JOURNAL OF MANAGERIAL ISSUES
Vol. XXXII Number 2 Summer 2020

Managing Climate Change: The Case for a Climate Security Fund

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While economists like William Nordhaus (1991), William Cline (2004), and others have for years been studying the possible economic effects of climate change, the landmark Review by economist Nicholas Stern (2007) put the issue squarely on the map. As scientific reports over the past decade emphasize rising global temperatures, the precarious conditions of the planet's icecaps, and rising sea levels, there has been a growing chorus of cries for action. The Paris Agreement of the United Nations Framework Convention on Climate Change (UNFCCC) in December 2015 committed almost 200 countries to "do something" about climate change. The agreement was ratified in November 2016.

Despite the apparent consensus, the road to a meaningful global collaboration is likely to be slow. Aside from resolute deniers that there even is a problem, or at least that humans bear the responsibility, there continues to be enormous uncertainty about how climate change would play out in the future, and therefore the matter of whether sacrifice today to address the problem would be economically worthwhile. There also are ethical issues relating to the inequality of the expected impacts across generations. Some, moreover, even believe that climate change, like many other challenges, is best left to the market. All of the above appear to conspire against substantive climate policy.

These conflicts are addressed with a scheme that could be satisfactory to most political antagonists. A climate security fund is proposed that would set aside specific amounts on an annual basis to help address adverse climate change impacts in the future. The proposal, unlike many others, proposes to save money rather than spend it.

Also, it is meant to complement the measures that are anyway already being taken privately—i.e., "clean" technologies, sea walls, floating cities, etc. Finally, while not global in scope, and not requiring the cooperation of other governments, the payment scheme, if successful, could lead to synergistic emulation.

A range of possible outcomes is considered, mostly relating to future climate and economic conditions. Some scenarios call for very modest sacrifice today, while the most pessimistic would be far too expensive to try to avert. The primary goal is not to estimate future damages and use the figures to justify a particular policy. On the contrary, the argument in support of the climate security fund is based on the great uncertainty confronted. As the uncertainty is reduced, either through advances in forecasting ability or simply the passage of time, the target amount of the climate security fund proposed in this paper would adapt to provide sufficient funds to finance better-informed policy.

UNCERTAINTY, THE FUTURE, AND POLITICS

Three Types of Uncertainty

Climate change is arguably a unique policy challenge not only in the potential magnitude of its future impacts, but also in its great underlying uncertainty. If there were no uncertainty about the future effects of climate change then the policy discussion, as discussed in the next section, would solely focus on the intergenerational aspects of the problem. The proposed climate fund recognizes the magnitude of the uncertainty and sidesteps the problem by not allowing it to dominate the policy process.

Torras (2016) has distinguished among three different types of uncertainty, all highly relevant to the problem. The first, *predictive* uncertainty, relates to the still very limited understanding regarding the complex climate system (see, e.g., Allen and Frame, 2007; Rosen and Guenther, 2014; Woodward and Bishop, 1997). The immense complexity of the global climate signifies that it could be highly sensitive to relatively small changes in system parameters like temperature, oceanic acidity, and the like. Compounding matters is the presumably wide variety of both positive and negative feedback loops relating to ice melting, permafrost and methane, and ocean temperatures, among other variables. The ability to predict future climate events is severely hampered by the very limited availability of any information required to reasonably approximate the net effects of complex interplay between these and other phenomena. Dovers and Handmer (1995) state that ignorance is a more precise term than uncertainty in describing the understanding of many aspects of climate science.

The second type of uncertainty is *valuational* uncertainty, which concerns the problem of how to assign monetary values to uncertain damages—or to the uncertain benefits of averting them. Most of the relevant benefit and cost values are from outside the market. While there exists a voluminous literature on valuation of natural resources and the environment (see, e.g., Bagstad *et al.*, 2013; and Harclerode *et al.*, 2015), methods of approximating such values are necessarily highly subjective and dependent on simplifying assumptions. This is especially the case for calculations involving estimates of the value of a typical human life. In such situations, uncertainty is unavoidable.

Finally, *moral* uncertainty concerns the ethical conundrum found in the choice between benefiting ourselves today at the expense of future generations or vice-versa. There is no "correct" answer to the question of how much relative importance to accord future generations. At the core of the dilemma is the matter of the proper "social discount rate" – that is, the discount rate used to evaluate the temporal costs and benefits of projects with direct and indirect social impacts. Unlike the standard discount rate used to calculate the present value of future costs and/or revenues, a social discount rate requires that social and ecological impacts be made commensurable for their aggregation. Choosing such a rate is therefore a patently subjective exercise.

Only the first of the preceding three categories is generally treated as "uncertainty" in the economics literature. Calling attention to the other two types – valuational and moral – underscores how difficult it is to make precise assessments about the nature of the problem, hence how unreliable, incautious and superficial policy is likely to be. It must therefore be emphasized how, because of this, *flexibility* in future policy is imperative. A climate fund targeted to adaptation but with the flexibility to adapt to changing information can take account of all three types of uncertainty.

Social Discounting and Future Generations

Any temporal evaluation of climate change damages that future generations are expected to experience requires social discounting. To be sure, discounting is a familiar and uncontroversial concept when applied to problems of private savings or investment. In any risk-free setting, the discount rate represents the pure rate of time preference (a measure of impatience) in the case of the decision of whether to consume or save.[1] In the case of investment, it represents the opportunity cost of capital—i.e., the prevailing return on alternative equally risky projects, with this rate higher than the pure rate of time preference to reflect the incremental risk of the future cash flows.

