Trends on the Social Cost of Carbon from 2008 - 2023: A Review of Environmental Damage Valuation and Possibilities for Future Applications

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ABSTRACT

Throughout 2008 and 2023, the United States Environmental Protection Agency (EPA) and Interagency Working Group (IWG) published several technical documents estimating the social cost of carbon dioxide (SCC), a monetary measure of long-term damage done by one metric ton of carbon dioxide. These estimates have greatly fluctuated throughout those years, making it difficult for environmental policy to consistently be implemented. In this paper, I evaluate the factors that contribute to measuring the social cost of carbon within the United States, as well as compare trends within the 2008 to 2023 SCC estimates, nominalized to 2020 dollars. The results show that there has been a larger change in estimates of SCC between the years 2010 and 2013, and again in 2021 and 2023, due to an increase of scientific literature incorporated within damage functions for integrated assessment models, as well as changes in discount rates used and agendas from different political administrations. Additionally, this paper compares three case studies on estimates of the cost of averting one metric ton of CO2, and finds there is a large range of estimated values [$2.6 - $1,000+] for the cost of one metric ton of CO2 emission reduction, depending on the policy and target method of abating. These findings suggest that the SCC depends greatly on what policies are implemented and how it is calculated. I conclude that there is insufficient standardization and room for improving the SCC estimates by standardizing parameters related to its estimates, as well as possibilities of implementing the social cost of carbon outside of legislative cost benefit analysis that would help society internalize environmental damages, improving welfare towards more socially optimal levels.

KEYWORDS

externalities, climate change impact, carbon emission reduction, welfare, environmental economic valuation, environmental policy

INTRODUCTION

The Social Cost of Carbon (SCC) is a monetary estimate of the economic impacts from emitting one unit of carbon dioxide and is used in cost benefit analysis for legislators and policymakers to determine whether an environmental policy is justified. This places great importance in the valuation of the social cost of carbon due to its role in determining whether environmental policies are suitable to pass, based on monetary cost benefit analysis. Thus, this paper provides an analysis of the literature on the SCC since its official formation in 2008, including estimates of the SCC published by the US federal government, and further evaluates the contributing factors in the valuation to provide an overview on how the SCC estimates have evolved over time. On a larger scope, this paper provides a literature analysis examining the possibilities of internalizing the social cost of environmental externalities, relating the SCC to economic welfare performance indicators, such as GDP.

Objective

The objective of my research is to evaluate trends in the United State's federal estimates of the social cost of carbon since its inception in 2008, and to conduct a landscape analysis on how these estimates compare to SCC estimates elsewhere. Obtaining an oversight on SCC valuation trends can provide a better understanding on the multitude of factors that contribute to environmental damage valuation and environmental policy implementation, which allows us to gain a better grasp on how it will change in the future. Moreover, we review literature around the social cost of carbon estimates in relation to social welfare and further discuss possibilities of internalizing the social costs.

Economic welfare, as we know it, typically relies on index measures such as gross domestic product (GDP) or gross national product (GNP) to indicate economic activity within a region. However, the problem with crude GDP or GNP is that it neglects certain discrepancies between production and welfare because these indices calculate production, instead of consumption, which is arguably a better indicator of economic welfare. This poses a problem for the environment, as environmental damages are often neglected in determining economic welfare. One method towards accounting for these discrepancies is using a "measure of economic welfare" (MEW), a concept introduced by William D. Nordhaus and James Tobin in 1973, which accounts for other variables relating to consumption, such as the value of leisure time, amount of unpaid work as well, and most importantly, it subtracts environmental damage caused by industrial production and consumption from its welfare calculations. However, indicators such as MEW are not widely used on a global scale and did not gain much traction in its use for economic welfare analysis. Thus, I am evaluating the social cost of carbon because of the breadth of literature on environmental damage evaluation and its potential to be used for Pigouvian taxes towards more socially optimal levels of welfare.

Social cost of carbon principles

The social cost of carbon is a measure, in dollars, of the long-term damage done by a ton of carbon dioxide (CO2) emissions in a given year and also represents the value of damages avoided for emission abatement (EPA 2017). Retrospectively, the estimates of the social cost of carbon have been unstable. The SCC values have ranged from $9-$40 per tCO2 for a high discount rate and $112-525 per tCO2 for a lower discount rate in the past 10 years, with a generally used interim value of $43/mtCO2 under the Obama administration, $3-5/mtCO2 under the Trump administration, $51/mtCO2 at a 3% discount rate under the Biden administration in 2021, and most recently estimated $190/mtCO2 at a 2% discount rate in 2023 by the EPA (Tol 2023). Scientists have often argued various criticisms towards the specific discount rates and valuation techniques used to calculate the SCC, and climate researchers may argue that carbon prices are below its estimated value almost everywhere and should be increased (Tol 2023).

Social discount rates arguably play the largest role in determining the scale of the SCC and consequently, actions towards climate change mitigation. The discount rate is the rate at which future effects are considered in terms of present effects. For instance, a higher discount rate implies that future effects are valued much less significant than the present, while a lower social rate implies the value of the future effects are similar to present effects. The social discount rate has philosophical implications as well - it represents the trade-off between present and future consumption, meaning that a high discount rate of 7% corresponds to more consumption of environmental goods and services related to carbon dioxide emissions in the present, but almost nil consumption or value in about 25 years time, ultimately affecting the livelihoods of those in the future and the future costs people have to pay for impacts of the carbon dioxide emitted in the present. In contrast, a lower discount rate values environmental goods and services at relatively the same value as the present for a longer period of time. Since 2008, the social discount rates in determining the SCC ranged from 1.5 - 7% in official US Federal Government projections, significantly altering the SCC estimates.The difference in values for the SCC using a change in discount rates of 2 % and 3% (Figure A1).

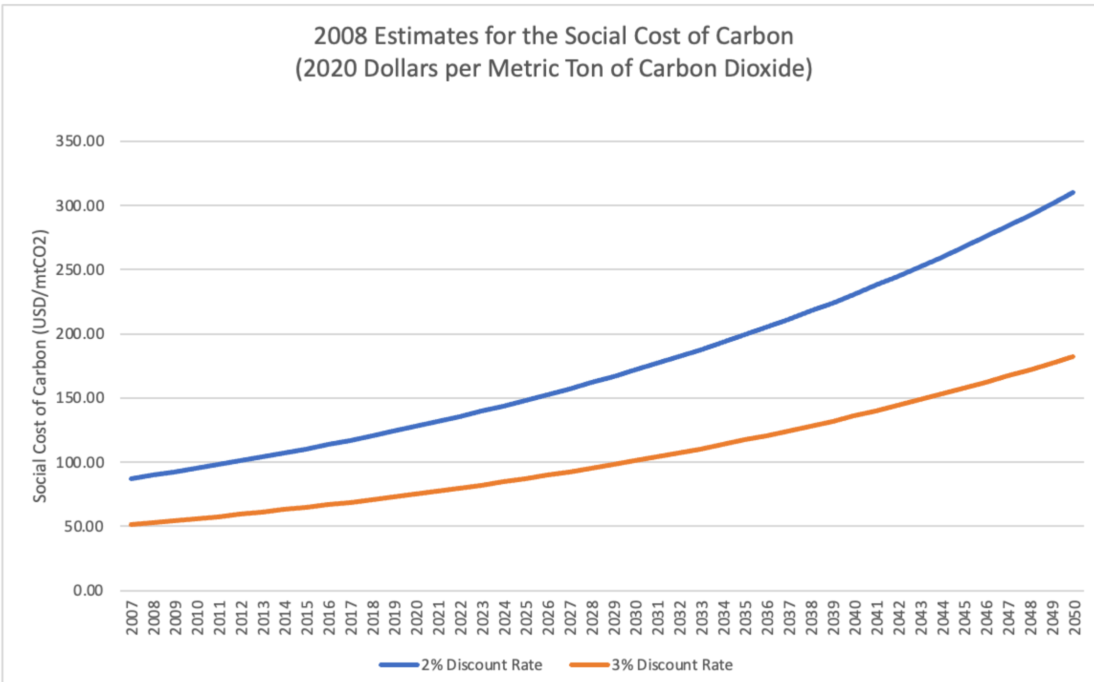

Figure 1. 2008 estimates for the SCC with a 2% discount rate and 3% discount rate. Data was downloaded from the United States Environmental Protection Agency advance notice of proposed rulemaking (ANPR) document published in 2008. The advance notice of proposed rulemaking (ANPR) document was published in response to the U.S. Supreme Court case Massachusetts v. EPA.
Sources: EPA (2008), http://epa.gov/climatechange/anpr.html

