



Grantham Research Institute on
Climate Change and
the Environment



ADAPTATION TO CLIMATE CHANGE AND ECONOMIC GROWTH IN DEVELOPING COUNTRIES

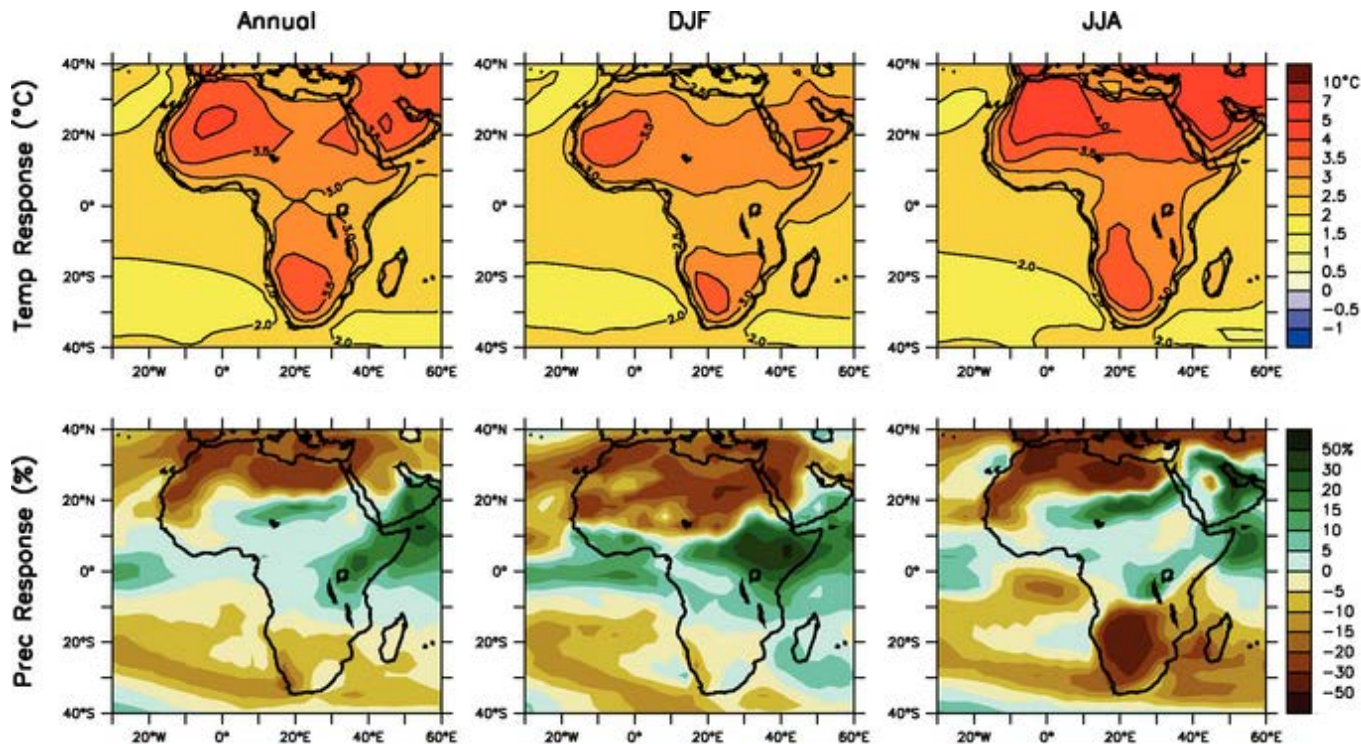
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STYLIZED FACTS

Developing countries, particularly in sub-Saharan Africa, are highly vulnerable to climate change:

- Geographic location
- High sensitivity (e.g. share of GDP in agriculture)
- Low adaptive capacity (e.g. finance, institutions, knowledge)



Even if (and that's a **BIG** "if") we get effective mitigation, climate change will occur due to long residence time of atmospheric CO₂.

THIS PAPER IN A NUTSHELL

How should developing countries adapt to climate change?

- “Development is the best form of adaptation” – i.e. invest as usual in productive capital
- “Development is contingent on adaptation” – i.e. invest to ‘climate-proof’ productive capital

Towards adjudicating between these positions, we:

- Construct a fully dynamic, easy to interpret, analytical model of adaptation as an investment problem at the macro level
- Apply the model empirically to Sub-Saharan Africa, with extensive sensitivity analysis

We find that in most contingencies it will be optimal to grow the stock of adaptive capital rapidly over the next 50 years.

MODEL SET-UP

Modified Ramsey-Cass-Koopmans growth model (cf. DICE)

Two capital stocks

- ‘Vulnerable capital’ – productive, but damaged by CC
- ‘Adaptive capital’ – unproductive in the absence of CC, but reduces CC damages to vulnerable-capital output

Two controls

- Consumption/investment in vulnerable capital
- Investment in adaptive capital

Exogenous temperature change (small developing country/region), population and TFP

Convex cost of investment in adaptive capital – captures barriers to adapting quickly such as planning costs, policy delays and corruption

MODEL EQUATIONS

Social Planner's Objective: $\max_{c(t), I(t)} \int_0^T L(t)U(c(t))e^{-\rho t} dt$

