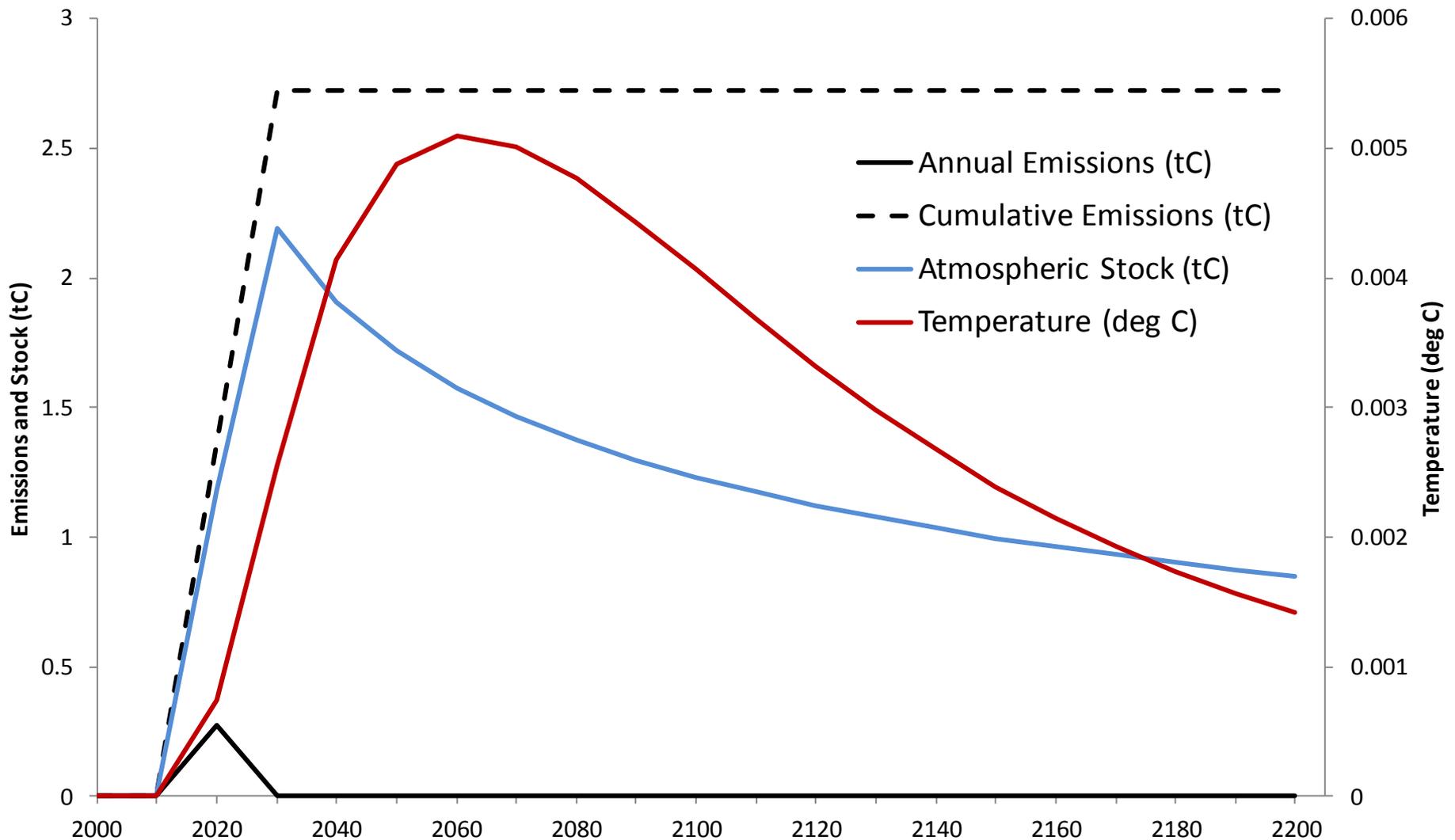
- Emissions pulse: added 1 ton CO2 to the global total in 2020 (could as easily have simply re-evaluated the climate model)
 - Very small pulse
 - What is the “uncertainty” here? Inventory uncertainty?
- GDP pulse: adjust target output growth downwards from 2010-20 and upwards from 2020-30 so that benchmark GDP in 2020 is 0.5% lower (and the same in subsequent periods)

```
grow("2010",rg) = (1 - 0.005)**0.1 * (1 + grow("2010",rg)) - 1;
```

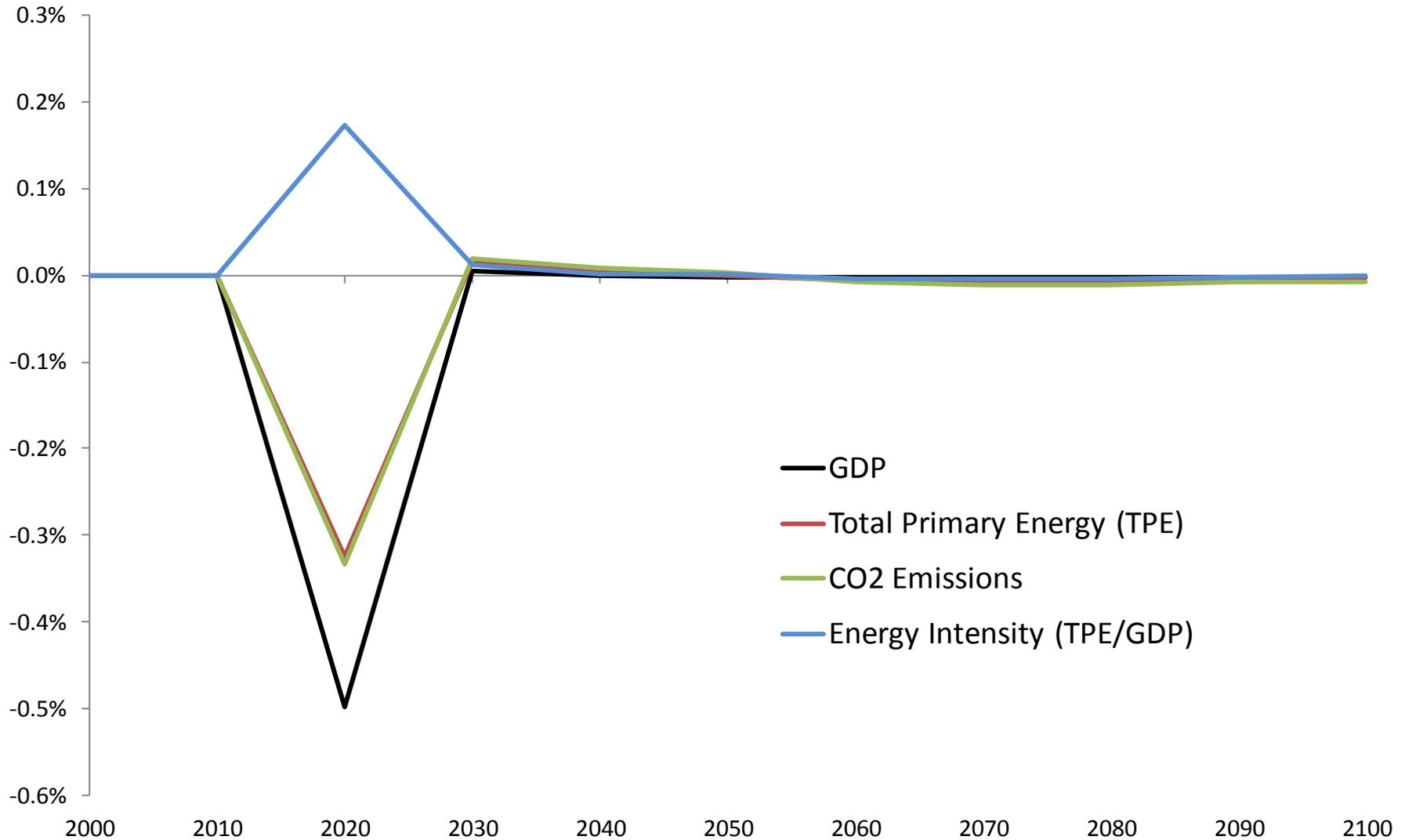
```
grow("2020",rg) = (1 + 0.005)**0.1 * (1 + grow("2020",rg)) - 1;
```