History and volatility of SCC estimates from 2008 - 2023

The initial push towards governmental valuation for the future costs of climate change started in 2007, when the Center for Biological Diversity took the National Highway Traffic Safety Administration to court over new fuel economy standards, arguing a need for reform within cost and benefit analysis since alternative fuel economy standards assigns zero value to the benefit of carbon dioxide (CO2) emissions reduction (9th Cir. 2007). In 2008, another court case, Massachusetts v. EPA, challenged the EPA's refusal to regulate greenhouse gas (GHG) emissions, which ultimately led President George W. Bush to issue Executive Order 13432, calling for the protection of the environment with respect to greenhouse gas emissions in a manner consistent with the analysis of benefits and costs (Cassedy 2008). Shortly thereafter, the federal government created preliminary SCC estimates in the 2008 EPA's Advantage Notice of Proposed Rulemaking for GHG in response to the Massachusetts v. EPA court case. The initial values of the social cost of carbon were estimated at $68 and $40 per tCO2 for discount rates of 2% and 3%, respectively, and have changed drastically since 2008. In 2009, President Obama created the Interagency Working Group (IWG) to consolidate the best available science and create consistent estimates for final estimates used by the government. The IWG combined SCC estimates from existing literature to use a interim values, and valued it at $33/mtCO2 and $5/mtCO2 for 3% and 5% discount rates, respectively, with a central value of $19/mtCO2 and assumed an increase of 3% annually. The first estimates created by IWG's own evaluation was published in 2010, and placed the SCC at $5/mtCO2 at a 5% discount rate, $21/mtCO2 at a 3% discount rate, $35/mtCO2 at a 2.5% discount rate, and $63/mtCO2 at a 3% discount rate in the 95th percentile, all based in 2007 dollars. The 2010 publication used a central value of $24/mtCO2 in 2015 and $26.3/mtCO2 in 2020. In 2011, the Department of Transportation used the social cost of carbon in cost benefit analysis for the Corporate Average Fuel Economy (CAFE) standards, utilizing $33/mtCO2 for the global SCC value, and $2/mtCO2 for 2007 emission reductions in 2007 dollars - similar to the 2010 IWG estimates using the 2.5% discount rate (IWG 2010).

The IWG published its second official estimate in 2013. There was a major increase in the SCC as a result of updates to the three integrated assessment models used, including the analysis of damage from sea level rise and changes in the climate. During this time, the IWG estimates the SCC to equate to $7-$17/mtCO2 at a 5% discount rate, $26-$43/mtCO2 at a 3% discount rate, and $42-65/mtCO2 at a 2.5% discount rate, with a central value of $43/mtCO2 in 2020 - about 63.5% greater than the estimates created in 2010 (IWG 2013). This estimate was revised in 2015, with very similar results. The only differences were very slight decreases in the revisions.

Tables 1 & 2. Revised estimates of the social cost of carbon, published by the Interagency Working Group in 2013 and 2015. These estimates illustrate the changes in predicted social costs, normalized to 2007 dollars.

2013 IWG Estimates

Revised Social Cost of CO_2, 2010 – 2050 (in 2007 dollars per metric ton of CO_2)

Discount Rate Year	5.0% Avg	3.0% Avg	2.5% Avg	3.0% 95th
2010	11	32	51	89
2015	11	37	57	109
2020	12	43	64	128
2025	14	47	69	143
2030	16	52	75	159
2035	19	56	80	175
2040	21	61	86	191
2045	24	66	92	206
2050	26	71	97	220

2015 IWG Estimates

Revised Social Cost of CO_2, 2010 – 2050 (in 2007 dollars per metric ton of CO_2)

Discount Rate Year	5.0% Avg	3.0% Avg	2.5% Avg	3.0% 95th
2010	10	31	50	86
2015	11	36	56	105
2020	12	42	62	123
2025	14	46	68	138
2030	16	50	73	152
2035	18	55	78	168
2040	21	60	84	183
2045	23	64	89	197
2050	26	69	95	212

Sources: IWG (2013); IWG (2015) under the Obama administration

In August 2016 before the change in presidential administrations, the IWG published another updated version of the SCC estimate fairly similar to the 2013 estimates. In 2016, the SCC estimates for 2020 were valued at $12/mtCO2 at a 5% discount rate, $42/mtCO2 at a 3% discount rate, $62/mtCO2 at a 2.5% discount rate, and $123/mtCO2 at a 3% discount rate in the 95th percentile (IWG 2016).

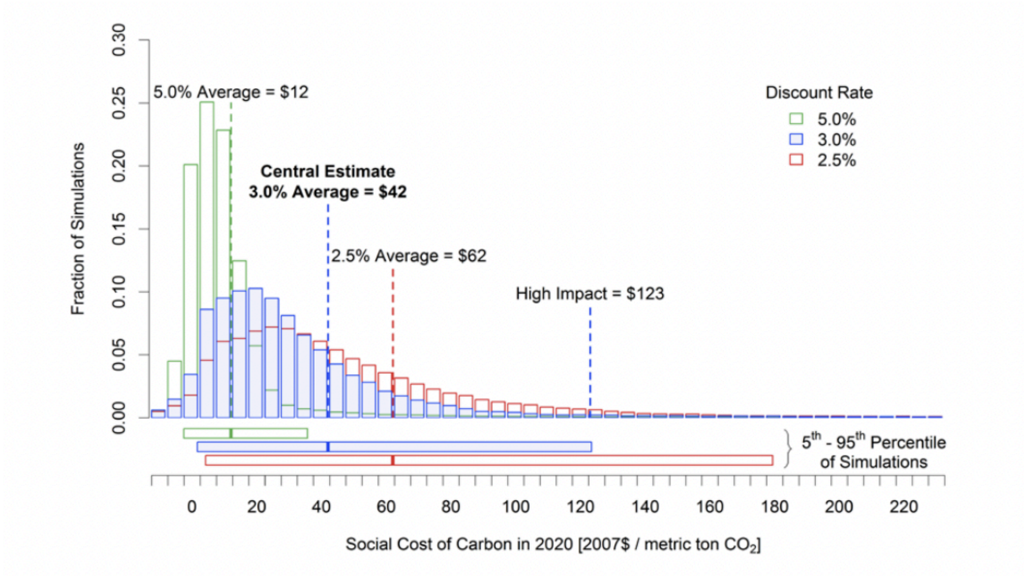

Figure 2. Frequency distribution of SCC estimates for 2020 (conducted in 2016). Data was obtained from the United States Interagency Working Group from a technical document published in 2016.
Sources: IWG (2016)

Throughout 2013 to 2016, the SCC estimated by the IWG remained relatively similar. However, in 2017, President Trump issued Executive Order 13783, which disbanded the Interagency Working Group and called for the rescission and review of several climate-related Presidential and regulatory actions as well as for a review of the SC-GHG estimates used for regulatory impact analysis arguing that it was not representative of government policy. During this time, several agencies provided estimates by calculating only the domestic social cost of carbon - significantly less than the overall cost of carbon - and further employed discount rates of 3 to 7% for use in primary analysis by the EPA under the new administration. This altered the discount rates to be about seven times lower than under the Obama administration, at about $1-7/mtCO2. Using a 2.5% discount rate, the average estimate for 2025-2035 was $10-12/mtCO2 in 2016 dollars (EPA 2018).

In addition to the larger discount rates, a large factor in the decrease of the SCC values related to the use of the domestic SCC, instead of the global SCC. The domestic value reflects the cost of damages that directly relates to the United States from emitting one metric ton of carbon dioxide emissions, whereas the global SCC reflects the value of damages overall, worldwide - since carbon emissions create costs beyond the nation's borders.

