NERA
ECONOMIC CONSULTING

Sensitivity of the Social Cost of Carbon to Analysis Framing Decisions

Anne E. Smith and Paul M. Bernstein

Session A.2: *Issues in Climate Policy*
8th Annual Conference of Society for Benefit-Cost Analysis
Washington, DC
March 17, 2016

Insight in Economics™

Scientific Uncertainty vs. Analysis Framing Judgments

NERA ECONOMIC CONSULTING

- Every climate IAM represents a large number of physical and behavioral processes that are marked by vast uncertainty
  - ➔ these are – in principle – subject to scientific observation
  - ➔ IAM developers must make judgments to represent the currently available evidence/understanding (and to simplify)
  - ➔ can be addressed probabilistically, if desired

- Every use of IAMs to inform a policy decision requires the IAM user to make a number of choices about how to frame the analysis to fit the decision context
  - ➔ these are not objective in nature, but philosophical
  - ➔ the right choices depend on the decision context, such as the nature of the upside and downside consequences of the decision
  - ➔ not appropriate to resolve by applying probabilities

Framing Choices Can Be As Important As Scientific Assumptions

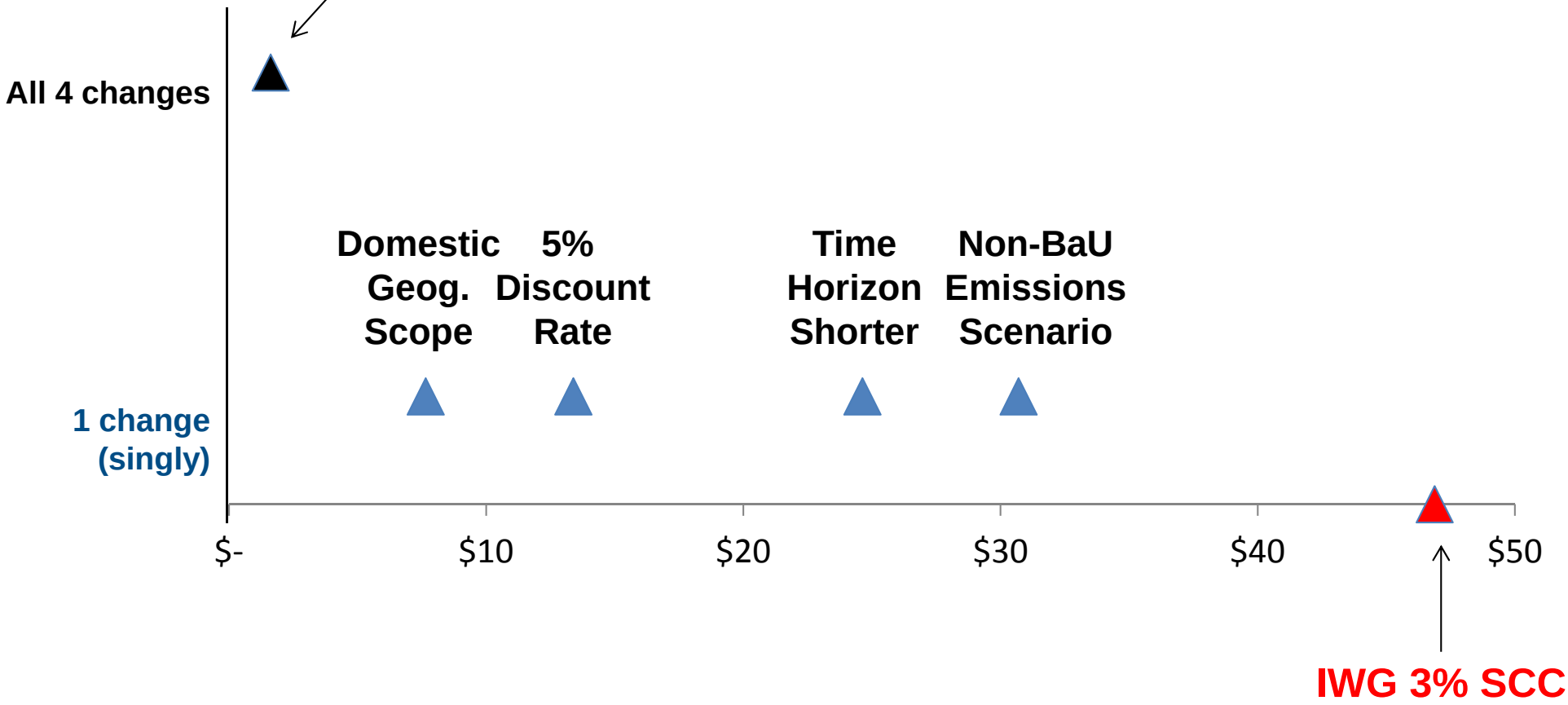
NERA ECONOMIC CONSULTING

- IWG computed SCC values under a set of assumptions using 3 different IAMs and 5 future scenarios.
  - 15 expected values of SCC resulted: from $13/tonne to $91/tonne, averaging $43/tonne (2007$ for 2020 emissions, 3% discount rate)
  - This range of -70% to +110% is supposed to represent differences of view among the original IAM modelers on scientific matters
- The IAM analysis also depends "framing choices" that are not scientific in nature and are in the hands of the IAM user.
  - Four of particular importance are:
    - Discount rate
    - Geographic scope
    - Future scenario of emissions and GDP
    - Time horizon
- Varying these framing choices over a reasonable range of alternative values reduces the $43/tonne estimate by up to -97%

Sensitivity of SCC Values to Alternative Framing Assumptions, -- Singly and in Combination

NERA ECONOMIC CONSULTING

With all 4 framing choices changed, SCC falls 97% below IWG's – with no change to scientific assumptions



Source: NERA model runs of IWG's IAMs. SCC values are in 2014$ per tonne emitted in 2020

Discount Rate Is the One Framing Choice Sensitivity Reported by IWG

NERA ECONOMIC CONSULTING

Range of SCC Estimates Recommended by IWG (2007$/tonne CO_2)

Discount Rate	5.0%	3.0%	2.5%	3.0%
Year	Avg	Avg	Avg	95th
2010	11	33	52	90
2015	12	38	58	109
2020	12	43	65	129
2025	14	48	70	144
2030	16	52	76	159
2035	19	57	81	176
2040	21	62	87	192
2045	24	66	92	206
2050	27	71	98	221

Source: Interagency Working Group, Technical Support Document, May 2013, p.3

Choosing Appropriate Geographical Scope for SCC Estimate

NERA ECONOMIC CONSULTING

- IWG SCCs include full weight to benefits in all countries
- BCA only guides a community to welfare-enhancing decisions if potential compensation principle is applicable
  - There is no international political structure to make the PCP a reasonable assumption for GHG controls
  - Weight to give to non-domestic benefits could depend on the global effect of the policy decision itself in creating reciprocal action (because this alters the domestic risk of the policy action)
- Altruistic weight for non-domestic benefits may exist but should receive less weight than domestic benefits

Disaggregation of IWGs SCC values to U.S. and Non-U.S. (2007$/tonne emitted in 2020)

