

# Discounting in Integrated Assessment of Climate Policy

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taught jointly with J. Paul Kelleher.





Integrated assessment models (IAM) are numerical frameworks which combine the main features of society and economy with the biosphere and atmosphere into one modelling framework. The goal of integrated assessment modelling is to accommodate informed policy-making.

Frameworks for integrated assessment:

- Cost-benefit analysis, or
- Cost-effectiveness analysis.

## **NB!**

IAMs are often *equilibrium* models solved using large-scale constrained nonlinear optimization methods. They incorporate multiple independent, optimizing agents who interact through markets in which allocations are mediated by prices.



- 1 Explicit representation of the problem to be addressed, incorporating behavioral responses.
- 2 Framework for assessing alternative approaches to the climate problem, and assessments of efficiency and equity.
- 3 Logical appeal of general equilibrium foundations.
- 4 May incorporate both environmental and technology constraints.
- 5 Address issues of risk and uncertainty which are centrally involved in climate policy design.



- 1 Misrepresentation and/or misunderstanding of model capabilities on the part of policy makers. Modesty is warranted. For starters, we don't have a reliable and parsimonious model of how policy interventions affect economic growth.
- 2 The modeling framework does less well when we abandon the simplifying assumption of selfish, optimizing agents.
- 3 Effective application requires detailed understanding of the underlying economic theory, climate dynamics and energy technologies.
- 4 Climate policy confronts economist with ethical issues which are unfamiliar and complex.<sup>1</sup>

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<sup>1</sup>For a philosopher's perspective, see J. Paul Kelleher, *The Social Cost of Carbon Ethics and the Limits of Climate Change Economics*



The Manne and Hogan (1977) invented the *Fable of the Elephant and the Rabbit*:

- The energy value share of GDP is typically on the order of 4-5% in industrial countries.
- This is something like *elephant-rabbit stew*. If such a recipe contains just one rabbit (the energy sector) and one elephant (the rest of the economy), doesn't it still taste very much like elephant stew?
- But what if energy prices double, triple or quadruple, and there is sufficient time for the economy to respond? How much will this cost the rest of the economy?
- For large reductions in energy use, the value share of energy in aggregate output need not remain fixed. If the value share rises, the metaphor of the elephant and the rabbit may no longer be appropriate.



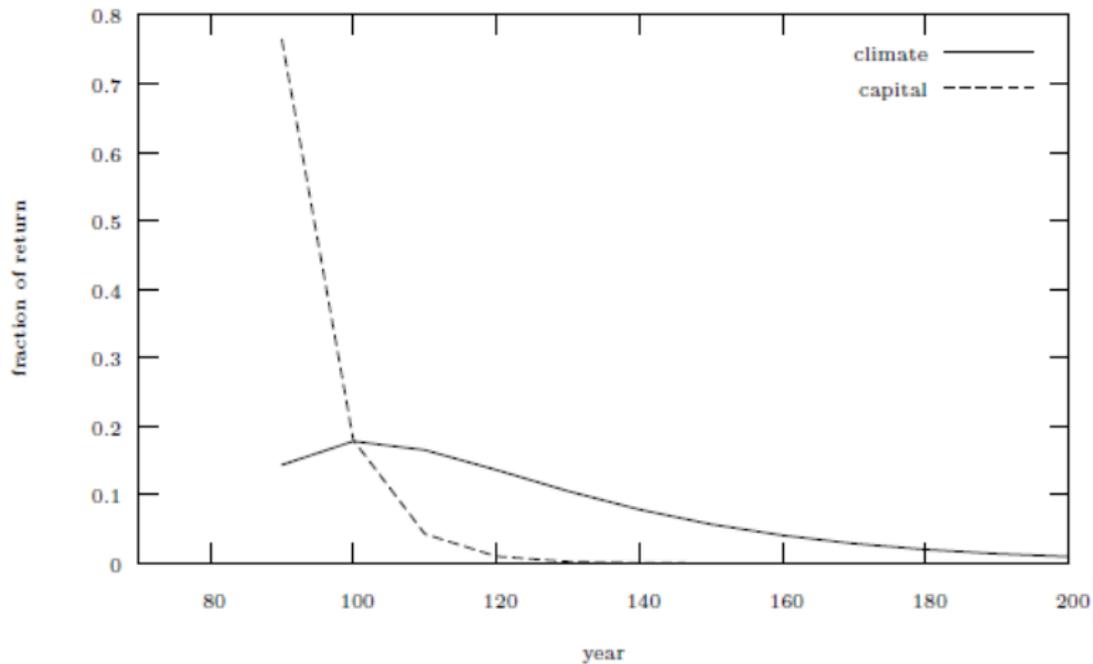
- In many energy policy studies, the energy sector is appropriately viewed in isolation from the remainder of the economy.
- In some situations this may be inappropriate, as there may be *two way interdependence* between energy markets and the rest of the economy.
- Even a large change in energy markets may represent a small fraction of aggregate economic output.
- There may be virtual one-way linkages: growth in aggregate GDP influence energy demand, but not vice versa.
- If, however, two-way linkages are important, then the analysis of energy market issues demands an economy-wide perspective.



