Comment by:

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on the

Office of Management and Budget's Request for Comments on the Technical Support Document entitled *Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*

Submitted January 27, 2014

Docket ID: OMB-2013-0007-0001

Agency: Office of Management and Budget

Parent Agency: Executive Office of the President

Due Date: January 27, 2014

Comment:

Summary

The determination of the social cost of carbon (SCC) as made by the Interagency Working Group (IWG) and detailed in the May 2013 Technical Support Document (updated in November 2013) is discordant with the best scientific literature on the equilibrium climate sensitivity and the fertilization effect of carbon dioxide—two critically important parameters for establishing the net externality of carbon dioxide emissions, at odds with existing Office of Management and Budget (OMB) guidelines for preparing regulatory analyses, and founded upon the output of Integrated Assessment Models (IAMs) which encapsulate such large uncertainties as to provide no reliable guidance as to the sign, much less the magnitude of the social cost of carbon.

The OMB should act not just to revise the current determination of the SCC, but to suspend its use in all federal rulemaking. It is better not to include any value for the SCC in cost/benefit analyses, than to include a value which is knowingly improper, inaccurate and misleading.

We highlight some of the major flaws in the current SCC determination in our following comments.

Domestic vs. Global Costs

The IWG only reports the *global* value of the SCC which the IWG determines to accrue from continued carbon dioxide emissions in the United States. This is in direct violation of existing OMB guidelines.

OMB Circular A-4 (September 17, 2003) regarding Regulatory Analysis explicitly states:

> Your analysis should focus on benefits and costs that accrue to citizens and residents of the United States. Where you choose to evaluate a regulation that is likely to have effects beyond the borders of the United States, these effects should be reported separately.

In reporting the SCC, the IWG argues away the need to "focus on benefits and costs that accrue to citizens and residents of the United States" and instead bases its SCC solely on its determinations of "effects beyond the borders of the United States." Rather than reporting the latter "separately," as recommended by OMB guidelines, the IWG only reports the global costs and makes no determination of the domestic costs. Considering that the majority (if not all) of the federal regulations incorporating the SCC into cost/benefit analysis apply to rules regulating domestic activities, reporting only the global impact—the knowledge (in all areas, i.e., economics, social, environmental, etc.) of which is far less constrained than potential U.S. impacts—imparts a huge degree of uncertainty and is a grossly misleading. Thus, the IWG's determination of the SCC is not appropriate for use in federal regulatory analyses.

During the public comment period associated with new regulations which incorporate the SCC, a distinction should be made between domestic costs/benefits and foreign cost/benefits such that the public can judge for itself the value of the regulation. As it currently stands, the public likely has no idea that the benefits of the proposed regulations on *domestic* activities that supposedly accrue from incorporating the SCC are largely conferred upon *foreign* nations. This is clearly not a "transparent" situation.

Discount Rates

In the same manner, the IWG ignores OMB guidelines in its selection of discount rates to use in calculating the SCC. OMB Circular A-4 refers to OMB Circular A-94 which states that "a real discount rate of 7 percent should be used as a base-case for regulatory analysis" and to show the sensitivity of the results to the discount rate assumptions "[f]or regulatory analysis, you should provide estimates of net benefits using both 3 percent and 7 percent."

Instead, the IWG opted to determine the SCC using discount rates of 2.5, 3, and 5 percent, and did not include results for a 7 percent rate.

This has ramifications throughout the federal regulatory agencies. For example, in Environmental Protection Agency discussions of a proposed new rule regulating discharges from steam electric power plants (and how the rule may impact emissions from the plants), the EPA includes a Table of the annualized benefits of the emissions reductions from NOx, SO2, and CO2. Following OMB guidelines on how to calculate costs and benefits—the EPA reports its findings using both a 3% and a 7% discount rate. Yet as explained in a footnote to the Table (see below), the CO2 benefits are calculated using the 3% and the 5% discount rate "because SCC calculations are not available for the 7 percent discount rate." The reason they are "not available" is that the IWG ignored the OMB guidelines and did not provide the SCC at a 7 percent discount rate for use in regulator analyses.