Vulnerable capital K_V :

$$\dot{K}_V = A(t)D(K_A, X(t))F(K_V, L(t)) - \delta_V K_V - cL(t) - Q(I)$$

TFP \nearrow $A(t)$ Damages = $D(\text{Adaptive capital, Exogenous Temperature})$ \nearrow $D(K_A, X(t))$ GDP \downarrow $F(K_V, L(t))$ Depreciation \downarrow $\delta_V K_V$ Consumption \nwarrow $cL(t)$ Adaptation costs \swarrow $Q(I)$

Adaptive capital K_A :

$$\dot{K}_A = I - \delta_A K_A$$

Adaptive investment \uparrow I Depreciation \nwarrow $\delta_A K_A$

DEPENDENCE OF OPTIMAL INVESTMENT RULE ON CAPITAL (NO ADJUSTMENT COSTS)

$$I = R_X(K_V, K_A, X)\dot{X} + R_V(K_V, K_A, X)\dot{K}_V + \delta_A K_A$$

Proposition 1: If $\dot{X} > 0$ and $\dot{K}_V > 0$, then $I > 0$.

Proposition 2:

R_X is an increasing (decreasing) function of K_V when $\epsilon_{a,a} < \epsilon_{X,a}$ ($\epsilon_{a,a} > \epsilon_{X,a}$).
Moreover, if $f(K_V) = K_V^\alpha$ for $\alpha \in [0, 1]$, then R_V is a decreasing function of K_V .

Implications:

- 1) The strong “adapt through development” position is probably not optimal.
- 2) Richer economies respond proportionately less to changes in K_V but may respond proportionately *more* to changes in X if the damage reduction effect of a marginal unit of adaptive capital outweighs its effect on the returns to adaptive investment.

FULL DYNAMIC SIMULATIONS FOR SUB-SAHARAN AFRICA

Why Sub-Saharan Africa?

- Small emitter of carbon: reasonable to assume climate change is exogenous
- Highly vulnerable to climate change

Close the model:

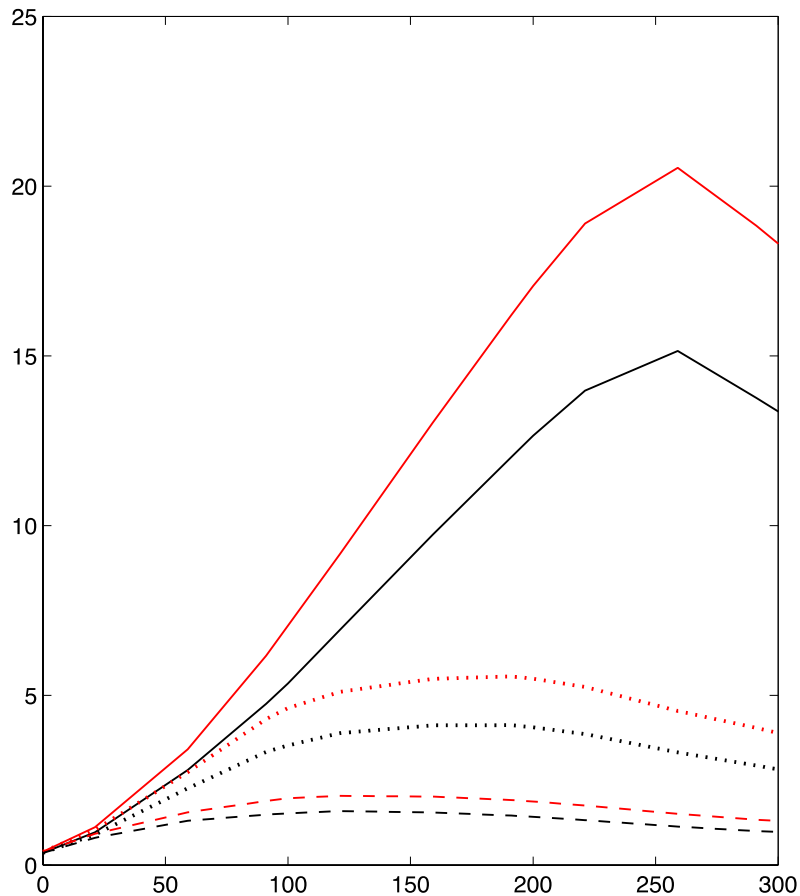
- Choose sensible functional forms for:
 $D(K_A, X)$, $F(K_V, L)$, $Q(I)$ and $U(c)$
- Calibrate model parameters based on IAM literature

Note calibration takes into account:

