Contents

Introduction to webDICE's Advanced Interface

November 6, 2013

1 What is webDICE?

webDICE is a web-based version of the most widely-used model of the economics of climate change. It allows users to estimate the effects of climate change and also to understand how the model's assumptions about what the future will bring, such as how fast we discover carbon-free energy or how large the harms from climate change will be, changes those effects.

webDICE is based on a model of the global economy in which industrial activity produces emissions, which cause climate change, which in turn harms the economy. The basic model runs under the assumption that there is no policy in place to control emissions. The model uses available data and, where there is no data, our best guess assumption. Many these guesses are just that – guesses – and you should view the outcome as just one possible scenario. Clicking on the "run model" button shows the results under this scenario.

The default scenario is only one of many possible futures, and we do not know what the future will bring. You can change the assumptions to see how these changes affect the economy and people in the future. For example, you can change how soon we will discover carbon-free sources of energy, how fast the economy will grow, the size of the harms from climate change, and most of the other assumptions of the model to see what your views on these matters mean for the future. None of us know what the future will bring, so we encourage you to run the model under a number of different choices to see how the results change.

The assumptions, which we call model parameters, are separated into basic controls and other (but still important) controls, which you can see by clicking on the Advanced tab. You can also add limits on emissions to simulate a climate change treaty. To change the assumptions or to see how controls on emissions affect the future, move the sliders to your preferred position and click run. webDICE will show how the results change for each run. You can also download all of your results as a CSV file (readable by Excel).

webDICE has a separate mode called optimization mode. In this mode, webDICE will compute the limits on emissions that best balances costs of reducing emissions with the resulting improvements to the economy.

2 Where does webDICE come from?

webDICE is based on the DICE-2007 model developed by Professor William Nordhaus of Yale University (updates from DICE-2010 can be viewed in the advanced tab). DICE is the most widely used model of the economics of climate change, but until now has required sophisticated computational expertise to run. DICE has become a standard tool used by academics to study climate change and has been used by the U.S. government in setting climate change policies.

Professor Nordhaus's book, *A Question of Balance*, Weighing the Options on Global Warming Policies, is a good place to find more details. We thank Professor Nordhaus for making his model equations and code pubicly available (at [% http://nordhaus.econ.yale.edu/DICE2007.htm]). Due to computational considerations, we have re-coded the model into a different computer language, python, so that this version may not run identically to the version in *A Question of Balance* or to other versions found on Professor Nordhaus's website.

3 How does webDICE operate?

webDICE is based on a standard but simple model of the economy in which capital and labor combine to produce income. The amount produced depends on the total amount of capital, the number of workers, and their productivity. Production results in emissions of CO_2. webDICE computes how these emissions change global temperatures through a model of the climate. The temperature increases feed back into and harms the economy. For example, temperature increases may harm the economy by making it more difficult to grow crops or by increasing the number of storms. Given this structure and the set of assumptions you choose, webDICE calculates how the economy will perform in a warmer future.

Although webDICE involves a large number of equations, it is vastly simpler than the actual economy. It only crudely models many important drivers of the economy and does not consider other important economic factors, such as unemployment or trade. We think of webDICE as a way of understanding how some of the most important factors interact and of understanding how the results change when we change assumptions. We do not think of it as a tool for predicting what will actually happen. It allows us to see which effects of climate change are relatively robust and which economic factors are the central drivers of our future.

In the default mode, there are no controls on emissions, representing a "business as usual" scenario. You can choose to control emisisons, either by setting specific reductions in 2050, 2100, and 2150, or, in optimization mode, by finding the carbon tax that produces reductions that maximizes the welfare of people living both now and in the future.

4 What is climate change?

The term climate change or global warming refers to the "very likely" effects of emissions of greenhouse gases into the atmosphere. The primary greenhouse gas is carbon dioxide, which we emit when we use of fossil fuels. In simplest terms, greenhouse gases act as a blanket and warm the surface of the earth. As we put more greenhouse gas in the atmosphere, we in effect put on a thicker blanket, warming the planet more.