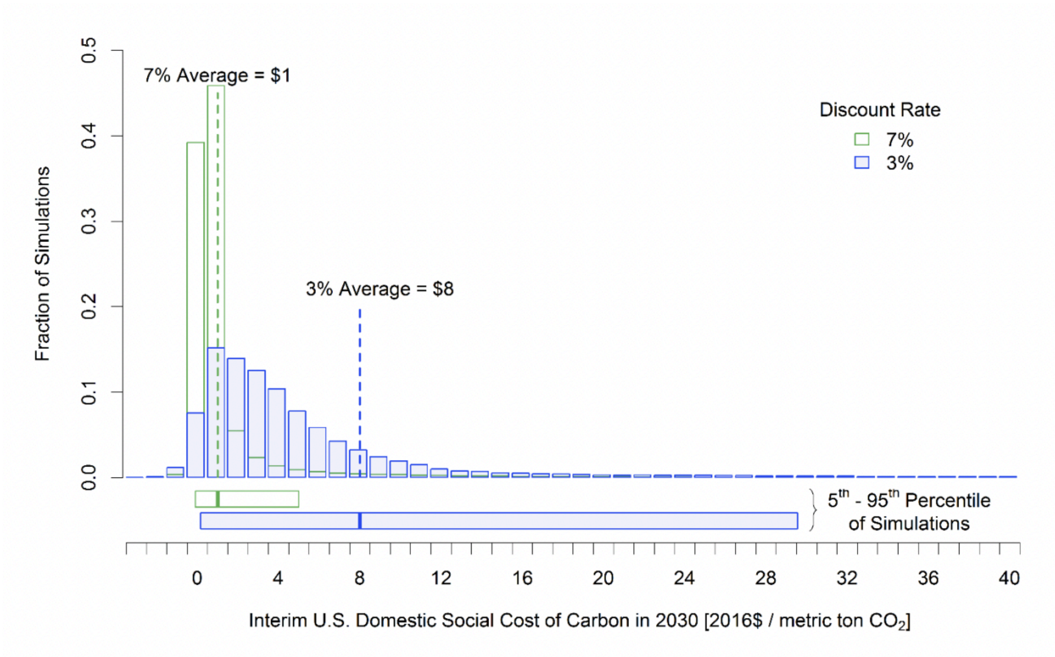

Figure 3. Frequency distribution of SCC estimates for 2030 (conducted in 2018). Data was obtained from the United States Environmental Protection Agency from a technical document published in 2018. The discount rates used in this report vary greatly from previous reports.
Sources: EPA (2018) under the Trump administration

There is an argument to be made for using the domestic SCC as opposed to the global SCC. According to economist Matthew J. Kotchen, the domestic SCC is consistent with a Nash equilibrium among countries on their choice of emissions while the global SCC is consistent with efficiency of global emissions. However, use of the domestic SCC will ultimately lead to potential distribution effects globally, as it creates spillover effects onto other nations (Kotchen 2017).

Following the transfer of power from the Trump administration to the Biden administration, President Biden issued Executive Order 13990 on January 20, 2021 to re-establishing the IWG to ensure that the US government's SCC reflected the best estimates based on available science. There was a significant jump in the SCC from the 2018 estimates conducted by the EPA under the Trump administration, compared to the 2021 estimates conducted by the IWG under the Biden administration. This was a pivotal point in the SCC estimates, as it incorporated an upward trajectory that scientists initially predicted since 2008, and it reverted the values back to the global SCC values. In 2021, the SCC estimates for 2020 were valued at $14/mtCO2 at a 5% discount rate, $51/mtCO2 at a 3% discount rate, $76/mtCO2 at a 2.5% discount rate, and $152/mtCO2 at a 3% discount rate in the 95th percentile (IWG 2021).

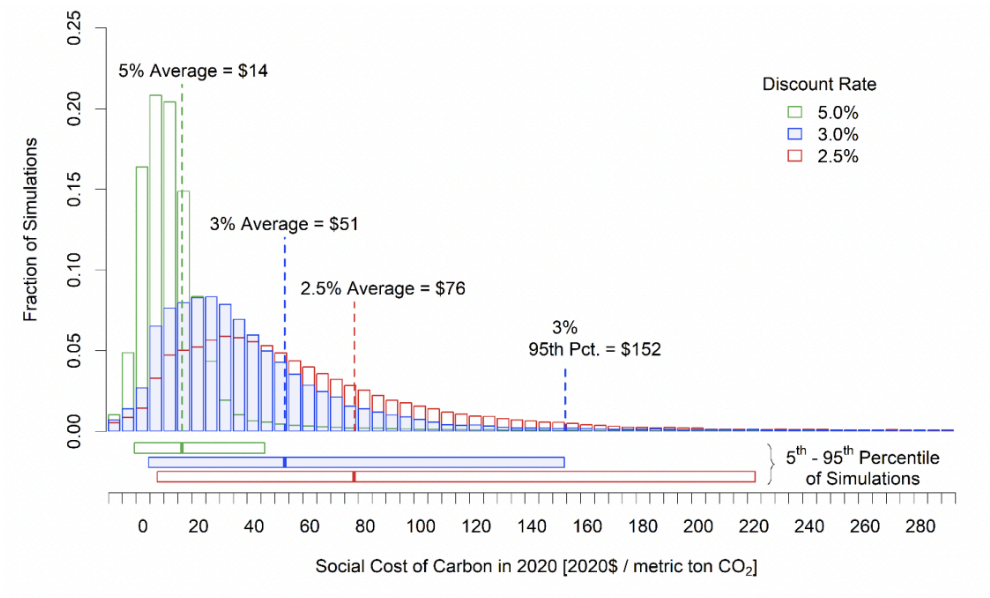

Figure 4. Frequency distribution of SCC estimates for 2020 (conducted in 2021). Data was obtained from the United States Interagency Working Group from a technical document published in 2021.
Sources: IWG (2021) under the Biden Administration

The most updated version of the social cost of carbon from the federal government as of April 2024, is the EPA's Report on Social Cost of Greenhouse Gases. Instead of using the 5%, 3%, and 2.5% estimates that the Obama administration preferred, this report focused on lower discount rates of 2.5%, 2%, and 1.5%. In 2023, the SCC estimates for 2020 were valued at $120/mtCO2 at a 2.5% discount rate, $190/mtCO2 at a 2% discount rate, and $340/mtCO2 at a 1.5% discount rate, with the central value at $190/mtCO2 (EPA 2023). These higher SCC valuations were released at the COP 28 Conference, spurring uproar from 10 states that filed an unsuccessful lawsuit against the administration, while others, such as climate scientists, celebrated the reform.

The differences in earlier SCC reports in comparison to the 2023 EPA report is majoritively due to newer research on climate impacts and damages. Michael Greenstone visualized the number of studies that have been published since DICE 2010, FUND 3.8, and PAGE 2009 were published (Greenstone 2016).