	U.S. SCC	Non-U.S. SCC
5% DR	2	10
3% DR	7	35
2.5% DR	11	54

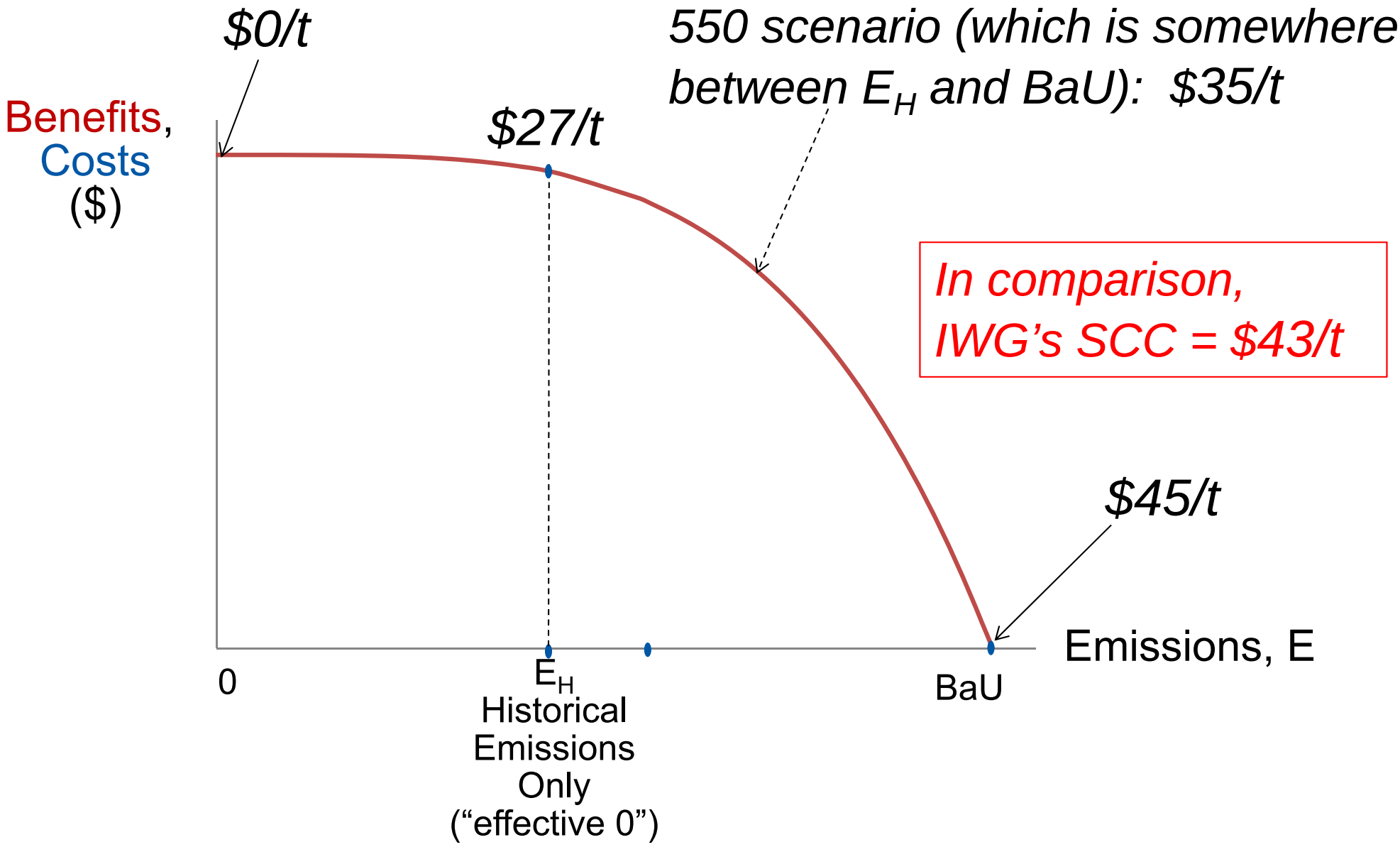
Source: NERA IAM runs replicating IWG's 2020 SCC values for FUND and PAGE, reporting their regional SCC values. Exclusion of DICE alters resulting avg. global SCC estimates by only ~$1/tonne

Choosing Appropriate Future Emissions Scenario

NERA ECONOMIC CONSULTING

- IWG used 4 business-as-usual scenarios and 1 stabilization scenario as fixed exogenous trends
  - Assumes that any effort to reduce a ton today will never be reciprocated by additional reductions in the future
  - The estimated marginal damage from one incremental ton emitted today is increased by the assumed lack of any further emissions reductions thereafter
