Macroeconomic modelling for climate and transition

Climate macro and finance course 2021 - Lecture 5

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Introduction

Last lecture

- A methodological wish-list to understand the macro-financial implications of climate change and the transition
- The birth of IAMs
  - Nordhaus and the DICE model
- Large-scale IAMs
  - Different models exploring a common set of scenarios (RCPs, SSPs)
- Analytical IAMs
  - Looking for simple optimal carbon price rules

Today's lecture

- We finish the IAMs part treating CGE as part of them
  - Unanswered questions on macro and finance
- What alternatives do we have?
  - Neoclassical approaches
    - DSGE models
    - Asset pricing models
  - Complexity-driven approaches
    - SFC modelling
    - Agent-based modelling
- Move to network analysis
  - Presentation of paper on 'cascades of physical stranding'

Computable General Equilibrium (CGE) models

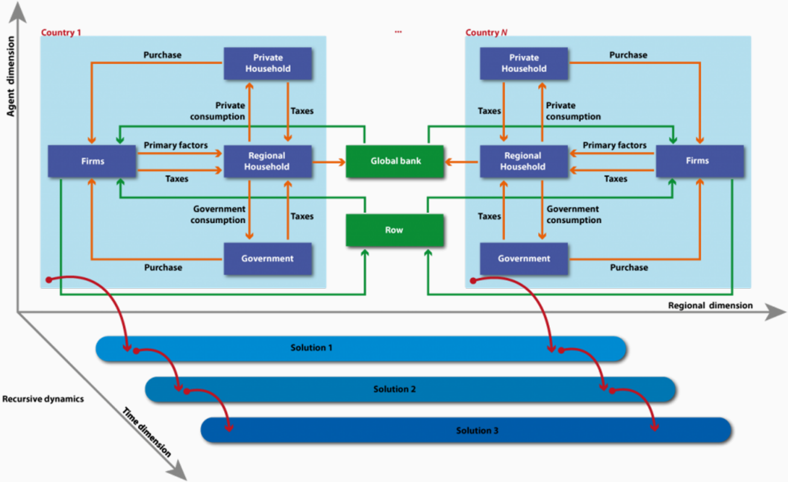
CGE models

- Start from actual data capturing economic inter-dependencies
  - Input-Output (IO) tables
  - Social Accounting Matrices (SAM) also include institutional accounts
  - e.g. GTAP Database
- Define a set of behavioural rules
  - Profit maximisation or cost minimisation by firms
  - Welfare maximisation by households
  - e.g. GTAP model
- Calibrate parameters on available data
  - E.g. Armington elasticity (of substitution between products of different countries)
- Introduce a change
  - E.g. a change in taxes or border tariffs
  - Observe how the system reacts to the change in prices

CGE models in climate economics

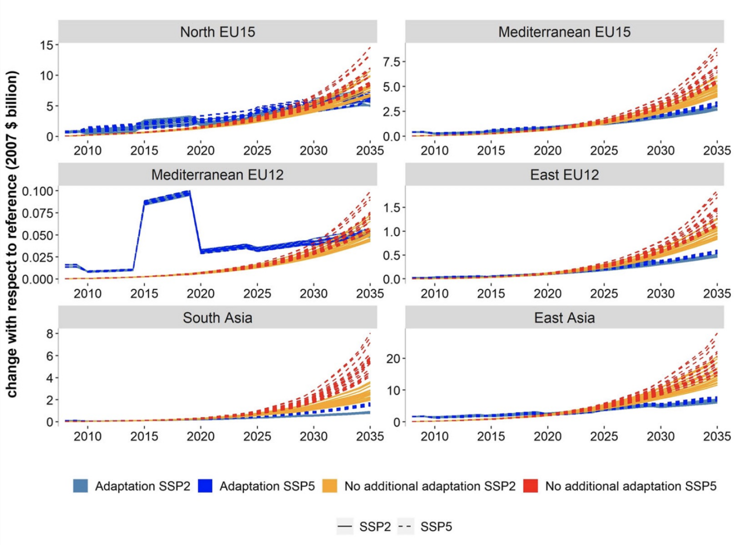
- They can adapted to include energy/environment
  - Impact of mitigation policies (carbon tax) or climate impacts
  - Multi-sectoral dimension is important (structural change)
  - Multi-regional dimension is important (trade impacts)
- Stylized representation of macro-financial dimension
  - All savings aggregated into a global banks that reallocates them according to relative returns
  - Crowding-out assumption (exogenous money)
- Example: ICES model (CMCC Venice)
  - Recursive model generating a sequence of static equilibria under myopic expectations
  - Derived from GTAP-E model
  - Cost-minimizing firms, representative household and government

