The Current State of Climate Economics

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I. *"Discounting"* plays a major role in climate policy cost-benefit analysis

- ***One*** way (but not the ***only*** way) of making intertemporal comparisons

- Keep in mind that economists of all persuasions have since the 1990s supported action to mitigate climate change

- The main disagreement among economists has been whether to act aggressively or "go slow"

- The discount rate *r* used to value future costs and benefits makes a huge difference in the outcome of any cost-benefit analysis.

- Where do economists get *r*?

Simplest possible intertemporal framework: Discounted expected utility (e.g., Cochrane 2005)

$$U[c_t, c_{t+1}] = u(c_t) + e^{-\delta} E[u(c_{t+1})] \qquad (1)$$

U and u are utility functions; c is consumption; δ is the "rate of pure time preference." Consider the purchase of an asset at t that pays x_{t+1} at $t+1$. The agent has exogenous endowments w_t and w_{t+1}. If θ units of the asset are purchased, the budget constraints are

$$c_t = w_t - p_t\theta$$
$$c_{t+1} = w_{t+1} + x_{t+1}\theta$$

The basic pricing equation for the asset is

$$p_t = E\left[e^{-\delta} \frac{u'(c_{t+1})}{u'(c_t)} x_{t+1}\right] \qquad (2)$$

Further simplification: CRRA Utility

(embodies "diminishing marginal utility of consumption")

$$u(c) = \frac{c^{1-\eta} - 1}{1-\eta}$$

$$u'(c) = c^{-\eta}$$

- Becomes logarithmic utility in the limit as $\eta \rightarrow 1$
- "Preference function of choice" in growth theory and macro

Without uncertainty:

Invest \$ 1 at t, receive \$ $(1 + r)$ at $t+1$

$$1 = e^{-\delta} \frac{u'(c_{t+1})}{u'(c_t)} (1+r)$$

$$= e^{-\delta} \left(\frac{c_{t+1}}{c_t} \right)^{-\eta} (1+r)$$

$$= e^{-\delta} (1+g)^{-\eta} (1+r)$$

Take logarithms, and

$$r = \delta + \eta g \qquad (3)$$

This **"Ramsey rule"** gives the discount rate r used in many Integrated Assessment Models (e.g., DICE, Stern, etc.)

Nordhaus (*Science*, 2007):

"Where does the return on capital come from? The Stern Review and other analyses of climate economics base the analysis of real returns on the optimal economic growth theory….in which the long-run equilibrium real return on capital is determined by $r = \delta + \eta g$.... ".

But note:

- Is $\delta > 0$? δ discounts *utility*, not goods, so $\delta > 0$ cannot be justified because future generations will be richer. The argument for positive r comes from ηg.

- If $g < 0$, $r < \delta$ (Tol 1994, Amano 1997, Dasgupta et al. 1999)

Uncertainty Changes Everything:

- Many ***different*** interest rates are observed in the market
- You can't ignore randomness in c_{t+1}, x_{t+1}
- ***The Ramsey rule is no longer valid***

From the basic pricing rule (equation (2)) and the elementary fact that for random variables Y, Z, we have $E[YZ] = E[Y]E[Z] + Cov[Y,Z]$, the pricing rule for asset i is (Cochrane 2005)

$$p_t^i = E\left[\frac{e^{-\delta}u'(c_{t+1})}{u'(c_t)}\right]E[x_{t+1}^i] \quad + \quad Cov\left[\frac{e^{-\delta}u'(c_{t+1})}{u'(c_t)}, x_{t+1}^i\right]$$

or, after some algebra,

$$E[r^i] \quad = \quad r^f \quad - \quad \frac{Cov[u'(c_{t+1}), r_{t+1}^i]}{E[u'(c_{t+1})]} \tag{4}$$

where the “riskfree rate” r^f is defined as

$$1 + r^f = \frac{1}{E\left[\frac{e^{-\delta} u'(c_{t+1})}{u'(c_t)}\right]} \qquad (5)$$

It is called the riskfree rate because it does not depend on randomness in the asset’s payoff, but only on randomness in the consumption path. As uncertainty in consumption diminishes, this becomes equivalent to the Ramsey rule.

