RESPONSE

Climate Policy and Uncertainty: α–Precautionary Principle Versus Real Options Analysis

by Alexander A. Golub

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Introduction

A near-term decision regarding climate policy should be made even in the context of uncertainties. The reaction of the climatic system to anthropogenic emissions is unknown. Furthermore, socioeconomic systems reaction to changes in the climatic system, reflected by adaptation cost and unrecoverable damages, is also unknown. While current emissions impose future costs on society measured by future damages, climate policy aimed to reduce emissions imposes current economic costs.

It is naïve to think that a regulator will be able to select an "ideal" policy before uncertainties are narrowed through knowledge accumulation in the fields of climate science and economics. In the future, when more complete information is available, initial policy would be inevitably corrected. When estimating the long-term cost of a climate policy a regulator should also take into account correction costs.

Significant uncertainties exist on the climate side of the analysis. Climate sensitivity is a major (but not the only) parameter that describes reactions of the climatic system to accumulation of greenhouse gases in the atmosphere. Uncertainties on the climate side are amplified by uncertainties on the socioeconomic side of the analysis. The combination of these uncertainties and incomplete information creates a difficult environment in which to select a climate policy. This decision inevitably generates risks.

The key issue is how quantitative methods of economic analysis and risk management can help to make the best possible decision given incomplete information. In other words, how can modern tools for economic analysis help policymakers process available information and make a decision that balances benefits and risks. The integrated assessment framework, described in this paper, provides a convenient analytical tool.

Conventional Approach to Cost-Benefit Analysis

When designing a climate policy, regulators balance costs and benefits associated with a certain environmental target. In terms of integrated assessment models (IAM) regulators select an emission target, which maximizes the difference between the benefits and cost of this policy. Note that regulators always try to solve a forward-looking problem, determining a long-run environmental target. In a deterministic case the cost associated with the selected environmental target is the present value of two elements: abatement cost and damage. Damage appears as a relatively permanent productivity shock on the economy that withdraws some fraction of output from investment and consumption. This could be interpreted as an adaptation cost or a cost of global environmental degradation. In the latter interpretation it includes adaptation costs and unrecoverable losses.

In order to solve a deterministic model when both damage and cost are uncertain, the central or "most likely" estimates of these parameters are usually substituted for actual cost and damage.[1] Since underlying uncertain parameters were substituted with their central (best guess or most likely) values, present values of abatement costs and damage turns out as the central estimates too. This way of substituting point estimates for uncertain parameters omits important information regarding variance and shape of distributions that describe these parameters. Therefore, central or expected values are not the best way to present an uncertain parameter. In the literature, there are many examples of substitutions that involve more than one point estimate: expected value and value at risk, or expected value and value in a percentile (say 90th or 95th), or α-precautionary principle.[2] While the methods mentioned above provide some tools for tail quantification (conditional value at risk is especially focused on tail quan-

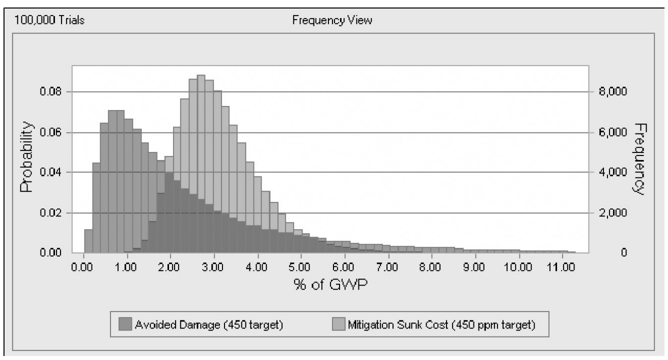
1. *See, e.g.*, William D. Nordhaus, Question of Balance (2008).
2. Daniel A. Farber, *Uncertainty*, 42 ELR 10725 (Aug. 2012).

tification), they do not make available an aggregated metric for valuing the underlying policy. Mean-variance analysis offers that aggregation, but this method significantly reduces information that could be retrieved from distributions. For instance, mean-variance metrics accounts for a fat tail poorly.