An example: the ICES model



ICES model structure. Source: ICES website

An application: Public deficit and adaptation to sea level rise



Impacts on public deficit. Source: Parrado et al. (2020)

Unanswered questions on macro and finance

- IAM/CGEs have no or little representation of macro-financial system
    - No banking or financial institutions
    - Production networks: yes in CGE; financial networks: no
    - No monetary/banking/financial policies
    - Physical/financial conflation (investments, capital)
    - Stranding possible only for fossil reserves
- Wider issues with IAMs
    - See Bob Pindyck's opinion
- What alternatives do we have?
    - Let's try to use traditional macro/finance tools
    - Methodological dichotomy: neoclassical vs complexity

Reminder: Two main methodological avenues

	Equilibrium	Non equilibrium
Behaviour drivers	Intertemporal optimisation of a welfare function	Macro-econometric relations
Determination of output	Supply-driven: output (production) is allocated between different uses (consumption and investment) Y=AKL	Demand-driven: output (income) is determined by the expenditure desires (consumption and investment) Y=C+I+G
Expectations	Forward-looking expectations by rational agents	Adaptive expectations by agents in a context of deep uncertainty
Decisions	Rational	Routines in a context of deep uncertainty
Equilibrium	The system moves to an equilibrium state (balanced growth path)	There is not necessarily an equilibrium (cycles, emergent behaviours)
Money	Money as a 'veil' (banks as intermediaries)	Endogenous money (credit creation by commercial banks)
Modelling approaches	IAM, CGE, DSGE, CAPM	SD, SFC, ABM
Communities	Economics, Finance, Environmental/Energy Economics	Social sciences, Ecological/Evolutionary Economics

Neoclassical macro approaches

Real Business Cycle (RBC) models

- Starting point: Lucas critique (1976)
    - Microfoundations against Keynesian macro-econometric models
- Real Business Cycle (RBC) models
    - Representative agents; perfect competition; rational expectations; market clearing; labour supply choice
    - Fluctuations explained by exogenous 'real' shocks to TFP
    - Relevant papers: Long & Plosser (1983); Kydland & Prescott (1982)

RBC applications to climate econ

- Initial papers introducing pollution in standard RBC setting:
  - See review in Fischer and Heutel (2013) on ARRE
- Fischer and Springborn (2011) on JEEM
  - Emissions in production function
  - Compare macro effects of three policies: carbon tax; cap-and-trade system; intensity targets
  - Different welfare/volatility outcomes; argue in favour of intensity targets
- Heutel (2012) on RED
  - Emissions and climate la DICE
  - Optimal environmental policy (either tax or cap) is procyclical
- A more recent paper:
  - Dissou and Karnizova (2016) on JEEM

‘New-Keynesian’ DSGE models

- Share the RBC root but include frictions:
  - Habit persistence
  - Nominal rigidities (e.g. pricing la Calvo, 1983 on JME)
  - Capital/investment adjustment costs (e.g. Christiano et al., 2005 on JPE)
- Financial variables are important too
  - Financial frictions: Kiyotaki and Moore (1997) on JPE, Bernanke et al. (1999)
  - Monetary policy shocks as cycle drivers: Taylor (1993); Clarida et al. (1999) on JEL

