Introduction + The big picture

Climate macroeconomics & finance course 2022/23 - Lecture 1

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Welcome to the course!

- Climate macroeconomics and finance (98724)
  - Formal title: 'Climate and transition risks: Uncertainties, complexity, and implications for economic and financial dynamics'
  - First module of integrated course 'Climate-related risks and commodity markets'
- Course teachers:
  - Lecturer: Emanuele Campiglio (emanuele.campiglio@unibo.it)
  - TA: Gabriele Cortini (gabriele.cortini3@unibo.it)
- Course online presence
  - Virtuale (course material and submissions)
  - Panopto (recordings)
  - UniBo course page (description and timetable)

Aim of the course

- Main aim:
  - Understand climate-economy interactions
- Main research questions
  - Present/future economic impacts of climate change?
  - Macro-financial implications of low-carbon transition?
  - Optimal climate mitigation/adaption strategies?
- Functional objectives:
  - Expand knowledge on facts, empirical evidence, theories
  - Familiarise with current scientific/policy research (focus on climate/transition economic modelling)
  - Develop and present original critical analysis

Course overview

1. Introduction and the big picture
2. Climate change: drivers, impacts, scenarios
3. Climate mitigation and adaptation
4. Climate-related policies and commitments
5. Modelling climate-economy interactions
6. Climate economics and Integrated Assessment Models
7. Macroeconomic modelling of climate and transitions
8. Climate, finance and money
9. Climate-related international implications
10. Student presentations and course wrap-up

Lecture structure

- Ten 3-hour lectures
  - Frontal lectures (except Lecture 10)
  - .. but open discussion very welcome
- Five 2-hour tutorial classes
  - Solution to problem sets and discussion
  - Discussion of advancements of groupworks
- Lecture/tutorial classes timing
  - Starts 5 mins past the hour (sharp)
  - 50-min blocks with 10-min breaks

Students' role

- Come to lecture/class
  - Lecture content key to pass the course
  - Recordings posted on Panopto with 2-week delay
- Participate
  - Diversity of backgrounds, knowledge and interests
  - $\rightarrow$ Lots to learn from and teach to each other
  - Raise your hand for questions, comments, news..
- Be on time
  - We start 5 mins, we end 5 mins to
- Stay focused
  - Laptops limited to note-taking
  - Mobile phones: please, no

Readings

Main readings

- Scientific and policy articles/reports
  - Key reading: IPCC Assessment Report 6
  - Other useful readings flagged on syllabus/slides/Virtuale
  - Readings available on Virtuale, through UniBo subscriptions or open access online
- No textbook. However, useful related textbooks
  - Economides, G., Papandreou, A., Sartzetakis, E. and Xepapadeas A. (2018) 'The economics of climate change', Bank of Greece (freely available at this link)
  - Tol, R. (2019) 'Climate Economics', 2nd edition, Edward Elgar Publishing (teaching material available at this link)
  - Keohane, N.O., and Olmstead, S.M. (2016) 'Markets and the Environment', 2nd edition, Island Press

Key reading resource: IPCC AR6

- UN Intergovernmental Panel on Climate Change (IPCC)
  - Aim: assess state of the knowledge on climate change, its impact and societal response options
  - No original research
- Periodic Assessment Reports (AR)
  - First IPCC report in 1990
  - Latest: AR6 (2021-22)
- Three Working Groups:
  - WGI: Physical science of climate system and climate change
  - WGII: Climate impacts, vulnerability, adaptation options
  - WGIII: Climate mitigation options
- Each WG publishes
  - Summary for Policy-Makers (SPM)
  - Technical Summary (TS)
  - Full report (with focused chapters)

Stay at the frontier of research

- Functional aim of course
  - Make you able to read some of the frontier papers, ongoing research shaping international debate on the topic
  - Tool: read recent papers on key journals or from key authors/institutions
  - Tool: show some of research inner workings
- Research applications during course
  - Where possible, I will refer to some paper I'm currently working on
  - Ideally, you will be able to read and understand their main assumptions and messages by the end of the course
  - Food for thought for your future research

Where is climate macro/finance research published?