- Also a very small pulse

Emissions Pulse Scenario (change from baseline)



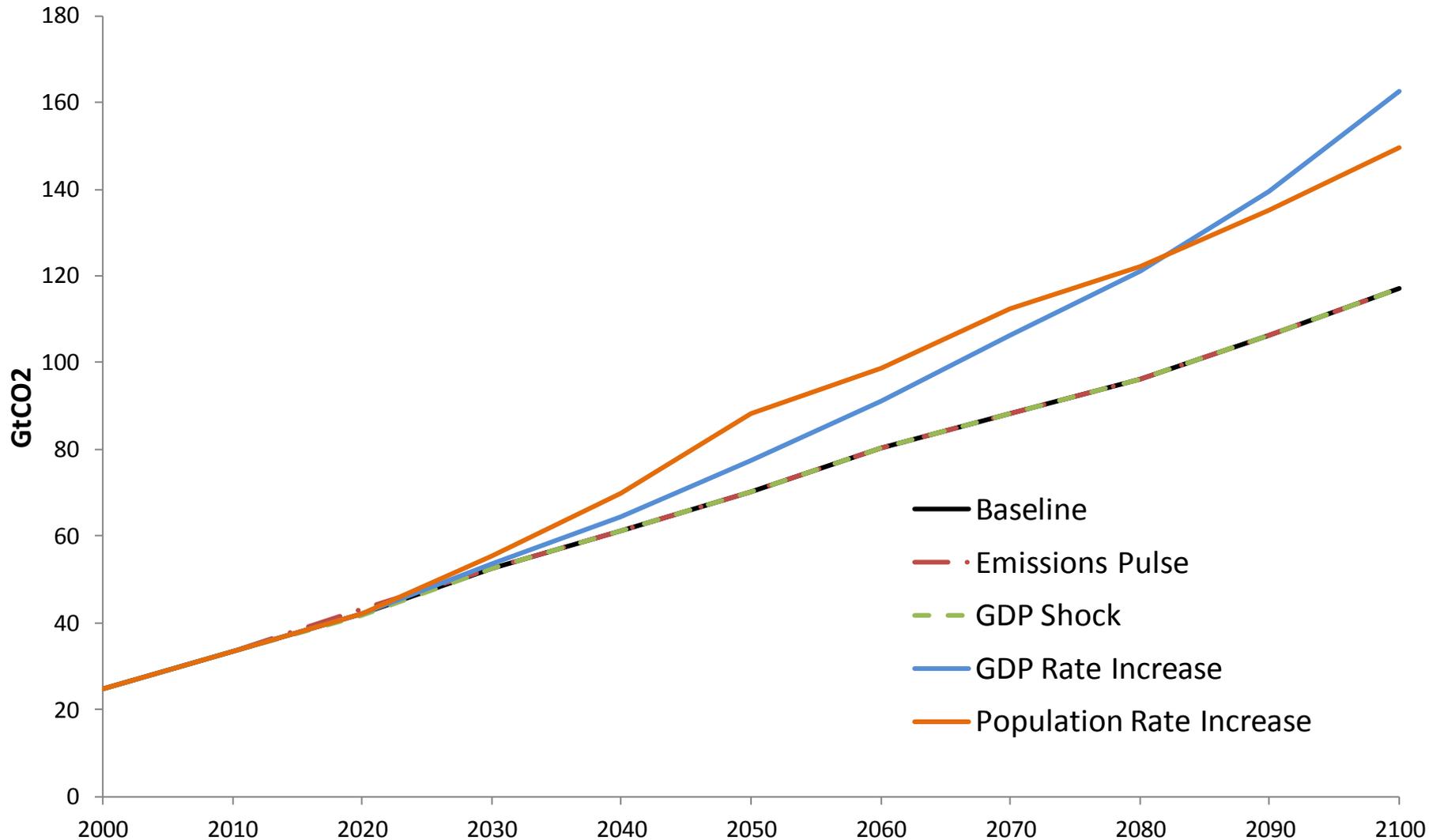
GDP Shock Scenario (% change from baseline)



