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A CARBON TAX, BUT AT WHAT PRICE?

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INTRODUCTION

A carbon tax has rightly been called a "textbook" response to climate change[1] and economists from across the political spectrum have endorsed it as the most efficient way to reduce greenhouse gas emissions.[2] But even to accept the case for a carbon price in principle leaves a key question: what should that price be?

Researchers have sought to determine the answer by estimating the overall costs and benefits caused by the emission of a ton of carbon dioxide. Known as the Social Cost of Carbon (SCC), in theory, this estimate can be used to set the "optimal" carbon price. In practice, however, matters are not quite so simple. Critics have raised a host of objections about how the SCC is set, and there are key uncertainties or judgement calls that go into calculating the number. In addition, there are factors beyond the likely damage from increased greenhouse gas emissions that legislators must consider.

Accordingly, this paper provides a brief overview and evaluation of some of the common criticisms of the SCC as a mechanism for setting a price on carbon. While some of these have more validity than others, two conclusions can be drawn: First, while there can be legitimate disagreements over what an appropriate carbon price should be, this is not an argument against having a carbon tax in the first place. Irrespective of whether we are sure if the "best" carbon price is $20 a ton or $50 a ton, the answer is not to set the price at $0. Second, calculating both the SCC and the optimal carbon price are not simply matters of science but rather, they involve inherently political value judgements. As such, the decision of where to set the price is best left to elected political bodies rather than administrative agencies.

HOW THE SOCIAL COST OF CARBON IS CALCULATED

In order to estimate the effects of the emission of greenhouse gases, researchers have developed "Integrated Assessment Models" (IAMs). There are three main IAMs in use. The most prominent is the Dynamic Integrated Climate Economy (DICE) model, developed by William Nordhaus of Yale University, who was recently awarded the Nobel Prize for his work. Also commonly used is the Policy Analysis of the Greenhouse Effect (PAGE) model, developed by Chris Hope of the University of Cambridge and the Framework for Uncertainty Negotiation and Distribution (FUND) model, originally created by Richard Tol of the University of Sussex and now overseen by Tol and David Anthoff of the University of California.

The IAMs are computer models that synthesize a wide range of data about both the physical and economic effects of climate change. First the models incorporate projections for

1. Jennifer A. Dlouhy, "Yellen Touts Carbon Tax as 'Textbook Solution' to Climate Change," *Bloomberg*, Sept. 10, 2018. https://www.bloomberg.com/news/articles/2018-09-10/yellen-touts-carbon-tax-as-textbook-solution-to-climate-change.

2. See, e.g., N. Gregory Mankiw, "Smart Taxes: An Open Invitation to Join the Pigou Club," *Eastern Economics Journal* 35 (2009), pp. 14-23. https://scholar.harvard.edu/files/mankiw/files/smart_taxes.pdf.

how socioeconomic factors such as population growth or GDP will change over the coming decades or even centuries. Next, they use this data to estimate likely greenhouse gas emissions if action is not taken to limit them and then project the likely consequences of this in terms of warming, changes to weather patterns, increased sea-level rise and other environmental impacts. Third, the models attempt to quantify the costs and benefits that these changes will have. Finally, a "discount rate" can be applied to future damages to correct for the fact that events are generally considered less pressing the further they are from the present. Based on this information, the models calculate the longer-term effects of emitting a ton of carbon dioxide or its equivalent and assign it a monetary value in present-dollar terms.[3]

The three models differ from each other in how they specifically estimate damage from climate change and in the various ways the assumptions in each model have changed over time. The models' results can also vary widely based on the value assigned to certain variables (such as the discount rate or climate sensitivity).

When people talk about the Social Cost of Carbon, however, they are often referring to the specific number released by the United States government, which is to be used by agencies in doing cost-benefit analyses for rulemaking. The official SCC estimate was developed by an interagency working group (IWG), which, in 2010, produced an initial, central estimate of $26 a ton for emissions in 2020. The group derived this number by averaging the results of DICE, PAGE and FUND, using middle-of-the-road assumptions for such inputs as climate sensitivity and discount rate.[4] The number has since been revised several times.