This leads to an absurd situation. Regulatory agencies, like the EPA, follow the rules and calculate cost and benefits using both the 3 percent and 7 percent discount rates. Yet, when they express the benefits of reducing carbon dioxide emissions at the recommended 7 percent rate, they are actually going to use a number that is incorrect and inaccurate, and explain in a footnote why they are doing so. This is an unacceptable situation of excuse-making that should be avoided. Again, the IWG's determination of the SCC is inappropriate for use in federal regulatory analyses.

summarizes the annualized benefits associated with changes in air pollutant emissions. Chapter 8 in the BCA report provides the details of this analysis.

TABLE XIV–6—ANNUALIZED BENEFITS OF CHANGES IN NO$_X$, SO$_2$, AND CO$_2$ AIR EMISSIONS

[Million 2010$]^c

Discount rate	Option 3	Option 4
3% Discount Rate (for NO$_X$, SO$_2$, and CO$_2$-related benefits)	$127.6	$170.5
7% Discount Rate (for NO$_X$, SO$_2$, and CO$_2$-related benefits) $^{a\,b}$	82.3	74.6

^{a} Because SCC values are not available for the 7 percent discount rate, EPA used the SCC based on a 5 percent discount rate to estimate values presented for the 7 percent discount rate. EPA uses 5 percent to discount CO$_2$-related benefits and 7 percent to discount benefits from changes in NO$_X$ and SO$_2$ emissions.

The OMB cannot blatantly disregard its own guidelines for both discount rate and domestic/global cost calculations in pursuit of a politically-driven outcome. To do so would undermine the OMB's own authority. Therefore, the OMB should require that the domestic SCC be calculated and reported as well as the SCC value using a 7 percent discount rate. These calculations should be included in the SCC tables and factored into regulatory analyses. To do less leads to confusion and undermines the applicability of OMB guidelines and recommendations.

Equilibrium Climate Sensitivity

In May 2013, the Interagency Working Group (IWG) produced an updated SCC value by applying updates to the underlying three Integrated Assessment Models (IAMs) used in its initial 2010 SCC determination, but did not update the equilibrium climate sensitivity (ECS) employed in the IAMs. This was not done, despite there having been, since January 1, 2011, at least 11 new studies and 17 experiments (involving more than 44 researchers) examining the ECS, each lowering the best estimate and tightening the error distribution about that estimate. Instead, the IWG wrote in its 2013 report: "It does not revisit other interagency modeling decisions (e.g., with regard to the discount rate, reference case socioeconomic and emission scenarios, or equilibrium climate sensitivity)."

The earth's equilibrium climate sensitivity is defined in the Interagency Working Group on Social Cost of Carbon 2010 (hereafter, IWG2010) report as "the long-term increase in the annual global-average surface temperature from a doubling of atmospheric CO_2 concentration relative to pre-industrial levels (or stabilization at a concentration of approximately 550 parts per million (ppm))" and is recognized as "a key input parameter" for the integrated assessment models used to determine the social cost of carbon.

The IWG2010 report has an entire section (Section III.D) dedicated to describing how an estimate of the equilibrium climate sensitivity and the scientific uncertainties surrounding its actual value are developed and incorporated in the IWG's analysis. The IWG2010, in fact, developed its own probability density function (pdf) for the ECS and used it in each of the three IAMs, superseding the ECS pdfs used by the original IAMs developers. The IWG's intent was to develop an ECS pdf which most closely matched the description of the ECS as given in the *Fourth Assessment Report* of the United Nation's Intergovernmental panel on Climate Change which was published in 2007.

The functional form adopted by the IWG2010 was a calibrated version of Roe and Baker (2007) distribution. It was described in the IWG2010 report in the following Table and Figure (from the IWG2010 report):

Table 1: Summary Statistics for Four Calibrated Climate Sensitivity Distributions

