Applied Economics Issues

Climate and the Economy: IAMs

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Key references

- Nordhaus, W. (2019). Climate change: The ultimate challenge for economics. *American Economic Review* 109:1991–2014, doi: 10.1257/aer.109.6.1991
- Pindyck, R. S. (2013). Climate change policy: What do the models tell us? *Journal of Economic Literature.* 51:860–872, doi:10.1257/jel.51.3.860.

Vulnerable Systems

- Some systems are vulnerable to climate change, e.g.:
  - Agriculture
    - especially if rainfed (Mendelsohn, 2009),
    - and in South Africa/Southern Asia (Lobell et al. 2008, Science),
  - Coastal communities impacted by sea-level rise
    - Agarwal et al. (2025, J. Public Econ.); Keys and Mulder (2020, NBER),
  - Forests impacted by wildfires
    - Wang and Lewis (2024, JEEM); Meier et al. (2023, JEEM).
- Some damages may be **irreversible** if thresholds are crossed (e.g., ice sheet collapse, coral reef extinction).

Economic Costs of Climate Change

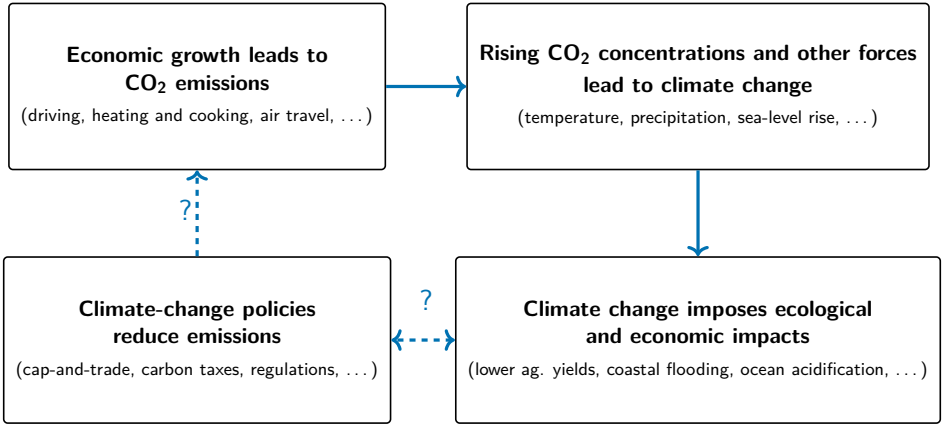
- One of the ways to measure the economic costs of climate change consists in using **Integrated Assessment Models** (IAMs) (see Meadows et al., 1972).
- IAMs link together:
  - **Economy**: growth, emissions, energy use,
  - **Climate system**: CO_2 accumulation, temperature rise,
  - **Impacts of climate**: damages to output, ecosystems, health
  - **Policies**: carbon pricing, abatement, adaptation
- IAMs aim to provide a unified (cost-benefit) framework to assess the **economic costs of climate change** and evaluate **policy responses**
- They allow to design carbon prices and evaluate policy scenarios.

IAMs

There are many types of IAMs (see Wang and Mullahy 2006 for a broad history since the 1970's). The main recent ones are:

- DICE (Dynamic Integrated model of Climate and the Economy) (Nordhaus 2010, PNAS)
  - single global economy, focus on intertemporal optimization of consumption,
  - note: RICE is a regional extension.
- FUND (Climate Framework for Uncertainty, Negotiation and Distribution) (Anthoff and Tol 2013, Clim. Change)
  - emphasizes regional distribution of costs/benefits, allows for adaptation and differentiated sectoral damages.
- PAGE (Policy Analysis of the Greenhouse Effect) (Hope 2012, Clim. Change)
  - explicitly incorporates uncertainty and risk analysis

The Circular Flow of Global Warming Science, Impacts, and Policy



Circular flow of global warming science, impacts, and policy (DICE model).
Source: Nordhaus (2019).