NK DSGE applications to climate economics

- Annicchiarico and Di Dio (2015) on JEEM
  - Calvo pricing, capital adjustment costs, monetary policy
  - Emissions/climate following Heutel (2012)
  - Policy options: tax, cap, intensity targets (as in F&S 2011)
  - Three shocks: TFP, government expenditure, monetary policy
  - Cap tames macro volatility, intensity targets fuels it
  - Policy welfare ranking depends on price stickiness
- Annicchiarico and Di Dio (2017) on ERE
  - Similar NK setting, but focus on policy interactions
  - Planner choosing both environmental (tax or cap) and monetary policy, or just one of them
  - Optimally missions are usually, but not always, procyclical, depending on monetary policy reactivity
  - Environmental policy might affect optimal monetary policy

Since then, expanding field

- Comerford and Spiganti: 'The carbon bubble : climate policy in a fire-sale model of deleveraging'
- Diluiso et al.: 'Climate Actions and Stranded Assets: The Role of Financial Regulation and Monetary Policy'
- Benmir and Roman: 'Policy interaction and the transition to clean technology'
- Carattini et al. 'Climate Policy, Financial Frictions, and Transition Risk'
- $\rightarrow$ Move to Andrea's presentation

Capital asset pricing models (CAPM)

- Simple formula is

$$E(r_i) = r_f + \beta_i(r_m - r_f)$$

  - r_i: return of an asset
  - $r_m - r_f$: market premium
  - $\beta_i = \dfrac{cov(r_i, r_m)}{var(r_m)}$
- Recursive utility (See Epstein and Zin 1989)
  - Distinguish risk aversion from intertemporal substitution (bundled in power utility)
  - E.g.

$$V_t = \left((1-\beta)c_t^{1-\rho} + \beta\left(E_t V_{t+1}^{1-\alpha}\right)^{\frac{1-\rho}{1-\alpha}}\right)^{\frac{1}{1-\rho}}$$

- Multiple stochastic processes (Brownian motions + jumps)
  - Including capital (physical/financial conflation)

Asset pricing insight for climate econ

- Bansal et al. (2017): Climate change and growth risk
- Dietz et al. (2018): The ‘climate beta’
- Daniel et al. (2019) on PNAS
- Karydas and Xepapadeas (2019): CAPM with Rare Disasters and Stochastic Probabilities
- Hambel et al. (2020): Asset Pricing and decarbonization: Diversification versus climate action
- $\rightarrow$ Move to Dilan’s presentation

Issues with neoclassical climate economic models

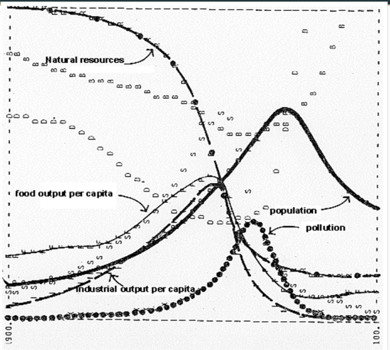
- DSGE heavily under attack after the GFC
  - Romer (2016): Fluctuations driven by 'imaginary causal forces'
  - Krugman (2016): 'Were there any interesting predictions from DSGE models that were validated by events?'
  - Stiglitz (2011): 'core DSGE models is not good theory'
- Equilibrium
  - Economies on a BGP until some random shock hits them
- Intertemporal optimisation
  - Behavioural economics/finance (heuristics, norms, networks)
- Hard to introduce heterogeneity
  - e.g. HANK model, see Kaplan et al. 2018 on AER
- Banks as pure intermediaries
- Supply-side approach
  - Little role for aggregate demand dynamics
  - Hard to have underutilisation of capital stocks