- A non-BaU emissions scenario is more appropriate, particularly given the lack of any adaptive response logic in the IAMs that the IWG used
  - Without adaptive response logic, the analysis assumes that if worst case outcomes gain higher probability, no future action will be taken in response….which overstates actual future damages from a ton today

NERA Ran IAMs to Estimate Sensitivity of SCC to Assumed Future Emissions



Source: 3% discount rate, average over 3 IAMs, 2007 $/tonne emitted in 2020

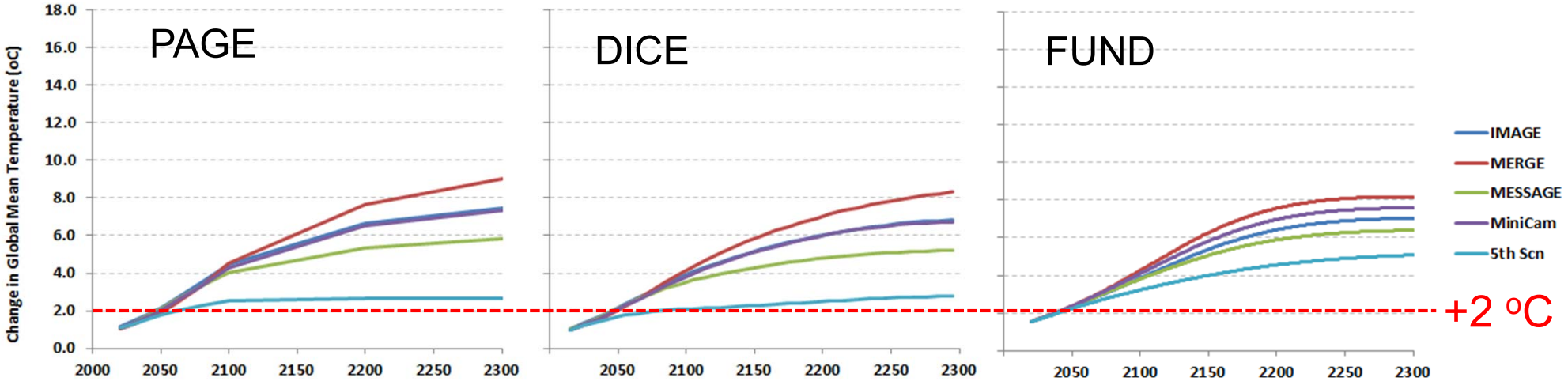
NERA
ECONOMIC CONSULTING

But Is Even the 5th Scenario Realistic Without Potential Adaptive Responses in the Analysis?