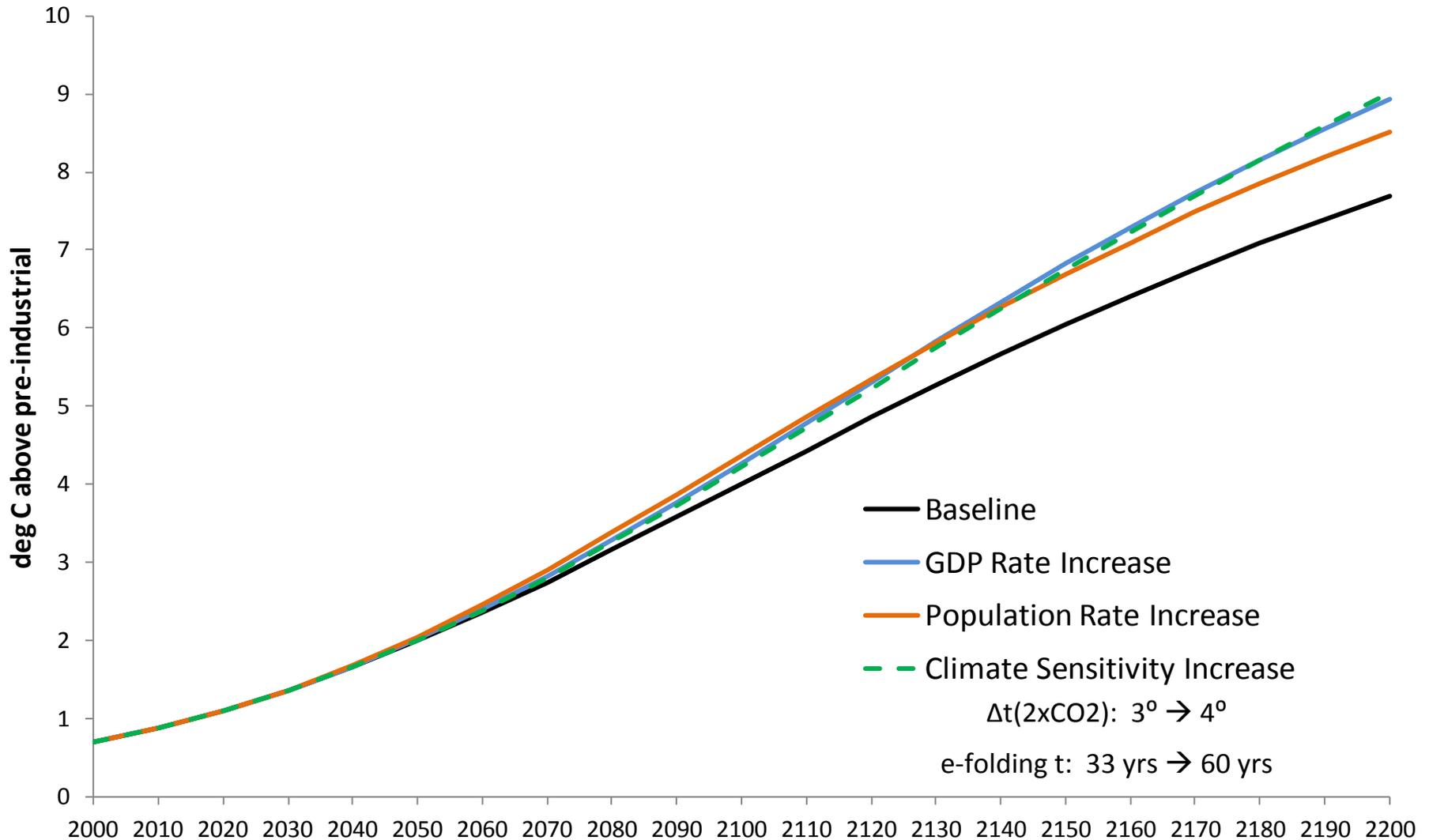
Implementation of Rate Change Scenarios

- Increase GDP growth rate between 2020 and 2100
- Increase Population growth rate between 2020 and 2050:
 - Straightforward to adjust target growth rates
 - Both result in higher GDP growth path
 - Benchmark energy path is calculated using the same energy intensity rates of change as in baseline
 - Results in a significant departure from baseline (for TPE, CO2)