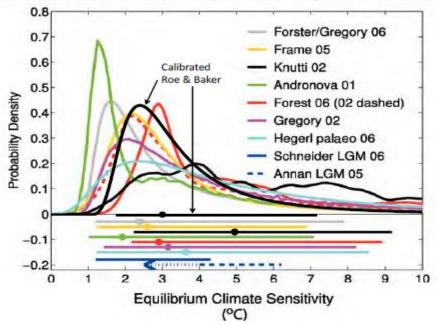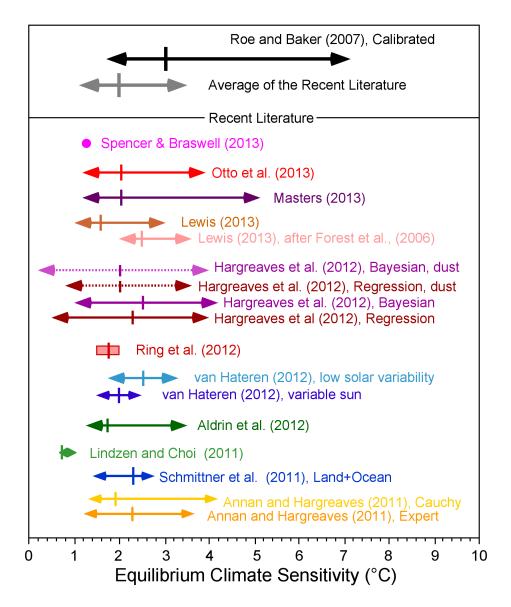|	Roe & Baker	Log-normal	Gamma	Weibull
Pr(ECS < 1.5°C)	0.013	0.050	0.070	0.102
Pr(2°C < ECS < 4.5°C)	0.667	0.667	0.667	0.667
5th percentile	1.72	1.49	1.37	1.13
10th percentile	1.91	1.74	1.65	1.48
Mode	2.34	2.52	2.65	2.90
Median (50th percentile)	3.00	3.00	3.00	3.00
Mean	3.50	3.28	3.19	3.07
90th percentile	5.86	5.14	4.93	4.69
95th percentile	7.14	5.97	5.59	5.17

Figure 2: Estimates of the Probability Density Function for Equilibrium Climate Sensitivity (°C)

The calibrated Roe and Baker functional form used by the IWG2010 is *no longer scientifically defensible;* neither was it at the time of the publication of the IWG 2013 SCC update.

The figure below vividly illustrates this fact, as it compares the best estimate and 90% confidence range of the earth's ECS as used by the IWG2010/2013 (calibrated Roe and Baker) against findings in the scientific literature published since January 1, 2011.

Whereas the IWG2010/2013 ECS distribution has a median value of 3.0°C and 5th and 95th percentile values of 1.72°C and 7.14°C, respectively, the corresponding values averaged from the recent scientific literature are 2.0°C (median), 1.1°C (5th percentile), and 3.5°C (95th percentile).

These differences will have large and significant impacts on the SCC determination.

CAPTION: The median (indicated by the small vertical line) and 90% confidence range (indicated by the horizontal line with arrowheads) of the climate sensitivity estimate used by the Interagency Working Group on the Social Cost of Carbon Climate is indicated by the top black arrowed line. The average of the similar values from 16 different determinations reported in the recent scientific literature is given by the grey arrowed line (second line from the top). The sensitivity estimates from the 16 individual determinations of the ECS as reported in new research published after January 1, 2011 are indicated by the colored arrowed lines. The arrows indicate the 5 to 95% confidence bounds for each estimate along with the best estimate (median of each probability density function; or the mean of multiple estimates; colored vertical line). Ring et al. (2012) present four estimates of the climate sensitivity and the red box encompasses those estimates. Spencer and Braswell (2013) produce a single ECS value best-matched to ocean heat content observations and internal radiative forcing.

The IWG2010 report noted that, concerning the low end of the ECS distribution, its determination reflected a greater degree of certainty that a low ECS value could be excluded than did the IPCC. From the IWG2010 (p. 14):

"Finally, we note the IPCC judgment that the equilibrium climate sensitivity "is very likely larger than 1.5°C." Although the calibrated Roe & Baker distribution, for which the probability of equilibrium climate sensitivity being greater than 1.5°C is almost 99 percent, is not inconsistent with the IPCC definition of "very likely" as "greater than 90 percent probability," it reflects a greater degree of certainty about very low values of ECS than was expressed by the IPCC."