The basic science behind climate change has been understood for more than 100 years. It is the same science that is used to explain why the Moon is cold, the Earth is the right temperature to support life, and Venus is too hot. The Earth's (and the moon's and Venus's) temperature is determined by the relationship between the energy the Earth absorbs from the Sun and the energy it emits back. These two have to be in balance for the temperature to remain stable. Because the Sun is hot, most of its energy is in the form of visible and near-infrared light. The Earth is much cooler, so the energy it emits back into space is has longer wavelengths; it is mostly in the infrared region of the spectrum. Without an atmosphere, the resulting balance of incoming and outgoing energy would mean that the average temperature of the Earth's surface would be about -20 °C (which is -4 °F)–too cold to support life. The reason the Earth is not actually this cold is that it is blanketed by the atmosphere. The atmosphere is nearly transparent to incoming solar radiation but it absorbs the infrared radiation coming from the Earth. In a sense, it acts like planetary insulation. The effect is to warm the Earth by nearly 35 °C, to an average temperature of around 15 °C.

The absorption of infrared radiation is due to only minor elements in the atmosphere – the greenhouse gases. The major components of the atmosphere, nitrogen and oxygen, are as transparent to infrared radiation as they are to visible light. The most abundant/significant human-caused greenhouse gas is carbon dioxide. It is only a trace element in the atmosphere, comprising now only about 395 parts per million (ppm), but it has strong effects.

Carbon dioxide occurs naturally in the atmosphere. Pre-industrial concentrations were about 280 ppm. Over the last century or so, however, humans significantly increased the concentration of carbon dioxide, largely through burning fossil fuels, land use change, and agriculture. When we burn fossil fuels, we inevitably emit the carbon in these fuels in the form of carbon dioxide. Roughly 60 percent of the annual emissions of greenhouse gases on a global basis come from fossil fuels (and 80 percent of U.S. emissions). Land use change alters the concentration of carbon dioxide in the atmosphere for many reasons. The most important reason is that trees absorb carbon dioxide through photosynthesis. When we cut down trees, we eliminate this carbon sink. In addition, if we burn the timber or it decomposes naturally, we release the carbon that they stored. A little more than 18 percent of global emissions are from forestry practices. Most of the remainder is from agriculture (13.5 percent globally), which produces emissions from the use of fertilizer and by releasing carbon stored in the soil.

There are some people who dispute the science behind climate change. It is not our goal to engage in this dispute; there are many places those who are skeptical or who want to be better informed can turn to. The Intergovernmental Panel on Climate Change has attempted to summarize the core scientific findings, and they have explanations of the basic ideas as well as detailed discussions of the most recent scientific results. For those who want to understand the core issues, we highly recommend the IPCC's FAQ on climate change, [http://www.ipcc.ch/publications_and_data/ar4/wg1/en/faqs.html]. For those interested in an accessible discussion of the most recent scientific papers, we recommend [% http://realclimate.org/]

We take the science to be beyond dispute and believe it is time to consider solutions. Our goal is to allow people to simulate the likely effects of climate change and how economic policies will change those effects.

While we take the science to be beyond dispute, the likely size of the effects – both how much temperatures will increase and how those increases will affect the economy – is highly uncertain. We allow you to change these assumptions so that you can see how your views on these matters may affect the future. For example, if you believe that climate change will likely be small or that it will not affect the economy very much, you can choose assumptions so that the model reflects these views. No matter how firmly you hold your views (either way) we recommend that you also see what happens if your views are not correct, as none of us can be sure about the magnitude of the effects.

5 Is climate change a hoax?

We understand that there are people who are skeptical about the science of climate change. There are many places to turn to for discussions of the science. This website is not one of them. For those who want more information about climate science, we recommend [http://realclimate.org/]

If you are skeptical of the science, however, this website might still be useful. You can set the model so that the temperature increases from emissions are relatively small and see how the economy performs. You can also see what happens if you are wrong by setting the model so that the temperature increases are high. Although we may hold our views strongly, any of us could be wrong and it is important to understand what might happen in that event. Everyone should test their assumptions and see what happens if we are wrong. Betting our future is a serious matter.