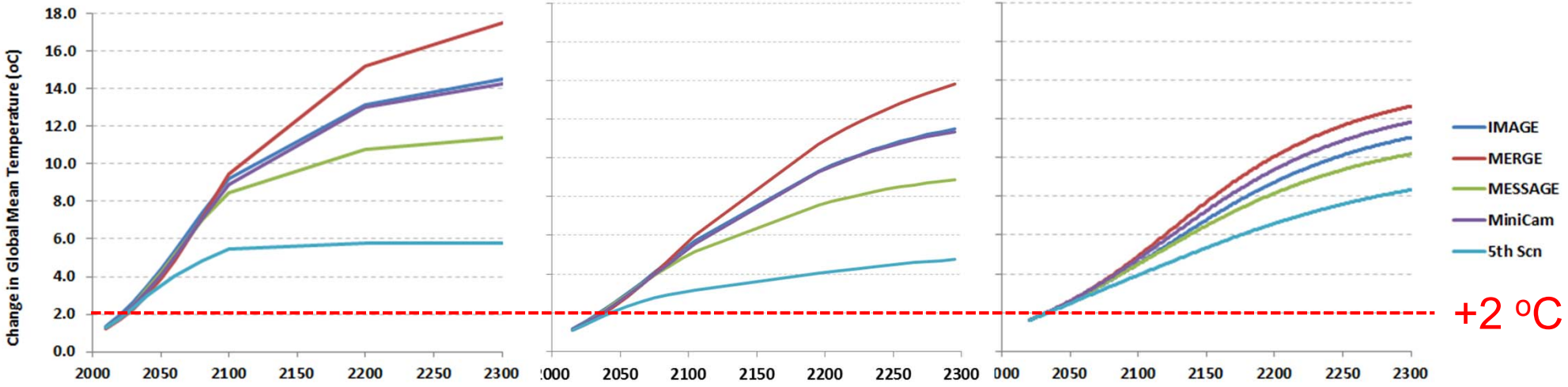
IWG SCC Scenarios Assume No Societal Response Even After Temperatures Have Far Exceeded 2 °C -- Including 5th Scenario

NERA ECONOMIC CONSULTING

- Temperatures under median ECS value used in IWG analysis



- Temperatures under 90th percentile ECS value of IWG runs



Choosing Appropriate Time Horizon for an IAM Analysis

NERA ECONOMIC CONSULTING

- IWG SCCs are based on damages calculated through 2300
- Such a long horizon may seem warranted based on physical duration of CO_2 in atmosphere, … but the damage calculations may be too speculative to be meaningful
  - Assumes away all adaptive changes in emissions levels
  - Even if emissions levels could not be changed, requires heavy reliance on extrapolation of damage functions to temperature increases far above 3°C (the limit of their basis in evidence)
  - Even if damage functions were reliable for near-term, impossible to assess $ value to society of damages after about 80 to 120 years

Percent of IWG SCC values due to damages calculated for years after 2100:

5% DR	25%
3% DR	47%
2.5% DR	>60%

← *Lower discount rates raise SCC estimates by increasing role of the most speculative elements of IAMs' calculations*

Source: NERA IAM runs replicating IWG's 2020 SCC values & same runs with time horizon = 2100

Conclusion

NERA ECONOMIC CONSULTING

- Scientific assumptions are only one major source of numerical sensitivity in developing SCC values
- The analysts using IAMs control the resulting SCC value equally as much via their framing choices
- *Therefore, a more vigorous examination of appropriate framing judgments should be part of the deliberations on SCC estimation*
- The fundamental flaw of using IAMs lacking the control cost side of the BCA equation -- or any other form of adaptive response logic – reveals that the SCC concept is itself an inappropriate tool for guiding climate policy decisions
  - *A risk management approach is what is needed instead*