Reasons to discount:

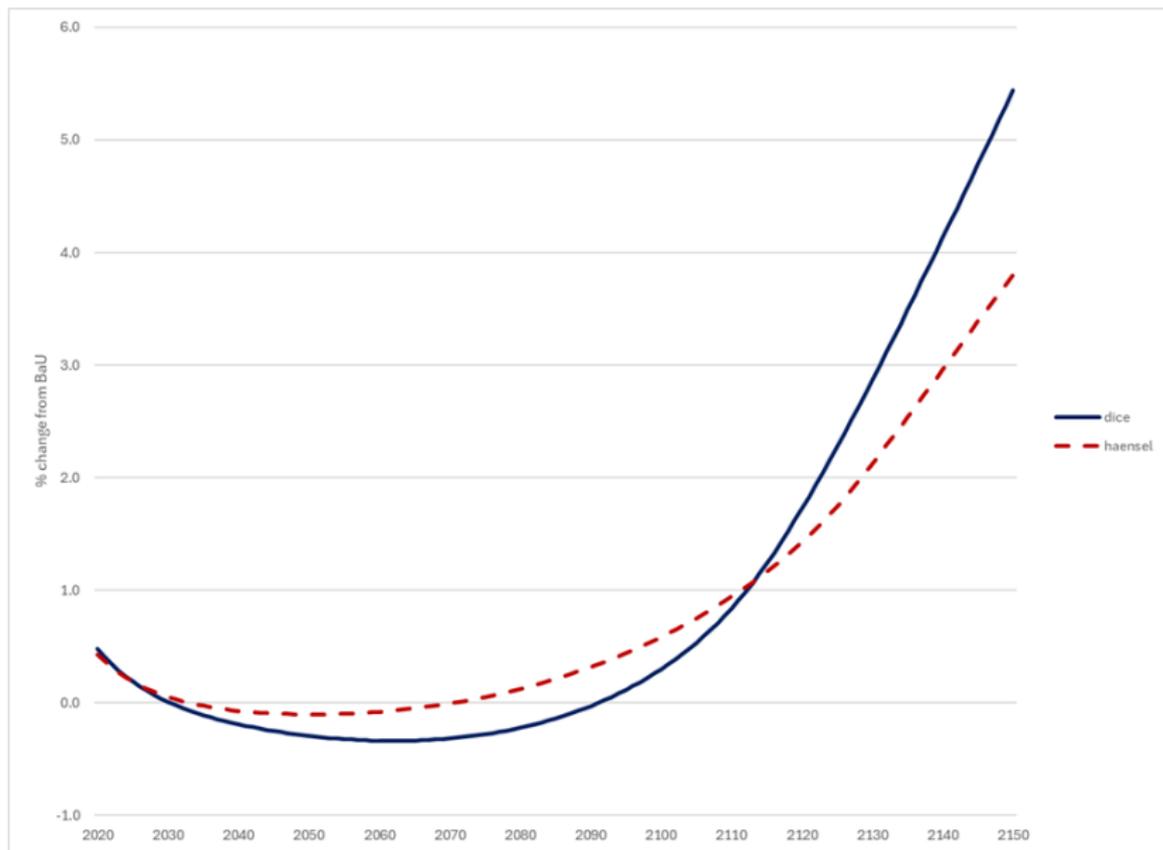
- Pure rate of time preference (time discounting) – preference for near term consumption.
- Economic growth (growth discounting) – future generations may be richer, hence it may be ethically defensible to reduce savings and investment.
- Productivity of capital – \$1 invested now will be worth \$1 plus the rate of interest.