THE KNOWLEDGE PROBLEM

Given the complexity of the IAMs and the uncertainties involved, it is not surprising that they have been subject to a number of criticisms. For example, some critics cite issues that could make the models potentially overstate the costs from climate change,[5] while others cite issues that mean that the model estimates underrate the costs.[6] In some cases, criticisms apply only to some of the IAMs or some versions of a particular one and thus the following few examples may help illustrate the point.

Climate Response

The amount of damage estimated by the IAMs is based upon the amount of warming. But how much warming results from a given amount of CO_2 emissions is the subject of a good deal of uncertainty. The most recent assessment of the Intergovernmental Panel on Climate Change concluded that doubling the concentration of CO_2 in the atmosphere would likely increase average temperatures between 1.5 and 4.5 degrees Celsius.[7] Warming outside that range is also possible. For example, MIT economist Robert Pindyck has pointed out that: "The IPCC suggests that the 95th percentile is about 7°C, i.e., there is roughly a 5 percent probability that the true climate sensitivity is above 7°C."[8] In layman's terms, this means that there is a small, even non-trivial possibility that the amount of warming generated by CO_2 emissions could be extremely high, which, as discussed in the section below regarding catastrophic outcomes, has serious implications for how the expected damage should be calculated.

And even these numbers are subject to revision. As economist Robert Murphy has noted:

> Reported best guess of 3.0°C warming from a doubling of CO_2 concentrations relies on feedback effects that, according to the IPCC models, have not yet fully manifested themselves [...] future climatologists may substantially revise their estimate of climate sensitivity because presumed feedbacks and offsetting factors are not currently being modeled correctly.[9]

The models, then, may give us a false sense that we know more than we actually do about the amount of warming likely to result from CO_2 emissions.

The models also differ from each other in their assumptions about how greenhouse gas emissions will translate into higher concentrations of CO_2 in the atmosphere. For example, the DICE model projects twice the warming in 2040 for a given amount of emissions in 2020 than does the FUND model. This is due to different assumptions about the carbon cycle

3. "Q & A: The Social Cost of Carbon," Carbon Brief, Feb. 14, 2017. https://www.carbonbrief.org/qa-social-cost-carbon.

4. "Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866," Interagency Working Group on Social Cost of Carbon, February 2010. https://19january2017snapshot.epa.gov/sites/production/files/2016-12/documents/scc_tsd_2010.pdf.

5. See, e.g., Robert P. Murphy, "Rolling the DICE: William Nordhaus' Dubious Case for a Carbon Tax," *The Independent Review* 14:2 (Fall 2009), pp. 197-217. http://www.independent.org/pdf/tir/tir_14_02_03_murphy.pdf.

6. See, e.g., Frank Ackerman et al., "Limitations of integrated assessment models for climate change," *Climatic Change* 95 (2009), pp. 297–315. http://frankackerman.com/publications/climatechange/Limitations_Integrated_Assessment_Models.pdf.

7. "Climate Change 2013: The Physical Science Basis, Summary for Policymakers," Intergovernmental Panel on Climate Change, 2013, p. 16. http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_SPM_FINAL.pdf.

8. Robert S. Pindyck, "Climate Change Policy: What Do the Models Tell Us?" *Journal of Economic Literature* 51:3 (September 2013), pp. 860-72. https://www.nber.org/papers/w19244.pdf.

9. "Rolling the DICE." http://www.independent.org/pdf/tir/tir_14_02_03_murphy.pdf.

and a different accounting for greenhouse gases other than CO_2, including methane.[10]

This matters because the Social Cost of Carbon is defined in terms of an amount of emissions, yet the impacts from climate change are all based on the amount of warming that results. To the extent that we are uncertain how much warming will result from the same amount of emissions, we will not know exactly how much damage a ton of CO_2 emissions is going to cause.

Cost Estimates for Adaptation

Estimating the costs from climate change requires a projection, whether implicit or explicit, of how easy it will be for society to adapt to a warmer world. For example, projected sea-level rise could result in major American coastal cities such as Miami falling below sea level. If nothing is done in response to this, the costs would be enormous. Yet, it is also possible that the costs could be minimized (at least up to a point) by, for example, building sea walls. Similarly, if climate change causes drought and makes it harder to grow crops in a given area, production could shift to other regions, limiting the overall damage.