NERA
ECONOMIC CONSULTING

Contact Us

Anne E. Smith

Senior Vice President
NERA—Washington DC
+1 202 466 9229
Anne.Smith@nera.com

Paul M. Bernstein

Vice President
NERA—Washington DC
+1 202 466 9216
Paul.Bernstein@nera.com

NERA
ECONOMIC CONSULTING

Additional Slides for Discussion

A Sensitivity Analysis on Inclusion of Adaptive Responses in IAMs

NERA ECONOMIC CONSULTING

- Ran IAM to obtain temperature outcomes under different climate sensitivity assumptions:

Increase in Temperature (°C) at 5th, 50th, and 95th percentiles of Roe-Baker ECS Distribution

	2015	2025	2035	2045	2055	2065	2075	2085	2095	2105
5%	0.9	1.1	1.3	1.5	1.7	1.9	2.2	2.4	2.6	2.8
50%	1.0	1.3	1.7	2.0	2.4	2.7	3.1	3.4	3.8	4.1
95%	1.2	1.6	2.1	2.6	3.2	3.7	4.3	4.9	5.5	6.1

- For each ECS level, modified the emissions input to reflect a response of phasing out global GHG emissions starting when observed temperature has increased by 1.3°C (to avoid exceeding 2°C).
- The SCC from the revised scenarios provides evidence of sensitivity of the SCC value to the inclusion of adaptive responses in the IAMs
- Using DICE w/ IMAGE forecast (3%) SCC estimate declined by ~25%
  - Equivalent to IWG 3% SCC estimate declining from $43/t to range of $30/t
  - Equivalent to using a model horizon of 2130 rather than 2300

Alternative to Discounting to Address Future Generations' Equity

NERA ECONOMIC CONSULTING

Real Undiscounted Consumption per Capita Over Time IAM Scenarios (Baseline Emissions)

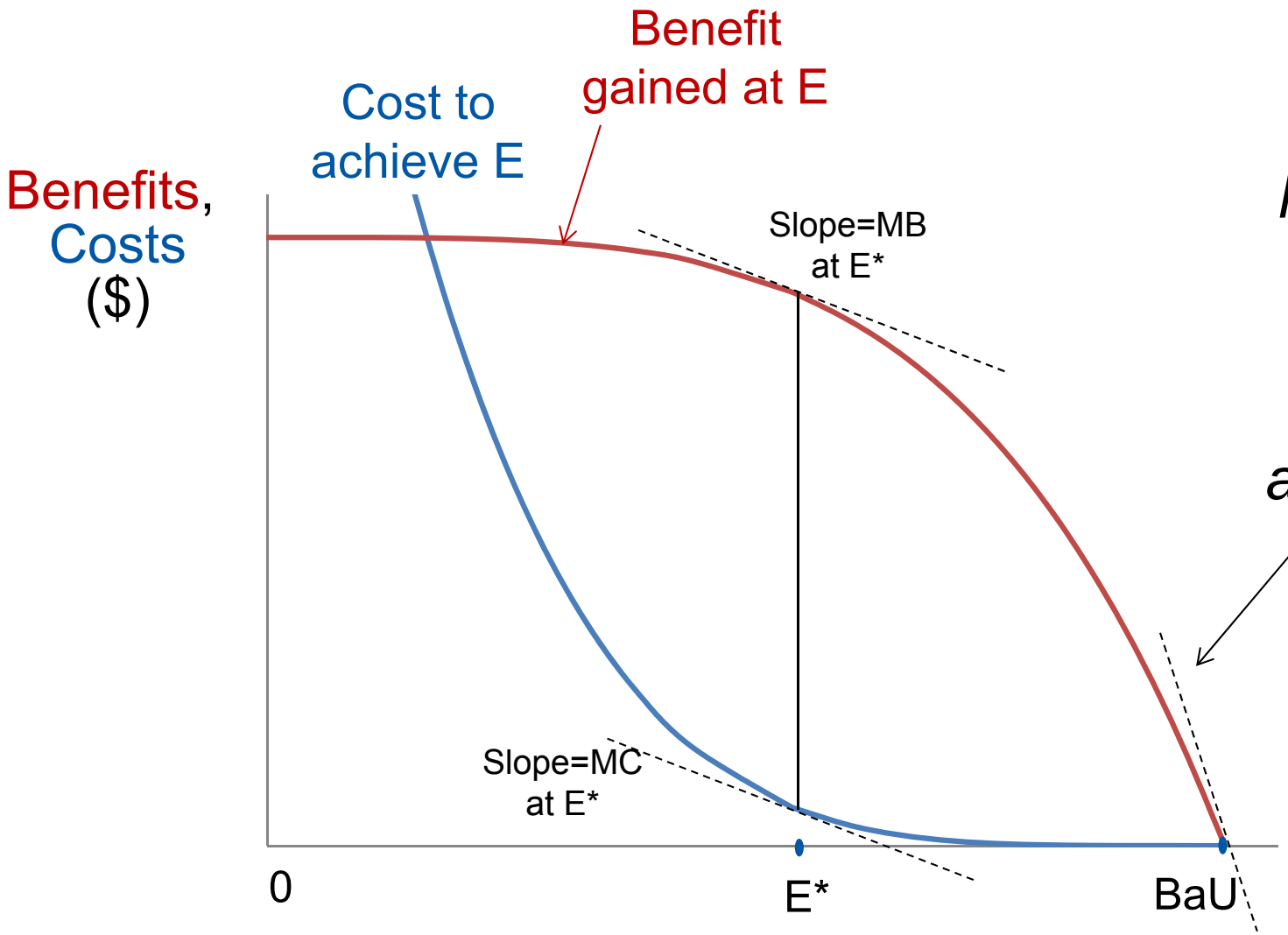
	IMAGE	MERGE	MESSAGE	MiniCAM	5th scenario
Real global consumption per capita					
2020	$ 9,194	$ 7,427	$ 8,595	$ 7,613	$ 8,171
2100	$ 37,133	$ 22,892	$ 26,912	$ 36,671	$ 31,106
2200	$ 125,365	$ 43,798	$ 53,759	$ 134,827	$ 90,555
2300	$ 169,660	$ 49,239	$ 63,872	$ 187,494	$ 122,001
Consumption relative to 2020 consumption					
2100 relative to 2020	4	3	3	5	4
2200 relative to 2020	14	6	6	18	11
2300 relative to 2020	18	7	7	25	15