All available information should be taken into account and carefully processed. Modern climatic science and modern economics of climate change provide a foundation for meta-analysis and quantitative representation of different states of the world. Based on available literature, climate sensitivity and damage function could be presented as a probability distribution function.[3]

Figure 1 below illustrates challenges associated with cost-benefit analysis in the context of uncertainty. The figure presents results of Monte-Carlo simulations for a particular numerical example that illustrates the methodology.[4]

Figure 1.[5] Costs and Benefits of Climate Policy



This example highlights an important aspect of climate policy analysis: the trade off between expected values, on one hand, and tail and variance, on the other. In this particular example, because the expected cost of the policy "outweighs" expected benefits, this policy is rejected on the basis of a conventional cost-benefit analysis. However, the presence of a fat tail in the benefits distribution suggests potential high damages if the policy is rejected. With relatively low, yet significant probability, the damage (if a 450 ppm policy is rejected) may reach double-digit figures. There is a 10% probability that the irreversible damage process results in costs of more than 5.7% of the gross world product (GWP), while there is a 90% probability that the cost of an abatement policy is less than 4.4% of the GWP. Therefore, the choice is between higher costs versus higher risk. The expected value approach masks this trade off.

α-Precautionary Principle

α-precautionary principle[6] offers an alternative to conventional cost-benefit analysis that focuses on a central estimate of underlying parameters. α-precautionary principle ". . . differs from current conceptions of the precautionary principle by considering both the worst-case and best-case scenarios, rather than focusing merely on uncertainty about harmful outcomes."[7] This approach ". . . is most crucial in situations in which uncertainty is especially grave and no quantitative assessment of probabilities is available, but it is also useful in cases in which uncertainty is limited to potential catastrophic risks rather than more moderate outcomes."[8] In sum, α-precautionary principle offers policymakers a method to obtain economic value of the underling uncertain outcomes based on three different numbers: (a) best-case scenario; (b) worst-case scenario; and (c) wait coefficient "alpha": ". . . the worst case scenario is grim, perhaps on the order of the end of civilization; the best case scenario is that harm from climate change is modest."[9] Selection of alpha (about 0.01) reflects the probability of catastrophic temperature increasing up to up to 20° C.[10]

While this assessment may be a good approximation for potential cost of BAU (or slightly below BAU) emission scenario (e.g., scenario with relatively high probability for global temperature rise to exceed 8° C), policymakers need an analytical tool to evaluate various emission scenarios (for example, GHG concentration targets in a range between a 400 and 600 ppm stabilization target). All three numbers, mentioned above, should be calculated for each scenario. It is obvious that for a lower stabilization target, a lower alpha should be considered. Then, selection of alpha should be done in the context of all available information on the climate science side. Climate science is offering some approximation for climate sensitivity distribution.[11] Modern literature continues to offer distributions for climate sensitivity. Similarly, economic literature offers a range of estimates for economic damage attributable to climate change. This research made its way into a regulatory document: Interagency Report on Social Cost of Carbon (SCC). Thus, instead of focusing on just two extreme states of the world it may be better to consider all plausible states of the world and then apply more advanced methodology to quantify the tail of a damage distribution.

"One way to understand these models [α-maxmin models] is that we might want to minimize our regret for making the wrong decision, where we regret not only disastrous outcomes that lead to the worst-case scenario, but also we regret having missed the opportunity to achieve the best case scenario."[12] This treatment of climate policy is consistent with application of the proposed real options

3. *See, e.g.*, Carolyn Kousky et al., *Risk Premia and the Social Cost of Carbon: A Review*, 5 Economics 2011-21 (2011), *at* http://www.economics-ejournal.org/economics/journalarticles/2011-21; Robert E. Kopp et al., *The Influence of the Specification of Climate Change Damages on the Social Cost of Carbon*, 6 Economics 2012-13 (2012), *at* http://dx.doi.org/10.5018/economics-ejournal.ja.2012-13
4. *See* Jon Anda et al., *Economics of Climate Change Under Uncertainty: Benefits of Flexibility*, 37 Energy Pol'y 1345 (2009).
5. *Id.*
6. Farber, *supra* note 2.
7. Daniel A. Farber, *Uncertainty*, 99 Geo. L.J. 901, 905 (2011).
8. *Id.*
9. Farber, *supra* note 2, at 10730.
10. *Id.*
11. *Id.* at 10729.
12. *Id.* at 10726.

analysis (ROA).[13] In the case of climate policy, regrets could be interpreted as unrecoverable damage or (and) sunk abatement cost. Regrets on the damage side are balanced by regrets on the abatement cost side. Higher concentration target results in lower regrets on the abatement cost side and higher on the damage side, and vice versa; lower emission target results in lower regrets on the climate side and higher on the abatement cost side. ROA offers the way to calculate a shadow price of these regrets and gives decisionmakers a tool to assess different emission reduction pathways, to act promptly in respond to new information and knowledge regarding the climatic system and economy.