In other words, the IWG used its judgment that the lower bound of the ECS distribution was higher than the IPCC 2007 assessment indicated. However, the collection of the recent literature on the ECS shows the IWG's judgment to be in error. As can be seen in the chart above, the large majority of the findings on ECS in the recent literature indicate that the lower bound (i.e., 5th percentile) of the ECS distribution is lower than the IPCC 2007 assessment. And, the average value of the 5th percentile in the recent literature (1.1°C) is 0.62°C less than that used by the IWG—a sizeable and important difference which will influence the SCC determination.

In fact, the abundance of literature supporting a lower climate sensitivity was at least partially reflected in the new IPCC assessment report issued in 2013. In that report, the IPCC reported:

Equilibrium climate sensitivity is *likely* in the range 1.5°C to 4.5°C (*high confidence*), *extremely unlikely* less than 1°C (*high confidence*), and *very unlikely* greater than 6°C (*medium confidence*). The lower temperature limit of the assessed *likely* range is thus less than the 2°C in the AR4…

Clearly, the IWG's assessment of the low end of the probability density function that best describes the current level of scientific understanding of the climate sensitivity is incorrect and indefensible.

But even more influential in the SCC determination is the upper bound (i.e., 95th percentile) of the ECS probability distribution.

The IWG2010 notes (p.14) that the calibrated Roe and Baker distribution better reflects the IPCC judgment that "values substantially higher than 4.5°C still cannot be excluded." The IWG2010 further notes that

"Although the IPCC made no quantitative judgment, the 95th percentile of the calibrated Roe & Baker distribution (7.1 °C) is much closer to the mean and the median (7.2 °C) of the 95th percentiles of 21 previous studies summarized by Newbold and Daigneault (2009). It is also closer to the mean (7.5 °C) and median (7.9 °C) of the nine truncated distributions examined by the IPCC (Hegerl, et al., 2006) than are the 95th percentiles of the three other calibrated distributions (5.2-6.0 °C)."

In other words, the IWG2010 turned towards surveys of the scientific literature to determine its assessment of an appropriate value for the 95th percentile of the ECS distribution. Now, more than three years hence, the scientific literature tells a completely different story.

Instead of a 95th percentile value of 7.14°C, as used by the IWG2010, a survey of the recent scientific literature suggests a value of 3.5°C—more than 50% lower.

And this is very significant and important difference because the high end of the ECS distribution has a large impact on the SCC determination—a fact frequently commented on by the IWG2010.

For example, from IWG2010 (p.26):

> "As previously discussed, low probability, high impact events are incorporated into the SCC values through explicit consideration of their effects in two of the three models as well as the use of a probability density function for equilibrium climate sensitivity. Treating climate sensitivity probabilistically results in more high temperature outcomes, which in turn lead to higher projections of damages. Although FUND does not include catastrophic damages (in contrast to the other two models), its probabilistic treatment of the equilibrium climate sensitivity parameter will directly affect the non-catastrophic damages that are a function of the rate of temperature change."

And further (p.30):

> *Uncertainty in extrapolation of damages to high temperatures*: The damage functions in these IAMs are typically calibrated by estimating damages at moderate temperature increases (e.g., DICE was calibrated at 2.5 °C) and extrapolated to far higher temperatures by assuming that damages increase as some power of the temperature change. Hence, estimated damages are far more uncertain under more extreme climate change scenarios.

And the entirety of Section V [sic] "A Further Discussion of Catastrophic Impacts and Damage Functions" of the IWG 2010 report describes "tipping points" and "damage functions" that are probabilities assigned to different values of global temperature change. Table 6 from the IWG2010 indicated the probabilities of various tipping points.

Table 6: Probabilities of Various Tipping Points from Expert Elicitation -

Possible Tipping Points	Duration before effect is fully realized (in years)	Additional Warming by 2100		
		0.5-1.5 C	1.5-3.0 C	3-5 C
Reorganization of Atlantic Meridional Overturning Circulation	about 100	0-18%	6-39%	18-67%
Greenland Ice Sheet collapse	at least 300	8-39%	33-73%	67-96%
West Antarctic Ice Sheet collapse	at least 300	5-41%	10-63%	33-88%
Dieback of Amazon rainforest	about 50	2-46%	14-84%	41-94%
Strengthening of El Niño-Southern Oscillation	about 100	1-13%	6-32%	19-49%
Dieback of boreal forests	about 50	13-43%	20-81%	34-91%
Shift in Indian Summer Monsoon	about 1	Not formally assessed		
Release of methane from melting permafrost	Less than 100	Not formally assessed.		