# Time Structure of Returns



Böhringer, Löschel and Rutherford, JEDC (2007)

# Consumption Impact of Optimal Mitigation





**Prescriptive** Interest rate is determined jointly by the pure rate of time preference ( $\rho$ ), the elasticity of the marginal utility of consumption ( $\eta$ ) and the growth rate ( $g$ ):

$$r = \rho + \eta g$$

Reasons for discounting future consumption:

- future utility may be treated as being worth less than current utility ( $\rho > 0$ )
- consumption may be believed to be higher in the future ( $\eta g$ )

**Descriptive** *Calibrate* the Ramsey model to a market interest rate, using the observed market rates of interest ( $\bar{r}$ ) and growth ( $\bar{g}$ ) to impute the pure rate of time preference:

$$\rho = \bar{r} - \eta \bar{g}$$



A September 1992 IIASA workshop in Austria provided the crucible for discussions on the economics of climate for IPCC purposes, with the last-minute addition of a session on discounting:

## **NEW SESSION BY POPULAR DEMAND: DISCOUNTING**

*Chairperson: T. Schelling*

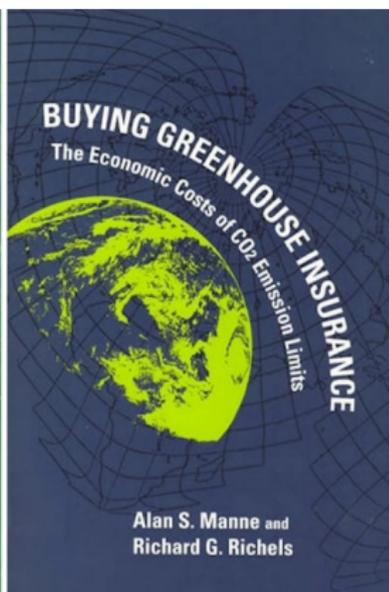
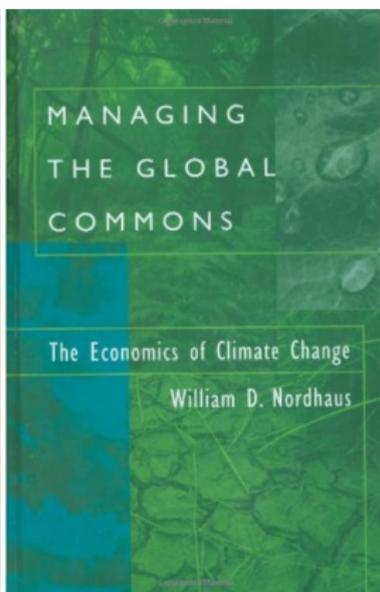
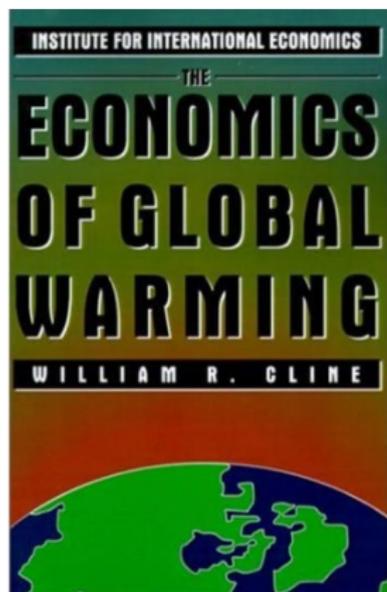
*Contributors: W. Cline, A. Manne, W. Nordhaus*

**17:00 Brief Presentations and Discussion**

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<sup>2</sup>The material in this section has been drawn from Beatrice Cherrier's [blog](#). She was first to report on the IPCC referee process related to discounting.