Failing to properly account for adaptation could cause the SCC estimate to be too high (if the projections about adaptation prove too pessimistic) or too low (if they prove too optimistic). With respect to the 2007 DICE model, Robert Murphy has argued that:

> The more pessimistic estimates [relied on by the model] commit serious methodological errors that bias their results, and they consequently likely overstate the damage from a given amount of warming.[11]

By contrast, a review by Michael Mastrandrea concluded that "in general, DICE assumes very effective adaptation, and largely ignores adaptation costs."[12]

The PAGE model assumes that, in developed countries, adaptation will avoid all of the projected market damages for temperature increases of less than 2 degrees Celsius, and 90 percent of the damages projected for temperatures above 2 degrees. Market damages for developing countries are reduced by 50 percent and non-market damages by 25 percent on the same assumption. The FUND model also explicitly includes adaptation in the model for certain sectors (such as agriculture). In fact, FUND assumes that adaptation will lead to net benefits for agriculture due to climate change for up to 3 degrees Celsius of warming for all regions except Australia.[13]

Dealing With the Risk of Catastrophe

The IAMs have struggled with how to deal with the possibility of catastrophic damage from climate change. Consider an airplane that has a 2 percent chance of crashing. Simply focusing on the most likely scenario (that the plane trip is uneventful) would give you an unreasonably rosy picture of the risks involved in the flight. Data on the effects of warming beyond 3 degrees Celsius, however, are scant and hard to extrapolate from existing data sources.

The makers of the IAMs recognize this as a limitation in the models. For example, with respect to an older version of DICE, Nordhaus wrote that his model "assumes that there are no genuinely catastrophic outcomes that would wipe out the human species or destroy the fabric of human civilizations."[14] Yet acknowledging this limitation of the IAMs does not make it any less significant. To quote Pindyck:

> IAMs can tell us nothing about the likelihood or possible impact of a catastrophic climate outcome, e.g., a temperature increase above 5°C that has a very large impact on GDP. And yet it is the possibility of a climate catastrophe that is (or should be) the main driving force behind a stringent abatement policy.[15]

There are a number of possible ways to resolve this problem. One would be to base the SCC calculations on "worst case scenario" assumptions. Alternatively, one could treat the SCC estimate from the IAMs as a kind of bare minimum that, in practice, ought to be somewhat higher given that it does not include all risks. As it stands, however, the models do an inadequate job of dealing with the feature of climate change that many people care most about, which is the risk of a truly catastrophic outcome.

GDP: Growths Rates vs. Levels

The way IAMs function assumes that climate damages will reduce GDP but will not affect growth rates. If this is true, then the costs of climate change are likely to be contained. However, this is a questionable assumption. Pindyck has

10. "Q&A: The Social Cost of Carbon." https://www.carbonbrief.org/qa-social-cost-carbon.

11. "Rolling the DICE," p. 204. http://www.independent.org/pdf/tir/tir_14_02_03_murphy.pdf.

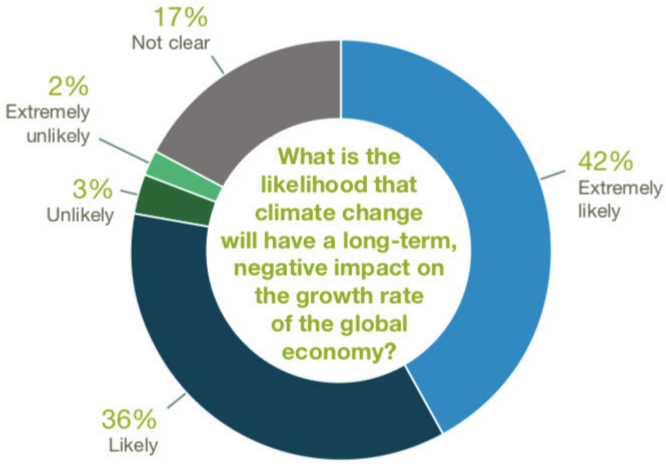
12. Michal D. Mastrandrea, "Working Paper: Calculating the benefits of climate policy: Examining the assumptions of Integrated Assessment Models," Pew Center on Global Climate Change, 2009. http://www.environmentportal.in/files/mastrandrea-calculating-benefits-climate-policy-12-22-09.pdf.