Note that:

- For *stocks*, E[r^i] > r^f

- For *insurance*, E[r^j] < r^f

One more simplification:

If (c_{t+1}/c_t) is lognormally distributed with

$E[\log(c_{t+1}/c_t)] = g$, and

$Var[\log(c_{t+1}/c_t)] = \sigma^2$

Then,

$$r^f = \delta + \eta g - \tfrac{1}{2}\eta^2\sigma^2 \qquad (6)$$

This is the generalization of the Ramsey rule for a "riskfree" asset. The term $-\tfrac{1}{2}\eta^2\sigma^2$ arises because of the demand for ***precautionary saving.*** Note that $r^f < \delta + \eta g$.

However, things are not so easy….

The Riskfree Rate Puzzle:

With $\delta = 0.01$, $\eta = 10$, $g = 0.018$, $\sigma = 0.036$: $r^f = 0.125 = 12.5\%$

With $\delta = 0.0$, $\eta = 2$, $g = 0.018$, $\sigma = 0.036$: $r^f = 0.0334 = 3\%$

But the annual real return on short term T-bills ≈ 1%

The Equity Premium Puzzle:

With the equilibrium condition that the growth rates of consumption and dividends are equal, then

$$r^e = \delta + \eta g - ½\, \eta^2\sigma^2 + \eta\sigma^2 \qquad (7)$$

so with $\eta = 10$, $r^e - r^f = 0.013 = 1.3\%$

But the average difference in annual real returns between stocks and T-bills ≈ 6%

Mehra and Prescott (2003, *Handbook of Econ. of Finance*):

"The puzzle cannot be dismissed lightly, since much of our economic intuition is based on the very class of models that fall short so dramatically when confronted with financial data. It underscores the failure of paradigms central to financial and economic modeling to capture the characteristic that appears to make stocks comparatively so risky. Hence ***the viability of using this class of models for any quantitative assessment, say, for instance, to gauge the welfare implications of alternative stabilization policies, is thrown open to question***." [emphasis added]

Weitzman (2007, *JEL*):

"If we treat [6] and [7] as two equations in two unknowns (δ and η), we can then invert the two equations that would back out the hypothetical values $\hat{\delta}$ and $\hat{\eta}$ that would "explain" the stylized-fact empirical observation that $r^f \approx 1\%$ and $r^e - r^f \approx 6\%$. When this is done (for $g = 2\%$ and $\sigma = 2\%$), it produces the mega-puzzle that the estimated rate of pure time preference is $\hat{\delta} \approx 151\%$ per year and the coefficient of relative risk aversion is $\hat{\eta} \approx 150$. ***One does not know whether to laugh or cry….***" [emphasis added]

But it gets much, much worse!
(following Weitzman 2007, 2008; Geweke 2001)

Up to this point, we have assumed that g and σ^2 are known. But suppose they are not known and have to be estimated from the data?

Drop time subscripts and normalize present consumption to 1. Define $y = \log(c)$. The present value of a "sure" unit of consumption in the future is given by

$$\frac{1}{1+r^f} = E\left[e^{-\delta} e^{-\eta y}\right]$$

$$= e^{-\delta} \int_{-\infty}^{\infty} e^{-\eta y} f(y) dy \qquad (8)$$

Observe that the integral is just the moment-generating function of the random variable Y.

Much, much worse (cont'd – still following Weitzman)

Without loss of generality, let g be known, and the sample variance (from a sample of size n) be v_n. Then with a Jeffreys' prior ($\propto 1/s$) on the (unknown) standard deviation s, straightforward Bayesian technique shows that the "posterior-predictive" PDF of y is given by

$$f(y) \propto \left(1 + \frac{(y-g)^2}{n v_n}\right)^{-(n+1)/2}$$

which is a Student's t distribution with n degrees of freedom.

