An integrated ABM approach to understanding the impact of pandemics and fiscal stimuli on the economy and climate

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1. **Climate Challenge:** Dealing with climate change is a complicated and long-lasting problem that requires a concerted effort (Bodin, 2017).

2. **Impact of COVID-19:** The global health crisis caused by COVID-19 not only affected public health but also led to economic and financial crises (Brodeur et al., 2021). It also had a significant impact on reducing carbon dioxide (CO_2) emissions, which presented new challenges for policymakers (Diffenbaugh, 2022; Shakil et al., 2020; Mofijur et al., 2021).

3. **Combined Risks:** There are additional risks that arise from both the pandemic and the materialization of climate-related risks (Phillips et al., 2020).
   - Increased Frequency and Intensity of Pandemics
   - Health Impacts
   - Social and Economic Disruptions
   - Infrastructure Challenges and Supply Chain Disruptions
   - Biodiversity Loss and Zoonotic Diseases
   - Inequity and Vulnerable Populations

4. **Missed Opportunities:** On the policy side, most governments appear to have missed the unique and critically important opportunity for promoting green investments or creating favorable opportunities to scale up green finance while tackling the recession and potential instabilities brought about by the pandemic (Hepburn et al., 2020; D'Orazio, 2021).

- Numerous **methodologies** are available to study ways to control and prevent the onset, spread, and resurgence of the COVID-19 pandemic (Gnanvi et al., 2021; Lorig et al., 2021), as well as its economic and environmental impacts (Forster et al., 2020; Shan et al., 2021; Le Quéré et al., 2021; Davis et al., 2022).
- However, existing research often **overlooks the interconnected risks** posed by climate change and the spread of diseases (Diesendorf, 2020; Martin et al., 2021; Ranger et al., 2021).
- It is crucial to **incorporate pandemic research into a broader framework** that addresses significant concerns related to the macro-financial impacts of climate-related risks (D'Orazio, 2021, 2023; Dunz et al., 2021).

- **Agent-Based Modeling (ABM) Approach for Disease Spread:**
  - Valuable for simulating the spread of diseases like COVID-19 by representing individual agents and their interactions with each other and the environment (Epstein, 2009; Currie et al., 2020; Gog, 2020).
  - Enables the study of policy impact on disease spread, potential outbreaks, and intervention effectiveness (Rockett et al., 2020; Squazzoni et al., 2020).
- **ABM Approach for Climate Change Modeling:**
  - Effective for modeling climate change and its effects on economic and climate dynamics (Gerst et al., 2013; Chappin et al., 2017; Savin et al., 2023).
  - Provides a more accurate depiction of micro-level behavior (heterogeneity and interaction) compared to traditional climate policy models (Farmer et al., 2015; Castro et al., 2020).

Our contribution: the CliMaPanLab

A modeling framework that integrates the (macro)economy and financial dynamics, a climate module, and accounts for the endogenous emergence of infectious diseases like the most recent COVID-19 pandemic.

- **Software**: A user-friendly toolbox for simulating and analyzing complex agent-based models.
  - **Built on AgentPy package**: Provides a flexible framework for designing and executing simulations.
  - **Efficient Processing**: Implements parallel thread processing to optimize CPU usage, overcoming multi-threading limitations of AgentPy.
- **Core Components**: Agents serving as building blocks, adaptable to various environments (e.g., networks).
- **Agent Heterogeneity and Behavior**: Determined by simulation models, defining logic and data flow for interactions.
- **Scenario Analysis**: Simulation experiments with different parameter settings and constellations for understanding model behavior under varied conditions.
- **Output Analysis**: Graphs aid quick identification and diagnosis of simulation issues.
- **Data Export**: Resulting data can be easily exported as CSV files for further analysis and visualization.
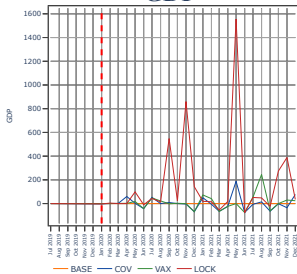
The model
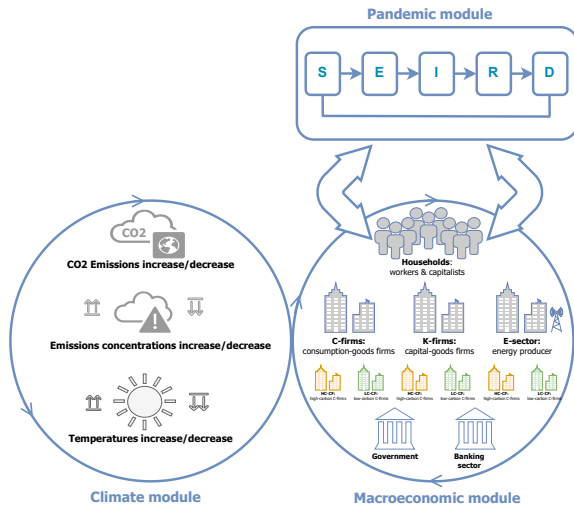
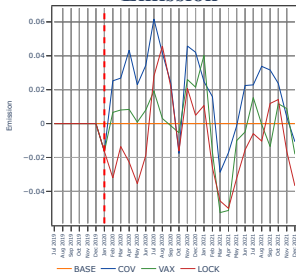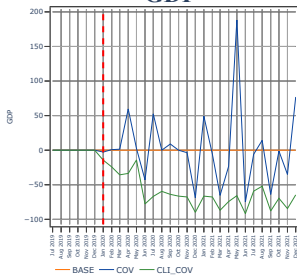# Pandemic diffusion: impacts of NPIs and vaccines