- Academic journals
  - Interdisciplinary journals: Nature/Science journals (in part. Nature CC), PNAS, Glob. Environ. Change, Climate Policy,..
  - Field econ journals: JEEM, JAERE, EcolEc, ERE, EDE, ..
  - General econ journals: Some key papers in top journals (AER, Econometrica, JPE, etc.)
  - Field review journals: REEP, ARRE, ARER, WIREs CC
  - Generic review journals: JEL, JEP, JoES
- Gray literature
  - Policy/technical reports, working papers, etc.
  - International institutions: World Bank, IMF, UNEP, ..
  - Central banks: NGFS, ECB, ..
  - Research centres, think tanks, NGOs..

Assessment

Assessment overview

- Course (module I) assessment methods
  - Problem sets (25%)
  - Groupwork (35%)
  - Exam (40%)
- Final grade scaling from 0 to 30
  - Lower than 18 $\rightarrow$ fail
  - Particularly excellent work $\rightarrow$ 'laude' (30L$\approx$33).
- Intermediate grading
  - Each assessment method assigns percentage points
  - Final 100-score translated into a 33-score (eg. 91*33/100$\approx$30)
- Overall grade for integrated course:
  - Unweighted average of the two modules

Problem sets (25%)

- Five empirical problem sets
  - Each 5% of total grade
- Timing
  - Each problem set will be given few days before tutorial class
  - Submission on Virtuale
  - Submission deadline: 23.59 of the day before tutorial
  - Problem sets will then be corrected during tutorial classes
  - Late submissions only via email (25% penalty)
- Submission/assessment is individual
  - Group-work is fine but free-riding is not
  - $\rightarrow$ Active participation required in tutorials
- Problem set 1 on the IPCC WGI Interactive Atlas available on Virtuale

Group-work (35%)

- Groups
  - Self-allocation via Virtuale
  - 3-5 members per group
- Topics
  - Each group will address a specific research-oriented topic
  - List of group-work topic sugggestions (see next slide)..
  - .. but alternative bottom-up proposals possible
  - Group choice on Virtuale, closes Sunday 25 Sept. 23.59
- Tasks
  - Give a presentation during Lecture 10 (24 October 2022): 20%
  - Submit an essay by 30 October 2022 via Virtuale (no word constraints): 15%

Group-work topic suggestions

- The role of policy uncertainty in shaping investment decisions
- Metrics to evaluate country-level climate-related risks
- Strategies to incentivise long-termist policy-making
- Strategies to incentivise long-termist financial behaviour
- Can we use experiments to find the right climate policies?
- Climate-related expectations/beliefs of financial investors
- International equity implications of low-carbon transition
- The political discourse on climate change and the transition
- Obstacles and strategies to finance low-carbon innovation
- Is inflation good or bad for climate mitigation?

Written exam (40%)

- Exam structure (1 hour time)
  - Broad essay-style questions
  - Choose one out of two available questions
- Essay-style answers expected
  - Showcase knowledge of concepts and literature..
  - .. but also develop substantiated critical analysis
- Exam preparation
  - Exam preparation slides on Virtuale
  - Last tutorial class
  - Mock exam also possible (tbc)
- Exam date
  - 2 November 2022, 10.00am
- Full exam alternative
  - Partial Module I exam is compulsory
  - If unsatisfied with grade $\rightarrow$ full exam (19 Dec 2022)
  - Module I problem-set and group-work grades will remain valid

Introductions

A bit more about me

- Current affiliations
  - Associate Professor, UniBo Department of Economics (DSE)
  - Scientist, RFF-CMCC European Institute on Economics and the Environment (EIEE)
  - Visiting Fellow, London School of Economics and Political Science, Grantham Research Institute
- Previous work
  - Assistant prof. at WU Vienna: 2016-2020
  - Postdoc at LSE: 2012-2016
  - PhD in Economics in Pavia: 2008-2012
  - Researcher at New Economics Foundation: 2010-2012
  - MSc Intl. development & cooperation (Pavia: 2005-2007)
  - BSc Economics for intl. institutions (Bocconi: 2000-2005)

A bit more about my work

- Main research focus at the moment:
  - Dynamic links between low-carbon transitions and macro-financial dynamics
  - Policies and institutions for a rapid and smooth decarbonisation
- Main thread: SMOOTH project
  - ERC Starting Grant (2020-25)
  - University of Bologna and European Institute on Economics and the Environment
  - 'Sustainable finance for a smooth low-carbon transition'
  - Link to project website
- Personal research profiles:
  - Personal website
  - Google Scholar
  - ResearchGate