Real Undiscounted Consumption per Capita Over Time in IAM Scenarios (Zero Manmade Emissions from 2015 Onwards)

	IMAGE	MERGE	MESSAGE	MiniCAM	5th scenario
Real global consumption per capita					
2020	$ 9,202	$ 7,433	$ 8,603	$ 7,620	$ 8,177
2100	$ 38,466	$ 23,954	$ 27,726	$ 38,072	$ 31,458
2200	$ 140,133	$ 51,271	$ 58,024	$ 151,673	$ 92,610
2300	$ 202,420	$ 63,738	$ 71,653	$ 224,995	$ 126,239
Consumption relative to 2020 consumption					
2100 relative to 2020	4	3	3	5	4
2200 relative to 2020	15	7	7	20	11
2300 relative to 2020	22	9	8	30	15

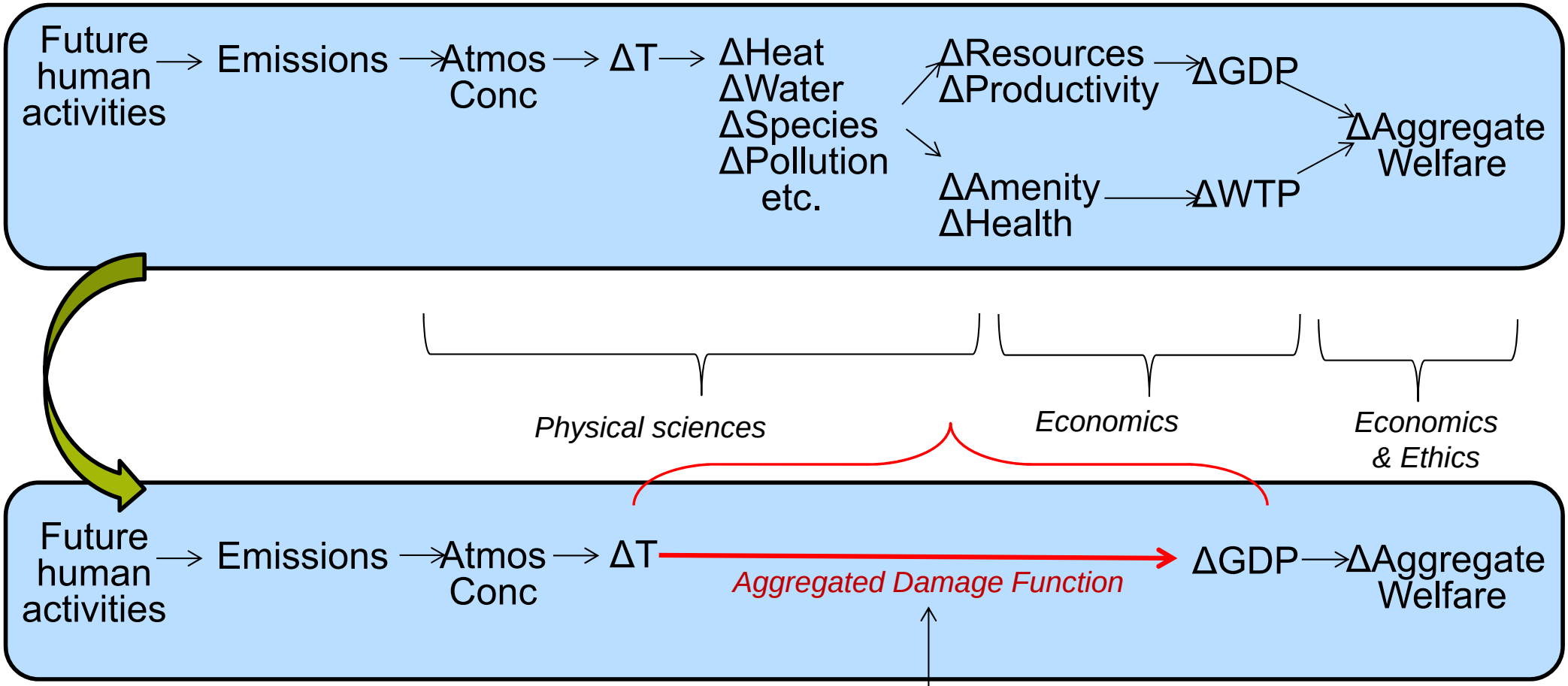
Source: NERA runs of DICE model using median equilibrium climate sensitivity (ECS=3)

