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The Social Cost of Carbon

Buried deep in the back pages of a minor, and seemingly unrelated, environmental regulation, the Obama administration has laid out its climate agenda. But estimating the results of greenhouse warming turns on a set of nested assumptions each of which can sway the ultimate answer

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All but dead in the U.S. Congress, climate policy has been limping along behind the scenes. The Environmental Protection Agency and other federal agencies are now taking measures to reduce greenhouse gas emissions, but those measures have more bark than bite. And the outlook for a more robust federal climate initiative is not good at all.

Here's the bark: Setting a price on carbon emissions is now the standard practice when assessing EPA, Department of Energy, and other federal regulations. If you are surprised, then you probably missed the Obama administration's seminal publication on the subject, Appendix 15A of the Regulatory Impact Analysis for its energy efficiency program for small electric motors. Squint deeply into the fine print of Appendix 15A (now reposted for your convenience on the Office of Management and Budget's website). There you will find our new national carbon price. The bite? A measly $21 per ton of carbon dioxide, or about the equivalent of $0.21 per gallon of gasoline.

Here's how to get a sense of the whether $21 a ton is big or small. The average U.S. resident emits about 21 tons of carbon dioxide every year. If the administration's carbon price were in effect across all sectors of the economy — à la Waxman-Markey, Kerry-Lieberman, and other dead-letter climate bills — 21 tons times $21 per ton would amount to $441 in extra "carbon charges" paid by each individual in each year, about 1.5 percent of the average persons' income, or $1.21 per day for each of us. Energy conservation measures would allow you to reduce those carbon charges, but only by a fraction. Would the chance to save some fraction of $441 a year be enough to make you change your behavior? Buy a hybrid? Insulate your attic? Wait for hotter temperatures before turning on the air conditioner? Perhaps. But would it change U.S. consumer preferences enough to inspire electric utilities to switch to carbon-free generation, or to provide the incentives to develop the public infrastructure needed to make electric cars a viable transportation option? Probably not.

The administration bases its carbon price on its estimate of the "social cost of carbon." That's the future damage that would be caused by emitting one extra ton of carbon dioxide. In the cost-benefit analyses required for all major federal environmental rules, a regulation (such as increased energy efficiency requirements for small motors) that would reduce emissions will now be assigned an additional $21 benefit per ton of carbon dioxide kept out of the

atmosphere, making it that much more likely for its benefits to exceed its costs. Obviously, the higher the assumed social cost of carbon, the better that environmental regulations look in cost-benefit terms.

In the field of economics, greenhouse gas emissions cause what are known as "negative externalities": damages (to someone other than the emitter) that no one is made to pay for. When federal regulations that reduce greenhouse gas emissions do not include a carbon price, it is as if federal agencies were assuming that these emissions have no negative consequences. If $21 really is the value of all future damages caused by emitting an extra ton of carbon, then including it as a benefit in the assessment of a new regulation would, as economists like to say, "internalize the externality" — as if polluters were charged for the damages that they caused or, equivalently, efforts to reduce emissions were rewarded for each ton of carbon dioxide avoided. The method has a solid pedigree in mainstream economics. The question remains: Is $21 the right price?

Appendix 15A presents a range of possible social cost of carbon estimates based on changes to several key assumptions, discussed below, but settles on the central estimate of $21 per ton. This value has made its way into subsequent federal Regulatory Impact Analyses, including evaluation of Corporate Average Fuel Economy standards. The Interagency Working Group that conducted the analysis averaged the results of three climate-economics models: the PAGE model calculated a social cost of carbon of $30 per ton; the DICE model, $28; and the FUND model, $6.

In a recent report for the E3 Network, a national group of economists, written by Frank Ackerman and myself, we took a close look at the Working Group's version of the DICE model to figure out what makes it tick. We found that the DICE model's $28 result is extremely sensitive to three choices made by the modelers regarding the discount rate, the degree of climate sensitivity, and the assumed relationship between temperature increases and economic damages.

First, the discount rate determines the importance of future costs and damages in current decisions. Climate damages from today's emission of greenhouse gases are expected to take place over the course of hundreds, and even thousands, of years. Estimating the social cost of carbon requires us to sum up all of the future damages caused by the release of an additional ton of carbon dioxide. If the discount rate is set to 0 percent, damages are simply added together, regardless of whether they occur in 2012, 2112, 2212, and so on. The higher the discount rate, the more that future damages are "discounted," or scaled down — like compound interest in reverse. At a very high discount rate, damages far off in the future appear vanishingly small and only damages that will take place in the next few years or decades are given any real weight. The Working Group's central estimate uses a 3 percent discount rate; it also tested out results at 5 percent and 2.5 percent.