The likelihood of occurrence of these low probability, high impact, events ("tipping points") is *greatly* diminished under the new ECS findings. The average 95th percentile value of the new literature survey is only 3.5°C indicating a very low probability of a warming reaching 3-5°C by 2100 as indicated in the 3rd column of the above Table and thus a significantly lower probability that such tipping points will be reached. This new information will have a large impact on the final SCC determination using the IWG's methodology.

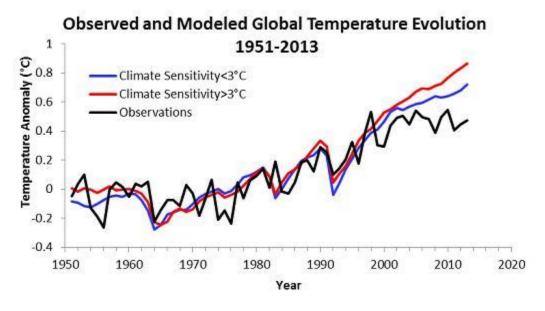The size of this impact has been directly investigated.

In their Comment on the Landmark Legal Foundation Petition for Reconsideration of Final Rule Standards for Standby Mode and Off Mode Microwave Ovens, Dayaratna and Kreutzer (2013) ran the DICE model using the distribution of the ECS as described by Otto et al. (2013)—a paper published in the recent scientific literature which includes 17 authors, 15 of which were lead authors of chapters in the recent Intergovernmental Panel on Climate Change's *Fifth Assessment Report*. The most likely value of the ECS reported by Otto et al. (2013) was described as "2.0°C, with a 5–95% confidence interval of 1.2–3.9°C." Using the Otto et al. (2013) ECS distribution in lieu of the distribution employed by the IWG (2013), dropped the SCC by 42 percent, 41 percent, and 35 percent (for the 2.5%, 3.0%, 5.0% discount rates, accordingly). This is a significant decline.

Waldhoff et al. (2011) investigated the sensitivity of the FUND model to changes in the ECS. Waldhoff et al. (2011) found that changing the ECS distribution such that the mean of the distribution was lowered from 3.0°C to 2.0°C had the effect of lowering the SCC by 60 percent (from a 2010 SCC estimate of $8/ton of CO2 to $3/ton in $1995). While Waldhoff et al. (2011) examined FUNDv3.5, the response of the current version (v3.8) of the FUND model should be similar.

These studies make clear that the strong dependence of the social cost of carbon on the distribution of the estimates of the equilibrium climate sensitivity (including the median, and the

upper and lower certainty bounds) requires that the periodic updates to the IWG SCC determination must include an examination of the scientific literature on the topic of the equilibrium climate sensitivity. There is no indication that the IWG undertook such an examination. But what is clear, is that the IWG did *not* alter its probability distribution of the ECS between its 2010 and 2013 SCC determination, despite a large and growing body of scientific literature that substantially alters and better defines the scientific understanding of the earth's ECS. It is unacceptable that a supposed "updated" social cost of carbon does not include updates to the science underlying a critical and key aspect of the SCC.

We note that there has been one prominent scientific study in the recent literature which has argued, on the basis of recent observations of lower tropospheric mixing in the tropics, for a rather high climate sensitivity (Sherwood et al., 2014). This research, however, suffers from too narrow a focus. While noting that climate models which best match the apparent observed behavior of the vertical mixing characteristics of the tropical troposphere tend to be the models with high climate sensitivity estimates, the authors fail to make note that these same models are the ones whose projections make the *worst* match to observations of the evolution of global temperature during the past several decades. The figure below shows the observed global surface temperature history from 1951-2013 compared with the temperature evolution projected by the collection of models used in the new IPCC 2013 report. We broke the climate models down into two groups—those which have a climate sensitivity greater than 3.0°C (as suggested by Sherwood et al., 2014) and those with a climate sensitivity less than 3.0°C. The Figure shows that while neither model subset does a very good job is capturing evolution of global temperature during the past 15-20 years (the period with the highest human carbon dioxide emissions), the high sensitivity models do substantially worse than the lower sensitivity models.
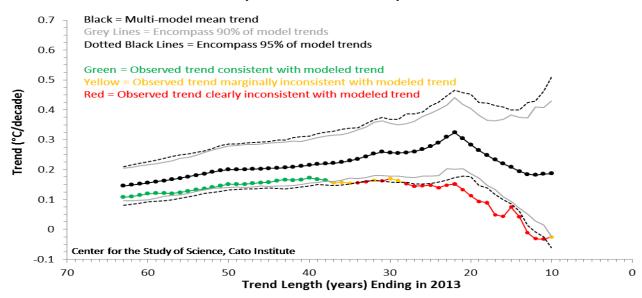