But the moment-generating function of Student's t does not exist; it diverges to ∞! Discounted expected utility analysis is incoherent.

What can this possibly mean?

- The divergence result can be fully generalized – Weitzman's "Dismal Theorem" (2008)
- *Uncertainty* not the same as *risk*
- Uncertainty can be more important than the risk-based discount factor
- No finite sample of data can eliminate the problem
- Potential ways out are ad-hoc or simply assumptions:
  - Arbitrarily limit disutility (e.g., wtp to avoid extinction ≤ GDP)
  - Arbitrarily change form of utility function
  - Arbitrarily restrict the prior
- ***The influence of the low-probability disasters dominates***

An "impossibility result" for discounted expected utility methods?

II. Can we solve the emissions problem through energy efficiency, renewable energy, and other zero-cost measures?

- Many cost-saving, energy-saving technologies exist
  - Combined heat and power
  - Efficient lighting
  - Computer-controlled HVAC
  - Etc., etc., etc.

- Can greenhouse gas emissions be reduced to ***20 – 30% of current levels*** through these technologies? Almost certainly not.

- How big an investment will be required? ***No one knows.***
  - 2% of GDP is approximately $260 billion/yr.
  - permanent 2% drop in GDP is approximately 7 months of economic growth

III. The problem of equity: Who pays?

- Lower portion of income distribution spends relatively greater fraction of income on energy

- Carbon tax or cap-and-trade with permits given to polluters according to their historic use would be regressive and the biggest cartel in the history of humanity

- Carbon tax or cap-and-trade with permit auction and recycling of the revenues on a per capita basis would ***raise*** the incomes of most citizens, at least initially

- The problem of ***international burden-sharing*** is primarily one of equity

Distributional Impact of a U.S. Sky Trust
(based on a carbon charge of $200/tC, with 100% recycling to individuals)

Per capita expenditure decile	Per capita expenditure ($)	Average household size	Per capita incidence ($)			As percentage of expenditures		
			Charge	Rebate	Net benefit	Charge	Rebate	Net benefit
1	1927	3.4	217	682	465	11.2%	35.4%	24.1%
2	3521	3.3	340	682	342	9.6%	19.4%	9.7%
3	4736	3.2	426	682	255	9.0%	14.4%	5.4%
4	5991	2.7	517	682	165	8.6%	11.4%	2.7%
5	7380	2.6	579	682	102	7.8%	9.2%	1.4%
6	8847	2.5	652	682	30	7.4%	7.7%	0.3%
7	10711	2.3	735	682	-54	6.9%	6.4%	-0.5%
8	13228	2.1	840	682	-159	6.4%	5.2%	-1.2%
9	17178	2.0	1029	682	-347	6.0%	4.0%	-2.0%
10	29943	1.8	1482	682	-800	4.9%	2.3%	-2.7%

Source: Boyce & Riddle (2007).