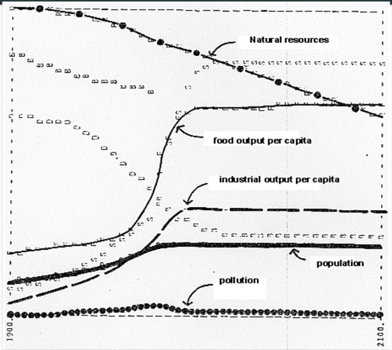
Non-equilibrium modelling

System dynamics

- System dynamics
  - Aim: capture real-world complexity (feedback loops, amplification, emergent behaviours)
  - Focus on stocks and flows (ecological modelling)
  - Macroeconometric approach: behavioural functions driven by estimation/calibration
  - Adaptive expectations (linear extrapolation to next period)
- The Limits to Growth (1972)
  - Forrester and MIT team; Meadows and Club of Rome
  - A continuation of business-as-usual would result into economic collapse driven by exhaustion of resources or pollution damages
  - Suggestion for radical policies
  - Economists were not happy (see Nordhaus, 1973)

The Limits to Growth (1972)





"Population and capital are the only quantities that need be constant in the equilibrium state. Any human activity that does not (..) produce severe environmental degradation might continue to grow indefinitely. In particular, those pursuits that many people would list as the most desirable and satisfying activities of man - education, art, music, religion, basic scientific research, athletics, and social interactions - could flourish."

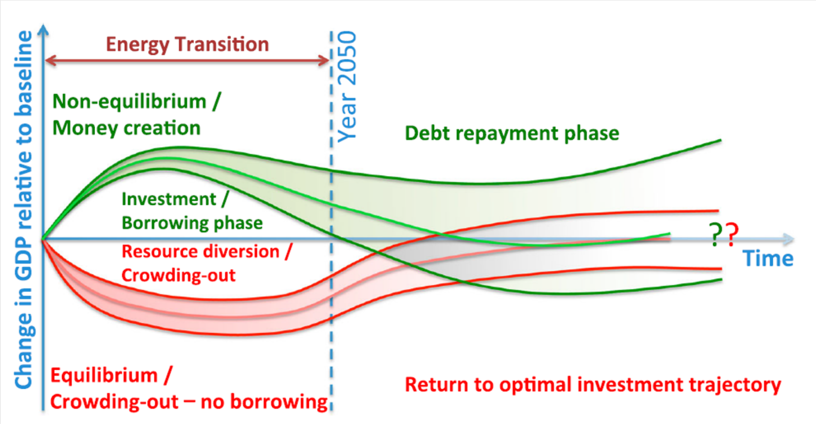
Stock-flow consistent (SFC) models

- Modelling approach based on a set of interacting balance sheets
  - Institutional sectors: households, firms, banks, government,..
  - Balance sheets made of assets and liabilities (deposits, loans, financial assets)
  - Productive capital only ‘net’ assets
- Sectoral behavioural functions
  - Usually based on post-keynesian theory
  - Radical uncertainty; no optimisation; adaptive expectations
- Rarely analytical solutions:
  - Numerical simulations of future scenarios (e.g. policy implementation)
- Key references
  - Godley, W., & Lavoie, M. (2007). Monetary Economics.
  - SFC tutorials by Dafermos

Post-keynesian economics

- SD or SFC per se are methodological approaches, not linked to any specific economic theory
  - However, SFC deeply rooted into post-Keynesian thinking
- Post-Keynesian modelling
  - Economies are demand-led: economic activity is driven by expenditure decisions
  - Aggregate behaviour is not an aggregation of individual behaviours (e.g. paradox of thrift)
  - Decisions taken in a context of fundamental uncertainty $\rightarrow$ heuristics, rules of thumb, social conventions, herd behaviour, path dependency, sentiments.. $\rightarrow$ Adaptive expectations
  - Prices are fixed by unit costs plus a mark-up (not by MPK)
  - Wages set by negotiations (not by MPL)
  - Banks do not have to wait for deposits before lending (endogenous money)