CAPTION: Observed global average temperature evolution, 1951-2013, as compiled by the U.K's Hadley Center (black line), and the average temperature change projected by a collection of climate models used in the IPCC Fifth Assessment Report which have a climate sensitivity greater than 3.0°C (red line) and a collection of models with climate sensitivities less than 3.0°C (blue line).

While Sherwood et al. (2014) prefer models that better match their observations in one variable, the same models actually do *worse* in the big picture than do models which lack the apparent accuracy in the processes that Sherwood et al. (2014) describe. The result can only mean that there must still be even bigger problems with *other* model processes which must more than counteract the effects of the processes described by Sherwood et al. After all, the overall model collective is still warming the world much faster than it actually is (see Figure below). In fact, for the observed global average temperature evolution for the past 30 years largely lies below the range which encompasses 95% of all climate model runs—an indication that the observed trend is statistically different from the trend simulated by climate models. And for periods approaching 40 years in length, the observed trend lies outside of (below) the range that includes 90% of all climate model simulations—and indication that the observed trend is marginally inconsistent with climate model simulations.

These results argue strongly against the reliability of the Sherwood et al. (2014) conclusion and instead provide robust observational evidence that the climate sensitivity has been overestimated by both climate models, and the IWG alike.

CAPTION: The annual average global surface temperature from 106 individual CMIP5 climate model runs forced with historical (+ RCP45 since 2006) forcings were obtained from the Climate Explorer website. Linear trends were computed through the global temperatures from each run, ending in 2013 and beginning each year from 1951 through 2004. The trends for each period (ranging in length from 10 to 62 years) were averaged across all model runs (black dots). The range containing 90 percent (grey lines), and 95 percent (dotted black lines) of trends from the 106 model runs is also indicated. The observed linear trends for the same periods were calculated from the annual average global surface temperature record compiled by the U.K. Hadley Center (HadCRUT4) (colored dots). Observed trend values which were less than the 2.5[th] percentile of the model trend distribution were colored red, observed trend values which were between the 2.5[th] and the 5th percentile of the model trend distribution were colored yellow, and observed trend values greater than the 5th percentile of the model trend distribution were colored green.

Agricultural Impacts of Carbon Fertilization

Carbon dioxide is known to have a positive impact on vegetation, with literally thousands of studies in the scientific literature demonstrating that plants (including crops) grow stronger, healthier, and more productive under conditions of increased carbon dioxide concentration. A recent study (Idso, 2013) reviewed a large collection of such literature as it applies to the world's 45 most important food crops (making up 95% of the world's annual agricultural production). Idso (2013) summarized his findings on the increase in biomass of each crop that results from a 300ppm increase in the concentration of carbon dioxide under which the plants were grown. This table is reproduced below, and shows that the typical growth increase exceeds 30% in most crops, including 8 of the world's top 10 food crops (the increase was 24% and 14% in the other two).

Average percentage increase in biomass of each of the world's 45 most important food crops under an increase of 300ppm of carbon dioxide.

