

TAXES, TARGETS, AND THE SOCIAL COST OF CARBON

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 - And then countries (smaller aggregations) bargain over their own emission reductions.
 - Like textbook examples of Coase Theorem, country negotiations can involve monetary payoffs from rich countries to poor (and to those most vulnerable to climate change).
- But is bargaining over country-by-country emission reductions the best we can do? Would agreeing a carbon tax be better?

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- No consensus answers, so climate negotiations (including Paris in December 2015) have had limited success.
- Approach to pollution externalities generally preferred by economists: Estimate social (external) cost of pollutant and impose a corresponding tax. In this case, estimate the SCC.

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 - Can be flexible. Need not prevent monetary transfers or other forms of side payments.

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- To understand shift to a temperature target, must ask why we cannot agree on SCC.

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 - "The fundamental point about radical uncertainty is that if we don't know what the future might hold, we don't know, and there is no point pretending otherwise." M. King, 2016.
- Yet we have a proliferation of IAMs, which have become the standard tool for estimating the SCC. But as I have argued elsewhere, IAMs unsuitable for policy analysis.

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- But if we don't use IAMs to estimate SCC, what to do instead?
- Proposal: Estimate an *average* SCC using expert elicitation.

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 - Much less sensitive to discount rate.
 - Lends itself to expert elicitation.

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- Note focus on extreme outcomes.

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- Experts will reach opinions in different ways — perhaps one or more IAMs, or studies of climate change and its impact. How experts arrive at opinions is not a variable of interest. Important that experts are selected based on their established expertise.

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 - Especially true for climate change impacts — theory and data provide little guidance.
- Experts will reach opinions in different ways — perhaps one or more IAMs, or studies of climate change and its impact. How experts arrive at opinions is not a variable of interest. Important that experts are selected based on their established expertise.
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- Might claim I use a model, but model has very few moving parts, and is much more transparent than IAM-based analysis.

Opinion of Hypothetical Expert: BAU Outcomes

HORIZON $T = 50$

% GDP Reduction, z	0	0.020	0.050	0.100	0.200	0.500
$\phi = -\ln(1 - z)$	0	0.020	0.051	0.105	0.223	0.693
Prob	.25	.50	.10	.06	.05	.04
$1 - F(\phi)$	1	.75	.25	.15	.09	.04

HORIZON $T = 150$

% GDP Reduction, z	0	0.020	0.050	0.100	0.200	0.500
$\phi = -\ln(1 - z)$	0	0.020	0.051	0.105	0.223	0.693
Prob	0	.22	.40	.20	.10	.08
$1 - F(\phi)$	1	1	.78	.38	.18	.08

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$$\phi_t = \phi_m [1 - e^{-\beta t}] \quad (1)$$

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- To get β , use average ϕ_t at T_1 and $T_2 > T_1$: $\bar{\phi}_1$ and $\bar{\phi}_2$. Using $\bar{\phi}_1$ and $\bar{\phi}_2$ from table:

$$[1 - e^{-\beta T_2}] / [1 - e^{-\beta T_1}] = \bar{\phi}_2 / \bar{\phi}_1 = 2.06 \quad (2)$$

Solution to eqn. (2) is roughly $\beta = .01$.

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- Benefit portion of SCC is the damages that are avoided by reducing emissions.

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- $\text{SCC} = B_0 / \Delta E$ (in dollars/ton).
- So need to estimate B_0 and ΔE .

Benefit of Abatement, B_0

- Instantaneous percentage benefit from truncating distribution is $\mathbb{E}_0(\tilde{z}_1) - \mathbb{E}_1(\tilde{z}_1)$, where $\mathbb{E}_0$ is expectation under full distribution, and $\mathbb{E}_1$ is expectation under truncated distribution:

$$\begin{aligned} B_0 &= [\mathbb{E}_0(\tilde{z}_m) - \mathbb{E}_1(\tilde{z}_m)] Y_0 \int_0^\infty [1 - e^{-\beta t}] e^{(g-R)t} dt \\ &= \frac{\beta Y_0 [\mathbb{E}_0(\tilde{z}_1) - \mathbb{E}_1(\tilde{z}_1)]}{(R - g)(R + \beta - g)(1 - e^{-\beta T_1})} \end{aligned}$$

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- Here $\beta Y_0 [\mathbb{E}_0(z_1) - \mathbb{E}_1(z_1)] / (1 - e^{-\beta T_1})$ is the instantaneous flow of benefits from truncating the distribution, and dividing by $(R - g)(R + \beta - g)$ yields present value of this flow.

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- Assume real cost per ton abated is constant, so discount future emission reductions at same rate R . (Need $R > m_0$.) So

$$\begin{aligned}\Delta E &= E_0 \int_0^{\infty} \left[e^{(m_0-R)t} - e^{(m_1-R)t} \right] dt \\ &= \frac{(m_0 - m_1)E_0}{(R - m_0)(R - m_1)}\end{aligned}\tag{4}$$

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 - Then implied $\text{SCC} = B_0 / \Delta E = \81 per metric ton.

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- Average SCC declines as R is increased, but much less sharply than marginal SCC.