A 3-percent discount rate is often recommended for U.S. government policy analysis, but then again, most policy analyses focus exclusively on impacts in the next few years or decades, not on damages that are expected to occur over many centuries, as in climate change. For climate impact assessments, the typical range of discount rates tends to be much lower than for short-term environmental policy issues. The Working Group itself notes that the widely employed "prescriptive" approach to discounting — based in part on a subjective judgment about how the current generation values costs and benefits experienced by future generations — has commonly been used to justify values as low as 1.4 percent. In the end, there is no "correct" discount rate, and the debate about it boils down to a question of ethics: How much weight should we give to future climate damages? (or, put another way, to the interests of future generations?). If the answer is "a great deal," then a 3 percent discount rate will result in an underestimate of the social cost of carbon.

Second, the Working Group's estimate rests on the assumption that greenhouse gas emissions' effect

on global temperatures is well known, when, in fact, this relationship is highly uncertain. If global emissions continue to grow at today's pace, by 2040 the concentration of carbon dioxide in the atmosphere could be twice as great as it was in preindustrial times. The effect of these emissions on temperatures begins immediately but can take a few centuries to be fully realized. Climatologists use a shorthand for the emissions-to-temperature-change relationship called "climate sensitivity," or the effect of a doubling of carbon dioxide in the atmosphere on long-term average temperatures. The higher the climate sensitivity, the higher the temperature for any given level of emissions. For example, research by the UK government suggests that today's pace of emissions growth and a 3°C climate sensitivity, which (when added to other effects) means global average temperatures 5.4°C higher than the preindustrial average by 2100; at a 6°C climate sensitivity, the same emissions would cause a 7.1°C temperature increase by 2100 — a big difference.

According to the most recent climate science research, the median, or best guess, climate sensitivity is 3°C — the value used in the administration's central estimate — but the real value is unknown (and, perhaps, unknowable) and, as the Working Group recognized, there is a broad range of possibilities. According to the Working Group's own analysis, there is about a two thirds chance that the true climate sensitivity lies somewhere between 2°C and 4.5°C, a 1-in-10 chance that it is greater than 6°C, and a 1-in-20 chance that it is greater than 7°C. Appendix 15A reports results for the 95th percentile (i.e., 7°C) climate sensitivity, but then uses only the median (3°C) value in its central estimate.

If climate sensitivity turns out to be higher than the best guess, the administration will have underestimated the correct price to place on carbon. At issue here is how best to make decisions about risky outcomes. Too low of a carbon price will mean an emissions reduction policy that offers too little too late. Should we use a carbon price with a 50-percent chance of resulting in insufficient emission reductions, or one with just a 1-in-20 chance? How about a 1-in-1000 chance for a little more breathing room between us and climate catastrophe? Again, there is no correct answer, just a lot of questions. One thing, however, is certain: Assuming a higher climate sensitivity would be a more risk-averse approach to estimating the social cost of carbon.

Third, while the Working Group picked out the discount rate and climate sensitivity behind its central estimate — tweaking the three models to follow a consistent set of assumptions — it accepted without adjustment or analysis the original PAGE, DICE, and FUND relationships between temperature increase and economic damages. Indeed, the differences in the damage assumptions used in these models account for most of the variation in their resulting social costs of carbon, from $30 per ton in PAGE to $6 per ton in FUND.

PAGE, developed by Chris Hope of Cambridge University and used in the well-known and well regarded Stern Review of the effects of climate change, includes the potential for catastrophic impacts in its damage estimates, but (outside of the Working Group's analysis) is designed to be run "Monte Carlo" style: averaging the results of running the model thousands of time at different climate sensitivities and other uncertainties, drawn randomly from a pool of values that is based on their expected probability. The administration's central value for the social cost of carbon includes only PAGE results using the median 3°C climate sensitivity.

The FUND model, developed by Richard Tol and David Anthoff, produces a social cost of carbon that is far lower than the other estimates. Multiple critiques of the model attribute its anomalous results to an out-dated representation of the physical dynamics of climate change (resulting in lower temperatures for the same emissions compared to other models) and the use of obsolete assumptions regarding the benefits of climate change to agriculture. In direct contradiction to the body of recent scientific literature, the FUND model assumes that climate change will not only bring a net increase to agricultural revenues, but that this increase would swamp climate damages in other sectors.