Crop	% Biomass Change	Crop	% Biomass Change
Sugar cane	34.0%	Rye	38.0%
Wheat	34.9%	Plantains	44.8%
Maize	24.1%	Yams	47.0%
Rice, paddy	36.1%	Groundnuts, with shell	47.0%
Potatoes	31.3%	Rapeseed	46.9%
Sugar beet	65.7%	Cucumbers and gherkins	44.8%
Cassava	13.8%	Mangoes, mangosteens, guavas	36.0%
Barley	35.4%	Sunflower seed	36.5%
Vegetables fresh nes	41.1%	Eggplants (aubergines)	41.0%
Sweet potatoes	33.7%	Beans, dry	61.7%
Soybeans	45.5%	Fruit Fresh Nes	72.3%
Tomatoes	35.9%	Carrots and turnips	77.8%
Grapes	68.2%	Other melons (inc.cantaloupes)	4.7%
Sorghum	19.9%	Chillies and peppers, green	41.1%
Bananas	44.8%	Tangerines, mandarins, clem.	29.5%
Watermelons	41.5%	Lettuce and chicory	18.5%
Oranges	54.9%	Pumpkins, squash and gourds	41.5%
Cabbages and other brassicas	39.3%	Pears	44.8%
Apples	44.8%	Olives	35.2%
Coconuts	44.8%	Pineapples	5.0%
Oats	34.8%	Fruit, tropical fresh nes	72.3%
Onions, dry	20.0%	Peas, dry	29.2%
Millet	44.3%		

Idso (2013) found that the increase in the atmospheric concentration of carbon dioxide that took place during the period 1961-2011 was responsible for increasing global agricultural output by 3.2 trillion dollars (in 2004-2006 constant dollars). Projecting the increases forward based on projections of the increase in atmospheric carbon dioxide concentration, Idso (2013) expects carbon dioxide fertilization to increase the value of agricultural output by 9.8 trillion dollars (in 2004-2006 constant dollars) during the 2012-2050 period.

This is a large positive externality, and one that is insufficiently modeled in the IAMs relied upon by the IWG in determining the SCC.

In fact, only one of the three IAMs used by the IWG has any substantial impact from carbon dioxide fertilization, and the one that does, underestimates the effect by approximately 2-3 times.

The FUND model has a component which calculates the impact on agricultural as a result of carbon dioxide emissions, which includes not only the impact on temperature and other climate changes, but also the direct impact of carbon dioxide fertilization. The other two IAMs, DICE and PAGE by and large do not (or only do so extremely minimally; DICE includes the effect to a larger degree than PAGE). Consequently, lacking this large and positive externality, the SCC calculated by the DICE and PAGE models is significantly larger than the SCC determined by the FUND model (for example, see Table A5, in the IWG 2013 report).

But even the positive externality that results from carbon dioxide fertilization as included in the FUND model is too small when compared with the Idso (2013) estimates. FUND (v3.7) uses the following formula to determine the degree of crop production increase resulting from atmospheric carbon dioxide increases (taken from Anthoff and Tol, 2013a):

CO_2 fertilisation has a positive, but saturating effect on agriculture, specified by

$$(A.4) \qquad A_{t,r}^f = \gamma_r \ln \frac{CO2_t}{275}$$

where

- A^f denotes damage in agricultural production as a fraction due to the CO2 fertilisation by time and region;
- t denotes time;
- r denotes region;
- $CO2$ denotes the atmospheric concentration of carbon dioxide (in parts per million by volume);
- 275 ppm is the pre-industrial concentration;
- γ is a parameter (see Table A, column 8-9).

Column 8 in the table below shows the CO_2 fertilization parameter (γ_r) used in FUND for various regions of the world (Anthoff and Tol, 2013b). The average CO_2 fertilization effect across the 16 regions of the world is 11.2%. While this number is neither areally weighted, nor weighted by the specific crops grown, it is clear that 11.2% is much lower than the average fertilization effect compiled by Idso (2013) for the world's top 10 food crops (35%). Further, Idso's fertilization impact is in response to a 300ppm CO2 increase, while the fertilization parameter in the FUND model is multiplied by $\ln(CO2_t/275)$ which works out to 0.74 for a 300ppm CO_2 increase. This multiplier further reduces the 16 region average to 8.4% for the CO_2 fertilization effect—some 4 times smaller than the magnitude of the fertilization impact identified by Idso (2013).

Impact of climate change on agriculture in FUND model.