6 How good (or bad) is the economic model used?

The model is an attempt to consider how the core factors driving the economy interact, using a very simple set of equations (at least as economic models go). It is, at best, only a very rough guide, and is best thought of as producing scenarios that help us understand the interaction of these core factors. It is not a prediction. Most things cannot be predicted, from inventions that improve everyone's lives to financial crises to world wars. Any or all of these may dramatically change the future in ways that we cannot yet imagine, and the model does not try to anticipate these events.

As economics models go, the model used here is very simple. For example, it includes only two factors of production, labor and capital and it treats the entire globe as a single region rather than having separate countries that trade with one another. The advantage of this simplicity is that the model can be easily understood and it allows us to see how some of the core features of the economy potentially interact. The disadvantage is that many other things that drive the economy are not included in the model.

7 What is the output of webDICE?

The model produces four default graphs showing the results. The most important is per capita income or GDP. This is the measure most commonly used in economics to measure how well a society is doing. The higher per capita income is, the richer we are. The graph shows how per capita income changes over time, which is a result of economic growth and harms from climate change. The other three graphs show (i) temperature increase over time as a result of emissions; (ii) the carbon dioxide concentrations in the atmosphere; and (iii) emissions per year.

If you click on the "customizable" graph tab you can graph any of the data produced by the model. You can do this by selecting the x and y-axes for the graph. Most of the time, you will want to leave the x-axis as time as most of the data reflects how variables change over time. You can also download all of the data as a CSV file (readable by Excel).

One important use of the customized graphing option is to see how your choices result in changes to the assumptions over time. For example, if you want to see how abatement costs change in the model based on your choices of the marginal cost of abatement and how fast the costs of abatement go down, you can do so. This is valuable as it is not always apparent how changing the values in the sliders change the inputs into the model.

8 Model Description

The 'advanced' version of the web tool allows you to control many of the other assumptions of the model. There are two versions of the 'advanced' interface: one based on DICE2007 and one with selected updates to DICE2010. For a more detailed explanation of the differences between these two models, please see this sites "Intermediate Documentation". The following description of the 'advanced interface' uses example from the 2007 version.

8.1 Model Structure

The model uses 10 year time steps. It shows output for 20 time steps or 200 years, starting in 2005. It runs for runs for 60 periods (600 years) in the background so that the end period does not influence the calculations of the social cost of carbon or the optimal emissions control rate (discussed below).

8.2 Base Economic Model

Pre-climate change economic output is determined by the interaction of labor, capital and productivity.

8.2.1 Labor

Labor or population is determined by a weighted average forumla between the initial population and an assumed asymptotic population. This asymptotic population is set in default webDICE to be 8.6 billion, but is adjustable by the user between 8.0 and 12.0 billion. The following figure illustrates how the growth in population changes for various parameter choices:

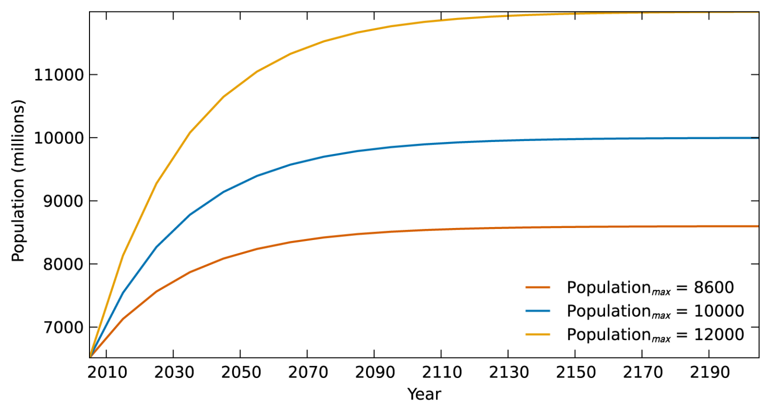

Figure 1: Pathway of population for user-choice of asymptotic population

8.2.2 Capital

The total capital available in a given period is determined by the sum of depreciated capital from previous time-periods and the amount of output saved. Capital, which can be thought of as investments towards future growth (e.g. buildings, infrastructure, machines), is assumed to depreciate over time, much like the value of a car depreciates over time. The default setting of webDICE assumes capital depreciates at a rate of 10% per time-step. The user can adjust this parameter between 8% and 20%. The model augments existing capital by assuming we save a fixed percentage of output in each time period. The model sets the default savings rate at 22%, but users can select a savings rate between 15% and 25%.