Equilibrium vs non-equilibrium models



Source: Mercure et al. (2019)

Behavioural functions

- Consumption
  - Function of disposable income and financial wealth

$$c_t = \alpha_1 Y^d_{t-1} + \alpha_2 v_{t-1}$$

  - Parameters change across household types (e.g. workers vs entrepreneurs)
- Desired physical investments
  - Can be function of capacity utilisation, interest rates, market valuation..

$$g_x = \eta_0 + \eta_1 u^e_x - \eta_2 rr_{l,x} \lambda_{x,-1} + \eta_3 q_{x,-1}$$

- Desired financial investments
  - Portfolio allocation matrix, e.g:

$$\begin{pmatrix} M_f \\ p_{c,e} e_c \\ p_{h,e} e_h \end{pmatrix} = \begin{pmatrix} \lambda_{10} & \lambda_{11} & \lambda_{12} & \lambda_{13} \\ \lambda_{20} & \lambda_{21} & \lambda_{22} & \lambda_{23} \\ \lambda_{30} & \lambda_{31} & \lambda_{32} & \lambda_{33} \end{pmatrix} \begin{pmatrix} 1 \\ \mathrm{R}_m \\ \mathrm{R}_c \\ \mathrm{R}_h \end{pmatrix} V.$$

SFC modelling applied to environmental economics

- Usually referred to as 'ecological macroeconomics'
  - See 2016 special issue on EcolEc
- Some papers using SFC modelling to study macro-environment links:
  - Dafermos et al. (2017) on EcolEc
    - See Filippo's presentation next week
  - Bovari et al. (2018) on EcolEc
  - D'Alessandro et al. (2020) on NatureSust
  - Jackson and Victor (2020) on EcolEc
  - Botte et al. (2021) on modelling transition risks

Agent-based models (ABMs)

- Atomistic representative agents poor representation of reality
  - Individuals are heterogeneous in their preferences, endowments, social networks, decision criteria, planning horizons..
- ABMs
  - Multiple populations of heterogenous agents
  - Interactions among agents (networks) create emerging macro behaviours
  - Heuristic behavioural rules (+ switching)
  - Innovation/imitation dynamics (Link to Schumpeterian literature)
  - Out-of-equilibrium dynamics
- Adaptive expectations
  - Methodological stance: bounded rationality
  - Computational limits

ABMs can be used to study climate-related issues

- They can be used to study diffusion of low-carbon technologies and environment-friendly behaviour
  - See recent review by Castro et al. (2020)
- A limited number of ABMs incorporate both environmental and financial dimensions
  - Safarzynska and van den Bergh, 2017) on transition-driven financial instability
  - Raberto et al. (2018) using EURACE model
  - D'Orazio and Valente (2019) on finance and environmental innovation diffusion
  - Lamperti et al. (2019) on public costs of climate-triggered banking bailouts $\rightarrow$ Student presentation?
  - Botte et al. (2021) on modelling transition risks

Issues with SFC/ABMs

- Expectations
  - Adaptive expectations are the norm (for both methodological preferences and computational complexity)
  - Limiting approach: no forward-looking behaviour
  - Combine with animal spirits literature? Franke et al. (2017), De Grauwe and Macchiarelli (2015)
- Black box problem ('garbage in garbage out')
  - Large number of assumptions on behaviour and parameter values (especially ABM)
  - Hard to empirically estimate and validate
  - Hard to interpret results and to extrapolate fundamental dynamics
  - What do we make of these models and their results?
- SFC: the sectoral classification is limiting
  - One can split in sub-sectors, but still no microeconomic behaviour

Alternative taxonomies

Mercure et al. (2019): Types of models

Table 2. Types of macro-models and summary of their assumptions regarding energy-related innovation and investment behaviour.