Interim Policy Target and Correction Cost of Climate Policy

If a regulator could know the exact values of exogenous parameters (climate sensitivity, damage function, abatement cost function, etc.) he would be able to compute an optimal emission trajectory at the outset. Unfortunately, these parameters are unknown. Their distributions reflect the current state of knowledge regarding climate and economics. Initially, selected environmental targets will unlikely mirror an "ideal" emission trajectory and will need to be corrected as new information becomes available and when a political cycle allows for corrections of the initial policy. Climate policy is sticky and it may take several years to implement adjustments. Correction of the policy and the target will result in additional costs, not accounted for when the initial environmental target was selected based on point estimates of damage and abatement costs. Correction costs could be considered as a "penalty" for deviation from the unknown "ideal" policy target.

Since any initial decision most likely will be reconsidered, cost-benefit (or cost effectiveness) analysis should also include the correction costs attributed to fixing this initial policy. Correction costs are an important element of the cost-benefit analysis of climate policy. Regulators should select an emission target that minimizes the sum of anticipated damage, anticipated abatement costs and correction costs. Each point estimate of economic damage (and abatement cost) has a pair, which is correction cost. Thus for each level of policy target (say, reflected in ppm) we consider two numbers instead of a distribution function: the point estimate of anticipated cost (central value or best guess) and the point estimate of correction cost.

Anticipated cost and correction cost are inversely proportional. If the higher value of the anticipated avoided damage assigned to emission target is imbedded into the decision procedure, then a lower correction cost should be considered. For example, a regulator may conservatively assign a point value of 5.7% GWP that represents avoided damage (benefits of climate policy aimed to meet 450 ppm target) in the 90th percentile. With a probability of 0.9, benefits of this policy (i.e. avoided damage) will not exceed 5.7% of GWP, actual avoided damage could be higher than 5.7% of GWP only with a probability of 0.1, and correction costs on the damage side would be relatively low. If, instead, a regulator takes the value of avoided damage in the 50th percentile, then actual damage could be higher than this point estimate with a probability of 0.5 and correction costs would be higher. At the same time, the relatively higher value of damage will result in a relatively lower (tighter) emission target and will raise anticipated abatement costs and correction costs on the abatement side.

What Are Correction Costs?

Let both anticipated benefits and cost equal to their expected values. Then, correction cost on the benefit side equals to zero, if actual damage is less than the expected value. Regulators could slightly "untighten" emission target in order to save on abatement cost in the future. The correction cost is positive if actual damage exceeds its expected value. The expected correction cost (ECC) is:

$$\mathrm{ECC} = \sum p_i \max(0, D_i - \overline{D})$$

where p_i is probability of an outcome D_i and $\overline{D}$ is the expected damage. Correction cost, as defined above, equals to an option value of call on adaptation services. If the response of the climatic system to an anthropogenic impact would appear higher than expected, then an actual adaptation cost (plus irrecoverable damage) D will be consistently higher than its expected level $\overline{D}$. Assume that in order to hedge these costs a regulator can buy at-the-money call option on adaptation. Holding this option a regulator will call for "adaptation services," if actual damage exceeds its expected value. Regulators may consider any other value for anticipated damage (for example, its median, or damage in 90th percentile), then the selected value for anticipated damage will be the trigger price.

The value of this option is a value of risk associated with the selected policy. Then, instead of a value of damage we consider an expected damage and price of the option on adaptation services. Selected emission targets will appear more expensive in terms of potential losses. Higher uncertainties on the climate side will drive the price of that option higher. Regulators include into calculations the price of at-the-money call option on adaptation services, or, in other words, a regulator adds the lost value of a call option on the climate asset. The same strategy could be applied to the abatement cost of the selected climate policy.