# Early Contributors to the Discounting Debate





- Cline derived the discount rate from utility theory adding up pure time preference (which he set to zero) and expected declining marginal utility - he did not use a full microfounded general equilibrium growth setting. This led to a low discount rate of 1-2%.
- Nordhaus pushed back, arguing that “while this [Cline’s] approach is philosophically satisfying, it is inconsistent with actual societal decisions on saving and investment.”

Nordhaus insisted “it is essential that the discount rate be based on actual behavior and returns on assets rather than on a hypothetical view of how societies should behave or an idealized philosophy about treatment of future generations.”



All these discussions set the stage for the IPCC team's draft of the discounting chapter, which was completed later in 1994. IPCC coordinators sent it to reviewers.

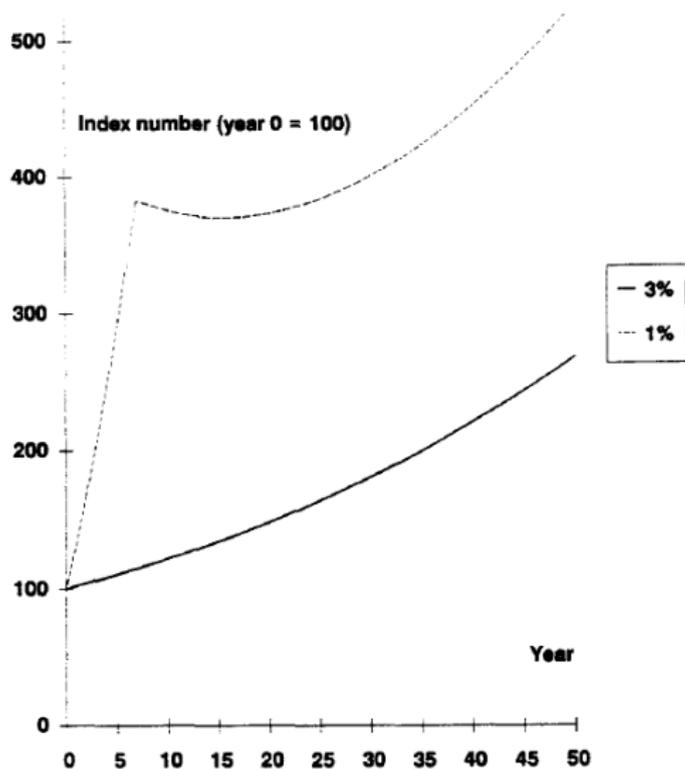
One reviewer, an ecological economist from a US environmental studies department flat-out rejected the whole discounting approach, along with utilitarianism and cost-benefit analysis. But this critique didn't seem to make much of a dent in the draft.

The second review was more nuanced. It endorsed the “welfare tradeoffs between generations” framework, including the Ramsey formula (its parametrization was discussed). However, the reviewer also pointed out that “the paper is based on a *prescriptive* rather than *descriptive* view of political economy. It virtually ignores the observable fact that the marginal productivity of capital . . . is in the range of 4-6% per year on the OECD countries.”



*With a real annual discount rate of 5% or more - and there are no significant climate impacts for half a century - these impacts have a present value that is virtually negligible. Within a cost-benefit framework, it then becomes exceedingly difficult to justify any near-term actions other than no-regrets policies. In the greenhouse debate, it is important to draw a clear distinction between prescriptive and descriptive reasoning.*

# Investment Response: Passing the Laugh Test?



**Figure 1** Net investment – alternative rates of time preference



Climate policy analysts who counsel a low rate of time preference face a fundamental challenge: economic growth models with low or zero discount rates are inconsistent with market interest rates. In the Ramsey optimal growth framework, changes in the utility time preference produce implausible changes in aggregate investment without a significant change in the marginal productivity of capital. Using technical language, Manne declares that integrated assessment models based on very low discount rates “fail to pass the laugh test.”