	Assumption type		Micro innovation	Macro innovation	Micro agent	Macro agent
Supply-led / Optimization	Optimal growth[1]		Does not have detailed disaggregated sectors	Knowledge accumulation in economy production function	Normative social planner optimizing utility inter-temporally	
	General Equilibrium	Computable General Equilibrium[2]	Can be linked to detailed technology models	Endogenous productivity in sectoral production functions	Representative agent with rational expectations (deterministic) optimizing utility, prices adjust to clear all markets	
		Dynamic Stochastic General Equilibrium	Can be linked to detailed technology models	Exogenous technological change	Heterogeneous stochastic representative agent	
	Partial equilibrium Cost-optimisation[3]		Learning curves, exogenous diffusion rates, vintage capital	Productivity not defined, can be linked to a CGE model	Can be heterogeneous, market segments	The normative social planner
Demand-led / Simulation	Macro-econometric[4]		Can be linked to detailed technology models	Technology progress indicators (fn. of cumulative investment)	Can be linked to detailed technology models	Investment behaviour derived econometrically
	Systems Dynamics	Discrete choice[5]	Vintage capital (fleets), learning curves	Productivity not defined, but can be linked to any macro-model	Multinomial logit regressions, heterogeneous agents	Can be linked to macro-model
		Diffusion[6]	Selection-diffusion evolutionary model, learning curves	Can be linked to a path-dependent economic model	Decision-making under bounded rationality, social influence	Can be linked to macro-model
	Agent-based	Sectoral[7]	Vintage capital (fleets), learning curves	Can be linked to a path-dependent economic model	Decision-making under bounded rationality, social influence	Can be linked to macro-model

Model examples: [1]RICE/DICE (Nordhaus, 2013), FUND (Anthoff & Tol, 2014), QUEST (DG ECFIN, 2015), [2]GEM-E3 (E3MLab, 2018a), IMACLIM (CIRED, 2018), [3]MESSAGE (IIASA, 2014), (PNNL, 2017), TIMES (IEA/ETSAP, 2016), PRIMES (E3MLab, 2018b), [4]E3ME (Mercure et al., 2018a), GINFORS (Lutz et al., 2009) Giraud stock-Flow (Giraud et al., 2016), DEFINE (Dafermos et al., 2017), EIRIN (Monasterolo & Raberto, 2018) [5]IMAGE-TIMER (Bouwman et al., 2006) [6]FTT (Mercure et al., 2014) [7]MATISSE (Köhler et al., 2009).

Source: Mercure et al. (2019)

Mercure et al. (2019): Schools of thought

Table 1. Schools of economic thought.

	School Name		Micro-foundations: Rationality / Agent	Money	Parameter-isation method	Innovation Technology	Economic change
Equilibrium/Supply-led	Neoclassical	Solow[1]	Rational expectations/ Representative Agent	Commodity	Optimization	Exogenous	Capital accumulation
		Endogenous Growth[2]	Rational Expectations/ Representative Agent	Commodity	Optimization	Knowledge in production functions	Capital & knowledge accumulation
		General[3] Equilibrium	Rational Expectations/ Representative Agent	Commodity	Optimization	Knowledge in production functions, learning curves, knowledge spillovers[10]	Capital & knowledge accumulation
Non-equilibrium/ demand-led	Post-Schumeterian	Evolutionary Economics[4]	Behavioural[8] Heterogeneous	Asset (Credit creation)	Dynamical systems, Historical approach[9]	Knowledge networks, Diffusion, learning	Entrepreneur, Innovation clustering, creative destruction
		Transitions Theory[5]				Historical	
		Technology Innovation Systems[6]				Case studies	
	Post-Keynesian[7]	Horizontalists	Behavioural[8] Heterogeneous	Asset (Credit creation)	Time series Econometrics	Sectoral tech. progress functions	Cumulative causation of knowledge accumulation
		Structuralists					
	Behavioural[8]		Numerous agents	–	Empirical	–	–
	Marxian		Classes	–	Econometrics	–	–