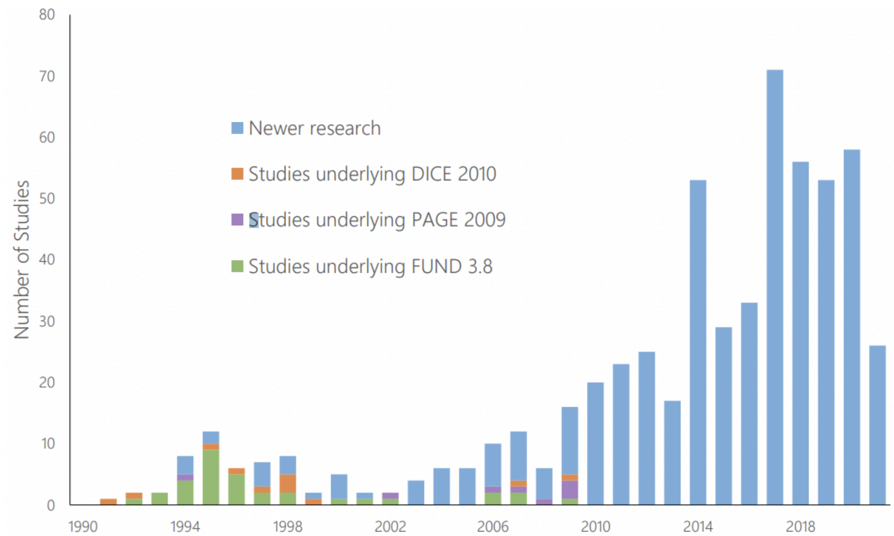

Figure 5. Research on climate impacts used within integrated assessment models. This graph was obtained from Greenstone (2016), and illustrates the newer body of climate change research that updated the new damage models used for integrated assessment models.
Sources: Greenstone (2016), updated in 2021

Calculating the SCC

There are a multitude of factors that contribute to calculating the social cost of carbon emissions. Firstly, the estimates are based on three types of integrated assessment models (IAMs), that use quantitative descriptions of key processes in economic and earth systems to model future climate impacts and responses. The IAMs used for the Interagency Working Group and EPA estimates are:

[1] Dynamic Integrated mode of Climate and the Economy (DICE)
[2] Climate Framework for Uncertainty, Negotiation and Distribution (FUND)
[3] Policy Analysis for the Greenhouse Effect (PAGE)

IAMs take into account both physical factors such as global mean surface temperature anomalies, temperature forecasting component, simple energy balance models of the climate system, rates of global warming, rising sea levels, the carbon cycle, and many other factors to relate it to the total economic impact (Calel et al. 2017). Integral to these evaluations are damage functions that map global mean temperature changes and impacts of climate change into economic costs, and are often updated to incorporate new research studies. Examples of damage functions include:

- Finite Amplitude Impulse Response (FaIR) model
- Building blocks for Relevant Ice and Climate Knowledge (BRICK) model for probabilistic projections of regional changes in sea level rise
- Coastal Impacts and Adaptation Model (CIAM) for sea-level rise damage calculations
- Global Change Analysis Model (GCAM) for building energy expenditures
- Data-driven Spatial Climate Impact Model (DSCIM)

On the social science side, IAMs utilize information including potential tipping points, scenario planning for populations, the economy and emissions, distribution of impacts and inequity aversion, uncertainties about impacts and risk aversion, changes in vulnerability and relative prices with development, and effects on industries such as agriculture, health, energy use, etc (Tol 2023).

As these factors are subject to researched measurements, there has been a lot of room for improvement since the initial estimates of the SCC in 2008 and is a factor for why the estimates have changed greatly in recent years. Limited amounts of climate science data impact the comprehensiveness of integrated models, and therefore can imply that IAMs are a lower bound estimate since they do not include all important physical, ecological, and economic impacts of climate change. Another factor contributing to the estimate's volatility is that integrated assessment models require non-market valuation methods that can provide estimates in a wide range. The estimates are also reliant on specific climate sensitivity estimates that are placed on these models, which are defined by the extent to which greenhouse gasses affect the Earth's temperature, and consequently, the human population (Nordhaus 2017). Furthermore, the timing of emissions release or reduction and discount rates are key in determining how much we are discounting the future, and valuing the present.

As mentioned prior, the estimates of the SCC relies on the use of the global SCC or the domestic SCC as well. The global SCC incorporates all of the costs associated with emissions towards the atmosphere, whereas the domestic SCC focuses on cost within the nation's border, which will bring spillover effects to other nations since greenhouse gasses spread globally. In retrospect, the use of global SCC estimates versus domestic SCC estimates typically correspond to political party administrations, and their intent on having a larger or smaller SCC estimate.

Trends

There is an upward trend in the social cost of carbon due to several factors, including (1) price inflation, (2) estimates are reported for later years, (3) later analysis uses lower discount rates, and (4) larger incremental damages in future emissions. Adjusting for the first two factors, the SCC value increases at about *2.2% a year (Tol 2023). The last two factors play the largest role in explaining why there is an upward trend with SCC estimates. In accordance with the majority of scientific recommendations, recent estimates since 2021 have focused on using lower discount rates in their analysis, increasing the value of the SCC estimate. Furthermore, the incremental damage from emitting one ton of carbon dioxide has a larger marginal damage, impacting the damage functions that are used in the SCC's integrated assessment models. As the global mean surface temperature increases, the climate changes more rapidly, nearing tipping points that cause global environmental damage. Carbon dioxide emissions directly impact global surface temperature anomalies that increase the global temperature, which has been rapidly increasing and projected to continuously increase in the future, and in turn leads to an increase in the SCC as well. Impacts related to emitting one metric ton of CO2 will have a larger effect on the damage functions, and result in increasing SCC values over time. Additionally, the EPA notes that GDP is growing over time and many damage categories are modeled as proportional to gross GDP. We will discuss this further in the discussion section of this research paper to analyze the relationship between welfare and the social cost of carbon.

*This value was determined by Richard S. J. Tol in May 2023, and therefore did not take into account EPA estimates from November 2023. Paper can be found at https://www.nature.com/articles/s41558-023-01680-x#Fig1

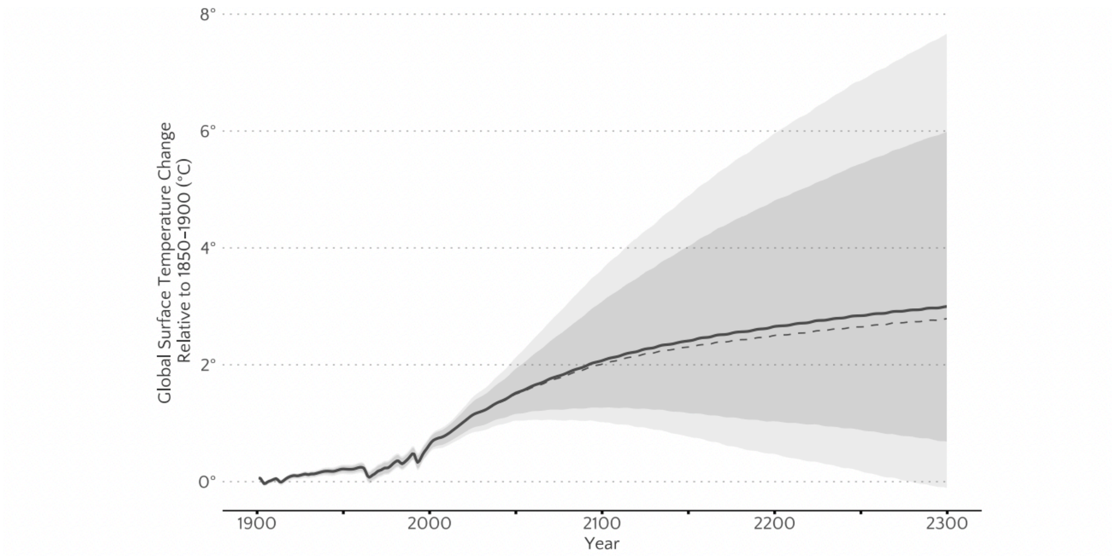

Figure 6. Global mean surface temperature change from 1900 - 2300. This graph was obtained from an EPA report published in 2023, and illustrates the projected range of change in global mean surface temperature change as calculated by FaIR 1.6.2. Mean (solid) and median (dashed) lines are shown along with the 5th to 95th (dark shade) and 1st to 99th (light shade) percentile ranges.
Sources: EPA (2023)

Uses within policymaking

At the core of environmental policy cost benefit analysis is the social cost of carbon. Since its inception in 2008, the social cost of carbon allows policymakers and legislators to weigh the costs and benefits of implementing environmental policies, rather than counting the costs of greenhouse gas emissions as zero - which would cause a free-riding problem in the scheme of social optimal emission levels. The first uses of the SCC in policymaking started with the Joint EPA/DOT Light-Duty Vehicle Greenhouse Gas Emissions Standards and Corporate Average Fuel Economy (CAFE) Standards after the first SCC estimates were released. This type of policy uses command-and-control techniques, and allows for proper economic analysis to determine if the policy was justified to pass. Since then, it has been used for many environmental policy analyses, including but not limited to: Amendments to the National Emission Standards for Hazardous Air Pollutants and New Source Performance Standards (NSPS) for the Portland Cement Manufacturing Industry; Regulatory Impact Results for the Reconsideration Proposal for National Emission Standards for Hazardous Air Pollutants for Industrial, Commercial, and

Institutional Boilers and Process Heaters at Major Sources; Proposed National Emission Standards for Hazardous Air Pollutants (NESHAP) for Mercury Emissions from Mercury Cell Chlor Alkali Plants; Standards of Performance for New Stationary Sources and Emission Guidelines for Existing Sources: Commercial and Industrial Solid Waste Incineration Units Standards; Final Mercury and Air Toxics Standards; Joint EPA/DOT Rulemaking to establish Medium- and Heavy - Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; and Proposed Carbon Pollution Standard for Future Power Plants (EPA 2008). In total, regulations with more than $1 trillion written for the United States use the social cost of carbon in their economic analysis (EPA 2017).