8.2.3 Productivity

Total Factor Productivity (TFP) describes how efficiently capital and labor produce economic output. The initial value of this parameter is set to produce 2005 output given observed capital and labor in that same year. DICE assumes that TFP will continue to increase in the future, but at a decreasing rate. The model sets the rate at which TFP growth declines to 0.1. Users can adjust this parameter between 0.05 and 0.15. The following figure illustrates how changing the rate at which TFP growth declines, Δ_a, affects the evolution of productivity:

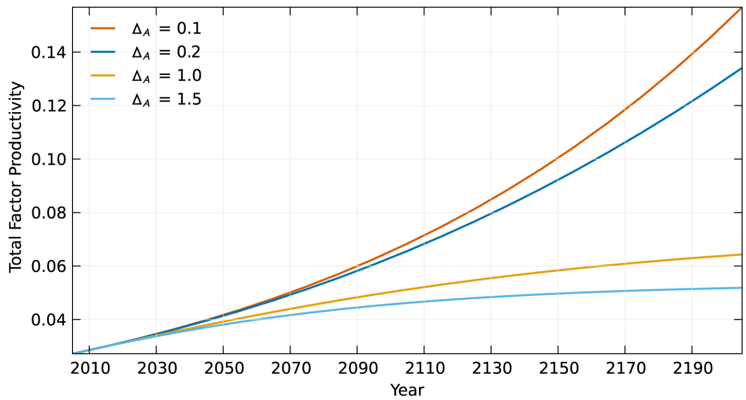

Figure 2: Pathway of TFP for user-choice of the rate at which productivity growth declines

8.3 Carbon Intensity and Emissions

Total emissions in DICE are assumed to be the sum of emissions from industry and land-use change. The creation of economic output, as described in the previous section, produces emissions.

8.3.1 Industrial Emissions

Industrial emissions are are determined by the carbon intensity of the economy multiplied by total economic output (and reduced by emissions control). In DICE carbon intensity is assumed to decline (even without any policy interventions) due to improvements in energy efficiency. However the rate of decarbonization of the economy is assumed to decline at a decreasing rate. The rate at which decarbonization slows is set in the default model to be 0.3%, but can be adjusted by the user between 0% and 6%. The following figure illustrates how carbon intensity evolves for choice of this parameter:

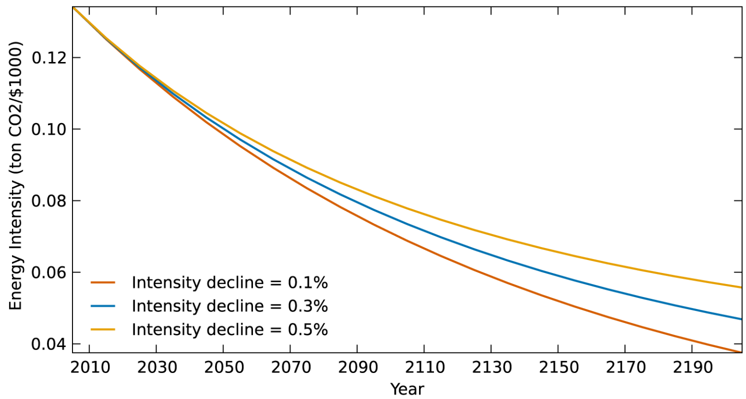

Figure 3: Pathway of carbon intensity for user-choice of decarbonization rate

Cumulative industrial emissions are limited by the total available amount of fossil fuels. This cap is currently set at 6,000 gigatons of carbon dioxide, but users can increase this amount.

8.3.2 Emissions from land-use change

Emissions from land-use change is currently exogenous to the model, but do contribute in a limited amount to total emissions.