Global CO2 Emissions



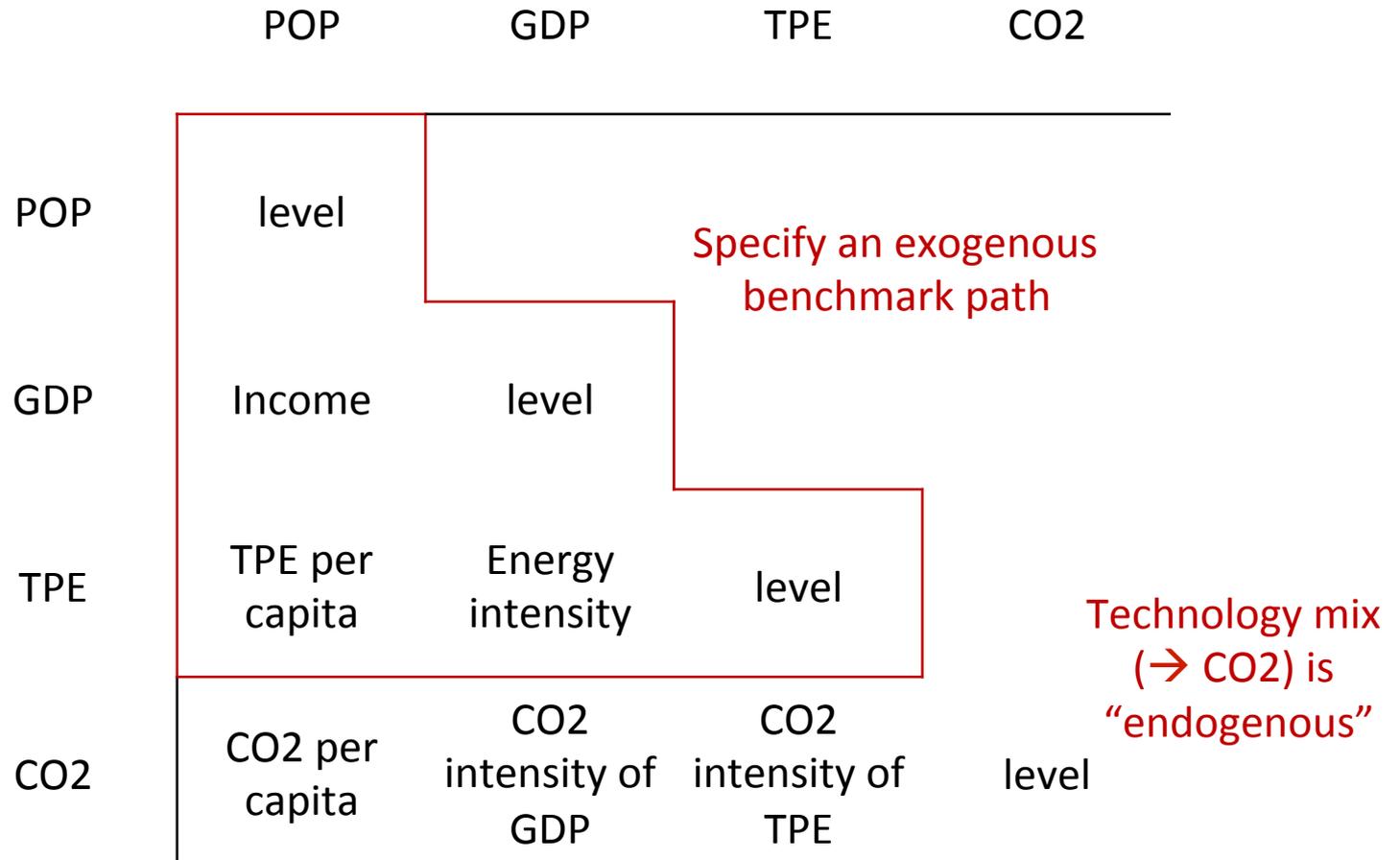
Global Average Surface Temperature



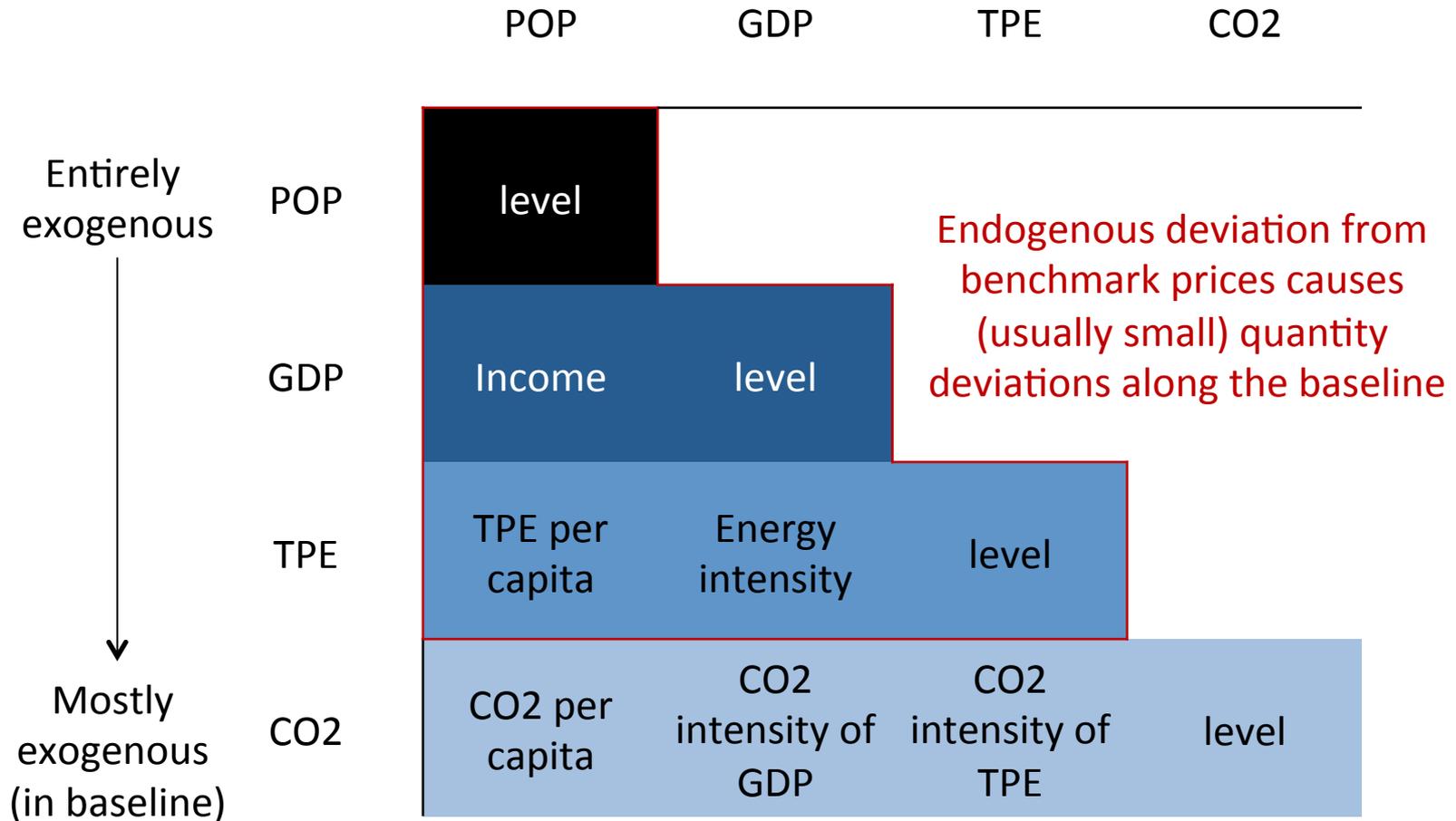
Baseline Specification in Energy-Economy Model

	POP	GDP	TPE	CO2
POP	level			
GDP	Income	level		
TPE	TPE per capita	Energy intensity	level	
CO2	CO2 per capita	CO2 intensity of GDP	CO2 intensity of TPE	level

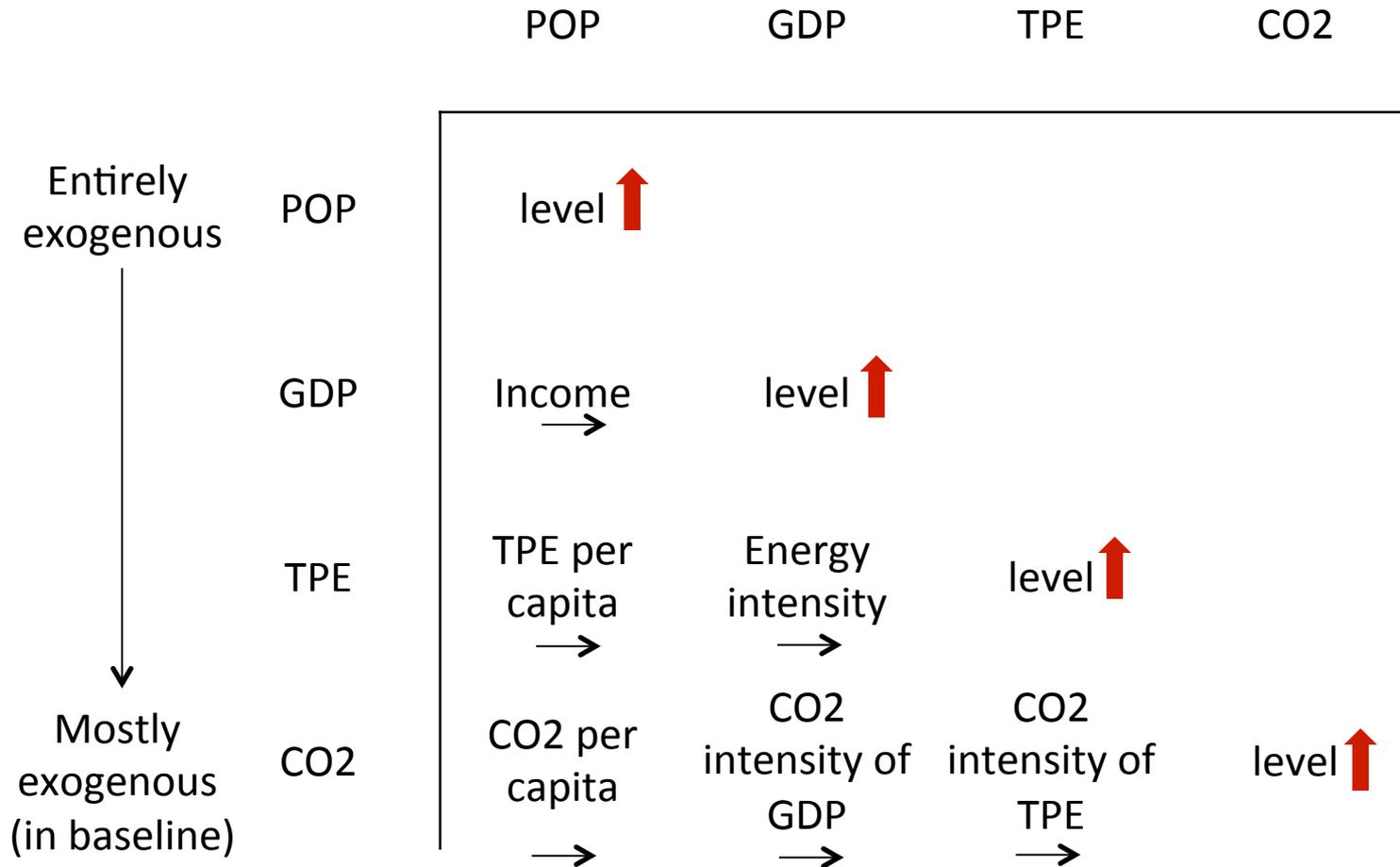
Baseline Specification in Energy-Economy Model