Political landscape

The current 2023 EPA estimates put forth by the Biden administration places a relatively large value on the SCC, in comparison to the previous estimates, and thus will most likely allow for more environmental regulations to pass.

Political changes within the United States every four years heavily influence the SCC estimates, as different administrations have varying agendas on implementation of environmental policy. In examining the volatile history of SCC estimates, we see central values change from $43/mtCO2 under the Obama administration, to $3-5/mtCO2 under the Trump administration, and now to $51-190/mtCO2 under the Biden administration. It alters with the discount rates used and whether the estimate is based off of domestic or global costs. As priorities change, the administrations are additionally responsible for whether the Interagency Working Group, responsible for standardizing and compiling a federal estimate for the social cost of carbon, exists in the first place.

Perspectives on the SCC estimates

There are contradictory perspectives on the SCC valuations with some believing it overvalued or undervalued. A report argued that the estimate of the equilibrium climate sensitivity distribution used in the 2013 evaluations were not updated, and if it was updated, the 2020 estimate of SCC would decrease by more than 40% (Dayaratna et al. 2013). However, the climate sensitivity number used in this report was the most conservative distribution used by the EPA. Others believe that there is a need for a higher SSC. William Nordhaus, the economist who created the DICE model, reflected in a research paper in 2022, calling for a higher SCC to include the carbon cycle and economic growth assumptions. Along the same view, a group of scientists published a research paper calling for an estimate of $185/mtCO2 in 2022 (2020 dollars) that incorporated updated scientific understanding using open-source GHG impact value estimator (GIVE), a newer IAM (Rennert et al. 2022). Furthermore, they recommend a preferred discount rate of 2%, based on updated literature studying discount rates in housing markets (Giglio 2014).

In 2021, the IWG Technical Support Document noted that new empirical evidence suggested that consumption interest rates were below the previous estimate of 3 percent (IWG 2021). This change in interest rate implied that the 2021 SCC values were undervalued.

METHODS

I analyzed the trends within the SCC by downloading raw data from technical support documents published by the Interagency Working Group under the White House and the Environmental Protection Agency from 2008 to 2023, and uploaded estimates for the social cost of carbon for all discount rates evaluated with the documents based on available data. Through this, I was able to chart out all the data points in Excel to determine the trajectory of growth for each discount rate used, determined in 2008, 2010, 2013, 2016, 2021, and 2023 to compare these estimates to one another. This allowed me to compare the estimates over time and determine if there was a change in the SCC estimates during pivotal moments, such as changes in political administrations.

Study Site

The study site for analyzing ESG estimate trends is the United States. The population of the US is over 330 millions, and environmental legislation worth more than $1 trillion affects the population. Thus, the social cost of carbon within the United States plays a large role in economic policy analysis and is an interesting case study to research. For data, I use the U.S.

government's published datasets on the federally used social cost of carbon (SCC or SC-CO2) estimates from the Environmental Protection Agency (EPA) or the Interagency Working Group (IWG). The IWG is a governmental group focused on reporting the social cost of carbon, and it is made up of government agencies includes: Council of Economic Advisers Council on Environmental Quality; Department of Agriculture; Department of Commerce Department of Energy; Department of Health and Human Services; Department of the Interior; Department of Transportation; Department of the Treasury; Environmental Protection Agency; National Climate Advisor; National Economic Council Office of Management; and Budget Office of Science and Technology Policy. The data compiled by these departments are published as 'Technical Support Documents' reports under presidential executive orders, and provide analysis on what metrics have changed, and what the federal SCC estimates are. EPA reports are similarly published to note estimates of the SCC and address changes in its evaluation. I use reports from both the EPA and IWG, published from 2008-2023, to create my trendlines.

RESULTS

To provide a trend analysis of the SCC over time, I charted the different estimates for the social cost of carbon at the 5% discount rate, 3% discount rate, 2.5% discount rate, and the 3% discount rate 95th percentile, using the available data. I accounted for inflation by normalizing all values to 2020 dollars, and chose 2020 values because it is most relevant to the more recent data sets (2021 and 2023 estimates) than the 2007 dollars often used in the older data sets.

In charting the social cost of carbon at a 5% discount rate and the year of publication, we see that there is a large jump in SCC values from 2010 to 2013 estimates. From then, the 2013, 2016 and 2021 estimates oscillate between each other, staying relatively the same in its projection (Figure 7).

The IWG attributes the jump from 2010 to 2013 to an update in the integrated assessment models used. For the DICE IAM, the 2013 estimates used an updated calibration of the carbon cycle model and updated representations of sea level rise for the damage functions. The FUND IAM updated damage functions as well, focusing on space heating, SLR, agricultural impacts, changes to transient response of temperature to GHG buildup, and indirect effects of methane emissions. The PAGE IAM, there were updates in explicit representation of SLR damages, changes in regional scaling of damages, revised treatment of potential abrupt damages, updated adaptation assumptions, and revised that damages do not exceed 100% of GDP. These changes altered the SCC, causing a $7.875 jump from $5.875/mtCO2 in 2010 estimates for 2010, to $13.75/mtCO2 in 2013 estimates for 2010 (EPA 2016).