Similar reasoning would appear to apply when evaluating benefits and costs to future generations. Here, however, there exists a major problem: future populations potentially bearing the bulk of the climate change impact are not the same people who decide on a course of action today. Selecting a discount rate is therefore an unavoidably ethical exercise. There is considerable disagreement even among economists about the correct rate.

Nicholas Stern, for example, believes that any social discount rate should, on ethical grounds, be lower than the rate for private investments. His landmark Review (2007) on climate change concludes that much more aggressive policy than presently exists is warranted to combat climate change, but his conclusion follows from his chosen social discount rate (1.4 percent, much lower than normally used by many economists). In contrast, economists such as William Nordhaus (2007), a leading critic of Stern's, believe that social discount rates should approximate the private rate of discount. Others (e.g., Beckerman and Hepburn, 2007; Broome, 2008) are circumspect— ambivalent, even— about the "correct" discount rate, conceding the fundamental ethical nature of the decision.

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[1] Matters become more complicated in situations involving risk and uncertainty, where time preference becomes a mere parameter in the discount rate formula where the discount rate, d, equals $\delta + \eta g$, where δ is the pure rate of time preference, g is the expected growth rate in perpetuity, and η is meant to represent the decision-maker's appetite for risk. This method is based on the classic paper by Ramsey (1928). Such a formulation presents serious methodological problems for the use of social discounting for climate change (see, e.g., Sælen *et al.*, 2009; Beckerman and Hepburn, 2007) but this paper remains focused on the ethics of discounting.

Supporters of high social discount rates often justify their stance on the premise that future generations are likely to be richer than those alive today. Yet this expectation is not axiomatic. A high discount rate would, in theory, increase the rate of exploitation of the environment and natural resources. Martinez-Alier (1987) has argued that expecting future generations to be richer under such circumstances (i.e., deep discounting of future benefits and costs) requires assuming an extraordinary elasticity of substitution between the natural environment and whatever might replace it. Furthermore, while it is reasonable to be optimistic about the advance of scientific knowledge, such optimism does not imply a belief in the discovery of substitutes sufficient to maintain present patterns of consumption in perpetuity, never mind at such a rate to allow for their *growth*, which is, as noted by Martinez-Alier (1987), what would be inferred from a positive social discount rate.

To what degree should individuals (or societies) risk uncertain damages to future generations in return for a greater net benefit today? It is fundamentally a question of *how much importance* to accord to future generations relative to the present one. Even leaving aside this ethical dilemma, there is the matter of the future risk of catastrophic change. One could quite plausibly argue that it is in the interests of the present generation to avert a future human extinction that might result from a greater than expected global temperature increase or dramatic sea level increases from melting ice.

Although seldom stated in this way, the use of a social discount rate is an attempt to "commensurate" incommensurables. In other words, even though near-term and relatively knowable policy costs (mostly monetary) are incommensurable with longer-term and highly uncertain potential damages, social discounting requires some common metric. It is why social discounting is imprudent, particularly in the context of global and inter-temporal problems like climate change. The use of a discount rate should be limited to cases dealing with concrete, and consistently measurable flows, as in the policy prescription to be elaborated later.

Any policy approach in relation to future generations entirely depends on a dichotomous choice: Either *some* responsibility is taken for the wellbeing of future generations, or none is. In the latter case, "business as usual" would prevail; in the former, proactive policy would need to be developed. Since both authors here are "temporally impartial," it is believed that some manner of future planning is advisable. In what follows, it is argued that the proposed climate fund is a solid step in that direction.

Mitigation, Adaptation, and Policy

Assuming acceptance of the prevailing view that potential climate change risks were both serious and highly uncertain, and that it is owed to future generations to do something about them, there would remain the question of *what* to do. One option would be to aggressively reduce greenhouse gas emissions in the hope of limiting the human-induced impact on the global climate. This is generally referred to as mitigation. Mitigation is somewhat analogous to the use of vaccines to forestall a disease outbreak, where the costs of the vaccine can be weighed against the costs and risks of not undergoing inoculation.

Given what climate scientists have revealed in recent years (Hansen and Sato, 2016; IPCC, 2007), it might appear to some that the country should be pursuing an aggressive mitigation strategy, at least until it could be demonstrated that doing so would not be worthwhile. Yet it is one thing to accept science's interpretation of the evidence of climate change; it is quite another to claim to know more about future benefits and costs than is actually known. For example, *how much* will climate actually change in terms of, say, average global temperature, and how long will it take to do so? What are the likely effects on human societies? Will all global icecaps eventually melt? What is the expected extent of the overall damage? Finally, and possibly most important, is catastrophic change possible – and if so, with what probability?

Given a heavy dose of predictive uncertainty, and smaller, though significant, doses of valuational and moral uncertainty, academics and practitioners are nowhere close to having precise answers to these important questions. It is not even clear that such answers are being *approached* over time. Skeptics are actually correct in stating that it is not known if sacrifice today—in terms of reducing material and energy flows, slowing down the economy, etc.—would be "worth it" in the long run. From an economic standpoint, it could make more sense to focus on the main alternative to mitigation, known as adaptation, which aims at investing in technologies to better equip to deal with a changed global climate in the future.