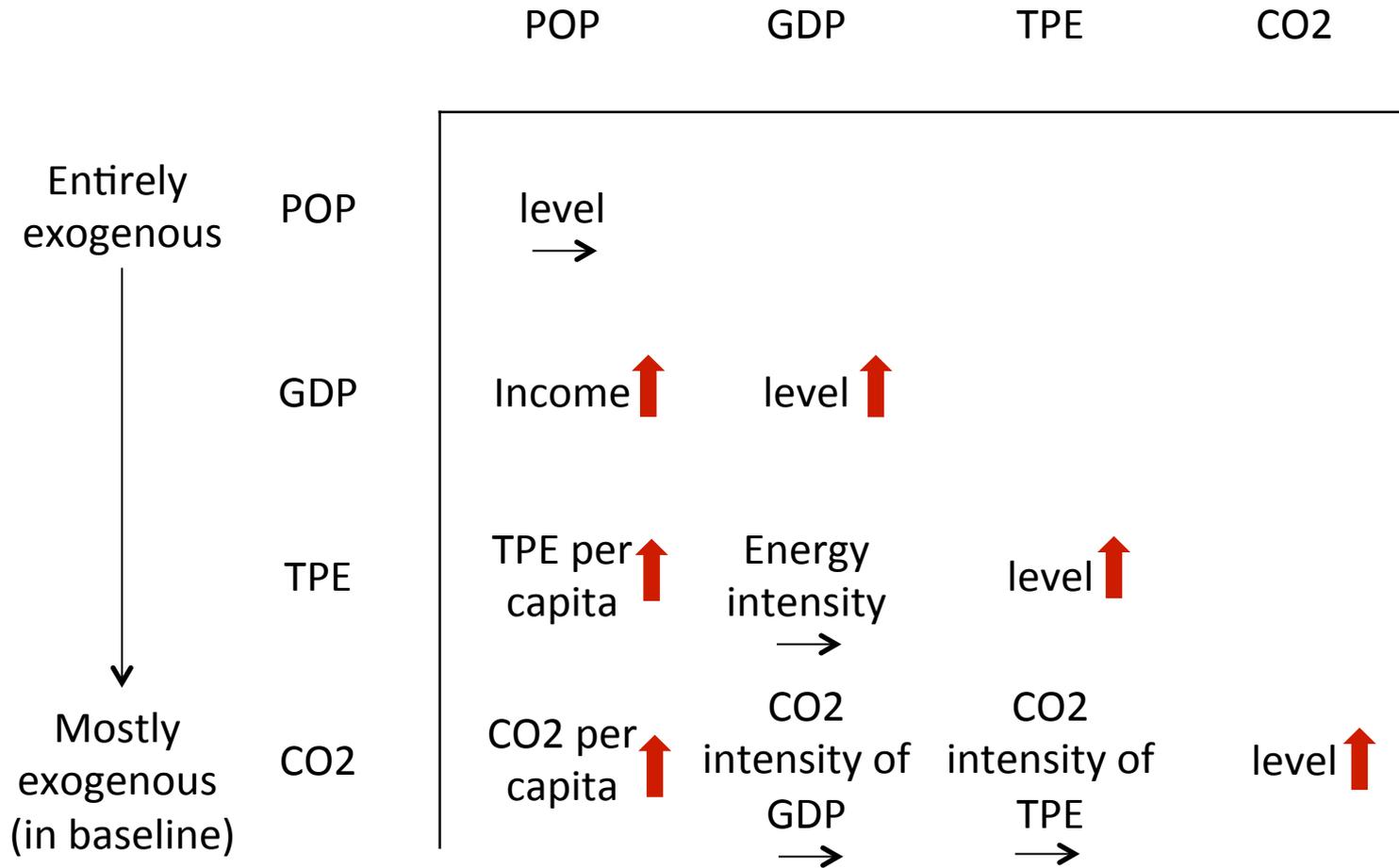
Baseline Specification in Energy-Economy Model