13. Ibid, p. 33.

14. William Nordhaus, *A Question of Balance: Weighing the Options on Global Warming Policies* (Yale University Press, 2008), p. 28. http://econdse.org/wp-content/uploads/2014/02/nordhaus_a_question_of_balance_2008.pdf.

15. Robert S. Pindyck, "The Use and Misuse of Models for Climate Policy," Review of Environmental Economics and Policy 11:1 (January 2017), pp. 100-14. http://web.mit.edu/rpindyck/www/Papers/PindyckClimateModels2015.pdf.

FIGURE I: LIKELIHOOD OF NEGATIVE IMPACT ON GLOBAL ECONOMIC GROWTH RATE



SOURCE: Howard and Sylvan.

offered several reasons to think that climate change would affect growth rates and not just levels of GDP:

> First, some effects of warming will be permanent; e.g., destruction of ecosystems and deaths from weather extremes. A growth rate effect allows warming to have a permanent impact. Second, the resources needed to counter the impact of warming will reduce those available for R&D and capital investment, reducing growth. Third, there is some empirical support for a growth rate effect.[16]

Pindyck's concerns are widely shared among economists. In a 2015 survey of economists on the effects of climate change, 42 percent of respondents thought it was "extremely likely" that climate change would harm growth rates, while another 36 percent thought it would "likely" do so. By contrast, only 5 percent thought it was either "unlikely" or "extremely unlikely" that climate change would negatively impact growth rates.[17] A recent report by the Richmond Federal Reserve has also concluded that climate change could reduce economic growth by as much as one-third over the course of the 21st century.[18] The question of whether climate change could cause slower growth is an important one because even a small reduction in the rate of growth can result in society being much poorer over the long term.

Discount Rates

Even if we could be certain what the damages from climate change would be for any given level of warming, this would settle the question of what the SCC should be. This is because much of the cost from global warming lies decades or even centuries into the future. A cost that will be borne in the future is generally considered less pressing than one that must be endured today. As such, the IAMs typically use a discount rate that reduces future damages to determine their equivalent present cost.

Which discount rate to use is a matter of great controversy. Some economists have argued in favor of using market-based interest rates since, in theory, a society could deal with the cost of future warming by investing money today and using the proceeds to pay for the costs later.[19] Others have argued that lives of future generations are just as valuable as those today and therefore the "social-discount" rate should be zero.[20] Even those who favor a social-discount rate of zero, however, may still want to discount future damages somewhat to account for the fact that future generations are likely to be wealthier than those of today and thus may be better able to bear the costs of warming. By contrast, other commentators have suggested that the discount rate effectively ought to be 100 percent beyond a certain point in the future, and that we simply shouldn't consider damages beyond a certain point, either because the uncertainties involved are too great or because we owe nothing to generations so disconnected from us in time.[21]

Whatever the number, the choice of discount rate can have a huge impact on the final value assigned to the SCC. It also has a significant impact on how a carbon tax based on the SCC would change over time. A low discount rate implies that a carbon tax should start at a higher rate but grow gradually, whereas a high discount rate would mean a low initial tax rate that grows rapidly.

Perhaps the most important thing to note about the discount-rate debate is that the appropriate rate is not something that can be settled scientifically. To quote Pindyck:

16. "Climate Change Policy," p. 870. https://www.nber.org/papers/w19244.pdf.

17. Peter Howard and Derek Sylvan, "Expert Consensus on the Economics of Climate Change," Institute for Policy Integrity, December 2015. https://policyintegrity.org/files/publications/ExpertConsensusReport.pdf.