If funds were put aside today for this purpose, adaptation would be more akin to a self-insurance solution. Examples might entail constructing higher walls to keep seawater out or, if this proved ineffective, building floating cities. Alternatively, or in addition, underground communities might be built in the future as shelter from extreme heat. One could undoubtedly imagine numerous other examples.

The adaptation strategy evokes the uncomfortable possibility that substantial future damage is already irreversible. The idea is to accept this possibility and engage in precautionary measures (adaptation) to guard against the worst, potentially catastrophic risk (see Hartzell-Nichols, 2014). While such pessimism is never fashionable, it is not inconceivable that it is already too late to do anything to meaningfully reverse or counteract climate change through mitigation, at least over a range of time that would be relevant to humans.

The authors are somewhat skeptical about humanity's ability to willfully reverse climate change, and therefore slightly more predisposed to adaptation solutions. Yet while there might be a tendency on the part of mitigation proponents to exaggerate how much is known about the future adverse consequences of a fundamentally altered planet as well as about humans' ability to take effective corrective measures, care must be taken not to allow *doing nothing* to masquerade as adaptation. Champions of the idea that climate change is a hoax might have it this way, but what is meant here by adaptation is a more active stance that involves planning and appropriate technological investments.

Both mitigation and adaptation have already, to some extent, been observed, and neither is likely to abate in the foreseeable future. If anything, expect acceleration. Why, then, not simply leave the matter to the market?

The idea of policy intervention to protect the environment goes back to Arthur Pigou (1920), whose work gave rise to the notion of a "Pigovian tax." The premise is that environmental costs are borne by third parties not involved in a transaction, justifying a tax on the private parties who produce the environmental costs.[2] The reason that a tax (or some other form of policy intervention like pollution permits) is often justified in

[2] Also known as externalities, Friedman (1962) calls them "neighborhood effects."

the case of environmental problems is that a laissez-faire regime often offers insufficient remedy for them.

Both mitigation and adaptation can be viewed as public goods, in the sense that they are both non-excludable and non-rival.[3] Theory teaches that the market invariably underprovides public goods relative to the theoretical optimal amount. In short, public goods are underprovided because there is too much incentive for any individual to "free ride" on the expected effort of others in providing the benefit.

Mitigation and adaptation both satisfy this criterion. The challenge is to design a suitable policy aimed at socially optimal levels of mitigation and adaptation. It is to this that the remainder of the paper is devoted.

THE CASE FOR A CLIMATE SECURITY FUND

There has been a global political impasse conspiring against addressing climate change, with politicians at odds over the urgency of the problem, and about whether to burden the private sector with emissions reduction or "share the pain" across the general population. Many, moreover, believe that despite evidence of climate change, it would be more fair to saddle future generations—which, by their reckoning, will be richer than us—with the problem.

Policy intervention to address climate change is warranted, for three reasons: (1) being proactive today affords greater flexibility in the future, which is indispensable in a condition of extreme uncertainty; (2) the argument for leaving the problem to future generations is both unconvincing and unethical; and (3) mitigation and adaptation benefits, because of their public goods nature, are unlikely to be provided to a sufficient degree absent any policy intervention.

Some have argued that climate "federalism" is ineffective at best, and counterproductive at worst (see, e.g., Casado-Asensio and Steurer, 2016; and Steurer and Clar, 2015). But the policy intervention proposed here does not involve direct spending today. Rather, funds are to be "saved" for a future in which, it is hoped, climate uncertainty would be substantially diminished. The national climate security fund proposed to help offset potentially huge costs of dealing with climate change is something analogous to the social security trust fund, although monies here are to be used in the future to pay for innovative technological means of adapting to climate change. It is not unlike the "precautionary polluter pays principle" (4P) approach first introduced by Costanza and Cornwell (1992). The plan is, however, far broader in scope and would require tax payments by the general population.

The amount to set aside would be based on a projected financial need, say a century into the future, where said need would be based on an assessment of the expected damage from climate change. An annuity payment stream (elaborated upon in the next section) would fund the climate security, and the dollar amount would be flexible over time. That is, experts would be convened on a regular (say, annual or bi-annual) basis to parse the new and recent knowledge gained, and to adjust the financial need and corresponding payment.

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[3] For more detail on the nature of public goods, see, e.g., Heal (1999). Not explored is the argument that they may not be *pure* public goods in the sense of being perfectly non-excludable or non-rival. While potentially reasonable, the argument is not material to the argument presented in the paper.

The proposal is different, both in scope and objective, from mitigation or adaptation programs currently in place at the government, NGO, and private levels. For example, in 2014 the U.S. Government spent just under $11 billion on climate change research and clean energy technologies, but only $100 million on adaptation initiatives to address concerns such as rising sea levels.[4] NGO mitigation and adaptation projects, largely funded by individual country contributions, include the Global Environment Facility, the Climate Investment Fund, and the Green Climate Fund, all having garnered many billions of dollars in grants over the past 25 years. In addition, numerous private foundations provide funds for mitigation and adaptation projects. All of the above are primarily focused on providing funding for current projects, while this proposal seeks to fund *future* needs on grounds that what precisely the needs are can only become clearer over time. Moreover, the scale of the proposal is one to two orders of magnitude greater than current efforts.