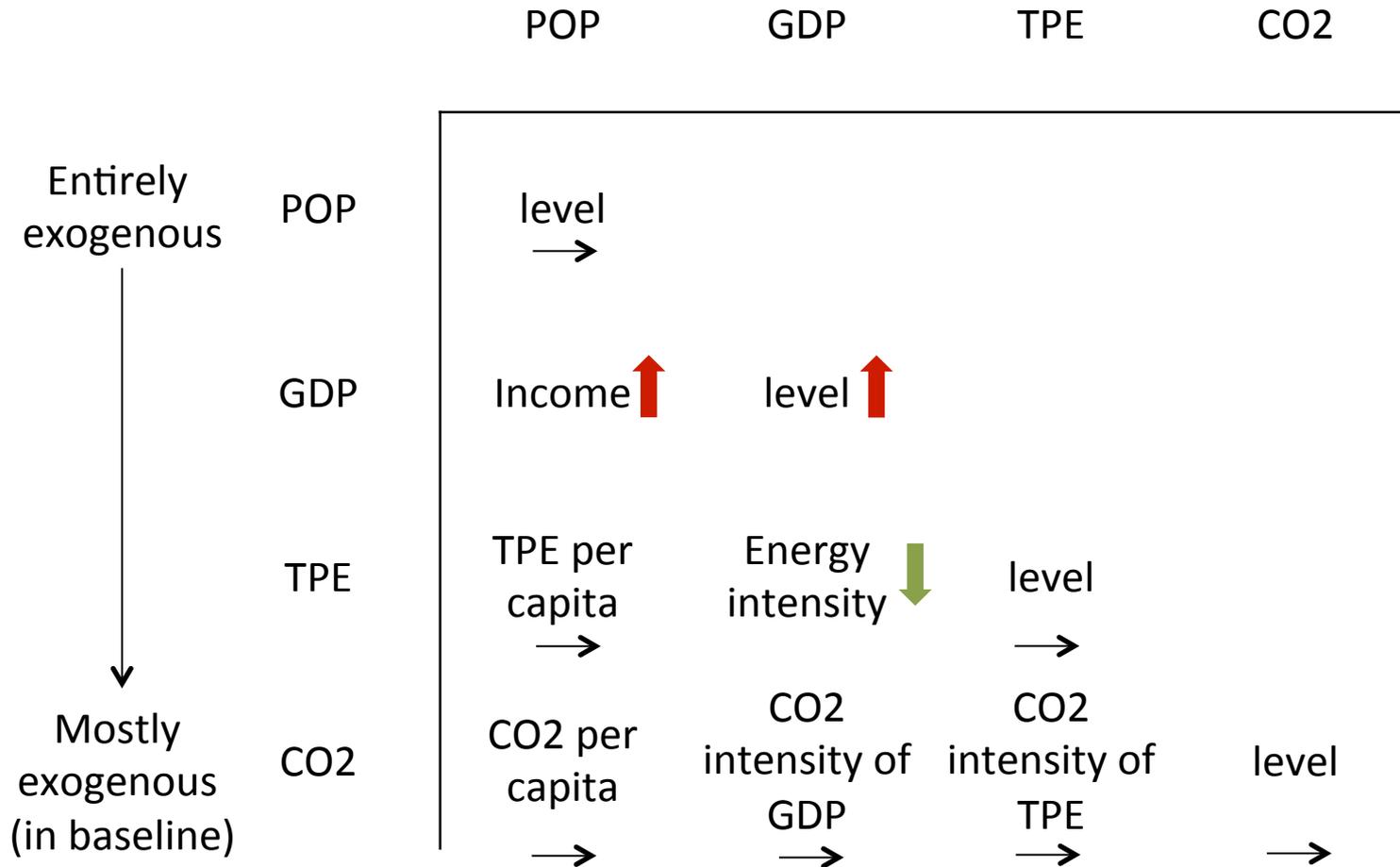
Population Rate Increase Scenario



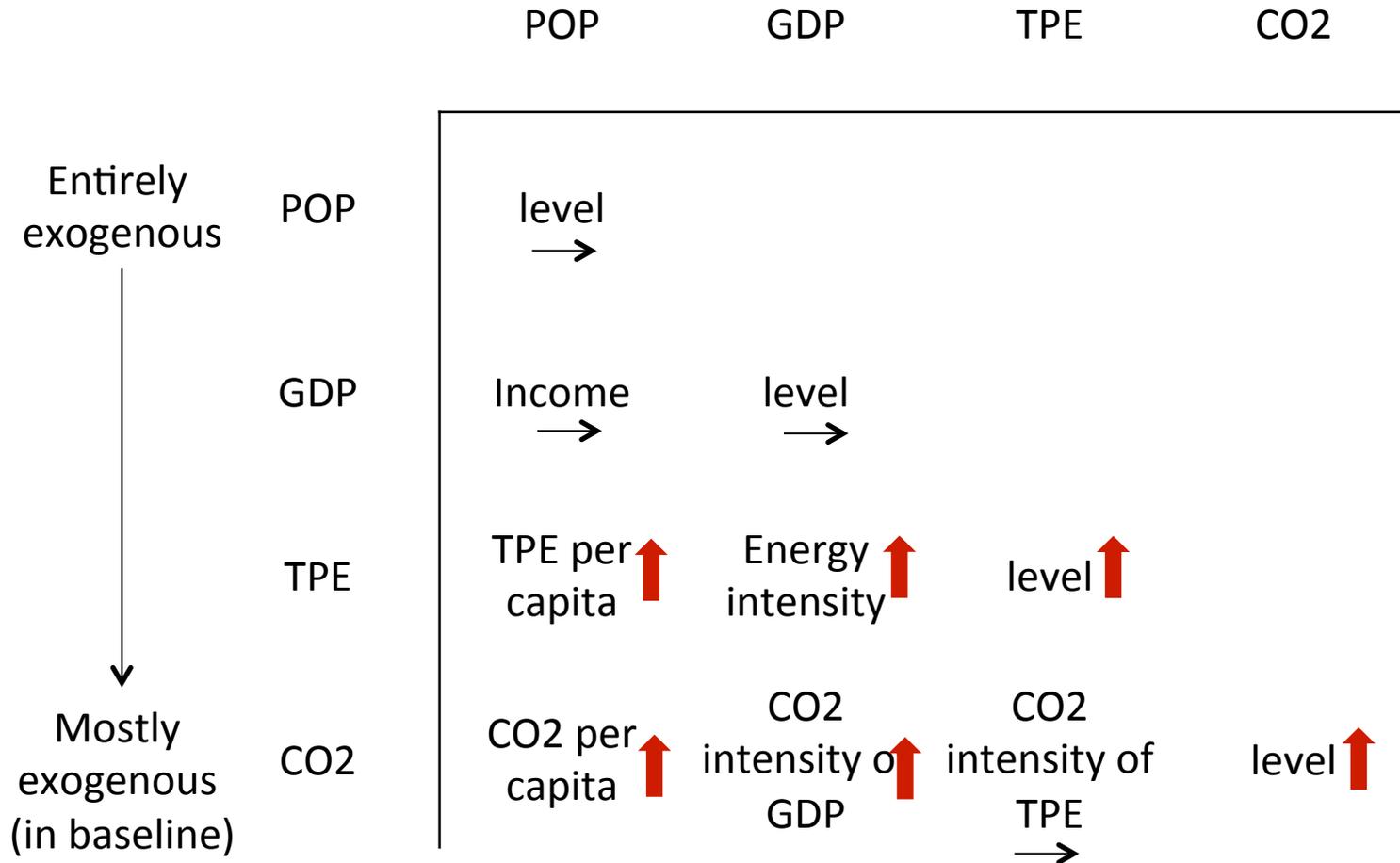
GDP (via income) Rate Increase Scenario



Compensated GDP Rate Scenario



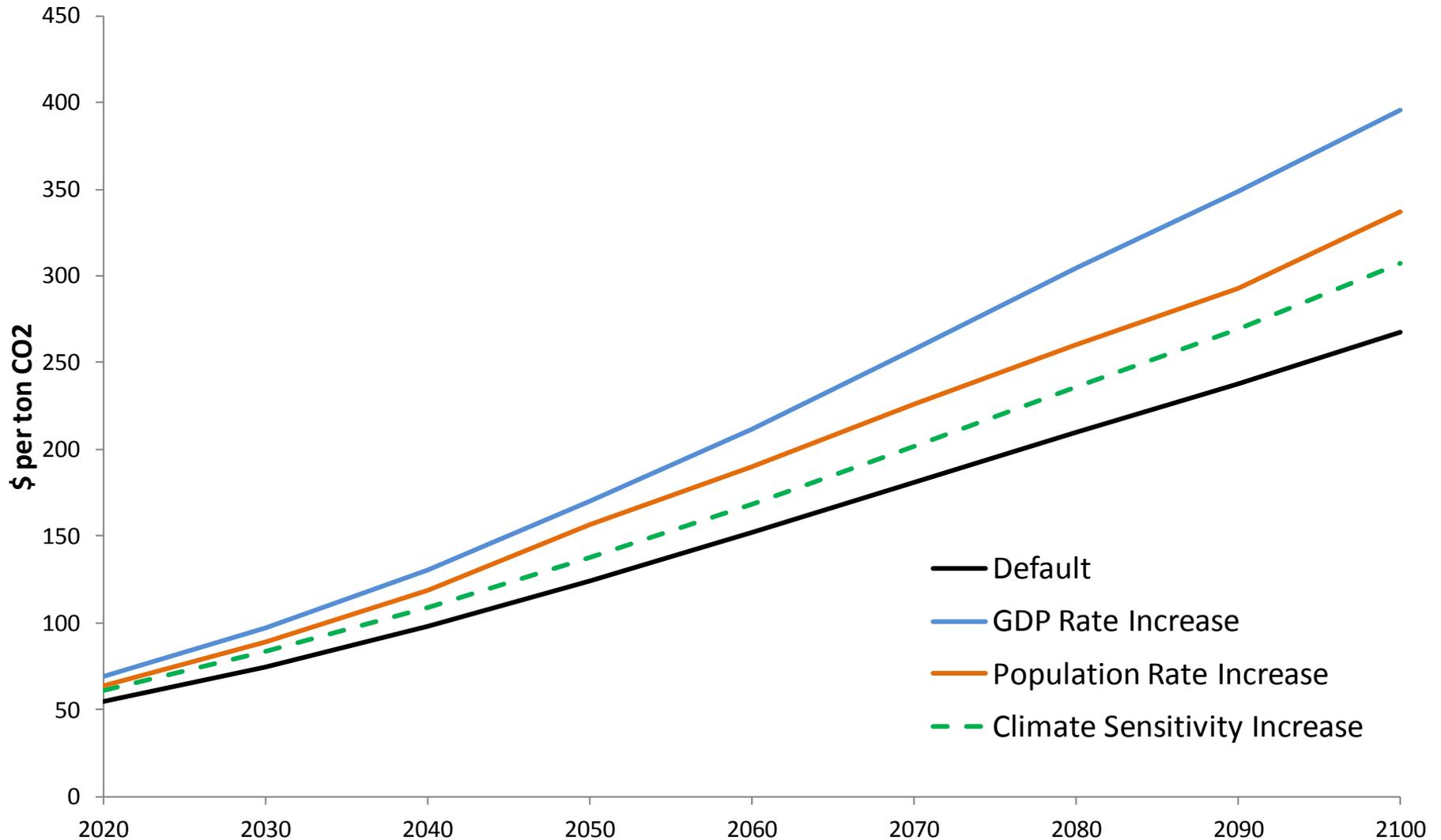
Hypothetical TPE (via EI) Increase Scenario