Representative Models: [1]RICE/DICE (Nordhaus, 2013), [2]REMIND (PIK, 2016), [3]IMACLIM (CIRED, 2018), AIM (NIES, 2012), GEM-E3 (E3MLab, 2018a), [4]Evolutionary Economics (Safarzyńska & van den Bergh, 2010), [5]Geels (Geels, 2002), [6]Technology Innovation Systems (Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007), [7]E3ME-FTT (Mercure et al., 2018a), GINFORS (Lutz, Meyer, & Wolter, 2009), Giraud stock-Flow (Giraud, Mc Isaac, Bovari, & Zatsepina, 2016), DEFINE (Dafermos et al., 2017), MINSKY (Keen, 1995), [8]Prospect theory (Kahneman & Tversky, 1979), Discrete choice theory (Domencich & McFadden, 1975), [9]historical approach (Freeman & Louçã, 2001; Geels, 2002), [10]Note that although the method is in use (e.g. in GEM-E3), some but not all GE models feature learning curves or knowledge spillovers.

Source: Mercure et al. (2019)

Ciarli and Savona (2019) with focus on structural change

Table 2
Aspects of structural change in different modelling traditions. Some models are better equipped than others to capture the relation between aspects of structural change and environmental impact. In particular those that do not require a closed form solution in equilibrium.

Models	Aspects of structural change					
	Sectors	**IO**	**Technical change**	**Employment**	**Demand**	**Institutions**
IAM	No: aggregate & exogenous – no sectoral changes	No	Partial: Exogenous, LBD, induced TC, but aggregate	No	Limited: time preferences change with pollution	No (policy experiments)
CGE	Partial: many sectors, with technical change that may affect GHG	No: I/O maps diversification, but static	Partial: Semi-exogenous, LBD, induced TC, but aggregate	No	Limited: change consumption patterns, not preferences	No (policy experiments)
SCM	Yes	Yes, but only a couple of models	Yes, but only a couple of models	No	Limited: two populations	No (policy experiments)
EMK	Partial: labour composition	Not yet	No	Yes	Limited: wage distribution	No (policy experiments)
EABM 1	Partial: weaker on the environmental effects	Limited: firm size & industrial dynamics	Largely Yes	Yes	Yes, although not developed	Partial: interaction & response to policies
EABM 2	No	Limited: mainly industrial dynamics	Yes	No	Yes	Partial: evolution of power and tech. opportunities

Notes: IAM: integrated assessment models; CGE: computable general equilibrium models; SCM: structural change models; EMK: ecological macroeconomics (Keynesian); EABM 1: evolutionary and multi agent models (macro); EABM 2: evolutionary and multi agent models (innovations).

Source: Ciarli and Savona (2019)

Nikas et al (2019)

Category	Economy	Impacts	Energy	Climate
Optimal growth models	Neoclassical growth Highly aggregated Tracks long-term trajectory of economy (dynamic) Single production function Single representative agent Policy optimisation Global	Highly aggregated monetary damage function that translates temperature change to loss of GDP All damages in monetary terms	Aggregated energy sector (top-down)	Reduced-form equations linking emissions to temperature
General equilibrium models	Multisectoral (multiple production functions) Single representative agent Optimising behaviour of producers and consumers Global, regional, national, local More difficult to incorporate dynamics	Shocks introduced into production functions, e.g. reduction in crop yields reflected in agricultural production function leading to a shift in supply Shocks can be based on expert judgements or drawn from biophysical or statistical models of impacts	Often detailed description of energy system (multiple energy sources explicitly modelled) Often linked to bottom-up energy system models	Climate scenarios are exogenous and used to drive climate variables and impacts
Partial equilibrium models	Detailed modelling of a single sector, e.g. agriculture Static and dynamic Often combined or linked with other top-down models	(a) Detailed biophysical model of impacts to specific sector relating key climate variables to impacts (b) Statistical analysis leading directly to monetary value of impacts	Little or no representation of energy sector	Exogenous climate scenarios used to drive impacts
Energy system models	Can be considered as a subcategory of partial equilibrium models (with some instances including a macro feedback) Often linked to top-down models (making them "hybrid")	Used to assess costs of reducing emissions; no need to represent impacts	Detailed representation of alternative energy technologies and mitigation opportunities and policies	Focus on emissions rather than climate change
Macroeconometric models	Input-output econometric (multisectoral) Macroeconomy components Simulation: agents not assumed to feature optimising behaviour "Keynesian" Dynamic	Used primarily to evaluate mitigation and adaptation policies rather than evaluate damages arising from climate change	Detailed description of energy system	Exogenous scenarios
Other models	Various simple representations of economy or exogenous scenarios of economic growth	Variety of detailed representations of impacts and damages both physical and monetary	Various aggregated and detailed energy models	Reduced-form equations linking emissions to temperature and other variables