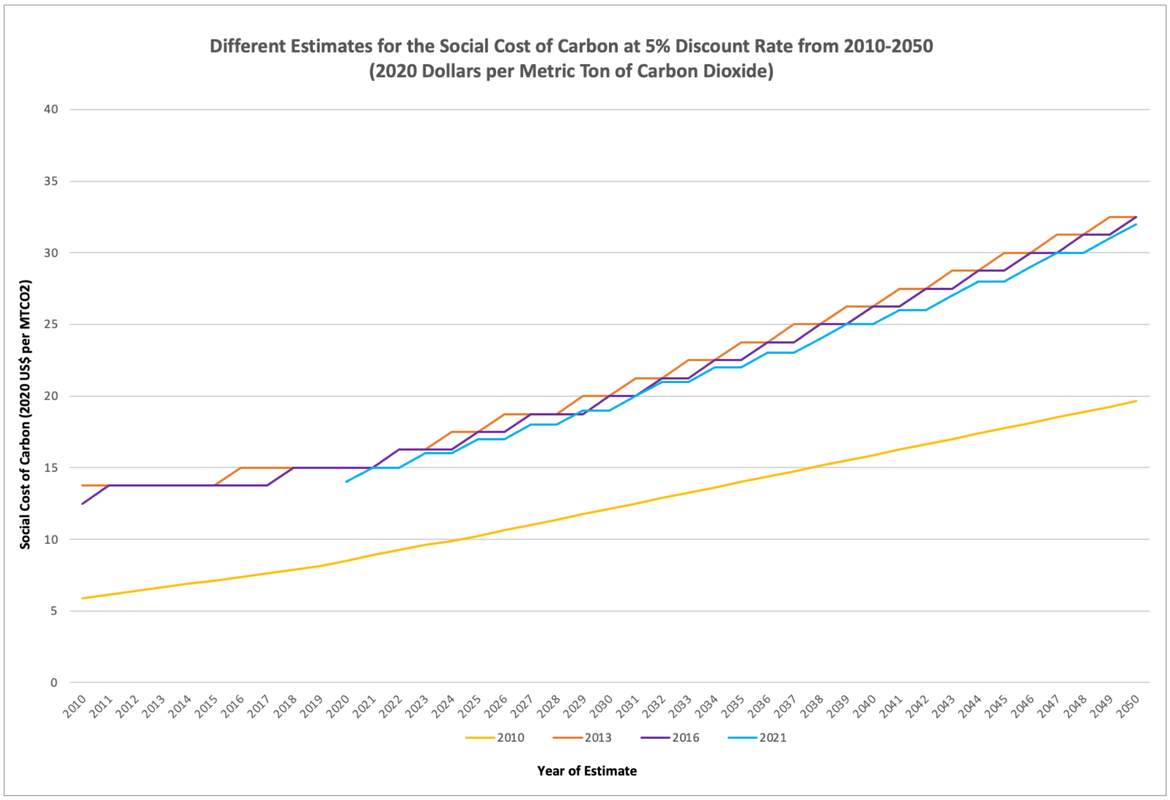

Figure 7. Estimates for SCC at 5% discount rate. This data was obtained from the United States Environmental Protection Agency and the Interagency Working Group. There were no estimates from the 2008 or 2023 data sets to account for the 5% discount rate. The lack of data points in 2010 - 2020 in the 2021 estimates are because those were published more than a decade after 2010, and the 2021 official report did not include estimates for past years. *Sources:* raw data obtained from EPA and IWG estimates

There is a similar gap between 2010 estimates, compared to 2013, 2016, and 2021 estimates (Figure 8). However, I was able to incorporate 2008 data because published federal estimates used the 3% discount rate in determining 2008 values. The 2008 estimates were far over the estimates for 2010-2021, but this can be attributed to the lack of data and comprehensive evaluation in 2008 (Figure 8). The estimates in 2008 were preliminary estimates conducted from obtaining information from preexisting bodies of literature, in contrast to estimates obtained from using integrated assessment models, as done in 2010 - 2021.

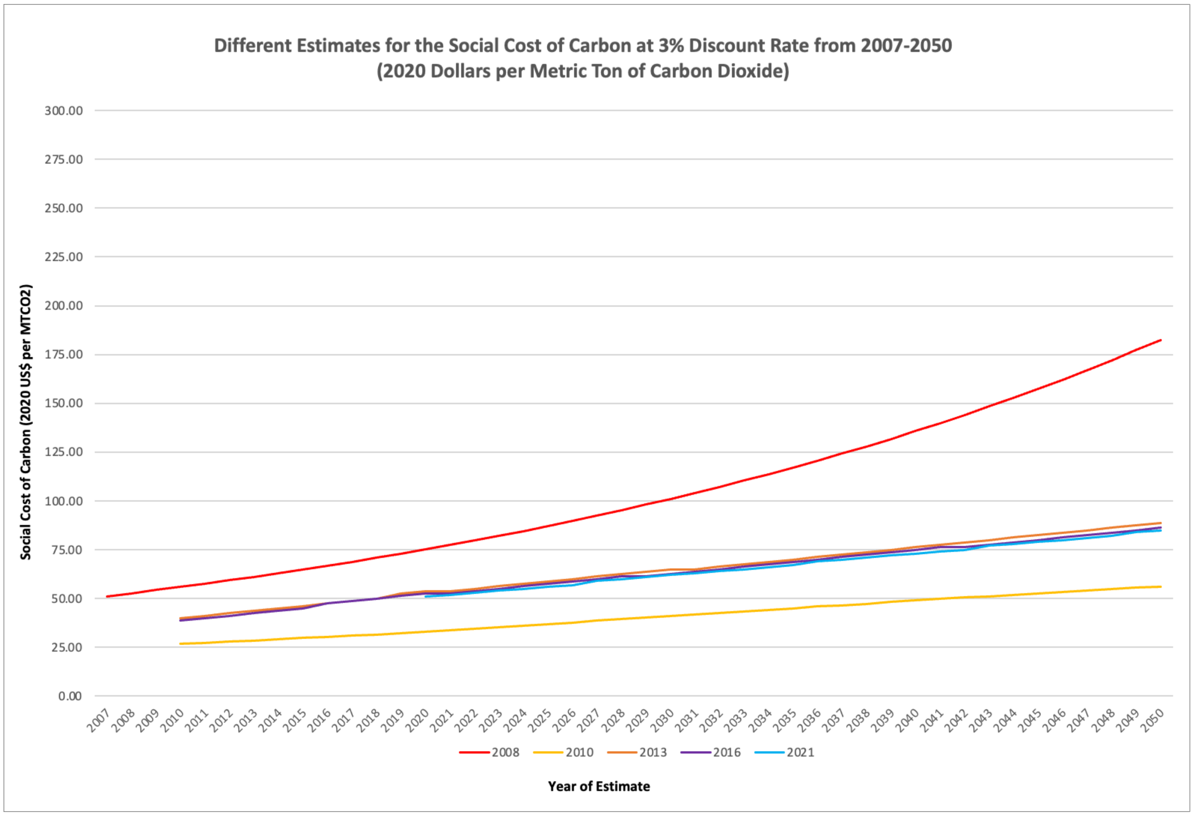

Figure 8. Estimates for SCC at 3% discount rate. This data was obtained from the United States Environmental Protection Agency and the Interagency Working Group. There were no estimates from 2023 data sets to account for the 3% discount rate. The lack of data points in 2007 - 2010 for the 2010, 2013, 2016, and 2021 data sets are because they did not include estimates for the past years before the 2010 decade. The lack of data points in 2010 - 2020 for 2021 estimates are because those were published more than a decade after 2010, and the 2021 official report did not include estimates for past years.
Sources: raw data obtained from EPA and IWG estimates

We are first able to compare the estimates to the 2023 SCC values for 2.5% because of the lower discount rates used in the 2023 projections. We see the gap between 2010 estimates, and the cluster of 2013, 2016, and 2021 estimates which demonstrates a slight decrease in SCC estimates from 2013 to 2021, when normalized to 2020 dollars (Figure 9). This could be due to higher inflation rates during that period in addition to changes in scientific literature. This slight decrease in estimates is surprising to see, since the trajectory of estimates were predicted to go up. Most notably, there is a massive increase in the SCC estimates in 2023, in comparison to previous years. The 2023 estimates used more scientific literature that affected its high valuation. The 2023 estimates at a 2.5% discount rate ranged from $117-205/mtCO2 from 2020-250.