1. Exogenous flow adaptation
2. Relationship between income and damages

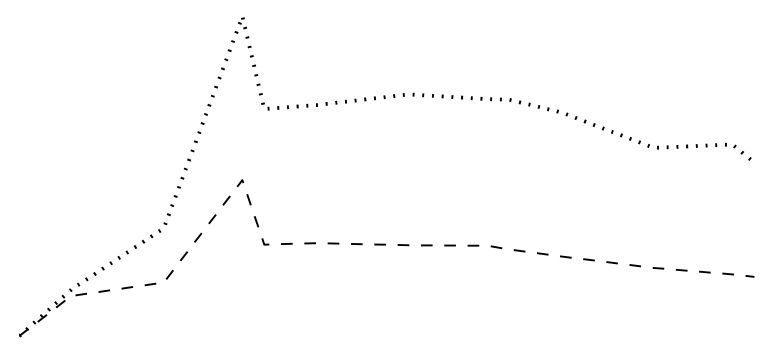
BASE CASE : COSTS & BENEFITS

Damages as % GDP



Investment Costs as % GDP

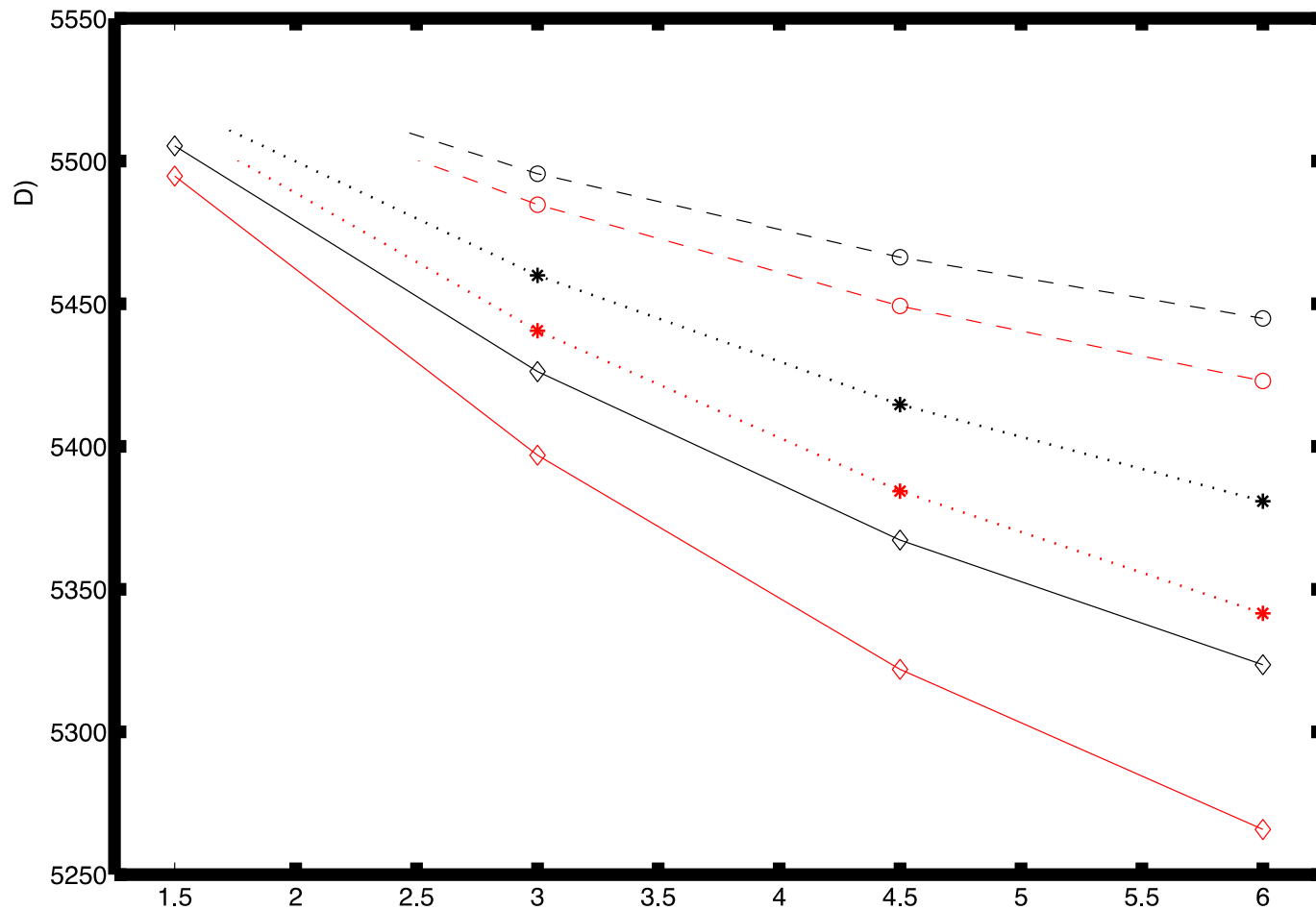
Investment as % GDP



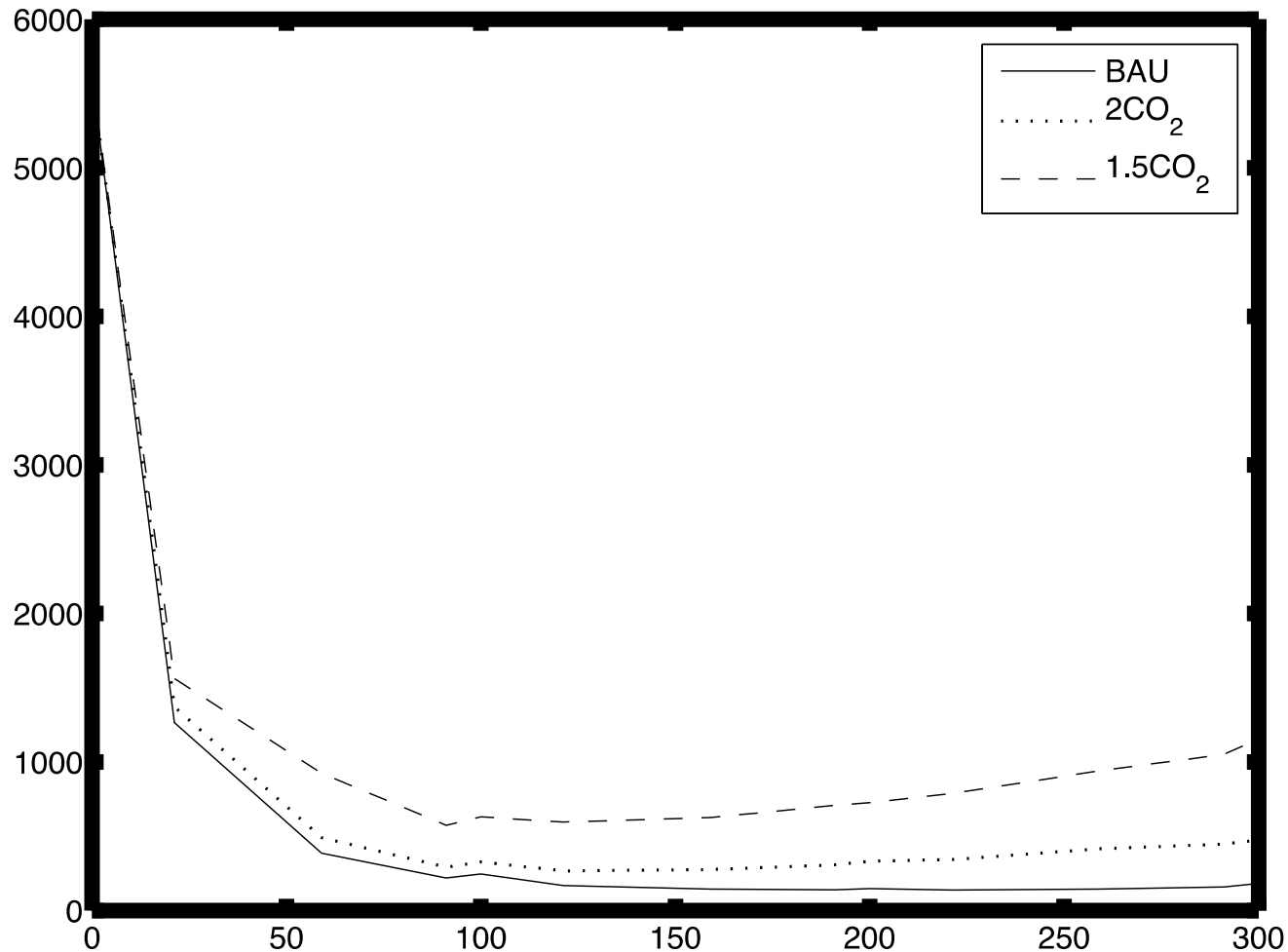
Same order of magnitude as AD-WITCH model.