Economic Optimization in IAMs (1/2)

IAMs are typically set up as an **intertemporal optimization problem**; objective: maximise the **intergenerational welfare** (discounted utility of consumption):

$$\max_{c(t)} W = \max_{c(t)} \left[\int_0^{\infty} U[c(t)] e^{-\rho t} \, dt \right] \tag{1}$$

subject to:

$$M(y(t); z(t); \alpha; \varepsilon). \tag{2}$$

- $c(t)$: consumption
- $y(t)$: other endogenous variables (e.g., global temperature)
- $z(t)$: exogenous variables (e.g., population)
- α: parameters (e.g., climate sensitivity)
- ρ: pure rate of time preference
- ε: random variables

Economic Optimization in IAMs (2/2)

- In other words, IAMs ask: **how should society balance the costs of reducing emissions today against the future damages of climate change?**
- How it works:
  1. Project future **economic growth** and resulting **emissions**,
  2. Translate emissions into **climate change** (temperature rise),
  3. Estimate **economic damages** from higher temperatures (costs are estimated as a percentage of the output),
  4. Model the **costs of policies** (carbon pricing, technology switch).
- The model **optimizes consumption and investment** over time, choosing an **emissions path** that maximizes long-run welfare.
- The model outputs, as a by-product, the **social cost of carbon**, i.e., the monetary value of the **damage** caused by one extra ton of CO_2 (Pearce, 2003).

The Social Cost of Carbon

How to measure the social cost of carbon (SCC)?

- In IAMs, the global economy and climate system is simulated **with and without an extra ton of emissions**.
- The SCC is the difference in the present value of consumption between these two scenarios (see Wang et al. 2019, J. Cleaner Prod. for different formulas).
- Economically, it is the **shadow price of carbon**, the value of tighter emissions constraints.
- This measure can be used to define the **optimal carbon tax**, which should equal the SCC.
- For example, if SCC= \$40tCO_2: emitting one extra ton of CO_2 today reduces the present value of world consumption by \$40.

The Social Cost of Carbon

- There is no consensus in the value of the SCC
  - In a review based on meta-analysis, Wang et al. (2019) found that the estimated SCC range from $-13.36/\$tCO_2$ to $+2386.91/\$tCO_2$, with a mean value of $54.70\$/tCO_2$,
  - the estimation strongly depends on key parameters such as climatic sensitivity α, intergenerational discount rate ρ (Pizer et al. 2014, Science).

Critiques of IAMs (1/2)

IAMs are not perfect tools. In a position paper, Pindyck (2013, JEL) argues that they are "*close to useless*" for policy analysis:

- they rely on **arbitrary inputs**: the discount rate and the risk aversion are chosen arbitrarily, and these choices have a huge impact on SCC,
- the **damage functions** linking temperature to GDP are *ad-hoc*, not theory- or data-driven,
- the **climate sensitivity** (how temperature would change from a doubling of CO_2) involves uncertain or unknowable feedback loops.
- since they provide SCC that seem precise, IAMs create an **illusion of precision**, but in reality IAMs can be tuned to yield almost any result,
- They ignore the possibility of **catastrophic outcomes** (either economic or climatic).

Critiques of IAMs (2/2)

For more critiques, see, e.g., Auffhammer (2018, JEP) or Rose (2012).

According to Pindyck (2013, JEL), climate policy should:

- be based on viewing abatement as **insurance** against low-probability catastrophic outcomes,
- use **plausible ranges** of outcomes and probabilities rather than IAM outputs.

1. Appendix

References I

Agarwal, S., Qin, Y., Sing, T. F. and Zhan, C. (2025). Sea level rise risks, adaptation strategies, and real estate prices in Singapore. *Journal of Public Economics* 241: 105290, doi: 10.1016/j.jpubeco.2024.105290.

Anthoff, D. and Tol, R. S. J. (2013). The uncertainty about the social cost of carbon: A decomposition analysis using fund. *Climatic Change* 117: 515–530, doi: 10.1007/s10584-013-0706-7.

Auffhammer, M. (2018). Quantifying economic damages from climate change. *Journal of Economic Perspectives* 32: 33–52, doi: 10.1257/jep.32.4.33.

Hope, C. (2012). Critical issues for the calculation of the social cost of co2: why the estimates from PAGE09 are higher than those from PAGE2002. *Climatic Change* 117: 531–543, doi: 10.1007/s10584-012-0633-z.