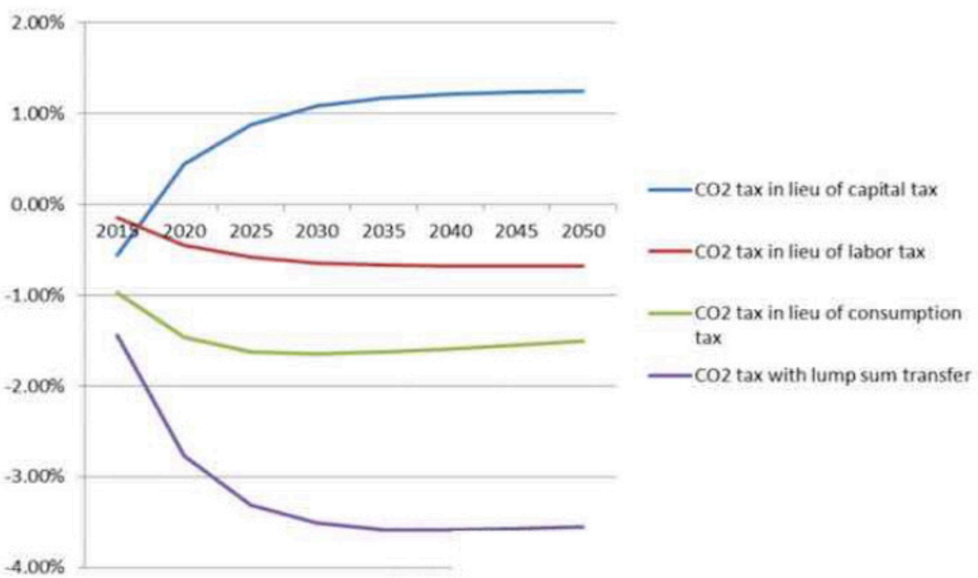
18. Riccardo Colacito et al., "Temperature and Growth: A Panel Analysis of the United States," *Federal Reserve Bank of Richmond Working Paper* No. 18-09, March 30, 2018. https://www.richmondfed.org/-/media/richmondfedorg/publications/research/working_papers/2018/pdf/wp18-09.pdf.

19. See, e.g., David Kreutzer, "Discounting Climate Costs," Heritage Foundation, June 16, 2016. https://www.heritage.org/environment/report/discounting-climate-costs.

20. Tyler Cowen and Derek Parfit, "Against the Social Discount Rate," in *Justice between Age Groups and Generations*, ed. James S. Fishkin and Peter Laslett (Yale University Press, 1992), pp. 144-61. http://www.stafforini.com/docs/Cowen%20&%20Parfit%20-%20Against%20the%20social%20discount%20rate.pdf.

21. Jordan McGillis, "The Social Cost of Carbon: Considerations and Disagreements in Climate Economics," Institute for Energy Research, Aug. 28, 2018. https://www.instituteforenergyresearch.org/climate-change/the-social-cost-of-carbon-considerations-and-disagreements-in-climate-economics.

FIGURE 2: PERCENTAGE DIFFERENCE IN GDP*



*NOTE: $30/ton Revenue-Neutral CO2 Tax Relative to Base Case
SOURCE: Resources for the Future.

> The rate of time preference is a policy parameter, i.e., it reflects the choices of policy makers, who might or might not believe (or care) that their policy decisions reflect the values of voters.[22]

Put simply, how to value future generations is a philosophical matter. As such, disputes over how high to set a price on carbon that revolve around the discount rate are fundamentally political.

OTHER CONSIDERATIONS

Suppose that all of the above issues could be resolved to everyone's satisfaction and that the resulting SCC turned out to be the same central estimate as the one initially given by the IWG: $26 a ton in 2020. Would this mean that we should enact a carbon tax of $26 a ton? Not necessarily. A carbon tax may be intended to correct for the damage imposed by greenhouse gas emissions but it also has other effects that could justify either a higher or lower carbon price, depending on the circumstances.

The Double Dividend and the Tax Interaction Effect

Like all taxes, a carbon tax generates revenue for the treasury. And, like all taxes, the revenue can be used wisely or poorly. If it is used wisely, the benefits can mitigate or perhaps even cancel out the costs from the tax entirely. Somewhat surprisingly, then, a carbon tax might make sense even if the environmental benefits from the tax were small. For example, if revenue from a carbon tax were used to replace existing, more burdensome taxes, the tax could result in higher economic growth. This idea is known as the "double dividend," which is a reference to the fact that the tax would have both economic and environmental benefits.