In addition to providing a fund for future adaptation costs, the climate security fund would provide a framework for evaluating the economic effect of alternative strategies taken in the near term. Moreover, if at any point the consensus view tilted in favor of mitigation, based either on a revision to projected costs, stronger consideration of catastrophic fat-tailed events such as discussed by Weitzman (2014), a reconsideration of the economic values of mortality and health, or other qualitative factors—or indeed, any combination of these—available funds could be used for this purpose.

While the issue of how to get most if not all of the world's countries to participate is not addressed, multilateral cooperation of this sort is not without precedent, as examples such as the International Monetary Fund, United Nations, and World Trade Organization clearly bear out. It is conceivable that this proposal ultimately could be aligned with the efforts of some of the NGOs cited above. Perhaps most important, the climate security fund should be politically feasible domestically, or at least more so than other alternatives. Instead of committing to spending abundantly today in a regime of great uncertainty, it is proposed to *save* the equivalent amount in the climate security fund. In this way, when superior climate change understanding is obtained, the country would be better prepared to deploy funds to purposes about which experts and policy leaders are likely to be more confident.

Equally important, the United States could introduce its security fund unilaterally—that is, focusing exclusively on potential benefits to U.S. citizens—and immediately. Adaptation projects financed by the fund would primarily benefit the United States, although there could be spillover effects to other countries as the United States becomes better positioned to deal with the adverse effects of climate change. Most important, the United States would be able to manage the fund to account for what other countries may or may not be doing to address climate change.

A mitigation program of the type being negotiated by global leaders, in contrast, requires an international consensus, or at least the participation of most of the major carbon producers. A unilateral mitigation strategy would be ineffective, at least initially, not the least because of the "free rider" problem. While future steps by other countries to address climate change could eventually lead to a global mitigation path, there is no guarantee that this would happen in time to make an appreciable difference. The

[4] Data from the Obama Administration's expenditures report to Congress (United States Government, 2013).

security fund is an opportunity for the United States to at least be doing something in the meantime.[5]

In the unlikely event that the effects of climate change were less severe than anticipated, the funds could be returned to the public or be used to retire outstanding government debt. While some opposition to doing anything at all about climate change is certain to remain, the proposal presented here would reduce it considerably.

PROJECTIONS

The climate security fund proposal requires an estimate of the value of the economic consequences to be averted and/or remedied. The problem is that there has been an extremely wide range of estimates of adverse climate change impact, ranging from no discernible effect to more than ten percent of GDP (see, e.g., Tol, 2009 and 2014). Many studies project out to the year 2100, and reflect different carbon build-up assumptions, temperature changes, and climatic responses to these changes, all then being used to estimate economic and wellbeing-related costs.

For example, based on the results of integrated assessment models used by various researchers, the U.S. Government reports damage of an estimated 0.9 percent of GDP resulting from a warming of three degrees Celsius above pre-industrial levels. Average global temperatures are presently more than one degree over pre-industrial levels and, even with significant mitigation efforts, it is likely that they will increase by at least an additional degree. So the 0.9 percent estimate mostly captures the damage from the third degree increase above pre-industrial levels, especially since the damage is almost certain to increase exponentially with temperature.

One possible scenario is climate change damage of one percent of GDP (rounding off of the 0.9 percent), also assuming – optimistically – that the global average temperature will level off at plus three degrees in the long run. But as alternatives, the less optimistic possibilities are considered where either the temperature increase exceeds three degrees and/or the damage resulting from even a three-degree increase exceeds expectations. All explanations and calculations for the analysis to follow can be found in Appendix 1.

Starting with the baseline damage assumption of one percent of GDP, the monetary value of climate change damage in the year 2100 is approximated. If damage equals one percent of GDP, it puts the damage figure in the neighborhood of $6 trillion. Keep in mind that this figure is for a *single year*. In order to obtain a clear sense of the funding requirements to prevent *all* future damages, the cumulative effects from 2100 to 2200 need to be calculated.[6]

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[5] The issues of whether the United States has an obligation to fund the expected adaptation costs of other countries, particularly those of less developed countries that have not, as of yet, contributed nearly as much to carbon production, and whether the obligation to future non-U.S. generations is negated by those countries' lack of participation in such a funding program, are not taken up here.

[6] Allowing the sum of damages to extend in perpetuity leads to the absurd outcome of infinite damages (under the realistic assumption that GDP grows at the rate of interest in the long run). While potentially reasonable to some from a philosophical standpoint, it renders the analysis infeasible. Therefore, the scope is limited to nearly 200 years into the future, what seems like a reasonable time frame.

Damage of one percent of GDP is, of course, one of many plausible assumptions. Economic impact might even initially be positive and only later—as warming increased toward the three-degree level or beyond—turn negative. Tol (2009), for example, notes that plants (well-known carbon assimilators) grow faster with an increase in carbon dioxide, and global warming is expected to reduce heating costs and cold-related health problems in the highly populated temperate zone. It should be emphasized that even in the short run, net benefits are only likely to be observed in some of the regions. Over time, even such benefits will probably be outweighed by the expected costs of climate change as warming continues.