8.4 Carbon Cycle, Alternative Carbon Cycles and Temperature Change

8.4.1 Default carbon cycle

The default DICE carbon cycle uses a linear three-reservoir model to track carbon stocks in the atmosphere, upper ocean and deep ocean. Emissions enter the atmosphere in each time period and move through the cycle in a manner described by the aforementioned model. This model only accounts for carbon dioxide. Other greenhouse gasses are assumed to be exogenous and enter the forcing equation seperately.

Alternative carbon cycle (Simplified BEAM) Glotter et al. demonstrate that the default DICE carbon cycle representation fails to accurately model oceanic carbon uptake.[1] In the default DICE carbon cycle, the atmospheric concentration of carbon in each time period is determined by the concentration from the prior time period augmented by emissions and reduced by a constant fraction

[1]Glotter, Michael and Pierrehumbert, Raymond T. and Elliott, Joshua and Moyer, Elisabeth J., A Simple Carbon Cycle Representation for Economic and Policy Analyses (September 1, 2013). RDCEP Working Paper No. 13-04. Available at SSRN: http://ssrn.com/abstract=2331074 or http://dx.doi.org/10.2139/ssrn.2331074

which is absorbed by the ocean. It is this constant fraction, which accounts for the unphysical linear absorption of carbon by the oceans in the default DICE model.

Actual carbon uptake by the ocean is highly non-linear, characterized by a rapid initial uptake period followed by a long-tail equilibrium stage. The BEAM model does a much more complete job than DICE at capturing the relevant physics of oceanic carbon uptake. webDICE uses the simplified version of BEAM presented in Glotter et al. The authors demonstrate that their abbreviated version of the model, which excludes temperature-dependent coefficients, offers very similar results to the full BEAM model. webDICE utilizes simplified BEAM for ease of computation.

BEAM will estimate that carbon stays in the atmosphere longer than with the default carbon cycle. As a result, damages from climate change will persist for a longer period of time and be higher overall.

8.4.2 Radiative Forcing

Radiative forcing quantifies the change in the earth's energy balance from the addition of greenhouse gasses and other climate forcers to the atmosphere. DICE links the amount of carbon dioxide added to the atmosphere since 1750 to radiative forcing. Radiative forcing is then related to temperature change. This relationship is governed by a key parameter: climate sensitivity. This parameter is a way of representing the equilibrium temperature from doubling the concentration of CO_2. The default setting of the model specifies a $3°C$ rise in temperature for a doubling of CO_2. The user can set this between $1°C$ and $5°C$.

8.4.3 Linear Carbon Model

Recent studies estimate that peak warming is linearly proportional to cumulative carbon emissions. [2] The linear carbon model uses this relationship to estimate temperature change as a function of cummulative emissions. The model does not include a carbon cycle or equations for radiative forcing, and as a result values for total carbon in the atmosphere or the upper and lower oceans are not computed. The default climate sensitivity is set to 3.2°, as in the other two carbon cycle models. This implies that we will increase global average temperature by two degrees Celsius for roughly every trillion tonnes of carbon that are emitted (since pre-industrial times).

8.5 Abatement Costs

The abatement cost, is the fraction of output spent on limiting emissions based on the specifications of a given climate policy. More specifically, it is the cost of reducing emissions of greenhouse gasses, measured as a fraction of total output. There are three components to abatement costs: the emissions control rate, the participation fraction, and the cost of replacing all fossil fuels with carbon-free energy

[2] Allen, M. R. et al (2009) Warming caused by cumulative carbon emissions towards the trillionth tonne, Nature, 458:1163-1166.

(the backstop technology). In general, abatement costs to increase with the emissions control rate, decrease as the participation fraction increases and decrease as the cost of the backstop technology decreases. Changing the abatement cost function only matters if you have chosen emissions controls of you are in optimization mode.

8.5.1 The emissions control rate

Under the business as usual scenario there are no controls on emission, so the emissions control rate is set to zero. When optimized or set by the user, this can take on any value between zero and one, a reflection of the fraction of total emissions that have neen reduced. This fraction is raised to an exponent to represent increasing marginal costs of abatement. The rate at which marginal costs increase is determined by the user. The default model sets this exponent to 2.8, but the user can adjust it between 2 and 4.