A bit more about UniBo

- Department of Economics
  - Environmental and resources econ cluster. See research profiles
  - Several econ/finance people incorporating climate in their work (e.g. sustainable finance econometricians)
  - Host of the EAERE2022 conference!
  - Teaching: RESD Master programme; other Bologna-based courses (e.g. Environmental Economics and Policy)
- Lots of other climate research at/around UniBo
  - STAT $\rightarrow$ GrEnFin master programme!
  - AlmaClimate interdepartmental centre
  - UniBo research project by SDG
  - Bologna Business School: Initiative for Sustainable Society and Business
  - Euro-Mediterranean Centre on Climate Change (CMCC)
- Strong advice
  - Go explore, meet faculty, attend events

A bit more about you!

- Who are you? What did you study before?
- How much do you know already about climate economics?
- How familiar are you with quantitative methods?
- What are you looking for in this course?

The big picture

Overall object of study

- We will study the interaction between two main 'systems'
  - The climate system
  - The economic system
- Climate system
  - Dynamic planetary system connecting atmosphere, water, ice, land and ecosystems $\rightarrow$ Wider Earth system
  - Existed and evolved even without humans
  - Is climate system changing very rapidly? Yes.
  - Is this change driven by humans? Yes, mostly
- 'Climate'
  - IPCC AR6 definition: Statistical description in terms of mean and variability of relevant quantities over period of time (WMO: 30 years). In wider sense: state of the climate system.

Climatic variables of interest

- Temperature
  - Key variable: mean global temperature
  - Observe change w.r.t. a baseline (e.g. 'pre-industrial levels')
  - Maximum/minimum temperatures
  - Δ Temperature $\rightarrow$ short/long-term feedback effects (e.g. ice melting + ocean warming $\rightarrow$ sea level rise (SLR) for centuries)
- Concentration of greenhouse gases (GHGs)
  - Key GHGs: CO2, CH4, N20
  - Atmospheric GHGs affect Earth's energy balance $\rightarrow$ warming
- Precipitations and humidity
  - Water dynamics: rain, rivers, glaciers
  - Precondition for life, health, agriculture, ecosystems
  - Extreme events: droughts, floods, cyclones
- Oceans
  - Temperature, sea ice concentration, SLR, acidity

How do we study climate?

- Paleoclimatology
  - Tree rings, ice drilling (up to 800ka), marine sediments (up to 100Ma), geomorphology
  - Paleoclimate Modelling Intercomparison Project (PMIP)
- More recently: Instrumental observation
  - Surface stations, weather balloons, satellites..
  - Temperature, GHG concentration, precipitations, sea
- Dynamic models
  - Investigate future scenarios, replicate the past to explain it
  - Several families/generations of climate modelling approaches
  - Strategy: address same questions across models
  - $\rightarrow$ Reference scenarios: RCPs, SSPs, etc.
  - Coupled Model Intercomparison Project (CMIP)

Evidence on climate change

- Key IPCC AR6 conclusions
  - Recent decades: rapid acceleration in climate system changes
  - Unprecedented increase in temperature (1.09°C wrt 1850-1900)
  - Other changes: sea level rise, increase in extreme events, etc.
  - $+$ other Earth system changes ('planetary boundaries')
  - $\rightarrow$ Impacts on human systems
- Where could this lead us?
  - Deep uncertainty about the future
  - Several socio-economic and policy scenarios possible
  - Plus model uncertainty
  - But general scientific consensus: unmitigated climate change might be negative/catastrophic for human societies
  - Current policy consensus: keep temperature below 1.5-2°C

Why is this happening?

- Anthropogenic drivers
  - Observed climate changes cannot be explained by natural phenomena (attribution studies)
  - GHG emissions $\rightarrow$ GHG atmospheric concentration rises $\rightarrow$ Temperature rise $\rightarrow$ Wider climate change
- Where do GHG come from?
  - CO2: combustion of fossil fuels (energy, transport, industry)
  - CH4: livestock and rice production; gas leaks; landfills
  - N20: nitrogen fertilizer use
- Strong increase in GHG emissions
  - Clean technological progress, but..
  - ..overcome by expansion of population and income

How can we adapt to climate change?