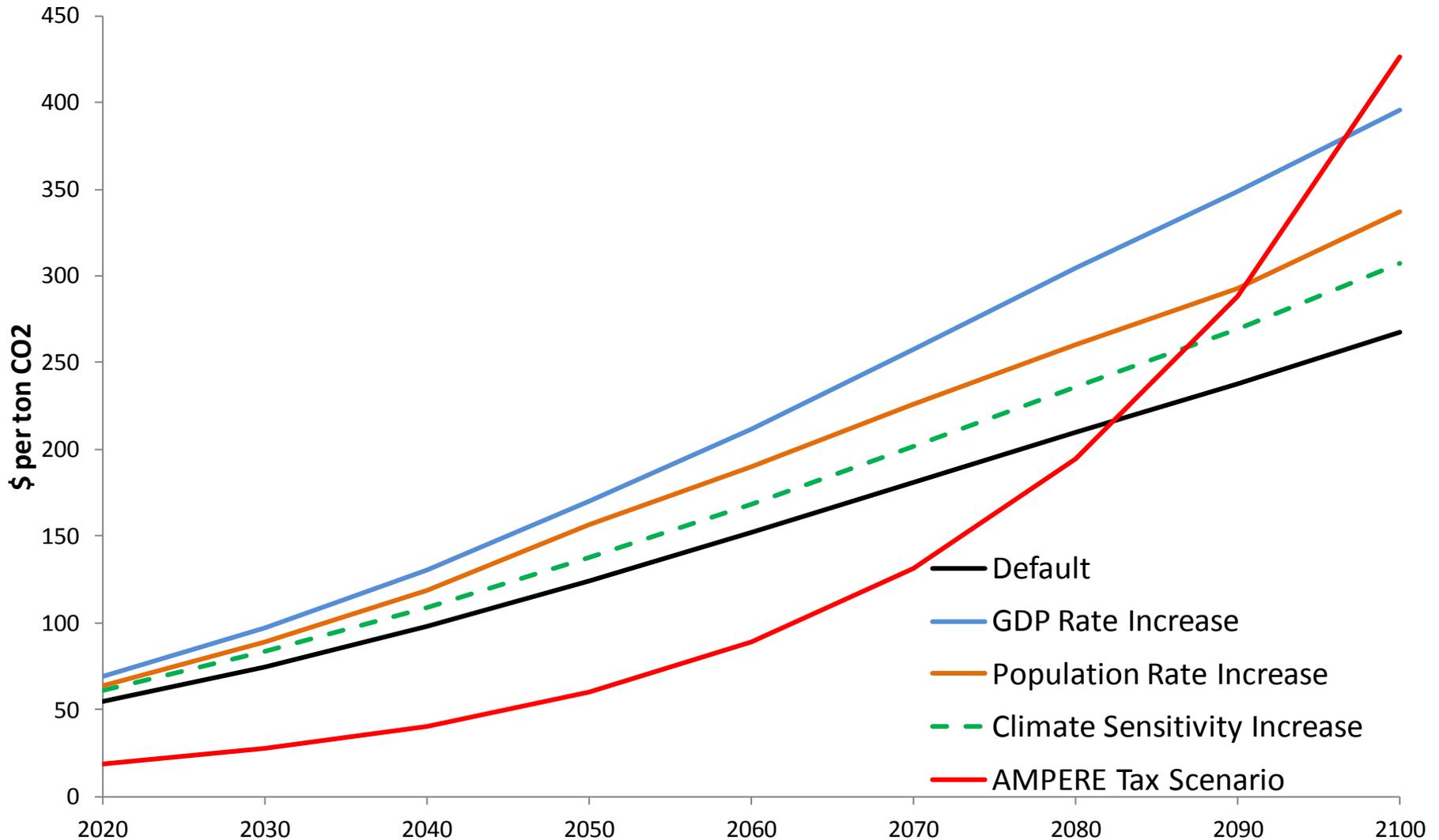
My view of an uncertainty study

- Question: what's the optimal level of abatement up to 2020?
- Most relevant uncertainties in answering that question:
 - **How big an energy system will we have in the future?**
 - **What will be the relative cost of low-carbon energy?**
 - **How will lower emissions translate into climate outcomes?**
 - **How much would I/my grandchildren be willing to pay to avoid the impacts associated with those outcomes?**
- First step: what's the range of optimal abatement under appropriate ranges for each of these factors?
- Second step: what's the optimal hedging path given current state of knowledge / probabilities? Computationally intense!