CLIMATE SENSITIVITY VS. WELFARE

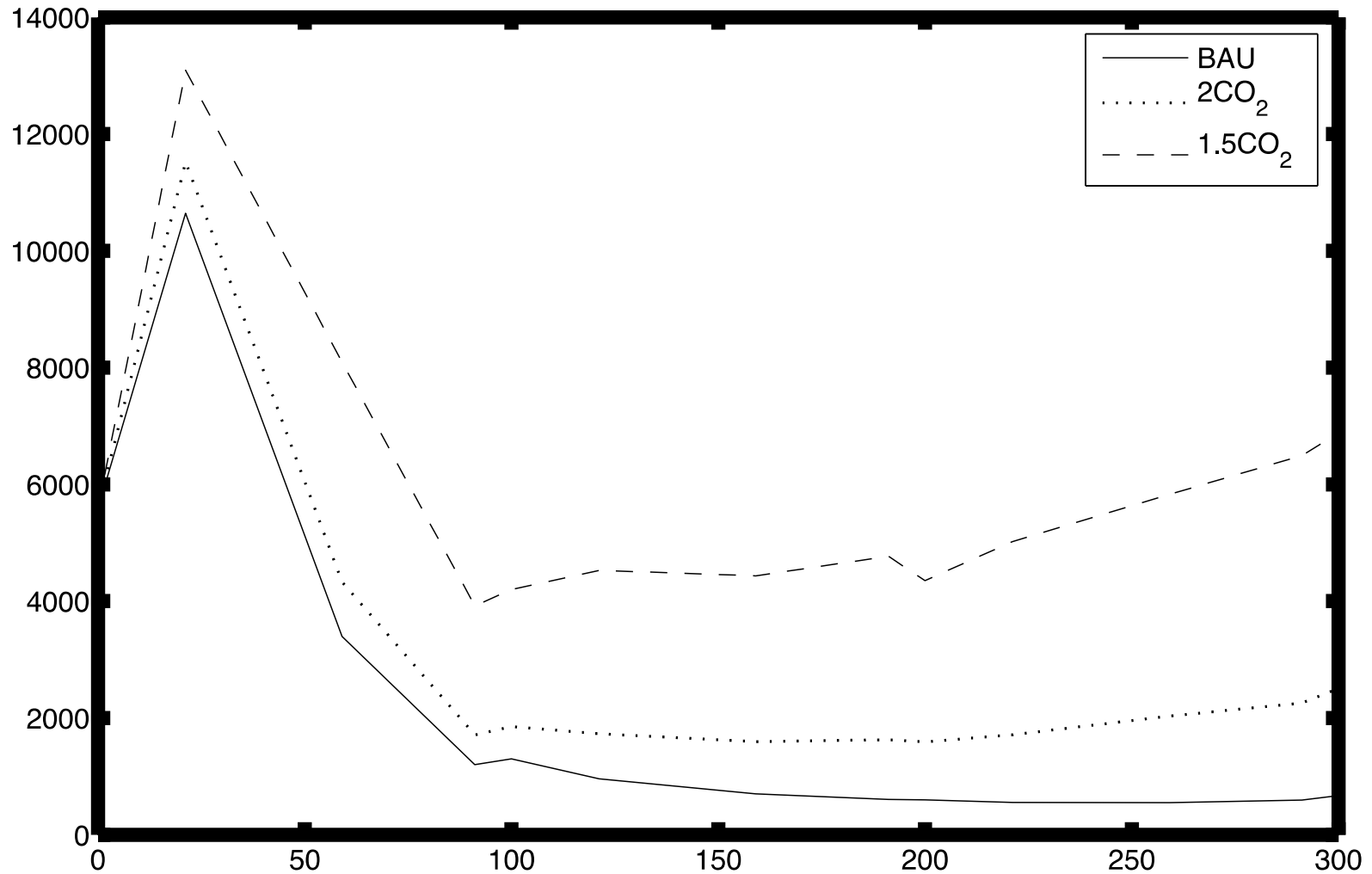
WITH AND WITHOUT ADAPTATION



BASE CASE: RATIO OF VULNERABLE TO ADAPTIVE CAPITAL AS FUNCTION OF TIME (BOTH CHOSEN OPTIMALLY)