Abatement costs will be positive in two circumstances: if the model is run in optimization mode or if the user sets emissions controls. In optimization mode, the model solves for path of emissions controls that maximizes the discounted sum of utility over time. The user can indirectly set the emissions control rate by applying a climate treaty or a carbon tax:

Climate treaties Users have the option of simulating a climate treaty by setting carbon caps in three years, 2050, 2100 and 2150. The caps are specified as a percentage of emisssions in 2005 and apply in each time period until the next cap. These caps can be set anywhere between from 100% (which caps emissions at the 2005 levels) to 0% (which reduces emissions to zero). For example, if the cap in 2050 was set to 100%, emissions in the each year between 2050 to 2100 can be no more than 2005 emissions, and if the cap in 2100 was set to 70% emissions in each year between 2100 to 2150 can be no more than 70% of 2005 emissions.

The model implements the user-defined caps by solving for the appropriate emissions control rate in each time period if emissions exceed the cap. For example, if in the year 2070 industrial emissions exceeds the user-defined cap in 2050 the model will determine the emissions control rate needed to meet the cap.

The participation fraction The participation fraction is the percentage of global emissions that are subject to the user-selected climate policy. If less than all countries participate in an emissions control regime or some industries are exempt the value of the parameter is less than one. This does not affect the emissions control level specified by the user, but rather affects the cost of reducing emissions to the selected level. This implies that the base-line economic and emissions trajectory will not change significantly, if it changes at all. By decreasing the participation fraction, users are essentially increasing the abatement costs by increasing the cost of complying with the user-mandated climate treaty.

User-chosen carbon tax Alternatively, users can select a carbon tax to take effect in the same years as the emissions caps (2050, 2100 and 2150) (see section 2.1.2). A carbon tax can be set anywhere between \$0 and \$500 at each threshold. In terms of the model, the tax rate is used to calculate the implied emissions control rate. The carbon tax cannot be set at the same time as a climate treaty or the participation fraction.

8.5.2 Backstop technology

The final component of the abatement cost is the cost of replacing all fossil fuels with zero-carbon energy. This cost reflects the cost of the technology (called the backstop technology) needed replace the last ton fossil carbon and the energy intensity of the economy. The backstop technology is assumed to start at a relatively high price, $\$1,170/tonC$, and to go down according to an exogenous (user chosen) path.

The user can define both the end point of this pathway (i.e. the cost of the backstop technology in the final time-step) as well as the speed at which we approach that price. The two parameters that are adjustable within this component of the abatement cost are:

How low will the costs of renewables go?

Determines the cost of the backstop technology in the final time-step. Default webDICE sets this parameter to 2.0, but it is adjustable between 1.0 and 4.0. The following figure illustrates the evolution of the backstop price for choice of this paramenter (*ratio*):

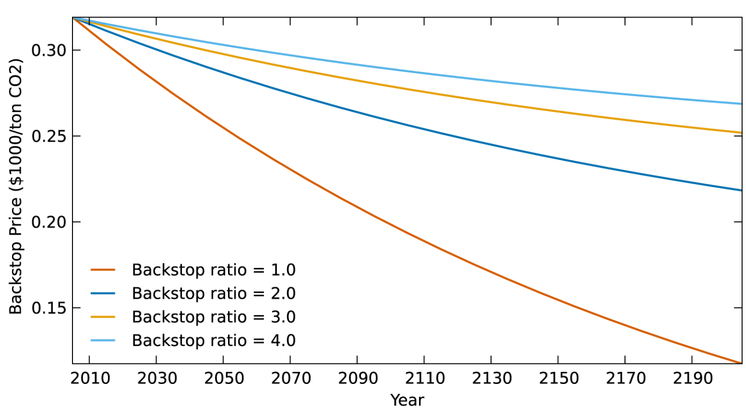

Figure 4: Pathway of backstop price for user-choice of *ratio*

How fast will the costs of renewable energy decline?

Detemines how quickly we reduce the price of the backstop technology. The default setting of webDICE assumes a 5% reduction in the price per year, however the user can set this between 0% and 20%.