*The label “consumption discount rate” has been used for two very different notions: what we will call the social-welfare-equivalent consumption discount rate ( $\rho_{SW}$ ) and the finance-equivalent consumption discount rate ( $\rho_F$ ). Distinguishing the two concepts can resolve a good part of the controversy over “the” discount rate. Distinguishing the concepts also can substantially clarify the ways in which ethical and empirical considerations become relevant to the choice of discount rate.*

Bilevel programs are mathematical programs with optimization problems in their constraints. The main problem is called the upper-level problem or *the leader* and the nested problem is called the lower-level problem or *the follower*. One application is the design of optimal tax instruments: the tax instrument is modeled in the upper level while market equilibrium conditions are represented in the lower level optimization:

$$\max_t \mathcal{W}(x; \rho_{SW})$$

subject to:

$x$  solves

$$\max_x \mathcal{U}(x; t, \rho_F)$$

$$h(x; t) \geq 0$$

in which the second level optimization problem takes  $t$  as given.



Algebraic modeling languages like GAMS and JULIA/JUMP facilitate the description of a problem in mathematical terms and to link the abstract formulation with data-management systems on the one hand and appropriate algorithms for solution on the other.

Most models are mathematical programming problems such as linear programs (LPs), nonlinear programs (NPs), mixed integer programs (MIPs), mixed complementarity programs (MCPs).

Extended Mathematical Programming (EMP) facilitates the *automatic reformulation* of new model types by converting the EMP model into established mathematical programming classes to solve by mature solver algorithms.



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parameter          rhoSW(tc)          Social discount factor;

variable           WELFARE            Social welfare;
equation           welfaredef;

welfaredef..       WELFARE =E= sum(t, rhoSW(t)* L(t)* U(C(t)/L(t)));