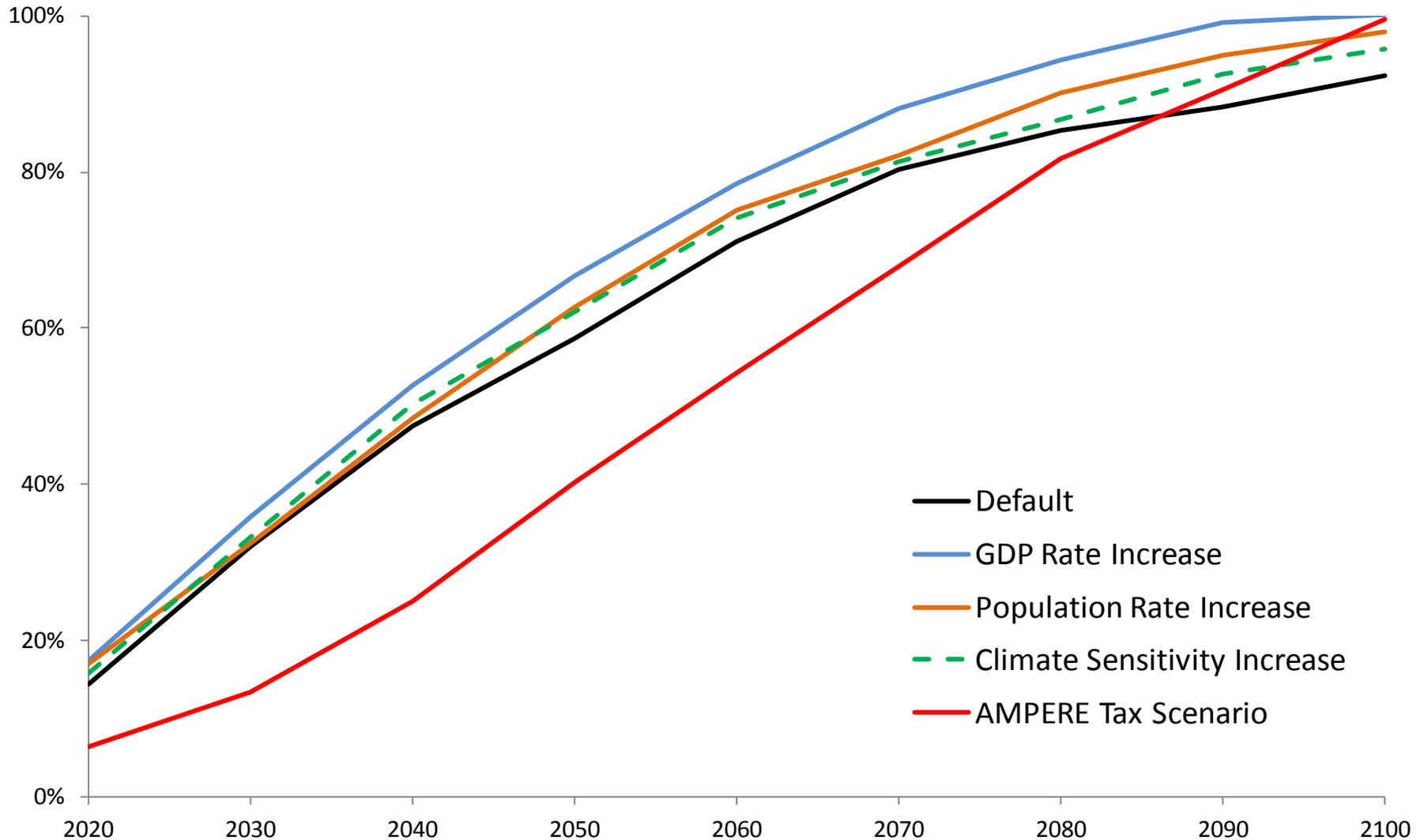
Price of Carbon with Optimal Control



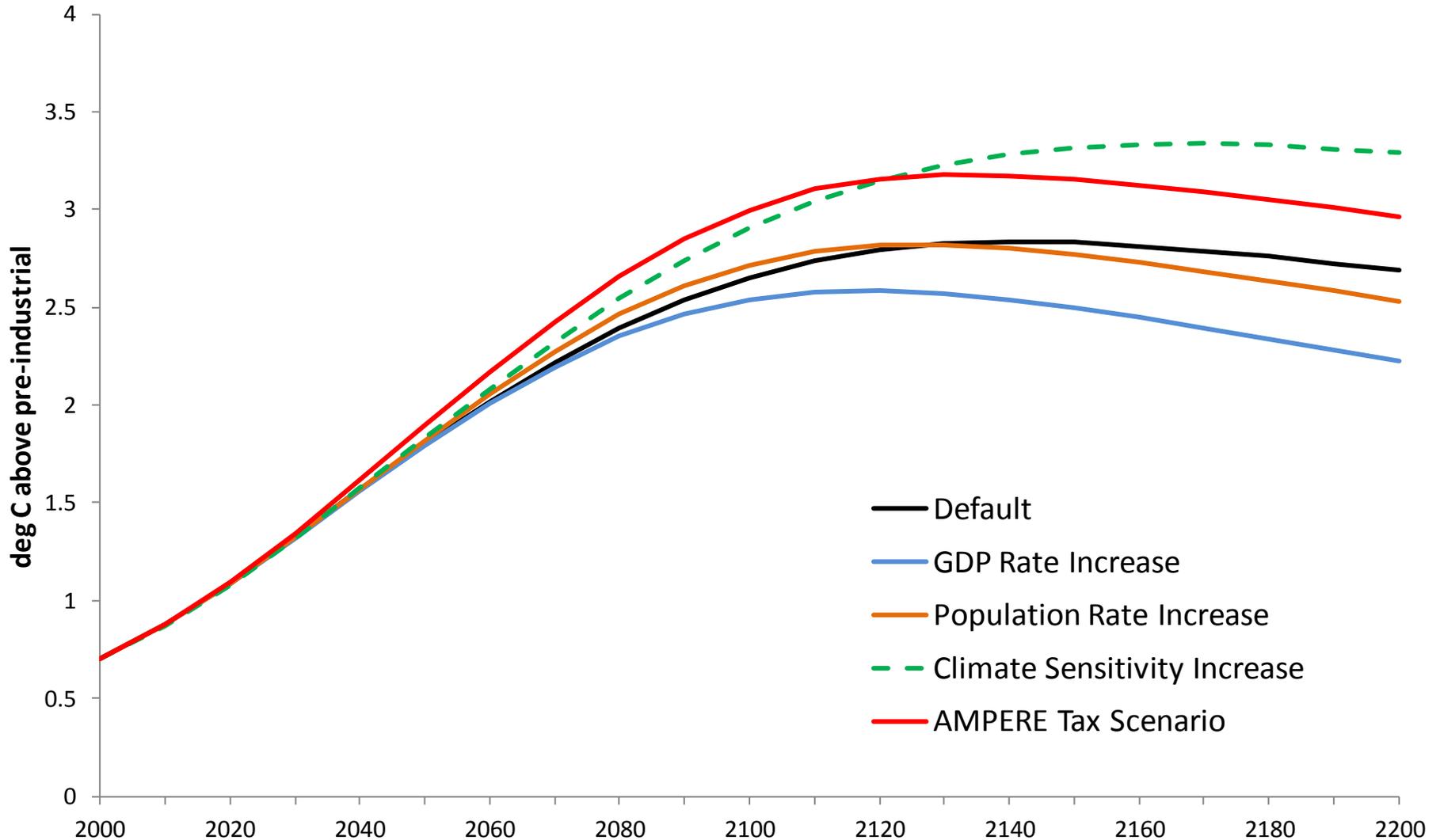
Optimal Carbon Price vs. AMPERE Tax Scenario



CO2 Emissions Abatement with Optimal Control



Temperature Change with Optimal Control



Suggestions for this study

- Posterior pdf of ... emissions? Not clear this is all that useful
 - Emissions are a function of policy choices we aim to inform
 - Not in business of predicting likelihood of emissions outcomes
- Understanding the distribution of optimal (in a cost-benefit sense) near-term choices is potentially much more useful
 - Baseline uncertainty just one piece
 - Climate sensitivity clearly important (joint with aerosols?)
 - Must include technological and, first and foremost, damages
- Harmonization across models will be a challenge

In a multi-model dataset...

- Frequency \neq Likelihood
- Variation \neq Uncertainty

Together...Shaping the Future of Electricity