8.6 Damages and the Damage Function

The relationship between a warming climate and its effect on the economy is governed by the damage function. The assumptions made in the choice of the functional form of this relationship can have a significant effect on the model's estimates. webDICE allows users to choose the form of the relationship between increasing temperature and economic damages.

8.6.1 Default DICE damages

The default DICE damage function approximates a polynomial relationship between temperature and economic damages due to climate change. That is, the fraction of output lost in each period increases to the user-defined power of the increase in temperature. The default setting of the model specifies a quadratic relationship between temperature and economic damage, however the user can define this relationship anywhere between linear and quartic. The choice of this parameter also affects the appropriate aleternative damage function. In the default setting of DICE damages, the model is calibrated so that 1.7% of GDP is lost when temperature increases by $2.5°C$.

8.6.2 Alternative damage functions

Environmental goods The default damage function implicitly assumes that different types of consumption goods can be readily substituted for one another. For example, if agriculture represents 24% of GDP, a 1% loss to agriculture would correspond with a 0.24% loss in GDP and a 100% loss in the agricultural sector would yield only a 24% drop in global GDP. This specification of the damage function yields limited damages because it implicitly assumes that other goods can be substituted for food.

The "environmental goods" damage function modifies the damage function to allow some goods to have limited substitutability. As the price of those goods rise a growing portion of GDP will be devoted to that good.

This damage function is based on a model by Sterner and Persson[3] as modified by Weitzman. Sterner and Persson include relative price effects in a modified version of DICE by setting utility to be a CES function of the consumption of material goods and of an unspecified environmental good. For a more detailed explanation of how damage function is implemented in DICE, please refer to the intermediate documentation.

Much like Sterner and Persson, the user will find that employing this damage function in the standard DICE model will yield "a far more stringent emissions policy than Nordhaus found with his multiplicive" form of the damage function.

[3] Thomas Sterner and U. Martin Persson, "An Even Sterner Review," *Review of Environmental Economics and Policy* 2 (2008): 61-76, doi: 10.1093/reep/rem024

Tipping Point Because of possible positive feedbacks in the climate system, once temperatures increase above a given point, damages may accelerate. For example, if warming is such that methane is released from the permafrost, this will increase warming, in turn causing more methane release. The tipping point damage function allows for this possibility.

webDICE uses the form of a tipping point damage function proposed by Martin Weitzman. With this damage function, damages drastically increase after temperatures have increased by around $6°C$.

Damages to productivity growth The DICE model offers limited ways in which climate change can affect the economy. The damage functions discussed above imply that climate change reduces usable output but does not otherwise directly change the economy. (There will be indirect effects because less usable output translates into less capital in future years.) Climate change however, may not only affect output itself, but how we produce that output.

This "damages to productivity growth" specification of the damage function, derived from Moyer et al.,[4] directs a user-specified portion of damages from climate change to the growth of total factor productivty (TFP). This implies that climate change may not only affect what we produce, but how we produce it.

This specification yields the same single period loss in consumption as the default DICE damage function but will significantly lower long term growth because productivity is reduce by climate change.

Comparison The following figure illustrates the effect choice of damage function will have on the output of the model. Each of the following pathways uses the default webDICE parameter choices:

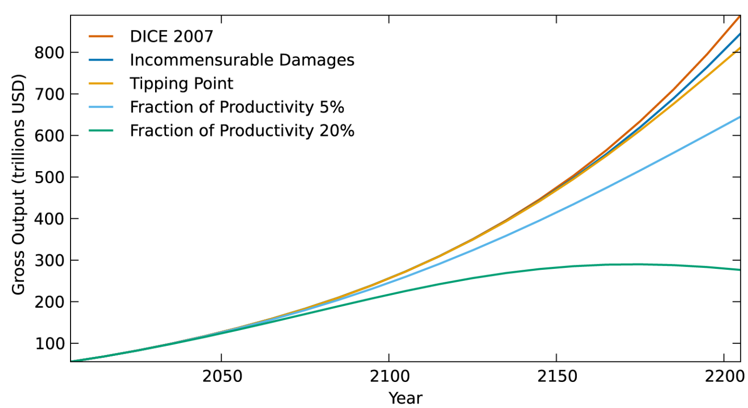

Figure 5: Comparison of gross output for user-choice of damage function

[4]Moyer et al. 2013

9 Optimization mode

In optimization mode, webDICE weighs the costs and benefits of reducing emissions and finds the set of emissions reductions that balance the two. By doing so, it finds emissions reductions that produce the overall best economic performance given the costs of climate change and the costs of reducing emissions.