IV. What About International Burden-Sharing?

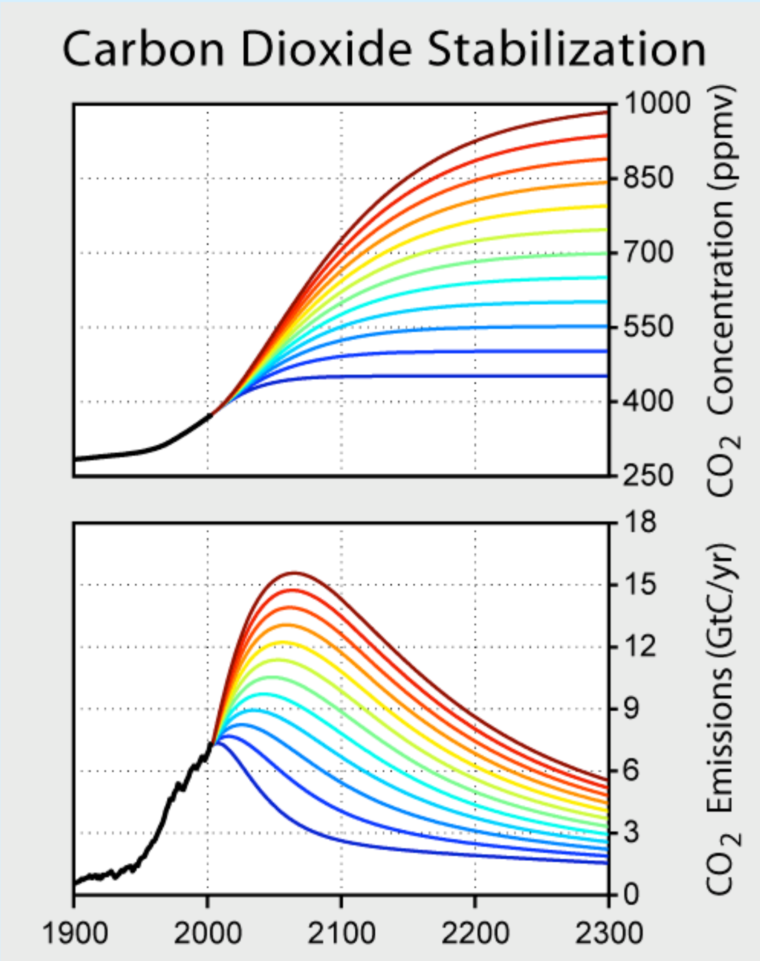
- 80% reduction from present global emissions levels is “safe”

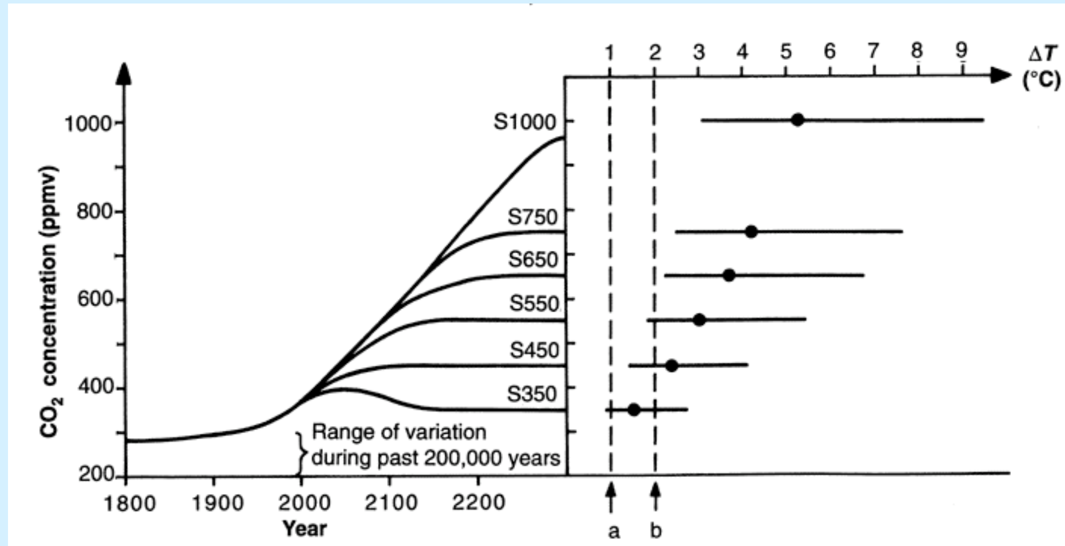
- Calibrate a model so that this is “optimal”

- Keep it as simple as possible; minimize mathematical apparatus

- Compute the consequences

Atmospheric stabilization scenarios:





Left: IPCC stabilization scenarios for atmospheric CO_2. Right: Corresponding equilibrium changes in global mean temperature since pre-industrial times (central values plus uncertainty ranges from IPCC (1996a). Other greenhouse gases and aerosols combined have been assumed to add 1 W/m2. The dashed vertical lines denote (a) the estimated range of variability of the change between in global mean temperature during the past 1000 years and (b) the 2^{o}C temperature considered as a long run climate policy target by the European Union. A temperature increase by 5-7^{o}C corresponds to the sustained average change in global average surface temperature that takes place during the transition from an ice age to an interglacial. Source: Azar & Rodhe (1997). /

http://www.globalwarmingart.com/wiki/Image:Carbon_Stabilization_Scenarios_png

Model Description:

- Single consumption good,
  standard utility function for each nation/region

- Emissions enter utility functions directly

- Production as simple as possible:
  "productive resources," CO_2 emissions, profit maximization

- Global utility function constructed using Negishi weights

- Different versions run according to distribution of
  emissions rights

Table 2 (continued)
Utilities (with Utility Ranks in boldface)

	(1) Status quo, allocation ⊠ $C0_2$ reserves: oil, gas, coal	(2) Status quo, allocation ⊠ oil and gas	(3) Status quo, allocation ⊠ CO_2 emissions	(4) Status quo, allocation ⊠ Population		(5) Negishi SWF, weights from (1)	(6) Negishi SWF, weights from (2)	(7) Negishi SWF, weights from (3)		(8) Per capita allocation, G from (5)	(9) Per capita allocation, G from (6)	(10) Per capita allocation, G from (7)
USA	85.209 **8**	84.907 **10**	85.254 **7**	84.950 **9**		93.558 **2**	93.172 **6**	93.621 **1**		93.233 **4**	93.227 **5**	93.239 **3**
EU	85.167 **9**	85.128 **10**	85.375 **7**	85.249 **8**		93.505 **5**	93.450 **6**	93.773 **1**		93.608 **3**	93.601 **4**	93.615 **2**
Japan	73.559 **9**	73.554 **10**	74.414 **7**	73.962 **8**		78.943 **6**	78.956 **5**	79.998 **1**		79.448 **3**	79.467 **2**	79.429 **4**
China	78.977 **9**	78.209 **10**	79.831 **8**	79.959 **7**		85.740 **5**	84.785 **6**	86.806 **4**		86.972 **2**	86.977 **1**	86.966 **3**
India	66.705 **7**	63.112 **10**	64.979 **9**	70.050 **5**		70.346 **4**	65.881 **8**	68.140 **6**		74.541 **2**	74.568 **1**	74.513 **3**
Eurostat	79.402 **8**	79.479 **7**	79.280 **9**	78.939 **10**		86.273 **2**	86.375 **1**	86.113 **3**		85.692 **5**	85.699 **4**	85.684 **6**
SA	70.438 **9**	71.394 **7**	70.280 **10**	71.058 **8**		75.029 **5**	76.252 **1**	74.803 **6**		75.806 **3**	75.831 **2**	75.780 **4**
CIS	70.861 **3**	69.640 **5**	66.261 **9**	64.120 **10**		75.559 **1**	74.055 **2**	69.752 **4**		67.103 **7**	67.144 **6**	67.062 **8**
Africa	59.926 **7**	59.304 **9**	57.981 **10**	64.223 **4**		61.841 **5**	61.113 **6**	59.346 **8**		67.232 **2**	67.272 **1**	67.190 **3**
Middle East	64.169 **4**	74.425 **2**	57.395 **6**	55.947 **10**		67.164 **3**	80.047 **1**	58.609 **5**		56.851 **8**	56.910 **7**	56.790 **9**
Asia/ Pacific	67.475 **10**	67.822 **9**	68.612 **8**	71.342 **6**		71.312 **7**	71.779 **5**	72.707 **4**		76.162 **2**	76.186 **1**	76.137 **3**
Reverse Borda Count	**88**	**99**	**93**	**74**		**51**	**59**	**50**		**31**	**23**	**39**