- Adaptation
  - React to actual climate changes
  - e.g. how do we protect cities from sea leavel rise?
  - e.g. how do we protect humans/labour from excessive heat?
- Market adaptation strategies
  - Individual market reactions, e.g. install air conditioning
  - Relocation choices: migration, firm relocation
  - Productive links: changing international supply chains
- Adaptation policies
  - Large infrastructure spending, incentivising adaptation choices
  - Problem: technically challenging, expensive, possibly useless
  - e.g. is Miami doomed?
- In any case, still soon to give up $\rightarrow$ mitigation!

How can we mitigate climate change?

- Main goal now:
  - Stabilise GHG concentration in the atmosphere
- Two main ways to achieve this:
  - Stop emitting GHGs
  - Sequester GHGs currently in the atmosphere
- Sequestering GHGs
  - Natural (eg. forests) vs technological (eg. direct air capture)
  - Hard or still far from technological/economic viability
- So, main strategy: reduce GHG emissions
  - First, where do GHG emissions come from?
  - Mainly from combustion of carbon stored in fossil fuels
  - Huge issue: fossil fuels at the very basis of modern human civilization (industry, electricity, transport, etc)

The big project: global decarbonisation

- Transition from carbon-based to carbon-free technologies
  - E.g. electricity productions from coal/gas to solar/wind
  - E.g. vehicle transport from oil to electricity
- Not the first technological transition
  - Many past technological transitions (e.g. lighting: gas→electricity; heating: coal→gas)
  - Generally beneficial for humans: some lose, some win, society progresses
- However, this transition might be different
  - Strong time constraint → more rapid transition
  - Not market-driven: no new more efficient/profitable emerging technology
  - Rather society-driven: painfully pushed via policies
  - Close to technological tipping point?

Do we have alternative technologies available?

- General status: tech still to be improved
  - Some exist, others possibly to come (CCS, fusion, SRM?)
  - Some compete with incumbents, some still not viable
  - Most advanced: Electricity generation from clean renewables
  - .. but: hard-to-abate industry: steel, cement, aluminium, chemicals, shipping, trucking, aviation..
- Key role of technological innovation in low-carbon transition
  - Innovation comes in different forms: market vs state
  - How do make sure it happens?
  - But also: without disrupting an already fragile socio-economic system? $\rightarrow$ transition risks

So, how do we make it happen?

- Push the transition via policies
  - Force/induce individuals to make desired choices
  - Affect all relevant economic choices: consumption, investment spending, financial investments etc.
  - Justified by economic theory when market failures present
- What kind of policies?
  - Command&control: introduce, monitor and enforce rules
  - Change monetary incentives: put a price on it
  - Nudge individuals/firms into desired directions (non-monetary)
- Focus on carbon pricing
  - Key policies: carbon taxes/markets, subsidies
  - Positive but spotty implementation so far
- Focus on finance-related policies
  - Monetary policy, financial regulation
  - New role of central banks and supervisors

What could go wrong?

- Rapid transition comes with its risks
  - Several firms/sectors/countries still very dependent on fossils
  - Changing productive basis can be very costly: new investment expenditure + loss of assets
  - Firms defaulting $\rightarrow$ occupational and demand impacts
  - Financial sector also potentially affected, mainly via firms
- Transition risk research
  - Conceptual frameworks and qualitative research
  - Empirical analysis (data collection, exposure, econometrics)
  - Modelling: find optimal strategies, explore future scenarios
  - Policy and political economy research: who should do what?
- Societal aim:
  - Avoid generalised disruption (a 'Climate Minsky moment' or 'Green Swan')

The big trade-off

- Two seemingly contrasting objectives
  - Limit chances of disruptive climate-driven impacts
  - Limit chances of prosperity loss due to technological transition
- Two extreme scenarios
  - BAU: we continue with fossil-based technologies $\rightarrow$ climate damages
  - Immediate transition: we stop using fossil fuels today $\rightarrow$ economic disruptions and asset stranding
- Window of opportunity
  - A rapid and smooth transition: is it possible?