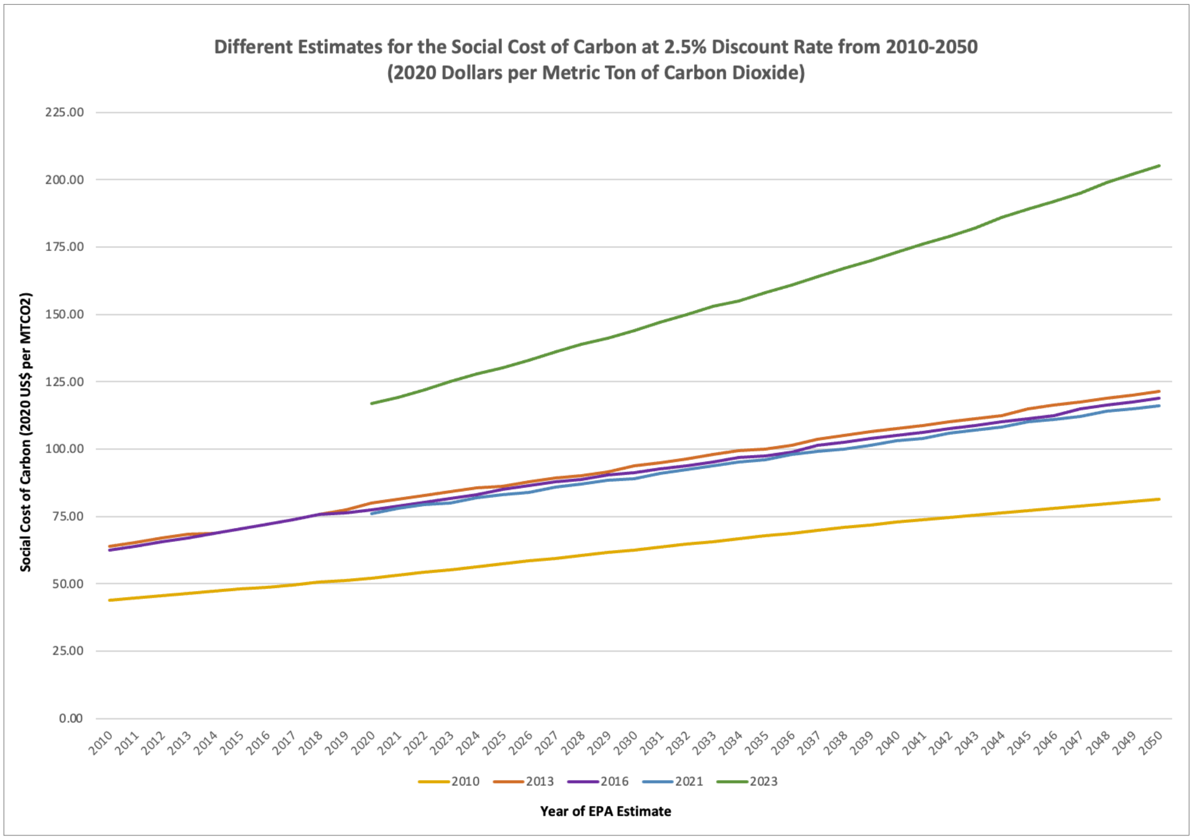

Figure 9. Estimates for SCC at 2.5% discount rate. This data was obtained from the United States Environmental Protection Agency and the Interagency Working Group. There were no estimates from 2008 data set to account for the 2.5% discount rate. The lack of data points in 2010 - 2020 for 2021 and 2023 estimates are because those were published more than a decade after 2010, and the 2021 and 2023 official reports did not include estimates for past years.
Sources: raw data obtained from EPA and IWG estimates

The final graph I created illustrates the discount rate comparisons for the 3% discount rate at the 95th percentile. It excludes the 2008 and 2023 estimates since there was no available data for the 3% discount rate at the 95th percentile for those years. There is a decreasing trend in SCC values for 2013, 2016, and 2021 estimates (Figure 10).

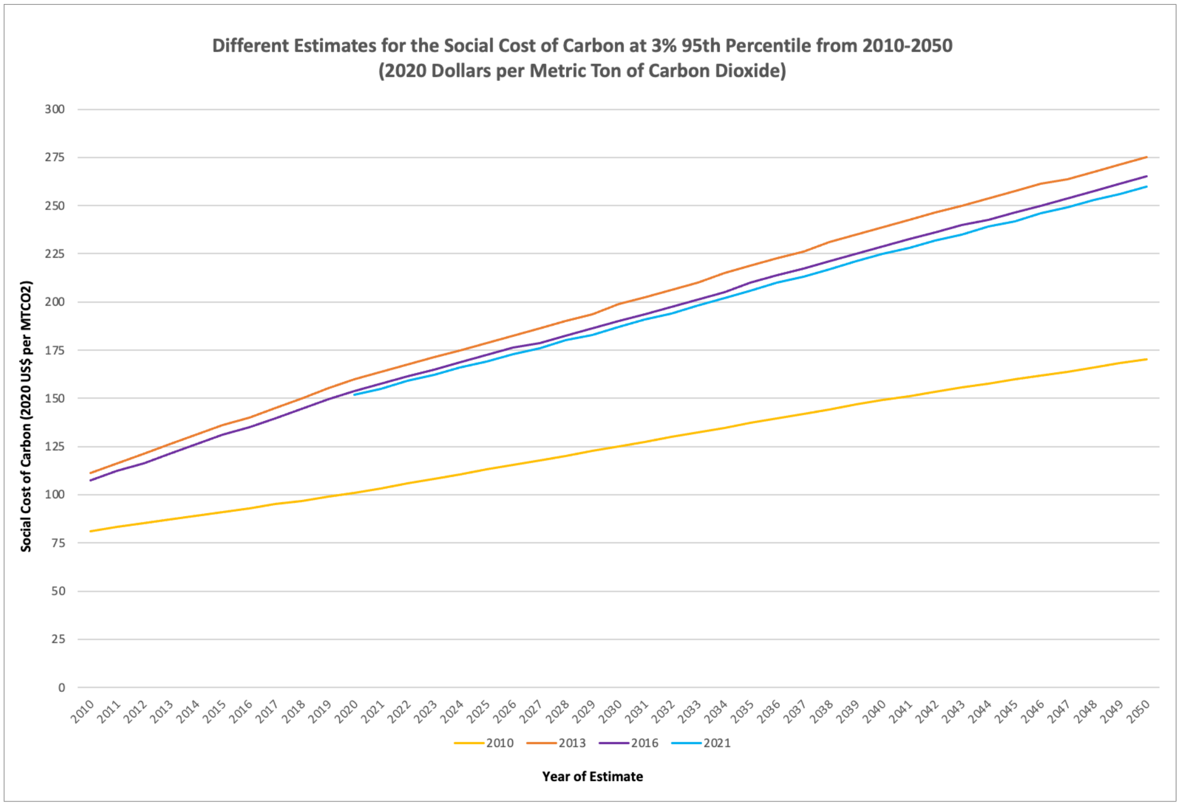

Figure 10. Estimates for SCC at 3% discount rate 95th percentile. This data was obtained from the United States Environmental Protection Agency and the Interagency Working Group. There were no estimates from the 2008 or 2023 data sets to account for the 3% discount rate 95th percentile.
Sources: raw data obtained from EPA estimates

Overall, what we see is that the biggest jumps for SCC estimates happened from 2010 to 2013, which then relatively stayed the same - albeit slightly decreasing estimates - for 2013, 2016 and 2021. There is another large jump in SCC estimates for 2023, which can be attributed to new scientific data.

DISCUSSION

It appears that the SCC estimates majoritively fluctuate based on a few factors, including updates in integrated assessment models, discount rates used, and agendas of different political administrations. The estimates increased from 2010 to 2013 due to increased data availability and updated damage functions within integrated assessment models. Through this trend analysis, we see that there is a slight decrease in 2013, 2016, and 2021 SCC estimates that were quite surprising, considering that scientists predicted an increase over time. In the midst of that time frame, there was a massive drop in federal SCC estimates in 2018 to $1-7/mtCO2 under the Trump administration, and a large factor in the drop was calculating the domestic costs of one metric ton of carbon dioxide emissions, rather than global costs that incorporate the entirety of the damage. The SCC estimates reverted to similar SCC values as 2016 in 2021, when the Biden administration reinstated the Interagency Working Group and used the global SCC instead of the domestic SCC. The biggest jump in SCC estimates occurred in November 2023, when the EPA released its central SCC value of $190/mtCO2 right before COP 28 in Dubai, UAE. Global advocacy for climate change action, as well as international pressure from global conferences like COP 13 and COP 28 have coincided with an increase in SCC values.

Beyond the federal estimates, I compare the EPA and IWG estimates to other calculations of the social cost of carbon in order to evaluate the validity of federal SCC values. I use three case studies that calculate respective social costs of carbon, including: (1) a randomized control trial on payments for ecosystem services in Uganda; (2) automaker trade permits under CAFE standards; (3) Gillingham and Stock's (2018) paper evaluating static costs of policies for reducing greenhouse gas emissions; and (4) Golosov et al. (2014) paper that incorporates SCC functions to estimate the global optimal SCC values. The purpose of using these case studies is to evaluate how the social cost of carbon plays out with various types of policies.

Case Study Comparison #1: RCT - Payment for Ecosystem Services in Uganda

In 2011 - 2013, a randomized control trial (RCT) was conducted in Uganda to evaluate the impacts of payments of ecosystem services (PES). This type of policy is the environmental equivalent of conditional cash transfers, a policy instrument used in order to incentivize families to invest in welfare programs designed to reduce poverty. In this case, the RCT randomly selected 60 out of 121 villages in the Hoima district and northern Kibaale district in Uganda with private forest owners, and allowed them to enroll all of their primary forest for conservation in return for 70,000 Ugandan shillings - roughly equivalent to $28 in 2012 USD - per hectare of forest per year. The study incorporated satellite data to evaluate the impact of the program on forest cover, and further conducted an estimate for the social cost of carbon through this program.