Source: DeCanio (2009)

Table 3
Coalitions and Salience of Grandfathering vs. Per Capita Allocations

Country/Region	(1) Average Grandfathering Allocation Rank	(2) Average Per Capita Allocation Rank	(3) Δ (Avg. Rank) Col. (1)–Col. (2)	(4) Δ (Avg. x_i) (Percent) Per capita – Grandfathering
USA	3	4	-1	- 3.5
EU	4	3	1	0.5
Japan	4	3	1	0.7
China	5	2	3	9.1
India	6	2	***4***	***25.2***
Eurostat	2	5	-3	- 4.1
South America	4	3	1	1.8
CIS	2	7	***-5***	***- 19.2***
Africa	6	2	***4***	***19.9***
Middle East	3	8	***-5***	***- 34.1***
Asia/Pacific	5	2	3	***18.0***

Source: DeCanio (2009)

IV. Conclusions (Economic)

- Let science establish "safe" atmospheric concentrations, economics help guide us there
- Catastrophic risks are more important than CBA
- Economics has much to say about consistent incentives, cost-effectiveness, win-win opportunities, ***but little or nothing to say about "optimal" policy***
- The big losers internationally are the oil and gas states, not the developing economies, the US, or the EU

Conclusions (Political)

- Scientific uncertainty is not a reason for inaction.
  It is the main reason to act now.

- Climate protection is best characterized as an
  insurance policy against irreversible planetary catastrophe

- Effect of climate policy on the poor depends on
  what is done with the tax or auction revenues.

- The United States cannot solve the problem alone.
  Global cooperation is needed.

- The United States must exercise ***leadership*** to achieve
  global cooperation. ***This requires bipartisan agreement.***

References

Cochrane, J. H. (2005) *Asset Pricing (Revised Edition)* (Princeton University Press, Princeton).

Nordhaus, W. (2007) "Critical Assumptions in the Stern Review on Climate Change," S*cience* 317 (13 July): 201-2.

Tol, R. S. J. (1994) "The damage costs of climate change – a note on tangibles and intangibles, applied to DICE," *Energy Policy* 22: 436–438.

Amano, A. (1997) "On Some Integrated Assessment Modeling Debates. Paper presented at IPCC Asia-Pacific Workshop on Integrated Assessment Models," United Nations University, Tokyo, March 10-12.

Dasgupta, P., Mäler, K. G., Barrett, S. (1999) "Intergenerational Equity, Social Discount Rates, and Global Warming." In: Portney, P. R., Weyant, J. P. (eds) *Discounting and Intergenerational Equity* (Resources for the Future, Washington, DC), pp. 51–78.

Mehra, R., Prescott, E. C. (2003) "The Equity Premium in Retrospect." In: Constantinides G. M., Harris M., Stultz R. (eds) *Handbook of the Economics of Finance* (Elsevier B.V., Amsterdam), pp. 889–938.

Weitzman, M. L. (2007) "A review of the *Stern Review on the Economics of Climate Change," Journal of Economic Literature* 45: 703–724.

Weitzman, M. L. (2008) "On Modeling and Interpreting the Economics of Catastrophic Climate Change." Available at http://www.economics.harvard.edu/faculty/weitzman/files/modeling.pdf.

Geweke, J. (2001) "A note on some limitations of CRRA utility," *Economics Letters* 71: 341-345.

Boyce, J. K., Riddle, M. (2007) "Cap and Dividend: How to Curb Global Warming While Protecting the Incomes of American Families," Political Economy Research Institute, University of Massachusetts Amherst, Working Paper 150.

DeCanio, S. J. (2009) "The political economy of global carbon emissions reductions," *Ecological Economics* 68: 915-924.

Questions and Comments Please!