The expected long-term government-borrowing rate of 4.25% is used as the discount rate to calculate the present value of the damage estimates to the year 2200 for a range of possible outcomes (Table 1).[7] In working out the nine scenarios, climate change damage as a percentage of (projected) GDP in 2100 is the reference point. A damage range from one to ten percent of GDP is considered, so that annual damage can now vary within one order of magnitude. An alternative is also entertained, with damage remaining constant over time in dollar terms, thus declining relative to GDP, as opposed to remaining constant in percentage terms. As a third alternative, damages for the second scenario accrue starting in 2050 instead of 2100.

Table 1
Present value of future damages in 2017, in trillions of dollars

	Damage as Percentage of GDP		
	1%	**5%**	**10%**
Damage Scenario 1 Constant Dollar	4.38	21.89	43.78
Damage Scenario 2 Constant % of GDP after 2100	18.90	94.50	189.00
Damage Scenario 3 Constant % of GDP after 2050	25.94	129.70	259.40

The range of outcomes from $4 trillion to over $250 trillion in the most catastrophic case is admittedly quite large; however, any number in this range is at least plausible, especially given the vast uncertainty faced – a *fortiori* for events after 2100. It is preferable to leave to scientists in the field and political decision-makers the question of which figure is most reasonable. It is the hypothetical values in Table 1 that are proposed as the starting point for calculating the correct amount of funding for the climate security

[7] Based on consensus forecasts from the Philadelphia's Survey of Professional Forecasters (SPF) (2016) for the ten-year treasury rate adjusted for the premium for longer-term rates based on a review of historical bond data. This is the same figure as used for the long run annual GDP growth rate, under the assumption that the interest rate should converge to the growth rate in the long run. In contrast to the social discount rate discussed earlier, here the use of a discount rate is not only appropriate, but also imperative. Instead of improperly using a discount rate to put incommensurable values on an equivalent metric, future adaptation payments are discounted in order to obtain a sense of how much needs to be set aside starting today.

program. Subsequent calculations, discussed below, presume that the program begins immediately, and that it is fully funded either in 2100 or in 2200.

POLICY ISSUES

Scenario Analysis

Three alternative payment schemes are examined.[8] The first is a constant annual payment from 2017 to 2100. Here the tax burden is front-loaded; since the dollar amount is fixed, the tax (assuming GDP growth continues) diminishes over time in relative terms. The second scheme, in contrast, requires an annual payment that is a constant percentage of GDP through 2100, so the burden is uniformly shared. The third scenario differs from the second only in that annual payments are through 2200, the premise being that the more distant generations should also contribute. Similar to the present value of the damage estimates, the breadth of results is quite large, with annual funding ranging from a fraction of a percent of GDP to well over 10% of GDP for the larger damage estimates (Table 2).

Table 2
Annual taxes under different scenarios
(in dollars or as a percentage of GDP)

	Damage at 1% of GDP	Damage at 5% of GDP	Damage at 10% of GDP
Damage Scenario 1			
Constant dollar to 2100	$192.1B	$960.6B	$1.92T
Percentage of GDP to 2100	0.28%	1.40%	2.79%
Percentage of GDP to 2200	0.13%	0.63%	1.27%
Damage Scenario 2			
Constant dollar to 2100	$829.5B	$4.15T	$8.29T
Percentage of GDP to 2100	1.20%	6.02%	12.05%
Percentage of GDP to 2200	0.55%	2.73%	5.46%
Damage Scenario 3			
Constant dollar to 2100	$1.14T	$5.69T	$11.38T
Percentage of GDP to 2100	1.65%	8.27%	16.54%
Percentage of GDP to 2200	0.75%	3.75%	7.50%

As noted, a relevant comparison to the climate security fund is the social security trust fund, where current payments are invested in government securities for future payout to beneficiaries. According to the Social Security Administration, current annual payroll tax contributions total approximately $800 billion, while annual disbursements total $900 billion.[9] For comparative purposes, an annual one percent of GDP paid into

[8] See Appendix 2 for all calculations.

[9] See data on *Old-Age, Survivors, and Disability Insurance Trust Funds from 1957 to the Present* on Social

a climate security fund would currently cost approximately $200 billion, or an approximately seven percent increase in current total federal tax receipts as reported by the Congressional Budget Office.[10]

Following the trust fund approach, since the U.S. government currently runs a deficit, current tax payments into the climate security fund could be lent back to the U.S. government and those funds used in lieu of additional government public borrowing. While future generations would need to fund the repayment of the endowment investment in government securities, those repayment obligations of current deficit funding would be the same as without a climate security fund. What is different is that future generations would not have the additional burden of funding future climate change damage remedies.

For example, if the government borrowed $100 today to finance its ongoing budget deficit, future generations would be taxed $100 plus interest to repay the debt and, in addition, the compounded future value of $100, equivalent to $100 plus interest, to fund climate adaptation solutions. If, on the other hand, the current generation were taxed $100 today to supply the climate security fund, the fund could lend the money to the U.S. government to finance its current deficit. Future generations would then only be taxed the $100 plus interest to repay the debt, and the replenished fund would have the compounded future value of $100, equivalent to $100 plus interest, to fund climate adaptation solutions. Of course, special care must be taken that the availability of the fund's assets does not lead policy makers to expand deficit spending in other areas. In the desirable, if unlikely, event that the government began to run a surplus, the fund could invest in existing government securities.