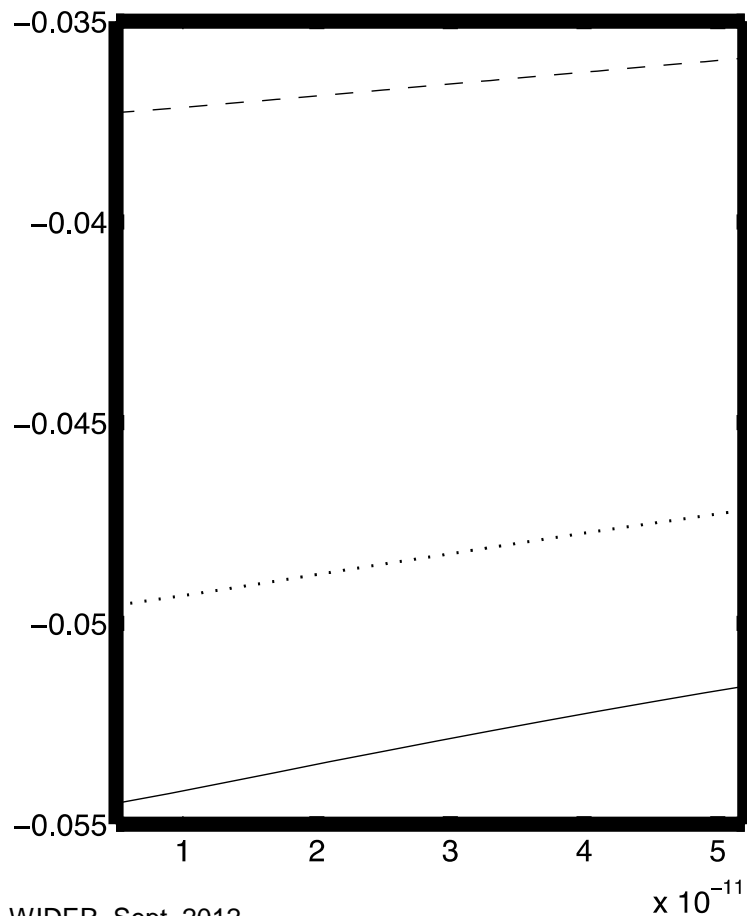


CAPITAL RATIO FOR LOW ADAPTATION EFFECTIVENESS

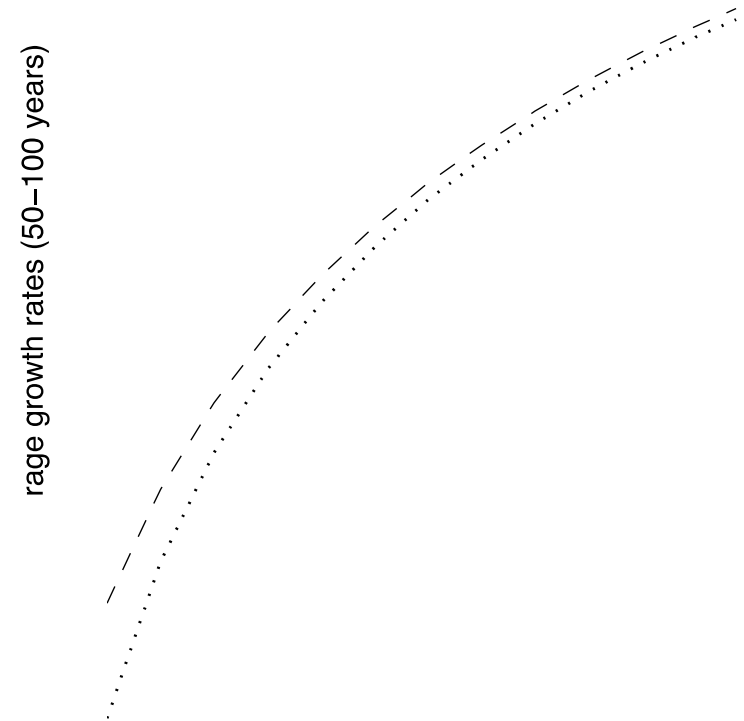


SENSITIVITY TO ADJUSTMENT COSTS: DIFFERENCE IN GROWTH RATES OF VULNERABLE AND ADAPTIVE CAPITAL VS. ADJUSTMENT COST PARAMETER

First 50 years

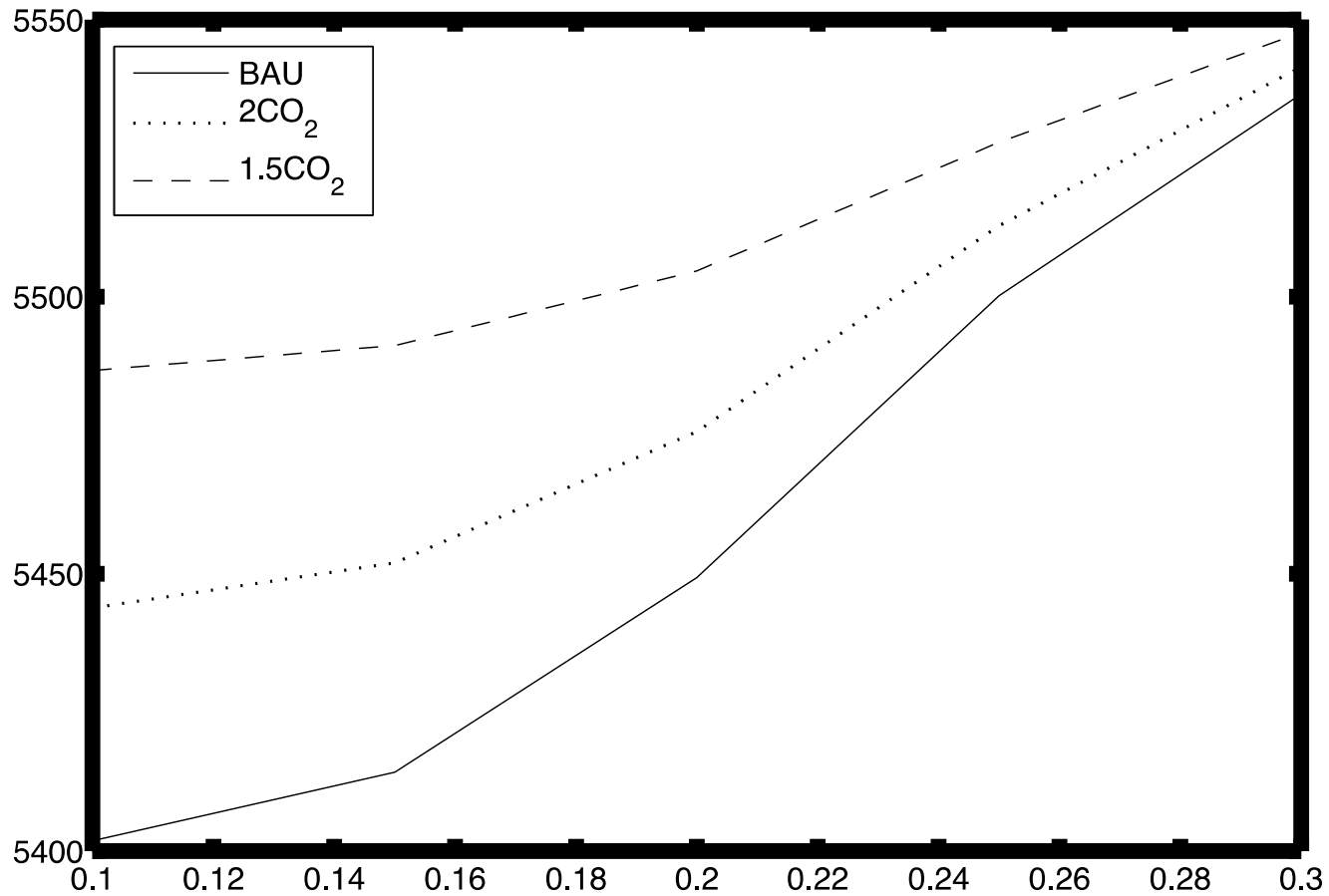


Second 50 years



SENSITIVITY TO ADAPTATION EFFECTIVENESS

WELFARE VS. ADAPTATION EFFECTIVENESS PARAMETER



CONCLUSIONS

Developed a simple, transparent model for informing policy discussions.

In most plausible cases, we find that it is optimal to grow the stock of adaptive capital rapidly over the next 50 years.