	Rate of change (% Ag. Prod/ 0.04°C)		δ_r^l		δ_r^q		CO$_2$ fertilisation (% Ag. Prod)	
USA	-0.021	(0.176)	0.026	(0.021)	-0.012	(0.018)	8.90	(14.84)
CAN	-0.029	(0.073)	0.092	(0.080)	-0.016	(0.009)	4.02	(6.50)
WEU	-0.039	(0.138)	0.022	(0.002)	-0.014	(0.013)	15.41	(11.83)
JPK	-0.033	(0.432)	0.046	(0.022)	-0.024	(0.030)	23.19	(36.60)
ANZ	-0.015	(0.142)	0.040	(0.071)	-0.016	(0.037)	10.48	(8.50)
EEU	-0.027	(0.062)	0.048	(0.097)	-0.018	(0.048)	9.52	(5.14)
FSU	-0.018	(0.066)	0.042	(0.075)	-0.016	(0.039)	6.71	(5.48)
MDE	-0.022	(0.032)	0.042	(0.071)	-0.017	(0.037)	9.43	(2.66)
CAM	-0.034	(0.061)	0.064	(0.043)	-0.030	(0.043)	16.41	(5.38)
SAM	-0.009	(0.060)	0.003	(0.005)	-0.004	(0.003)	5.96	(5.04)
SAS	-0.014	(0.021)	0.025	(0.024)	-0.011	(0.018)	5.80	(1.64)
SEA	-0.009	(0.482)	0.014	(0.004)	-0.010	(0.008)	8.45	(41.81)
CHI	-0.013	(0.075)	0.043	(0.076)	-0.017	(0.040)	19.21	(6.13)
NAF	-0.016	(0.023)	0.033	(0.043)	-0.014	(0.027)	7.27	(1.90)
SSA	-0.011	(0.026)	0.024	(0.034)	-0.010	(0.020)	5.05	(2.20)
SIS	-0.050	(0.103)	0.043	(0.077)	-0.017	(0.040)	23.77	(8.64)

Standard deviations are given in brackets.

Although approximately four times too small, the impact of the fertilization effect on the SCC calculation in the FUND model is large.

According to Waldhoff et al. (2011), if the CO$_2$ fertilization effect is turned off in the FUND model (v3.5) the SCC increases by 75% from \$8/tonCO$_2$ to \$14/tonCO$_2$ (in 1995 dollars). In another study, Ackerman and Munitz (2012) find the effective increase in the FUND model to be even larger, with CO$_2$ fertilization producing a positive externality of nearly \$15/tonCO$_2$ (in 2007 dollars).

Clearly, had the Idso (2013) estimate of the CO$_2$ fertilization impact been used instead of the one used in FUND the resulting positive externality would have been much larger, and the resulting net SCC been much lower.

This is just for one of the three IAMs used by the IWG. Had the more comprehensive CO$_2$ fertilization impacts identified by Idso (2013) been incorporated in all the IAMs, the three-model average SCC used by the IWG would be been greatly lowered, and likely even become negative in some IAM/discount rate combinations.

Conclusion

The social cost of carbon as determined by the Interagency Working Group in their May 2013 Technical Support Document (updated in November 2013) is unsupported by the scientific literature, not in accordance with OMB guidelines, fraught with uncertainty, and thus unsuitable

and inappropriate for federal rulemaking. As such, use of the SCC in cost/benefit analyses in proposed federal regulation should be suspended.

It is unlikely, in light of the large uncertainties and low level of understanding in critical economic, scientific, social, etc. factors that are vital to the projections of future climate impacts, that determinations of the SCC will ever become robust enough for use in federal rulemaking. M.I.T. economist Robert Pindyck (2013) recently summed up the situation as it applies to the use of Integrated Assessment Models (IAMs)—the preferred tool used by the IWG in their determination of the SCC:

> Given all of the effort that has gone into developing and using IAMs, have they helped us resolve the wide disagreement over the size of the SCC? Is the U.S. government estimate of $21 per ton (or the updated estimate of $33 per ton) a reliable or otherwise useful number? What have these IAMs (and related models) told us? I will argue that the answer is very little. As I discuss below, the models are so deeply flawed as to be close to useless as tools for policy analysis. Worse yet, precision that is simply illusory, and can be highly misleading.
>
> …[A]n IAM-based analysis suggests a level of knowledge and precision that is nonexistent, and allows the modeler to obtain almost any desired result because key inputs can be chosen arbitrarily.

Given the uncertainties that are involved, the OMB should not act to update the current SCC determination, but rather to discard it in its entirety.

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