Keys, B. and Mulder, P. (2020). *Neglected No More: Housing Markets, Mortgage Lending, and Sea Level Rise*. doi: 10.3386/w27930.

Lobell, D. B., Burke, M. B., Tebaldi, C., Mastrandrea, M. D., Falcon, W. P. and Naylor, R. L. (2008). Prioritizing climate change adaptation needs for food security in 2030. *Science* 319: 607–610, doi: 10.1126/science.1152339.

Meadows, D. H., Meadows, D. L., Randers, J. and Behrens III, W. W. (1972). *The Limits to Growth: a Report to the Club of Rome*. Universe Books, New York.

Meier, S., Elliott, R. J. and Strobl, E. (2023). The regional economic impact of wildfires: Evidence from Southern Europe. *Journal of Environmental Economics and Management* 118: 102787, doi: 10.1016/j.jeem.2023.102787.

References II

Mendelsohn, R. (2009). The impact of climate change on agriculture in developing countries. *Journal of Natural Resources Policy Research* 1: 5–19, doi: 10.1080/19390450802495882.

Nordhaus, W. (2019). Climate change: The ultimate challenge for economics. *American Economic Review* 109: 1991–2014, doi: 10.1257/aer.109.6.1991.

Nordhaus, W. D. (2010). Economic aspects of global warming in a post-Copenhagen environment. *Proceedings of the National Academy of Sciences* 107: 11721–11726, doi: 10.1073/pnas.1005985107.

Pearce, D. (2003). The social cost of carbon and its policy implications. *Oxford Review of Economic Policy* 19: 362–384, doi: 10.1093/oxrep/19.3.362.

Pindyck, R. S. (2013). Climate change policy: What do the models tell us? *Journal of Economic Literature* 51: 860–872, doi: 10.1257/jel.51.3.860.

Pizer, W., Adler, M., Aldy, J., Anthoff, D., Cropper, M., Gillingham, K., Greenstone, M., Murray, B., Newell, R., Richels, R., Rowell, A., Waldhoff, S. and Wiener, J. (2014). Using and improving the social cost of carbon. *Science* 346: 1189–1190, doi: 10.1126/science.1259774.

Rose, S. K. (2012). The role of the social cost of carbon in policy. *WIREs Climate Change* 3: 195–212, doi: 10.1002/wcc.163.

Wang, H. and Mullahy, J. (2006). Willingness to pay for reducing fatal risk by improving air quality: A contingent valuation study in Chongqing, China. *Science of The Total Environment* 367: 50–57, doi: 10.1016/j.scitotenv.2006.02.049.

References III

Wang, P., Deng, X., Zhou, H. and Yu, S. (2019). Estimates of the social cost of carbon: A review based on meta-analysis. *Journal of Cleaner Production* 209: 1494–1507, doi: 10.1016/j.jclepro.2018.11.058.

Wang, Y. and Lewis, D. J. (2024). Wildfires and climate change have lowered the economic value of western U.S. forests by altering risk expectations. *Journal of Environmental Economics and Management* 123: 102894, doi: 10.1016/j.jeem.2023.102894.

IAMs: Theoretical Formulation (Optional)

Planner's problem in the spirit of DICE models:

$$\max \sum_{t=0}^{\infty} \beta^t L_t \, u\left(\frac{c_t}{L_t}\right)$$

subject to:

$$\begin{aligned} Y_t &= A_t F(K_t, L_t)\,[1 - \Omega(T_t)], \\ c_t + I_t + \Phi(\mu_t) Y_t &= Y_t, \quad K_{t+1} = (1-\delta)K_t + I_t, \\ E_t &= \sigma_t (1 - \mu_t) Y_t, \\ M_{t+1} &= \mathcal{C}(M_t, E_t), \\ T_{t+1} &= \mathcal{T}(T_t, M_{t+1}). \end{aligned}$$

- μ_t: abatement rate, $\Phi(\mu_t)Y_t$: abatement cost.
- $\Omega(T_t)$: damages; E_t: emissions; M_t: carbon stock; T_t: temperature.

The social cost of carbon is the shadow price of emissions. Go back