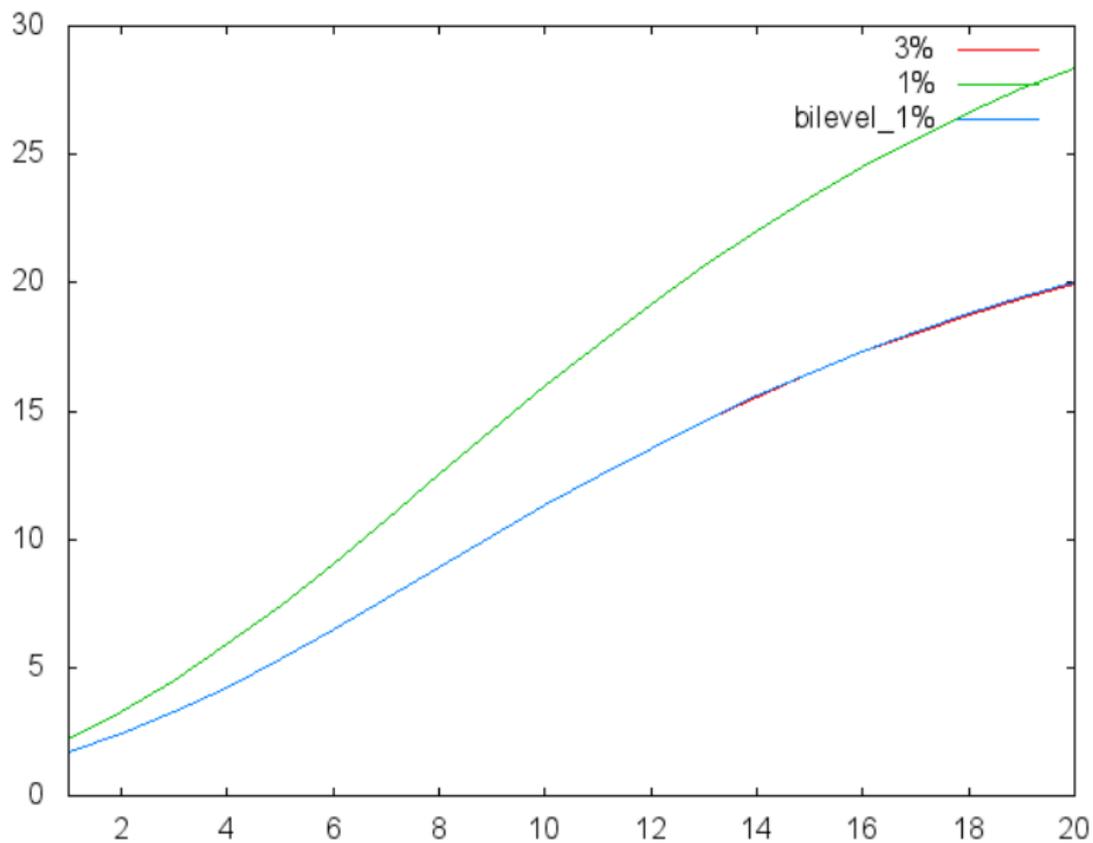
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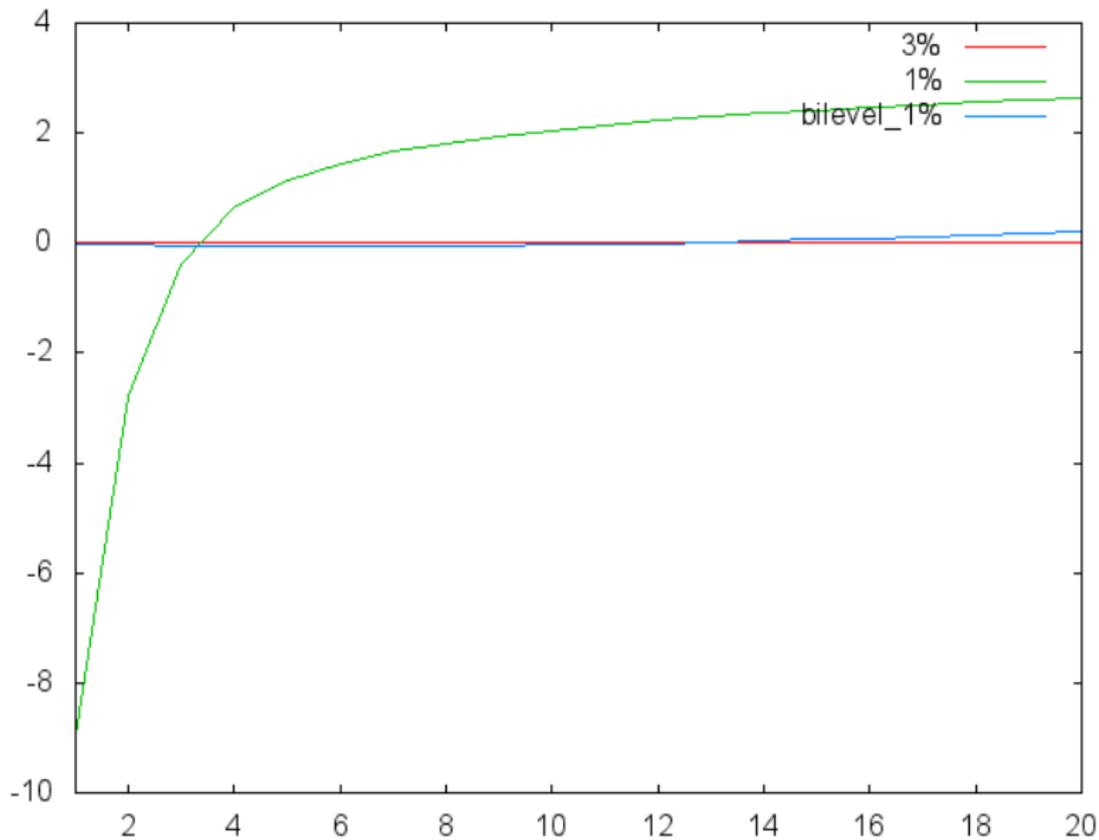
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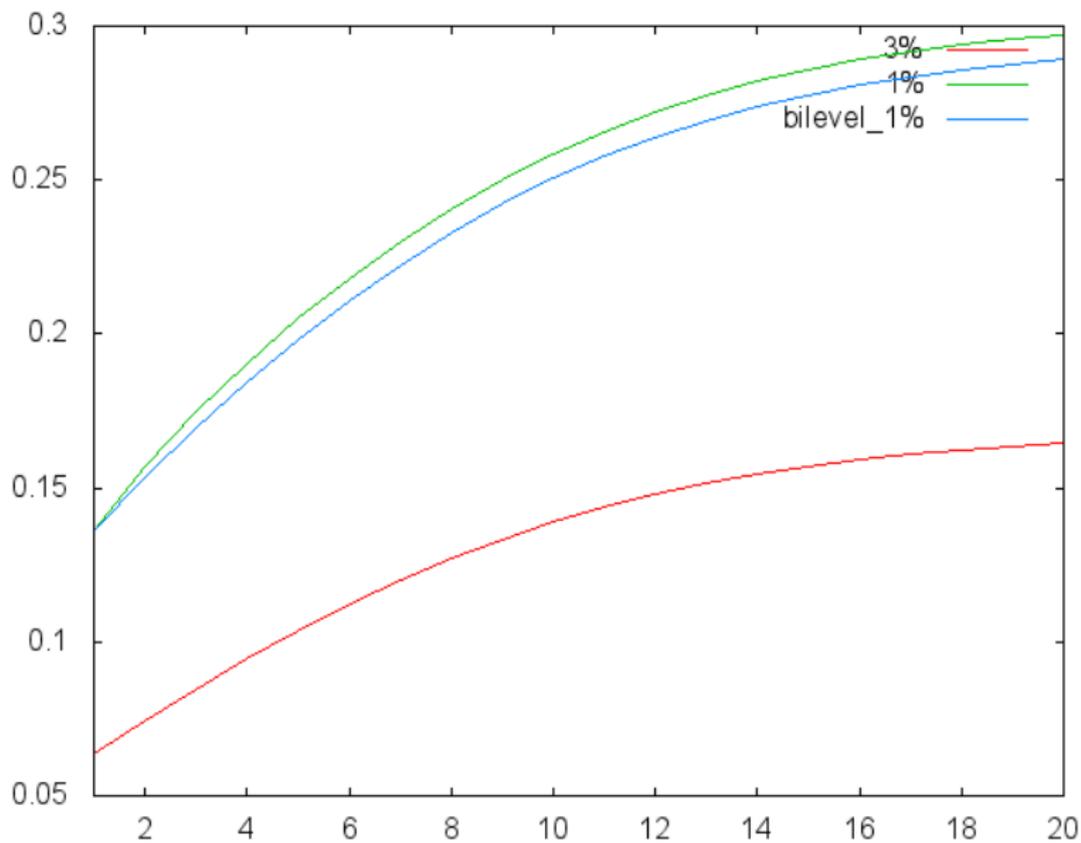
MAX utility *

UTIL YY AA DD QQ CC KK KC EE FORCE MM TTE TLE
$offput

solve dicebilevel maximizing welfare using emp;
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- There is may be substantial difference between descriptive and prescriptive discount rates. If this difference is ignored, the resulting uncalibrated model is almost surely useless in a partisan dialogue.
- *Bilevel optimization* provides a means of introducing both prescriptive ( $\rho_{SW}$ ) and descriptive ( $\rho_F$ ) discount factors. This offers a logically consistent assessment of optimal climate policies under low or zero social discount rates.
- The economic cost of mitigating climate change is small (as a fraction of GDP), but greenhouse gas mitigation is a challenging problem, in large part because the time horizon associated with climate “investments” is much longer than the time horizon associated with investments in physical or human capital.