Who works on climate macro & finance?

- The scientific community
  - Climate/natural scientists, energy modellers, economists and social scientists,..
  - IPCC scientific framework
- Governments
  - Rapid diffusion of climate policies but several obstacles
  - Policy (and societal) short-termism
  - Geopolitical frictions
  - Dependence on materials and energy
- Now also central banks on the macro/financial aspects:
  - Network for Greening the Financial System (NGFS)
  - Technical research from ECB and national EU/non-EU CBs
  - Focus on climate-related financial stability so far

How can economist help?

- Topics
  - Socio-economic/financial impacts of climate change
  - How do we finance a low-carbon transition?
  - Best and feasible policies to implement
  - Socio-economic/financial implications of a transition
  - .. and many variations around this
- Methods
  - Empirical analysis, econometrics
  - Prospective modelling
  - Policy and political economy analysis
  - Behavioural: surveys, experiments, text analysis

Our focus: economic modelling

- Climate economic modelling
  - The father of all IAMs: Nordhaus and the DICE model
  - Large-scale numerical Integrated Assessment Models (IAMs)
  - Computable General Equilibrium (CGE) models
  - Analytical IAMs and economic theory
- Macro-financial modelling of climate/transitions
  - Neoclassical macro applications: Dynamic Stochastic General Equilibrium (DSGE), CAPM, VARs, analytical IAMs again
  - Heterodox macro applications: Stock-Flow Consistent (SFC), Agent-Based Models (ABM)
  - Stress testing and other financial modelling
  - Models with heterogeneous dynamic expectations/beliefs
  - Model ensembles

A number of moving parts to study (I)

- Main economy-climate interactions
  - Economy→Climate: GHG emissions affect climate system dynamics
  - Climate→Economy: Climate impacts (damage functions)
- Zoom in the Economy: 'real' and financial subsystems
  - Non-financial firms combine inputs to produce, invest in new physical capital, requires external finance
  - Financial firms create or reallocate existing credit to non-financial firms, earn a return
  - Both have the shape of large heterogeneous dynamic networks
  - Both can be affected in non trivial ways by climate impacts or transition dynamics

A number of moving parts to study (II)

- Zoom further into the 'real' economic system
  - Dependence on material flows (Daly's pyramid)
  - Long-lived physical capital assets ($\rightarrow$ stranding?)
  - Availability of external finance for new investments
  - How do firms invest?
- Market vs state:
  - Policy-makers and regulators: governments, central banks, financial supervisors etc.
  - Policies for a rapid transition and related obstacles
  - Policy uncertainty and impact on investment decisions
  - Evolving institutional relations

Focus on investment behaviour

- How do individuals/firms invest?
  - Investments in both new capital stock and R&D
  - In principle, cost-benefit analysis of investment options $\rightarrow$ choose the most profitable option, under existing constraints
  - However, future is uncertain! CBA based on expectations
- How do individuals/firms form expectations about the future?
  - Ideally, based on the best available info, but..
  - Incomplete information
  - Behavioural biases
  - And future still uncertain
- Other important choice realms
  - Individuals: consumption, investment of savings, housing
  - Non-financial firms: input providers
  - Financial firms: bank lending, portfolio management
  - State: lending, spending

Focus on financial system

- No finance $\rightarrow$ no transition
  - Investments almost always require external finance
  - Private vs public finance: both necessary
- Key financial system actors
  - Households: accumulate/invest savings; mortgages
  - Banks: lend to households/firms (credit creation)
  - Financial firms: invest money on behalf of clients
  - The ESG craze
- Financial system guardians
  - Central banks: delegation for price/financial stability (or more)
  - Financial supervisors: delegation for consumer protection
  - Nowadays increasingly active in climate-related matters

Conclusions

Conclusions

- Challenging but interesting object of study
  - How do mitigate/adapt to climate change..
  - .. while ensuring human prosperity?
- An economist's perspective
  - Application to economics methods to the topics..
  - .. while keeping an eye on other disciplines (interdisciplinarity)
- Suggestions
  - Follow closely course advancement (attendance, problem sets)
  - Go beyond the course: research, internet, news
  - Ask yourself question, develop your understanding
- Next lecture
  - The past, present and future of climate change