The choices you make elsewhere, regarding climate sensitivity, harms from climate change, technological growth, abatement costs and so on will affect how much we should reduce emissions. For example, if you choose a pessimistic scenario, such as high climate sensitivity or very bad harms from climate change, it will be desirable to reduce emissions more. Conversely, if you choose an optimistic scenario, we will not want to reduce emissions as much. Optimization mode allows you to see how your choices affect climate change policy.

There are two parameters you can choose only in optimization mode, as these parameters only matter for optimization.

9.1 The declining value of additional income

The optimization finds the emissions reductions that make people as well off as possible by balancing the costs of reductions and the benefits. The model measures how well off people are not in terms of total consumption but instead in terms of their well-being or utility. The difference is that the measre of well-being assumes that as people get richer, the same increment in income or consumption matters less, something known as declining marginal utility of income. A dollar given to a poor person is more meaningful to him than the same dollar given to Mark Zuckerberg. If we get richer over time, say because of economic growth, it makes less sense to sacrifice today to help people in the future.

You can choose how fast marginal utility declines with income by choosing the value called the elasticity of marginal utility. A lower number means that marginal utility declines less with income – the dollar matters almost as much to Mark Zuckerberg as to a poor person. A higher number means that marginal utility declines more with income.

9.2 The discount rate

In optimization mode, webDICE finds the balance between costs emissions reductions and the benefits of those reductions to maximize well being. Because climate change will occur over hundreds of years and affect billions of people, we have to determine whose well being matters. The current version of webDICE does not allow you to choose who within a given generation matters – everyone alive at a given point is time is treated equally. You can, however, choose how to weight people living at different points in time. You can choose how much we care about the future. You do this by setting the "pure rate of time preference." This is a discount rate.

The default mode uses a value of 1.5%. This is based on the value used by Professor Nordhaus in DICE 2007. Because it is set to a postiive number, the default model discounts the well-being of people living in the future. It treats them as counting less than people living today and the future in the future they live, the less that they count. The effects are quite dramatic as even a very small positive number means people in the distant future matter very little.

Setting the pure rate of time preference is one of the most controversial choices in climate change policy. Many people believe that it should be set to a positive number while many other people just as firmly believe that it should be zero. The designers of webDICE have our own views on the proper number. The default mode reflects some of our views but not all. It is set based on the value used in DICE 2007. We encourage you to try different values.

9.3 What are emissions controls?

Optimization mode finds limits on emissions in each time period. It computes a series of caps, as if nations agreed to particular global limits. It is equivalent to a "cap-and-trade" system. Cap-and-trade systems are the standard design for global-warming policies today, for example, in the European Union and under California's proposal for a state policy. Under this approach, total emissions are limited by governmental regulations (the cap), and emissions permits that sum to the total are allocated to firms and other entities or are auctioned. However, those who own the permits are allowed to sell them to others (the trade).

webDICE can also compute an equivalent "carbon tax." A carbon tax is a tax when someone, such as a powerplant or a refinery, emits carbon dioxide. It makes using fossil fuels more expensive, to reflect the fact that using fossil fuels results harms to other people because of climate change. With no tax, markets are not really free in the sense that people can use the atmosphere – dumping their waste there – without paying for it. In a free market, when people use resources, land, machines, and so forth, they have to pay for them. The price reflects alternative uses of those resources. A carbon tax effectively makes people pay to use the atmosphere just like they pay to use automobiles, land, and livestock. Most economists believe that a carbon tax is the best way to control emissions. When webDICE computes a carbon tax, it finds the tax that results in the same emissions reductions as those found directly in optimization mode.