This conclusion is robust to changes in the values of all model parameters, *except*:

- i) Effectiveness of adaptation
- ii) Initial stock of adaptive capital (which is probably very low)

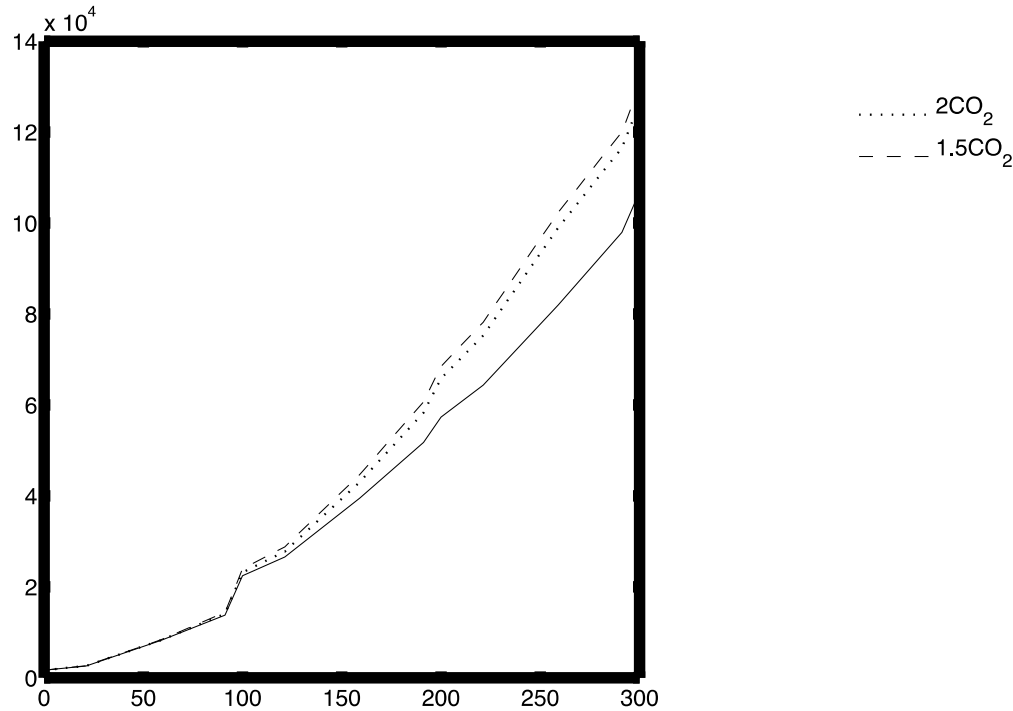
These are the parameters we should focus on pinning down empirically.

Our analytics show that simple *ad hoc* prescriptions are almost certainly wrong: Everything depends on empirical details.

Caveats: Uncertainty & Learning, Thresholds, Extreme Events, Institutions, etc., etc.

ADDITIONAL MATERIALS

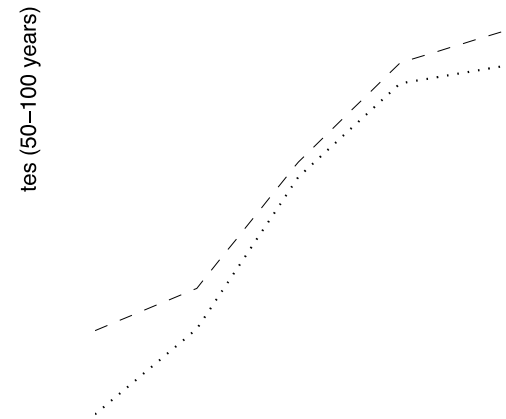
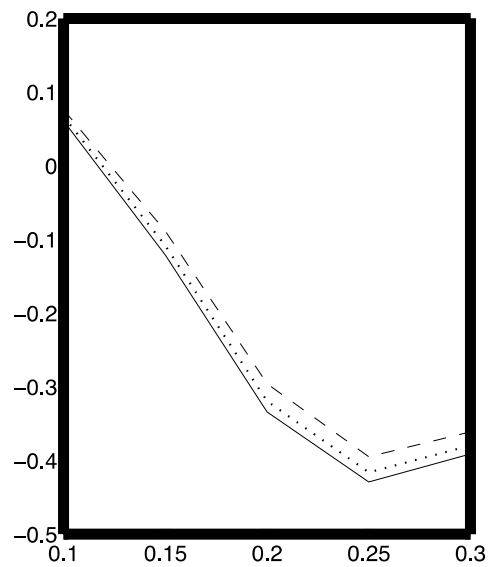
BASE CASE RESULTS: OPTIMAL CONTROLS