The proposed approach calls for substantial savings as a means of insurance for the future. What is important is to shift current resources from consumption-based to investment-based economic activities, where future generations would reap the output from the investments to fund adaptation programs. It would not even be absolutely *necessary* to utilize a tax for this resource shifting, since the government could carry out the proposal by reallocating government expenditures. Such an approach would be akin to the recommendation of Modern Monetary Theory proponents (e.g., Bell, 2000), who argue that taxes and borrowing are not the primary funding sources for government spending activities. But this admittedly intriguing alternative is beyond the present scope.[11]

Carbon Tax

Perhaps the most obvious means of financing climate security would be an income tax increase. This possibility is not explored for two reasons: (1) the literature on its benefits and disadvantages is already encyclopedic, and this article would add little to the discussion; and, perhaps more important, (2) political reality has recently tilted in

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Security website; specifically: https://www.ssa.gov/oact/STATS/table4a3.html#income

[10] The reader may refer to the historical data section on the Congressional Budget Office website: https://www.cbo.gov/about/products/budget_economic_data#2

[11] Although it is certainly gaining respect in the profession, Modern Monetary Theory has not yet been adopted by the mainstream in macroeconomic theory. While one of the authors is sympathetic with the basic argument, addressing it here would take the paper far afield from the topic at hand.

the opposite direction, as the recent tax reform has promised a reduction in tax burden for most.

One alternative to income taxes is carbon emissions taxes. In addition to being a source of climate security funding, such taxes offer the advantage of discouraging something of which society presumably wants less. Carbon taxes are a frequently proposed source of funding for climate policy, and they are presently in use in countries such as Norway and Sweden (see Goulder, 1994, and Morris, 2013). In some cases, a portion of the proceeds is used to finance mitigation programs (Ye, 2013). Carbon taxes could thus be utilized to fund climate security along the proposed lines, with the added benefit of an immediate contribution to mitigation.

An estimate of what is known as the social cost of carbon (SCC) is implicit in the calculations of the climate security funding requirements. For instance, the U.S. Energy Information Administration (EIA, 2015) estimates that the US currently produces 5,400 million metric tons of carbon dioxide per year. Using the one percent of GDP estimate, the tax in 2017 would be $35 per metric ton (one percent of $19 trillion divided by 5.4 billion metric tons), in line with Tol's (2014) $50 per metric ton estimate, and the ten percent damage estimate would yield a SCC of $350 per metric ton. For comparison, the EPA (2016) estimate of the SCC ranges from $11 to $56, depending on the choice of discount rate (they present data with rates ranging from 2.5 to 5 percent, with the higher rate yielding the lowest cost of carbon), along with a $105 sensitivity result based on a three percent discount rate intended to show not the average but the 95th percentile outcome. The EPA estimate could, however, reach much higher if the Agency considered future damage on the order of ten percent of GDP a serious possibility.

It is important to note that there is a difference between setting the carbon tax at the social cost of carbon versus the level necessary to create a break-even cost of energy when compared to non-carbon energy sources. Weyant *et al.* (2006) estimate that a carbon tax in the range of $50 -$100 per metric ton would be necessary for new electrical generation to be carbon free – i.e., the breakeven price where non-carbon solutions are economically equivalent with traditional carbon sources – and that a much higher tax would be required to de-carbonize transportation. In the decade or so since this estimate, prices of non-carbon alternatives such as wind and solar have continued to drop. The U.S. Government's Energy Information Administration (EIA, 2017) predicts that, *on average*, onshore wind projects will be cost effective for plants coming on line in 2022, including the benefits of current tax credits. However, for certain regions, the cost of onshore wind costs $17 per MWhr more than existing generation, including current tax credits, still resulting in a required breakeven tax of approximately $50-$100 for coal and natural gas, respectively.[12]

It is likely that a carbon tax would result in a combination of carbon reduction and fund revenue, potentially requiring an eventual increase in the carbon tax rate. More important, unless most major carbon producing nations agreed to a common mitigation plan, even a successful carbon tax in the United States could be neutralized by carbon production from other countries. In the extreme case, the United States could entirely de-carbonize, and in so doing eliminate future carbon tax revenue, possibly confronting a sizeable and largely unfunded adaptation cost.

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[12] For these figures, the reader may refer to the EIA website, specifically: https://www.eia.gov/tools/faqs/faq.php?id=73&t=11.

Energy Tax

Carbon taxes remain controversial. Some might view the tax itself as a form of mitigation, and argue that this proposal is little more than a Trojan horse for cutting carbon today, countering all the flexibility arguments of the plan. This is why a reasonable—and potentially more politically feasible—alternative to a carbon tax is a general energy tax, applied to all sources. The point would be to encourage greater efficiency in the use of *all* energy sources. And using a significant energy tax to partially offset taxes in other areas (especially income) might make the idea attractive across the board.[13]

The EIA estimates that the United States consumes 98 quadrillion BTUs of energy per year, with approximately 80 percent coming from carbon sources.[14] Again, for illustrative purposes, at a tax rate of roughly $2 per million BTUs, the energy tax would fully fund a climate security fund priced at one percent of GDP. The implied gasoline tax would be roughly 24 cents per gallon (see Appendix 3).

Since the tax would be applied to all energy sources, the climate security fund would grow regardless of whether the country moves off incremental carbon sources, which could be important in the event steps taken by the United States to reduce carbon are offset by carbon usage in other countries. Fund requirements would, of course, decline to the extent the cumulative effects of all nations results in lower projections of future U. S. climate costs.