Illustration of Overstatement in SCC When Ignoring Future Emissions Reductions to Match Current Reductions



MB at BaU is higher than for any scenario with future reductions and/or adaptive responses

SCC Estimates Are Calculated Using Aggregate Climate Change Integrated Assessment Models (IAMs)



Usual functional form: $\%\Delta GDP = \alpha_1 * \Delta T + \alpha_2 * \Delta T^{\alpha 3}$

- Models differ mainly in their choices of parameters of the above function
- Most assume $\alpha_1 = 0$. Many assume $\alpha_3 = 2$

Interagency Working Group (IWG) Used IAMs and Multiple Scenarios to Produce SCC Estimates

NERA ECONOMIC CONSULTING

- 3 existing IAMs were adapted for IWG: PAGE, DICE, FUND
- IWG range IAMs using "standardized" set of key inputs:
  - 5 socioeconomic scenarios (e.g., GDP, GHGs) through year 2300
    - 4 "business as usual" scenarios (i.e., no future reduction in growing global GHG emissions) based on IMAGE, MERGE, MESSAGE, & MiniCam models
    - 1 scenario with future controls, consistent with a 550 ppm stabilization, based on average of the above 4 models
  - A probability distribution for the "equilibrium climate sensitivity" (ECS) parameter (called "Roe-Baker") with 10,000 iterations
  - Re-run for 3 different fixed discount rates (5%, 3%, 2.5%)
- All other differences in IAMs and their results were attributed to differing views on scientific uncertainties held by the original IAM modelers

By Averaging All IAM Results for Each Discount Rate, IWG Derived Its SCC Range

NERA ECONOMIC CONSULTING

"Recommended" SCC values were average of 3 x 5 x 10,000 IAM runs

- Done for each discount rate separately
  ➔ hence a "range"
- Range also included the 95th percentile of each scenario's 10000 results at 3% DR, averaged over the 15 IAM/socioeconomic input combinations

Range of SCC Estimates Recommended by IWG (2007$/tonne CO_2)

Discount Rate	5.0%	3.0%	2.5%	3.0%
Year	Avg	Avg	Avg	95th
2010	11	33	52	90
2015	12	38	58	109
2020	12	43	65	129
2025	14	48	70	144
2030	16	52	76	159
2035	19	57	81	176
2040	21	62	87	192
2045	24	66	92	206
2050	27	71	98	221

IWG's "ranges" do not reveal any of the differences of views on scientific uncertainties held by the IAM modelers

➔ They reflect only IWG's policy judgments on intergenerational equity and risk management

Source: Interagency Working Group, Technical Support Document, May 2013, p.3

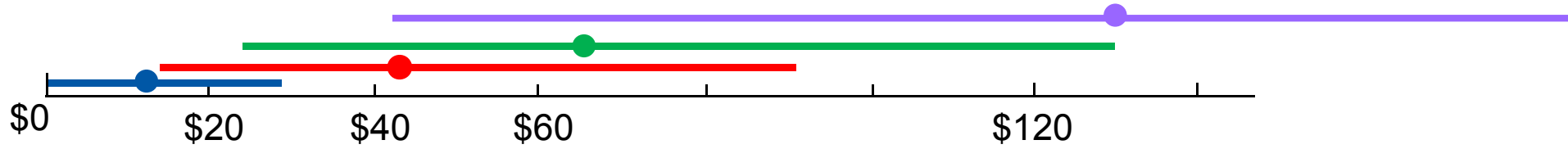
Model-to-Model Differences Regarding Scientific Uncertainty for Each SCC Estimate Are Very Large