There is a flip-side to the double dividend, however. Modern governments rely on a variety of taxes, the revenues of which would be adversely affected by the higher energy prices that a carbon tax could bring in the short term. For example, higher energy prices could reduce personal income growth, which would mean the government received less income tax revenue than it would have without the tax. The "optimal" carbon tax could therefore be less than the Social Cost of Carbon or it could be higher, depending upon how the money from the tax is used.[23]

Economic research suggests that a double dividend is most likely if revenue is dedicated to replacing taxes on capital income, such as the corporate income tax or capital gains. These taxes are highly burdensome such that cutting them in favor of a carbon tax would be a net-positive economically. By contrast, swapping a carbon tax for cuts in taxes on labor would have a slight negative impact (if you do not count

22. "Climate Change Policy," p. 865. https://www.nber.org/papers/w19244.pdf.

23. Robert P. Murphy, "Carbon Taxes and the Tax Interaction Effect," The Library of Economics and Liberty, October 2012. https://www.econlib.org/library/Columns/y2012/Murphycarbon.html.

environmental benefits) and a swap with consumption taxes would have a more significant one.[24]

Non-Climate Benefits

While carbon taxes apply to emissions of greenhouse gases, activities that emit greenhouse gases also tend to emit other pollutants, such a sulfur dioxide or particulate matter. A carbon tax would incidentally reduce these emissions, potentially leading to increased benefits in terms of air quality and public health. Consideration of these benefits might justify a higher carbon price or could justify less- costly direct regulation of these pollutants. For example, one recent study found that the benefits just from incidental reductions in conventional pollutants from a carbon tax were greater than the costs imposed by the tax for many countries.[25]

CONCLUSION

Given the myriad uncertainties involved, how much weight can we put on SCC estimates when designing climate policy? According to Pindyck, the uncertainties and limitations of the IAMs are so severe as to "make them close to useless as tools for policy analysis."[26]

It would be a mistake, however, to conclude that the limitations of the IAMs call into question the case for a carbon tax itself. It may be true, as Pindyck argues, that the IAMs can be used to obtain almost any result one desires."[27] But the key word here is "almost." As Pindyck notes elsewhere, using reasonable assumptions, the IAMs "can yield an SCC estimate as low as a few dollars per ton, as high as several hundred dollars per ton or anything in between."[28] Arriving at a carbon price of zero is not within that range. Indeed, addressing many of the criticisms of the IAMs detailed in this paper could result in a carbon price being higher—rather than lower—than the central estimate of the IWG. It should also be noted that, despite being one of the most prominent critics of IAMs as a climate policy tool, Pindyck himself favors a carbon tax and has thus criticized efforts to use his work to argue against it.[29]

What the above considerations show is that the decision about where to set a carbon price involves inherent political considerations that cannot be reduced to a matter of scientific or technical analysis. In this respect, it is no different from decisions about taxes generally. While economic models may try to determine the "optimal" top income-tax rate and while policymakers may use these models to guide their own thinking, no one would suggest that income-tax rates should be set mechanically according to the results of an economic model. Nor would anyone suggest that the fact that models cannot perform this task means that there should be no taxes at all. The irony is that while the Social Cost of Carbon is often discussed in the context of a carbon tax, the IWG analysis was developed not for a carbon tax but for use in the cost-benefit analysis used in regulatory rulemaking. Where carbon prices have been enacted, they have typically not been established based on an SCC estimate but rather have involved a variety of other considerations. This is as it should be.

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24. Josiah Neeley, "Prominent Carbon Tax Skeptic Admits it Could Boost Economic Growth," *R Street Blog*, Sept. 11, 2017. https://www.rstreet.org/2017/09/11/prominent-carbon-tax-skeptic-admits-it-could-increase-economic-growth.

25. Kirk Hamilton et al., "Multiple Benefits from Climate Change Mitigation: Assessing the Evidence," Grantham Research Institute, November 2017. http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2017/11/Multiple-benefits-from-climate-action_Hamilton-et-al-1.pdf.

26. "Climate Change Policy," p. 860. https://www.nber.org/papers/w19244.pdf.

27. Ibid., p. 5.

28. "The Use and Misuse of Models for Climate Policy," p. 100. http://web.mit.edu/rpindyck/www/Papers/PindyckClimateModels2015.pdf.

29. Robert S. Pindyck and James S. Stock, "We don't know what climate change will cost — that doesn't mean we can ignore it," The Hill, May 9, 2018. https://thehill.com/opinion/energy-environment/386952-we-dont-know-what-climate-change-will-cost-that-doesnt-mean-we-can.