In addition to addressing the problems caused by other countries not participating in a generalized carbon tax scheme, the alternative of a tax on energy independent of source appears more politically "neutral" and would thus be a more politically feasible alternative. It must be emphasized that the general energy tax would still provide incentive to move to more efficient and lower carbon energy solutions, especially since carbon forms of energy still account for the lion's share of all energy use. There is no denying that such a tax would incentivize *general* energy efficiency which, independent of its distribution across energy types, can only be a plus.

CONCLUSION

Despite itself being an ecological and climatological phenomenon, the greatest management challenge of climate change is arguably the political conflicts with which it is associated. If progress were to be made, climate change would need to be depoliticized—in other words, left to the scientists. Yet there is danger in misunderstanding the difference between science, and measurement precision. Such confusion can cause proponents of aggressive policy to overplay their hand by claiming to know more than can possibly be known at present. Therefore, the scheme laid out in this paper seeks to address climate change from a perspective of transparency to the vast uncertainty involved.

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[13] To be clear, this proposal does *not* support further increases to the budget deficit. There should be a "net zero" effect on the deficit. In other words, if there is any offset with income taxes, residual tax revenue will remain for the security fund. Of course, budgetary considerations are not limited to taxes.

[14] See "What are the major sources and uses of energy in the United States," from the EIA site, http://www.eia.gov/energy_in_brief/article/major_energy_sources_and_users.cfm

A climate security fund is proposed, along the lines of the social security fund, into which the U.S. Government would deposit a specified amount on an annual basis as an insurance policy against future adverse climate change effects. The amount to be deposited would be flexible, always based on knowledge at the time about technology, climate patterns, and economic conditions, as well as their likely future trajectories. The funding scheme would, therefore, be subject to regular updates or revisions as new information is obtained.

Most should find little with which to take issue. Funds would initially be saved rather than spent; the annual deposit is fairly modest in many, though not all, of the scenarios considered; and, perhaps most important, steps would be taken to do something about climate change. To those who would argue that such a scheme offers too little, too late, the answer is: Perhaps, but the progress that is already being made both with emissions reduction and development of adaptive technologies should also be kept in mind. The point is that where mitigation and adaptation services are public goods that theory stipulates the market would underprovide, the government has a role to play. The climate security fund is the policy recommendation.

A concluding caveat is in order. The exploratory calculations presented in this paper relied on the valuations of various climate models, and it is not clear that the value of the human lives impacted by climate change is subject to quantification. Nor factored in is the risk – potentially quite low, but decidedly nonzero – of catastrophe of the scale that threatens the entire human race. These risks must therefore also be monitored over the years as new funding amounts are calculated. Some might protest that the value of such consequences ought to be included at the outset, but again, it is self-defeating to make the security fund proposal politically a non-starter.

Appendix 1
Calculation of Climate Change Damage

Estimation of U.S. GDP and climate change damage in 2100

$$GDP_{2100} = (GDP_t)(1+g)^{(2100-t)}$$

where t = first year in which money is set aside for climate security fund (here 2017), and g = projected annual GDP growth rate from t to 2100, assumed to be equivalent to long-term interest rates and equal to 4.25%, based on Survey of Professional Forecasters 2016 forecasts for ten year treasuries.

Plugging in the relevant numbers obtains:

$$GDP_{2100} = 598T = (18.9T)(1.0425)^{(83)}$$

where, assuming that climate change damage were 1% of GDP, damage in the year 2100 would be $5.98 trillion.

Present value of cumulative damage from 2100 to 2200, assuming fixed dollar value of damage over time

Beginning with a standard annuity formula:

$$PV_{2100} = d(GDP_t)(1+g)^{(2100-t)} \left[\frac{\frac{1}{r} - \frac{1}{r(1+r)^{100}}}{(1+r)^{(2100-t)}}\right]$$

where PV_{2100} = Present value of cumulative damage from 2100 to 2200, from the perspective of 2100,
t = first year in which money is set aside for climate security fund,
g = projected annual GDP growth rate from t to 2100,
d = expected climate change damage as a fraction of GDP, and
r = the long-term interest rate.

Assuming that over the long term r=g, this formula reduces to:

$$PV_{2100} = d(GDP_t)\left[\frac{1}{r} - \frac{1}{r(1+r)^{100}}\right]$$

Assuming that damage equals 1% of GDP_{2100}, 598T/100 = $5.98 trillion is obtained as the annual damage amount starting in 2100, so:

$$PV_{2100} = 5.98T\left[\frac{1}{0.0425} - \frac{1}{0.0425(1.0425)^{100}}\right] = 138.51T$$

which is the present value of cumulative damage from 2100 to 2200. But this is from the perspective of 2100, so to bring it back to the present (2017), discount over 83 years and obtain:

$$PV_{2017} = \left[\frac{138.51T}{(1.0425)^{(2100-2017)}}\right] = 4.38T\,,$$

which is the number found at the upper left of Table 1. Calculation of the 5% and 10% figures for the top row of the table is trivial, as these are mere multiples of the first number.

Present value of cumulative damage from 2100 to 2200, assuming that value of damage increases in proportion with GDP

Starting from the damage in 2100, each year the damage grows at rate g. First calculated is the present value in 2100 of the next 100 years of damage, where the individual years are discounted at $(1+r)^t$.

