2. DICE-2013R and Other Integrated Assessment Models

"Integrated Assessment Models" (IAMs) are computer simulation models that integrate insights from different disciplines such as ecology, earth sciences and economics.[4] According to Weyant et al. (1996) IAMs serve three purposes: First, they allow assessing climate change control policies. Second, they integrate the different dimensions of climate change in the same conceptual framework. Third, they help to quantify the relative importance of global warming within the limits of other environmental and non-environmental problems that are faced by mankind.

For the climate issue there are more than 50 IAMs that differ with respect to modeling structure, complexity and assumptions regarding society parameters and the climate system.[5] IAMs can be divided into two different types: policy evaluation models and policy optimization models. Policy evaluation models are usually recursive or equilibrium models that simulate the effect of a single policy option on the biosphere, the climate and the economy.[6] In contrast, policy optimization models attempt either to determine the optimal policy or to simulate the impact of an efficient level of carbon abatement on the global economy.[7] Optimal solutions are determined by maximizing an objective function or welfare function that are characterized by either regulatory efficiency, where expected costs and benefits of climate protection are traded off against each other , or regulatory cost-effectiveness - a solution which minimizes the costs of achieving a particular goal.[8]

IAMs that calculate dynamically optimal emission paths have several specific features in common: They all postulate a single long-lived representative individual whose preferences provide the basis for the optimization. Furthermore, abatement costs and climate damages must be expressed in a common unit and the aggregated climate damage function is represented by a simple power function of temperature change. Last, to compare the costs over long-time horizons, a discount rate is applied.[9]

IAMs are frequently used in the field of climate economics as they allow to break down the complexity of the economic, climate and social systems to a very basic structure and to model their interdependencies over time in a consistent framework. Proponents of

---

[4] See Jeroen P van der Sluijs (2002), p. 1.
[5] See ibidem, p. 2.
[6] See Kelly and Kolstad (1999), p. 4 and Nordhaus and Sztorc (2013), p. 5.
[7] See Kelly and Kolstad (1999), p. 4.
[8] See Kelly and Kolstad (1999), p. 4 and Nordhaus and Sztorc (2013), p. 5.
[9] See Parson and Fisher-Vanden (1997), p. 605ff.

J. O. Zaddach, *Climate Policy Under Intergenerational Discounting,* BestMasters,
DOI 10.1007/978-3-658-12134-1_2, © Springer Fachmedien Wiesbaden 2016

climate modeling do not claim that IAMs provide "definitive answers" to climate change related questions but rather consider them as helpful tools to understand how changes in one system affect changes in another system. Even if outcomes might not necessarily be correct, they can "*at least* [give] *internally consistent* [answers] *and at best provide a state-of-the-art description of the impacts of different forces and policies.*"[10]

Nevertheless, the value of climate policy derived from integrated assessment optimization is controversial and was strongly challenged only recently. One central point of criticism is that current models underestimate substantial risks of climate change.[11] For instance, the assumption that climate damage can be represented by a simple power function is thought to be quite implausible as this means that damage is still modest even if it exceeds some apparently highly dangerous thresholds.[12,13] The omission of key factors such as large-scale migrations,[14] the potentially irreversible nature of climate damage[15] or (possible) "tipping points"[16] is another weakness of integrated assessment optimization.

Most of these problems in modeling arise due to uncertainties regarding the climate system, the ecosystem, the economy and society: Existing evidence is inconclusive of how increasing GHG emissions will affect the climate system once certain thresholds are exceeded. It is also unclear what consequences this might have for the ecosystem and human well-being. Though such uncertainty issues can be mitigated, for example via Monte-Carlo-Simulations,[17] the reach of such methods is limited as uncertainty is structural: Neither do we know how strong certain factors (climate sensitivity, long-term economic growth etc.) are nor how they interrelate with each other.[18] Economists such as Weitzman (2009) have attempted to address this problem by means of different stochastic approaches. Nevertheless, there are limits to the exact and precise modeling of uncertainty.

---

[10] See Nordhaus (2008), p. 9.
[11] See Stern (2013), p. 838.
[12] See ibidem, p. 848.
[13] Using DICE-2007 Ackerman et al. (2010) show that an increase of the global temperature of up to 19°C above current average temperature implies a reduction of output of not more than 50 percent. This clearly reveals the limits of IAMs as a corresponding environment should make live on earth almost impossible.
[14] See Stern (2013), pp. 844–845.
[15] See ibidem, p. 846.
[16] The term "tipping points" refers to critical thresholds of the earth's climate system. Once these thresholds are exceeded this might cause "*abrupt climatic changes*" with "*large and potentially serious economic and ecological impacts*", see Alley et al. (2003), p. 2005.
[17] See Annan (2001), p. 270.
[18] See Weitzman (2009), p. 2.