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Web of Science Search Terms

Single Search Terms	Joint Search Terms	
(A)	(B)	(C)
"climate change policy" "social cost of carbon" "climate policy" "climate-change policy" "climate forcing" "radiative forcing" "climate feedbacks" " climate sensitivity" "equilibrium climate response" "global mean surface temperature" "carbon price" "carbon-price" "price of carbon" "carbon tax" "tax on carbon" ("cap-and-trade" AND carbon) (carbon AND quota) (carbon AND trade AND cap)	"ocean temperature" "precipitation" "sea level rise" "sea level change" "ocean acidity" catastrophe catastrophic economy economics damages mortality productivity risk "discount rate" "atmospheric concentration" GDP "gross domestic product"	"climate change" "climate-change" "greenhouse gas" "greenhouse gases" GHG (CO2 AND emissions) ("carbon dioxide" AND emissions)

Note: Quotation marks mean phrase must appear exactly as written. Search results must include at least one term in column A *or* at least one term from *each of* columns B and C.

Publications and Authors by WOS Research Area

Research Area	(A) No. Pubs, Top 10% of Cites	(B) Distinct Authors	(C) No. Authors per Pub.	(D) No. Authors, 2.50 per Pub.	(E) % of Highly Cited Pubs.	(F) % of Authors
Agriculture	282	1506	5.34	705.6	7.3%	7.3%
Business and Economics	257	643	2.50	643.0	6.7%	6.7%
Environmental Sciences and Ecology	1873	8932	4.77	4686.1	48.6%	48.6%
Geology	629	3787	6.02	1573.7	16.3%	16.3%
Meteorology and Atmospheric Sciences	815	4919	6.04	2039.1	21.1%	21.1%
Total	3856	19,787	4.93	9647.5	100%	100%

Note: In (D), (E), (F), % of authors matched to % of highly cited publications in each area.

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- **Q4:** Under BAU, what is the *most likely* climate-caused reduction in world GDP we will witness in *the year 2150*?
- **Q5:** Return to the 50-year time horizon. What is the average annual growth rate of GHG emissions needed to prevent a climate-induced reduction of world GDP of 20% or more?

Questionnaire

- **Q1:** Under BAU (i.e., no additional steps taken to reduce emissions), what is best estimate of the average growth rate of world GHG emissions over the next 50 years?
- **Q2:** Under BAU, what is the *most likely* climate-caused reduction in world GDP we will witness in 50 years?
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- **Q5:** Return to the 50-year time horizon. What is the average annual growth rate of GHG emissions needed to prevent a climate-induced reduction of world GDP of 20% or more?
- **Q6:** What discount rate should be used to evaluate future costs and benefits from GHG abatement?

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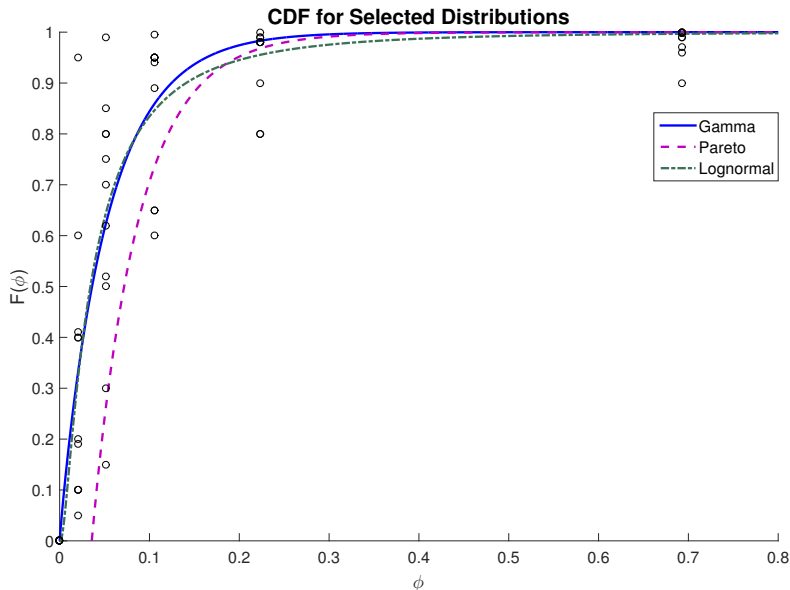
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- Figure shows least-squares fit of gamma, generalized Pareto, and lognormal cumulative distribution functions to the 11 responses to Question 3.

Responses from 11 Experts

Expert	Q1 (m_0)	Q2 ($\bar{z}_1$)	Q3					Q4 ($\bar{z}_2$)	Q5 (m_1)	Q6 (R)
			$\geq 2\%$	$\geq 5\%$	$\geq 10\%$	$\geq 20\%$	$\geq 50\%$			
1	.02	.04	.60	.20	.05	.01	.001	.10	0.00	.025
2	.03	.06	.59	.48	.35	.20	.04	.33	-.03	.0225
3	.02	.08	.90	.50	.05	.01	.00001	.33	-.04	.031
4	.02	.05	.80	.30	.05	.02	0.0	.15	0.00	.010
5	.02	.03	.95	.25	.06	.02	.002	.15	0.00	.025
6	.01	.04	.81	.38	.11	.02	0.0	.18	-.01	.0229
7	.02	.09	.90	.85	.35	.20	.10	.65	0.00	.020
8	.01	.02	.40	.15	.05	.02	.01	.10	.01	.020
9	.02	.06	.90	.70	.40	.10	.03	.15	0.00	.025
10	.01	.01	.05	.01	.005	.0005	.00001	.05	-.01	.020
11	.02	.04	.60	.20	.05	.02	.01	.08	-.01	.040
Avg.	.020	.047	.682	.365	.139	.056	.018	.21	-.010	.0238

Three Cumulative Distributions Fit to Responses from 11 Experts



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- Next step: elicit opinions of several thousand experts.

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- Survey is now being implemented. **Stand by for results.**