Option Value of Climate Policy

In conventional integrated assessment analysis the regulator is the only "agent." Therefore, a regulator bears all costs and benefits of the selected policy balancing expenses between risk prevention and mitigation, and across time periods. The regulator is simultaneously a buyer and underwriter of these options. Higher option prices are a

13. Jon Anda et al., *supra* note 4.

byproduct of economic growth. Accumulation of greenhouse gases in the atmosphere triggers negative changes in the climatic system. The monetary value of these changes constitutes an economic damage attributed to climate change. This damage represents a deferred external cost of climate policy. Thus, IAM is a dynamic optimal growth model with an additional module that represents dynamic feedback (negative, as a rule) between current economic growth and future economic growth affected by the degradation of the climatic system. Regulators maximize net discounted welfare by selecting savings rate and abatement strategy. Both savings invested into capital formation and abatement increase future production and, therefore, increase future welfare, but at the expense of current welfare reduction. Future welfare losses represent a deferred cost of current investment and environmental policy.

In IAM framework, we can interpret the correction cost as if a regulator is losing the value of call options to prevent damage of the selected policy, if this damage turns out higher than the expected cost. In time zero, the regulator has a real option on a relatively understated "climate asset." To be precise, regulators have a continuum of real options (assuming regulators can select a GHG concentration target from a continuous set of environmental targets). As soon as this selection is made, regulators give up some flexibility and, therefore, kill the option to prevent excessive damage, if the climate asset appears more vulnerable to GHG emissions.

Dynamic Hedging of Climate Policy

Assume that at some point in a distant future major uncertainties are resolved and an "ideal" target is finally calculated. Each correction of an interim emission target should narrow the gap between the current and the "ideal" target. For example, if an "ideal target" is 500 ppm, then the correction process, starting from an interim target of 600 ppm, may look like 600 ppm->450 ppm->550 ppm->510 ppm->490 ppm->500 ppm. The learning process would "narrow" probability distributions of uncertain parameters and, therefore, reduce the value of correction costs for a given interim target. Dynamics of the interim target may not be monotonic, but as long a "true value" of uncertain parameters was included into an initial set of its possible realizations, the magnitude of corrections should decline with each step, and convergence will be monotonic.

Simultaneously, the cost and benefits of the policy will be recalculated. Climatic processes could be irreversible and public policy may be "sticky." It will complicate adjustments and corrections of emission targets and result in extra cost associated with the corrections.

There are several elements of correction costs. If the climatic system turns out to be more sensitive to anthropogenic emissions and/or socioeconomic systems are more vulnerable to climate change, then adaptation cost would be higher than anticipated. The same logic works for abatement costs. The correction cost is equal to the call option value on abatement. On one hand, long-term damage attributed to climatic change is unknown; on another hand, near- and mid-term reactions of the economy for a selected climate policy (cost of carbon emission reduction) is unknown too. Regulators should select dynamically adjusted policy targets balancing between anticipated abatement costs and damage with correction costs on both sides.

Conclusions

As long as distribution has a finite variance, a fat tail risk is quantifiable, α-precautionary principle offers policymakers a method to obtain an economic value of environmental policy based on point estimates of the worst and the best outcomes, as well as an alpha-wait coefficient that could be derived from a probability distribution or set arbitrarily. In my view, climate science and economics of climate change have accumulated enough knowledge to propose plausible probability distributions for underlying uncertainty parameters or, at least, to construct a multi-step and multinomial event tree. In either case, application of real options analysis (ROA) would be possible and productive. ROA is the most reliable tool to assess multistep processes of climate policy formulation. Each decision point narrows future flexibility. Value of this flexibility equals to the lost option value.

If distribution exhibits infinite variance, then tail should be truncated at some point: "Rather than trying to solve the intractable problem of the potential infinities in fat-tailed distributions, we can cut off the tail at some plausible "worst case"—but then make up for our inability to directly account for the full spectrum of outcomes by giving heavy weight to the chosen bad scenario." In terms of truncation of a fat tail, option methodology could be explained as a more sophisticated truncation technique. Strike price is a truncation point. If strike price (lower truncation point) is lower, then an option value (higher waited value of "worst case scenario") is higher. Advanced option pricing formulas take into account all four characteristics of distribution: mean, variance, skewedness and kurtosis, and, therefore, will account for tail risk. As a hedging tool, options control the "invisible" costs of climate policy.