Assuming that r=g, the growth in damage is exactly offset by the increased discount of more distant flows, with the result that the discounted value in 2100 of the sum of the damages from 2100-2200 equals 100 times the damage in 2100:

$$PV_{2100} = 100d(GDP_t)(1+g)^{2100-t}$$

and the present value can therefore be calculated as follows:

$$PV_{2017} = \frac{100d(GDP_t)(1+g)^{2100-t}}{(1+r)^{2100-t}} = 100d(GDP)_t$$

Setting *d* equal to 5%, gives a present value of:

$$PV_{2017} = 100(.05)18.9T = 94.50T$$

which is the number found in the center cell of Table 1. The number to the left is one fifth of 94.5 trillion, and the one to the right is exactly double.

Present value of cumulative damage from 2050 to 2200, assuming that damage starts in 2050 at 50% of the 2100 damage-GDP ratio, incrementing by one percentage point per year until 2100, and as in the second scenario after 2100

To estimate climate change damage from 2050 to 2100, it is assumed that damage increments by one percentage point annually starting in 2050 at 50% of 2100 damage. In other words, damage in 2051 is 51% of 2100 damage; in 2067 it is 67%, etc. As before, GDP is extrapolated from the 2017 figure at annual growth rate g; damage ($dGDP_t$) is discounted at rate r. The present value of the cumulative damage up to 2100 is:

$$PV_{50} = dGDP_t\left(\frac{(1+g)^{2050-t}}{(1+r)^{2050-t}}\left(\frac{51}{100}\right) + \frac{(1+g)^{2051-t}}{(1+r)^{2051-t}}\left(\frac{52}{100}\right) + \cdots \frac{(1+g)^{2099-t}}{(1+r)^{2099-t}}\left(\frac{99}{100}\right)\right)$$

where PV_{50} = Present value of damage from 2050 to 2100. Again, assuming r=g obtains:

$$PV_{50} = dGDP_t(37.25)\,.$$

Adding this to the present value of damage post-2100 obtains:

$$PV_{2017} = \frac{100d(GDP_t)(1+g)^{2100-t}}{(1+r)^{2100-t}} + dGDP_t(37.25) = dGDP_t[100 + 37.25]\,.$$

Assuming in this case that climate change damage equals 10% of GDP, this yields:

$$PV_{2017} = (0.1)(18.9T)\,(137.25) = 259.4T$$

which is the precise number found in the cell at the lower right of Table 1. The two numbers to its left correspond to the 1% and 5% damage assumptions.

Appendix 2
Calculation of Tax

Constant dollar tax until 2100

All tax calculations are based on the present value figures from Appendix 1. The constant annual tax for the period from today to 2100 is arrived at using the annuity formula:

$$T = \frac{rPV}{\left(1 - \frac{1}{(1+r)^{2100-t}}\right)}$$

where T = the annual (constant) tax,
PV = the present value of all damages (from Table 1),
t = first year in which money is set aside for climate security fund, and
r = the long-term interest rate.

As an example of a damage scenario, assume damage of 10% of GDP (upper right cell in Table 1). The annual tax requirement starting in 2017 and paid through 2100 would be:

$$T = \frac{0.0425\,(43.78T)}{\left(1 - \frac{1}{(1.0425)^{2100-2017}}\right)} = 1.92T$$

which is exactly the figure found at the upper right of Table 2. All other numbers for this tax regime are calculated analogously.

Proportional tax until 2100

The tax rate is solved using the following formula:

$$\mathrm{PV} = \sum_{t}^{2100} \frac{xGDP_t(1+g)^t}{(1+r)^t}$$

where PV = the particular present value of cumulative damage (from Table 1)
x = the tax rate,
g = the GDP growth rate, and
r = the interest rate

For r=g,

$$PV = xGDP_t(2100 - t) = xGDP_t(83)\,,$$

and

$$x = \frac{PV}{GDP_t(83)}$$

As an example, using Damage Scenario 2 and damage of 5% of GDP (center cell in Table 1), PV is equal to $94.5 trillion. Plugging in to the above formula obtains:

$$x = \frac{94.5T}{(18.9T)(83)} = 6.02\%$$

which checks with the number in Table 2. The reader can now verify that each of the present value figures from Table 1 corresponds to a distinct tax percentage reported on Table 2.

Proportional tax until 2200

Here the only difference is that the period over which the tax is paid is extended for another 100 years, so the slightly altered formula is as follows:

$$\mathrm{PV} = \sum_{t}^{2200} \frac{xGDP_t(1+g)^t}{(1+r)^t}$$

with

$$PV = xGDP_t(2200 - t) = xGDP_t(183)$$

and

$$x = \frac{PV}{GDP_t(183)}$$

As a final example, assume Damage Scenario 3 with damage at 1% of GDP. The relevant number from Table 1 is $25.94 trillion. Plugging in obtains:

$$x = \frac{25.94T}{(18.9T)(183)} = 0.75\%.$$

Appendix 3
Energy and Gasoline Tax

$$Energy\ Tax = \$2\ per\ MBTU\ x\ 98\ quadrillion\ MBTU\ per\ year\ = \$196\ billion$$

$$Gasoline\ Tax = \$2\ per\ MBTU\ x\ 120{,}405 \frac{BTU}{gal} x1 \frac{MBTU}{1{,}000{,}000\ BTU} = \$0.24\ per\ gallon$$

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