To overcome these shortcomings, Stern (2013) identifies several key areas that require further research: First, it is important to find out if certain tipping points can be identified in the development path of the climate system. Because climate models predict that without further climate protection the median temperature is likely to exceed a threshold of 4°C one should also describe the economic and climatic consequences of such a scenario.[19] Second, IAMs should incorporate damage functions that take into account that damages from climate change do not only have short-term effects but also long-term effects on capital, land and productivity. Most current IAMs, such as DICE-2013R, do not incorporate these long-term effects and results are likely to be incorrect.[20] Last, future models need to reflect the risk of large-scale migration. It is reasonable to assume that strong changes in the climatic conditions, such as an increase of median temperature by 4°C, will cause considerable migration movements between nations and continents. History indicates that such movements involve high conflict potential and come at great costs.[21]

Apart from that, there are natural limits to modeling the climate and economic system. IAMs help to understand the complex nature of these systems and how they interrelate, but they are not capable of explaining and modeling them to the full extent.[22] Therefore, climate policy cannot fully rely on the outcome of one single model. It should rather be based on various models with different insights. Because we know that IAMs do not tell the truth, there is a need to explore additional indicators for good climate policy.[23]

DICE-2013R

One of the most popular IAMs for the cost-benefit analysis is the Dynamic Integrated Model of Climate and the Economy (DICE), which was designed by William D. Nordhaus. Since its first version from 1979, several updates with structural changes and data updates have been presented. The current version, DICE-2013R, was released in autumn 2013 and is consistent with the Fifth Assessment Report of Intergovernmental Panel on Climate Change (IPCC), released in 2013.[24] There are several other IAMs such

[19] See Stern (2013), p. 840.
[20] See ibidem, pp. 849–850.
[21] See ibidem, p. 1.
[22] See Nordhaus (2008), p. 9.
[23] See Stern (2013), p. 852.
[24] See Nordhaus and Sztorc (2013), p. 22.

as PAGE, FUND or MERGE that are of similar importance for the scientific community.[25] However, as DICE-2013R is state-of-the-art it should serve our purpose.[26]

The DICE model considers climate change from the perspective of neoclassical growth theory. This standard approach based on Solow (1970) assumes that there is a trade-off between today's and future consumption: If one wants to increase future consumption, today's consumption must be reduced to increase investment in capital, education or technologies. The DICE model adapts this approach in the sense that the climate system is regarded as an additional input factor: Production is positively correlated with GHG concentrations which enter as negative natural capital. The reduction of emissions comes at the cost of today's consumption. Simultaneously this reduces the damage to production caused by climate change and raises future consumption levels.[27,28]

Optimal climate policy is determined by the equilibrium in which a utilitarian social welfare function is maximized. This function ranks different consumption paths according to the preferences of a representative agent. It increases with per capita consumption $c(t)$ and with the number of existing people $L(t)$. Individual preferences are assumed to be identical and can be expressed by a constant intertemporal elasticity of substitution (CIES) utility function:[29]

Equation (1)

$$U[c(t), L(t)] = L(t)\left[\frac{c(t)^{1-\alpha}}{1-\alpha}\right]$$

The social welfare function, which is the sum of discounted welfare in all periods, is given by Equation (2):

Equation (2)

$$W[c(t), L(t)] = \sum_{t=1}^{T\,max} \frac{1}{(1+p)^t} L(t)\left[\frac{c(t)^{1-\alpha}}{1-\alpha}\right]$$

Generations are weighted in two dimensions: First, the generation's importance increases with the number of people that live in period t and with their per capita

[25] See Stanton et al. (2009), p. 167ff.
[26] The DICE-2013R model can be downloaded from Nordhaus' website: http://www.econ.yale.edu/~nordhaus/homepage/w
[27] See Nordhaus and Sztorc (2013), p. 4.
[28] For a detailed description of DICE-2013R see ibidem.
[29] See ibidem, p. 7.

consumption. Second, generations are weighted with regard to their time of birth, their relative importance being influenced by the pure rate of social time preference ρ and the elasticity of the marginal utility of consumption η.[30]

In the framework of Ramsey (1928)[31] this leads to the well-known Ramsey formula as a first-order condition

$$r = \frac{\partial Y}{\partial K} = \delta = \rho + \eta g^{32}$$

where the marginal opportunity cost rate r is equal to the marginal time preference rate δ.[33] The marginal time preference rate, in turn, is given by the sum of two components: The pure rate of time preference and the product of the elasticity of the marginal utility of consumption and the growth rate of consumption.

The Ramsey formula reflects two motives of discounting: On the one hand, consumption is discounted because individuals show preferences regarding the time of consumption. They rather consume today than tomorrow. This "impatience" motive is reflected by the pure rate of time preference ρ. On the other hand, consumption is discounted because future generations are likely to enjoy higher consumption levels than today's generations.[34] As the utility function shows diminishing marginal utility $\left(\frac{\partial^2 U[c(t),L(t)]}{\partial c(t)^2} < 0\right)$ future generations' marginal utility will be below the one of the earlier born generations. Therefore, redistribution in favor of the earlier born generation should increase aggregated welfare. This discounting motive is expressed by the elasticity of marginal utility η. It describes how fast the marginal utility declines as consumption increases. Higher values of η imply that the marginal utility of consumption declines more rapidly when consumption increases. It can also be interpreted as a measure of the aversion of society to inequality: The higher the elasticity of the marginal utility of consumption, the more weight is assigned to relatively poorer generations.[35]

---

[30] See Nordhaus and Sztorc (2013), p. 6.

[31] It is important to note that the derivation of the Ramsey formula is based on several assumptions: First, the economy is a competitive market, and the observed real consumption interest rate is equal to the marginal productivity of capital net of the rate of depreciation. Second, society can be represented by an infinitely-lived consumer who maximizes her utility function, see Roemer (2011), p. 372.

[32] For a detailed derivation see Appendix C.

[33] See Bayer (2003), p. 135.

[34] It is generally postulated that $g > 0$.

[35] See Nordhaus (1997), p. 316ff.

http://www.springer.com/978-3-658-12133-4

Climate Policy Under Intergenerational Discounting
An Application of the Dynamic Integrated
Climate-Economy Model
Zaddach, J.O.
2016, VII, 64 p. 17 illus., Softcover
ISBN: 978-3-658-12133-4