Results from this analysis found that the program averted 0.236ha of deforestation per eligible private forest owner, and the best estimate of costs to avert one metric ton of CO_2 for permanent delay is roughly $2.60, which encompasses incentive payments plus program administration costs. Note that the costs from this program is much lower than the 2012 EPA SCC estimate at $39/mtCO2. However, the estimated costs from this program does not account for estimated delayed deforestation after the program. If one assumes immediate deforestation within a year of the end of the program, and a 10 year delay consistent with 45% of the biomass being burned with immediate release and 45% decomposing within 15 years, and 10% as lumber with carbon stored, then the benefit-costs ratio would fall to 0.8. Due to the unaccounted effects of the program, the net present cost associated with averting one metric ton of carbon dioxide is a lower bound estimate, and is specific to Uganda where the purchasing power for payment for ecosystem services is much higher in comparison to the United States. Although this paper cannot generate a concrete value of abating one ton of carbon, it provides a good example of the costs to momentarily delay deforestation in a developing country - ultimately evaluating the global social cost of carbon when environmental policies are implemented in an area with higher purchasing power.

Case Study Comparison #2: CAFE Standards and Automaker Trade Permits

Through looking at automaker trade permits through bilateral trades in 2017, we see that a permit price for one metric ton of carbon dioxide is between $35 and $40, which are similar to median estimates of the social cost of carbon from federal estimates conducted by the IWG and EPA. The value of the permit price was obtained from two sources, including (i) a Department of Justice settlement with Hyundai and Kia resolving overstated fuel economy labels and (ii) Tesla Motors' SEC Filing Form 10-K from 2013 and 2014 reporting earnings from permit sales (Davis and Knittel 2016).

Case Study Comparison #3: Existing Research on Static Costs of Environmental Policies Based on a Compilation of Economic Studies

The Gillingham and Stock (2018) paper uses a complication of economic studies to evaluate the static costs of various policies. They found that the range of costs for policy interventions is extremely wide, ranging from less than $10/mtCO2 to over $1,000/mtCO2 depending on the type of policy enacted (Gillingham and Stock. 2018). Most of the costs are relatively expensive, exceeding federal estimates, implying that the costs of abatement for most policy instruments exceeds the social cost of carbon. These estimates provide context on the types of interventions that federal agencies can and cannot implement, based on the current SCC values. If we look towards implementing technologies with lower costs per mtCO2, then the overall social cost of carbon would be more affordable.

Tables 3. Static costs of policies based on a compilation of economic studies. This table was obtained from Gillianham and Stock (2018) to illustrate the various estimates for the social cost of carbon converted to 2017 dollars,, in relation to the type of policy

Policy	*Estimate ($2017/ton CO_{2e})*
Behavioral energy efficiency	−190
Corn starch ethanol (US)	−18 to +310
Renewable Portfolio Standards	0–190
Reforestation	1–10
Wind energy subsidies	2–260
Clean Power Plan	11
Gasoline tax	18–47
Methane flaring regulation	20
Reducing federal coal leasing	33–68
CAFE Standards	48–310
Agricultural emissions policies	50–65
National Clean Energy Standard	51–110
Soil management	57
Livestock management policies	71
Concentrating solar power expansion (China & India)	100
Renewable fuel subsidies	100
Low carbon fuel standard	100–2,900
Solar photovoltaics subsidies	140–2,100
Biodiesel	150–250
Energy efficiency programs (China)	250–300
Cash for Clunkers	270–420
Weatherization assistance program	350
Dedicated battery electric vehicle subsidy	350–640

Sources: Gillingham and Stock (2018)

Case Study Comparison #4: Existing Research on SCC Functions and Optimal SCC Values

Estimates from Golosov et al. (2014) show that the optimal carbon tax, which theoretically should equate to the social cost of carbon, is estimated at $7.9/mtCO2 in 1950 to $104.7/mtCO2 in 2019. At the time this paper was published in 2014, the authors estimated that the marginal externality damage cost of one mtCO2 with a 1.5% discount rate per annum equates to about $60, which is comparatively lower than the $77 price per ton of carbon traded within the European Union Emission Trading System(Golosov et al. 2014). These values are much higher than the EPA and IWG estimates published from 2008 - 2021 for the social cost of carbon. It is also important to note that the United States has never incorporated a federal carbon tax, and only started calculating the social cost of carbon in 2008. Using these values as a reference point, we see that the federal SCC estimates have been a lower estimate comparatively.

Summary

After witnessing the volatility of SCC estimates over time, we see that it is critical to use standardized parameters in estimating the social cost of carbon. These parameters include deciding whether to use the global SCC or domestic SCC, types of damage functions incorporated into the model, climate sensitivity estimates, discount rates, and trajectory of growth over time. The SCC values must be standardized and reliable year after year, allowing legislators, policymakers, and potentially the private sector in the future to anticipate methods of integrating environmental policies.

In order to keep the SCC values standardized, the agencies that calculate the SCC values must stay intact, which typically correspond to the priorities of the current political administration. Furthermore, it is important to continuously update the SCC values periodically to keep up with the most recent literature surrounding climate change from greenhouse gas emissions.

There is also a possibility to incorporate the social cost of carbon beyond policy making in the federal government. Since the SCC is supposed to represent the optimal Pigouvian tax to maximize welfare, the SCC value can be used as a carbon tax instead. There are limitations with incorporating a carbon tax, as taxes are often received with much backlash and often hard policies to pass. A carbon tax, however, would move us towards actions beyond the federal government that would benefit our well being environmentally. The social cost of carbon theoretically can be implemented to affect the private sectors as well. As of March 2024, the US Securities and Exchange Commission adopted a climate disclosure rule, regulating public companies to report on Scope 1 and 2 carbon emissions. If we, as a society, are able to calculate the social costs of carbon emissions of these companies within SEC regulations such as this, there is potential for large progress towards reducing our carbon footprint as a nation. There is currently a blatant tradeoff between environmental protection and GDP growth, since economic activity correlates with higher environmental damage in the IAM damage functions. Thus, incorporating the social cost of carbon in SEC reporting incorporates the social costs directly into economic activity.

Limitations

I found a lot of difficulties when attempting to find ways of incorporating ecocentric values into economic transactions, since there are no incentives in place to do this - outside of wanting to protect the environment. My original plan for my thesis was to relate ecocentric values, such as worth of biodiversity, into traditionally anthropocentric economics by seeing how payment for ecosystem services affects the gross domestic product or measure of economic welfare. However, I found myself lacking certain geographical data to do this and had to pivot my ideas last minute. In looking at the social cost of carbon, I was able to use an example on how the U.S. federal government is working to define an environmental externality and apply it to decision making. A limitation that I stumbled upon is the lack of standard parameters, such as discount rates, when defining the federal estimates of the SCC throughout the years.

CONCLUSION

In this paper, I conducted an analysis on the trends and evolution in the federal estimates of the social cost of carbon since its inception in 2008, and further compared federal SCC estimates to other valuations. The literature around the social cost of carbon tells us that there are a multitude of factors that influence the monetary cost of global damage done by one metric ton of carbon dioxide, and these factors include damage functions that comprise integrated assessment models, the discount rate used by the federal government based on interest rates, and the agendas of political administrations in relation to environmental policy making. These factors have made the SCC values vary greatly in the span of 2008 - 2023, which illustrate room for standardization and improvement in our estimations. Moreover, the social cost of carbon emissions have retrospectively been a lower bound estimate in comparison to the EU and other SCC estimates, and it is to our benefit for the SCC estimates to correctly represent the true social cost of emitting carbon dioxide. There is also the possibility for the SCC to be utilized outside of policy cost-benefit analysis - it can theoretically be implemented as a Pigouvian tax for economic activity, accurately representing the social cost of environmental degradation within our economic operations.

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