NERA ECONOMIC CONSULTING

Range of SCC Estimates Recommended by IWG
(2007$/tonne CO_2)

Discount Rate	5.0%	3.0%	2.5%	3.0%
Year	Avg	Avg	Avg	95th
2010	11	33	52	90
2015	12	38	58	109
2020	12	43	65	129
2025	14	48	70	144
2030	16	52	76	159
2035	19	57	81	176
2040	21	62	87	192
2045	24	66	92	206
2050	27	71	98	221

Source: Interagency Working Group, Technical Support Document, May 2013, p.3



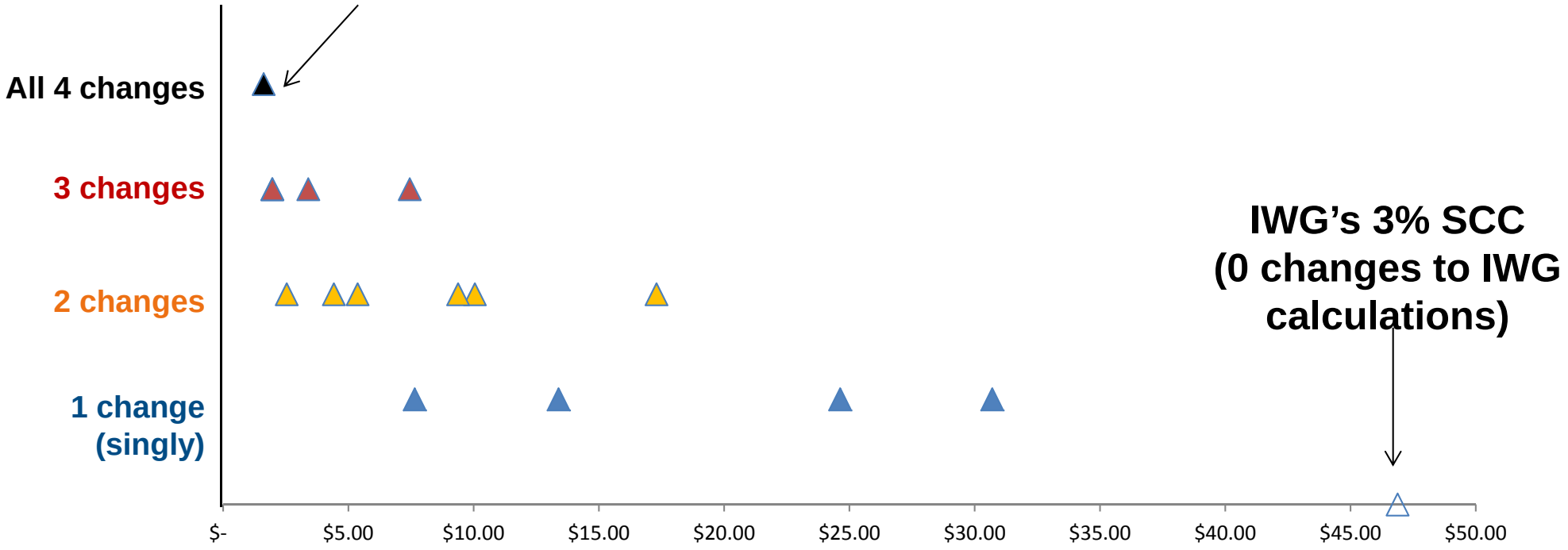
Impact of uncertainty in the equilibrium climate sensitivity (ECS) parameter is not shown as it is a scientific uncertainty specified by IWG, not IAM modelers. It is far wider and makes all the ranges appear equivalent.

Source for ranges in figure: IWG, Technical Support Document, May 2013, Tables A2-A4.

Sensitivity of SCC Values to other three Alternative Framing Assumptions, -- Singly and in Combinations

NERA ECONOMIC CONSULTING

With all 4 framing choices changed, SCC falls 97% below IWG's – with no change to scientific assumptions



Alternative cases are:

SCC at E_H not BaU
Discounting at 5% not 3%
Time horizon of 2100 not 2300,
0% not 100% weight on non-U.S. benefits

Source: NERA model runs of IWG's IAMs. SCC values are in 2014$ per tonne emitted in 2020