The DICE model, developed by William Nordhaus at Yale University, was the focus of our E3 Network research into the Working Group's methodology. It is the best known of the three models, and the easiest to modify. At $28 per ton, the DICE model assumes that a 2.5°C increase in temperatures will result in damages equal to 2 percent of world economic output. As temperatures rise even higher, damages increase at a leisurely pace, not reaching half of world output until 19°C.

This picture of future climate damages is hard to reconcile with the recent publications of climate scientists. To give just one example, scientists have

found that the majority of today's global population lives in areas that, if temperatures were to rise by 12°C, would experience temperatures too high for human survival at least once a year; without air conditioning, an impossible luxury for most families around the world, much of the developing world would be rendered uninhabitable. One estimate of nearer term damages put the cost of a 2.5°C rise in temperature at 7 percent of world output; another estimate suggests that half of world output would be lost at 6°C, and 99 percent at 12°C.

The DICE model's overly optimistic assumptions about the economic impacts of temperature change result in an underestimate of the social cost of carbon. As with the discount rate and the climate sensitivity value, we cannot know the exact dollar impact of future temperature increases, but we can make educated guesses based on the best, and most recent, scientific research available. The Working Group's analysis fails to do so and, when EPA (and other federal agency) regulation of carbon is the only game in town, the consequences for U.S. climate policy are grim.

The $21 per ton carbon price is based on a high discount rate, a low climate sensitivity value, and a conservative temperature-to-damages relationship — all modeling choices that lower the social cost of carbon. Trying out different combinations of the alternate assumptions discussed above results in estimates for 2010 that ranged from the original DICE model estimate of $28 per ton of carbon dioxide to $893 per ton. Taking these changes singly: Dropping the discount rate from 3 percent to 1.5 percent brings the social cost of carbon up to $118 per ton. Replacing the median climate sensitivity with the 95th percentile climate sensitivity brings the original value up to $56. And assuming that global damages will be 7 percent of output at 2.5°C, 50 percent at 6°C, and 99 percent at 12°C also brings the price up to $118. Making all three changes simultaneously, the result is a social cost of carbon of $893, or 32 times higher than the Working Group's central value for the DICE model.

While DICE, as used by the Working Group, returns a $64 social cost of carbon for 2050, estimates based on various combinations of the alternative assumptions presented here range up to $1,550. With a social cost of carbon that high, EPA regulations that include greenhouse gas emission reductions would have a far greater chance of approval. Carbon prices above $1,000 per ton are rarely discussed in policy circles, in part because lower prices would be more than sufficient to solve the climate problem if applied to all economic sectors throughout the world. Carbon prices in the $200 to $500 per ton range would, according to the International Energy Agency, the British government, and several independent research groups, provide sufficient incentive for the maximum emission reductions considered technically feasible — basically, doing everything possible to stop climate change as quickly as possible.

Once carbon prices are this high, the exact price no longer matters; price incentives and cost-benefit analysis have become fully precautionary, urging full speed ahead on emission reduction. A precautionary response to climate change — or to any uncertain but potentially catastrophic threat — calls for every possible measure to be taken to limit the risk of severe damages. That's also the meaning of any social cost of carbon greater than $500. When the benefit of stopping climate change is greater than the cost of emission reduction, the best course of action should be obvious: everything that we can do, as quickly as we can do it.

Here's another way to think about it. The carbon price represents the value that we, as a society, place on averting the worst climate damages. A $21 price says that we're not too concerned about it: the problem seems fairly small and most of its costs will be borne by future generations (we've got enough of our own problems without worrying about theirs). A $200 or higher carbon price sends a very different message, and would result in a very different outcome. A social cost of carbon that high would mean approval for just about any feasible and reasonably efficient EPA or DOE policy to reduce greenhouse gas emissions. If applied world-wide in every economic sector, a $200 to $500 per ton carbon price would provide enough incentive to bring emissions down to levels consistent with a 50/50 chance of keeping long-term temperatures under 2°C — a widely cited threshold for avoiding dangerous climate change.

A $200 or higher carbon price is the kind of bite that climate activists are striving for; a $21 social cost of carbon is a bark, certainly, but it lacks teeth. Buried deep in the back pages of a minor, and seemingly unrelated, environmental regulation, the Obama administration has laid out its climate agenda. Observers of the climate policy debate will recognize the $21 per ton value as far too little, while hoping that it is not too late for a serious emissions reduction policy backed by a big, loud carbon price — a social cost of carbon that shouts to the world that the United States government takes climate change seriously. •