Source: Nikas et al. (2019)

NGFS (2020)

Table 4. **Types of economic models to assess climate risks**

Lineage	Model type	Description	Example
Integrated climate-economy models[1]	Cost-benefit IAMs	Highly aggregated model that optimises welfare by determining emissions abatement at each step	DICE, DSICE (Cai et al., 2012, Barrage, 2020)
	IAMs with detailed energy system and land use	Detailed partial (PE) or general equilibrium (GE) models of the energy system and land use. General equilibrium types are linked to a simple growth model	PE: GCAM, IMAGE GE: MESSAGE, REMIND-MAgPIE, WITCH[2]
	Computable General Equilibrium (CGE) IAMs	Multi-sector and region equilibrium models based on optimising behaviour assumptions	G-CUBED, AIM, MIT-EPPA, GTAP, GEM-E3
	Macro-econometric IAMs	Multi-sector and region model similar to CGE but econometrically calibrated	E3ME, Mercure et al., 2018
	Stock-flow consistent IAMs	Highly aggregated model of climate change and the monetary economy that is stock-flow consistent	Bovari et al., 2018
Other climate-economy models	Input-output (IO) models	Model that tracks interdependencies between different sectors to more fully assess impacts	Ju and Chen, 2010 Koks and Thissen, 2016
	Econometric studies	Studies assessing impact of physical risks on macroeconomic variables (e.g. GDP, labour productivity) based on historical relationships	Khan et al., 2019 Burke et al., 2015 Dell et al., 2012
	Natural catastrophe models and micro-empirical studies	Spatially granular models and studies assessing bottom-up damages from physical risks	SEAGLASS (e.g. Hsiang et al., 2017)
Modified standard macroeconomic models	DSGE models	Dynamic equilibrium models based on optimal decision rules of rational economic agents	Golosov et al., 2014 Cantelmo et al. 2019
	E-DSGE	Slightly modified standard frameworks (that allow for negative production externalities)	Heutel, 2012
	Large-scale econometric models	Models with dynamic equations to represent demand and supply, coefficients based on regressions	NiGEM (e.g. Vermeulen et al., 2018)

1 IAM taxonomy adapted from Nikas et al., 2019.

2 Model documentation available at *www.iamcdocumentation.eu/index.php/IAMC_wiki*

Source: NGFS (2020)

Conclusions

Conclusions

- We have multiple dimensions to explore to understand how to achieve a smooth and rapid low-carbon transition
- Traditional climate economics (IAM/CGE) offers multiple insights..
  - Carbon prices, energy composition, energy investments, etc.
- .. but lacks several important dimensions
  - Namely, financial dynamics and related institutions/policies
- So, let's look at macroeconomics and finance literature
  - Dichotomy between neoclassical methods (DSGE, CAPM, IAM+)..
  - .. and complexity-driven approaches (SFC, ABM)
- They are all being used to study macro-financial implications of climate/transition