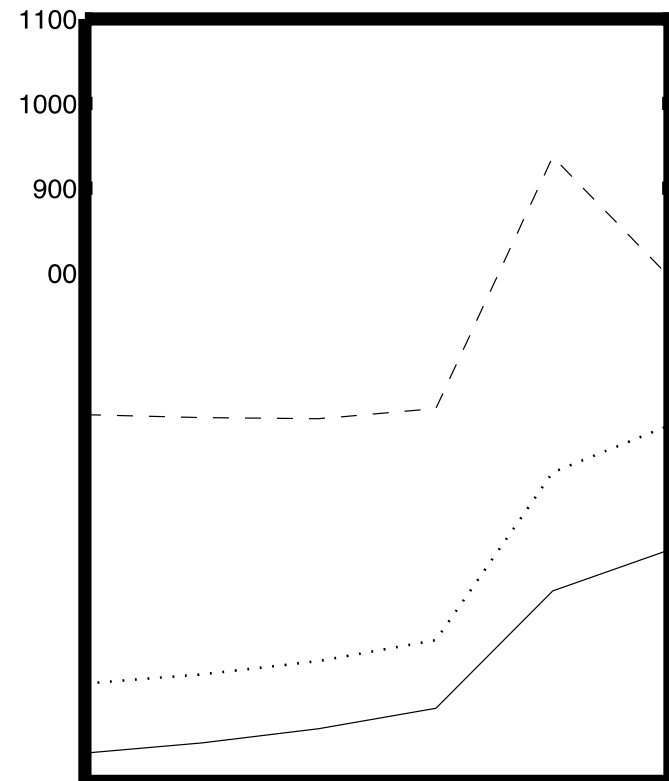
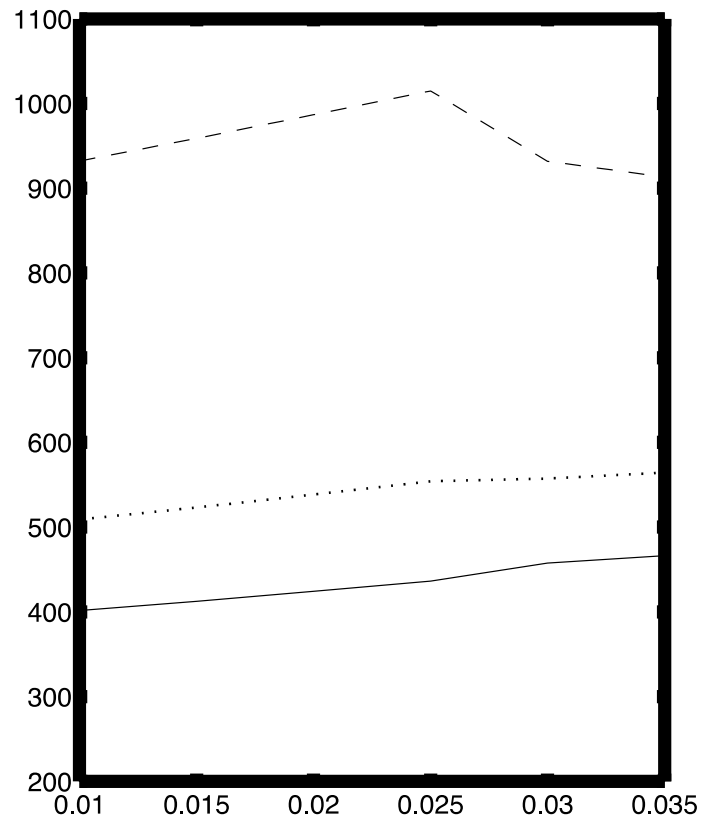
Consumption per capita vs. time

Adaptive investment per capita vs. time

SENSITIVITY TO ADAPTATION EFFECTIVENESS: $(G_V - G_A)$



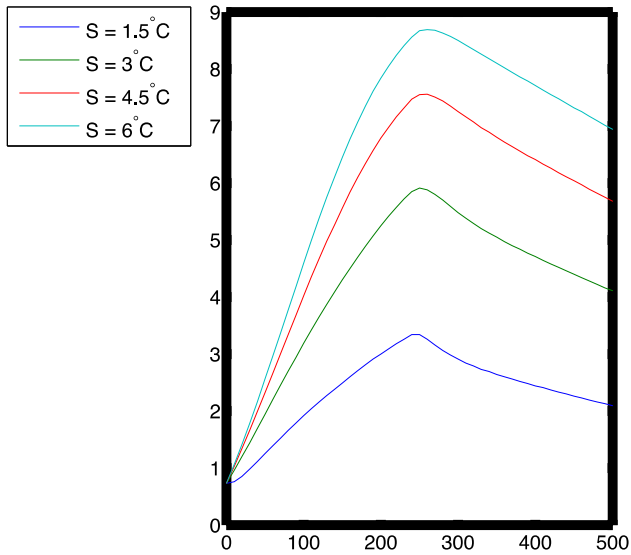
SENSITIVITY TO DISCOUNT RATE: CAPITAL RATIO



MODEL PARAMETERS – BASE CASE CALIBRATION

Parameter	Interpretation	Base case value
γ	Capital share of production	0.3
α_1, α_2	Gross damage multiplier parameters	$(2.22 \times 10^{-14}, 0.75 \times 10^{-14})$
β_1, β_2^*	Residual damage multiplier parameters (effectiveness of adaptation)	$(0.32 \times 10^{-2}, 0.17)$
δ_A, δ_V	Capital depreciation rates	10%/year
q^*	Cost of adjustment parameter	9.70×10^{-12}
η^*	Elasticity of marginal utility	2
ρ^*	Rate of pure time preference	1.5%/year
$L(t)$	Population	From RICE
$A(t)^*$	Total factor productivity	From RICE
$X(t)^*$	Temperature change	From DICE
$K_V(0)/L(0)$	Initial stock of vulnerable capital per capita	\$2796
$K_A(0)/L(0)^*$	Initial stock of adaptive capital per capita	\$0.50

GLOBAL TEMPERATURE TRAJECTORIES



CO₂

x

t