Evolution of Infection
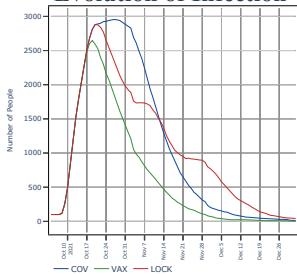
GDP

Emission

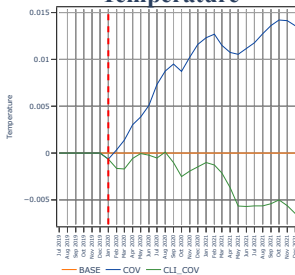# Joint materialization of climate shock and pandemic diffusion
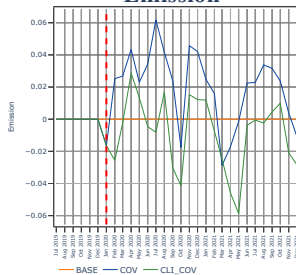
Impacts of "green" policymaking
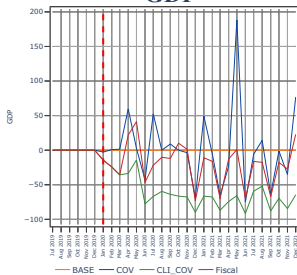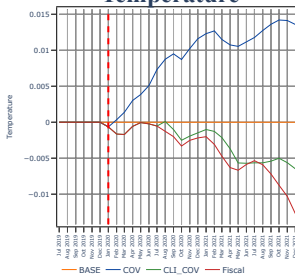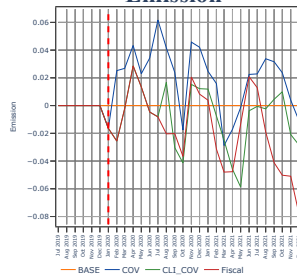
Concluding remarks I

- **Context:** Compound events involving climate risks and public health crises can lead to nonlinear amplification effects on vulnerable populations and economies (Diesendorf, 2020; Mahul and Signer, 2020; Simonovic et al., 2021).
- **Magnification Effect:** The magnification effect occurs when the combined impact of multiple shocks exceeds the sum of their individual effects (Phillips et al., 2020).
- **Importance of Understanding Connections:** Ignoring these interconnections and their compounding consequences can result in underestimating risks and crafting ineffective policies (Hoffart et al., 2022, 2023).

Concluding remarks (II)

- **Our Contribution:** We have developed a modeling framework and sophisticated simulation tool that integrates macro-economy and financial dynamics, a climate module, and accounts for the endogenous emergence of infectious diseases such as the recent COVID-19 pandemic.
    - **Comprehensive Understanding:** Integrating pandemic and climate risk dynamics offers a holistic perspective, acknowledging the interplay between environmental, societal, and economic factors.
    - **Detailed Analysis:** The Agent-Based Modeling (ABM) approach allows us to account for individual agents' behaviors, introduce local interaction rules, study the natural evolution of the disease by accounting for the individual properties of the agents, and investigate the interaction of the pandemic's dynamics with the economy and the climate module.
    - **Informed Policy-Making:** Policies can be crafted to balance pandemic control and climate mitigation efforts, ensuring effective strategies that address both challenges simultaneously.

Future research

- Continue developing the model.
- Add a behavioral framework for compliance with pandemic-related interventions (Alfers and D'Orazio, 2023).
- Add extra tests for validation and sensitivity analyses.
- Validate the COVID module empirically in a specific country context (analysis of developed vs developing economies).
- Work on longer horizons to study how to achieve short-term economic recovery while boosting longer-term sustainability.

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References I

Alfers, M. and P. D'Orazio (2023). Modeling the impact of social and behavioral factors on the spread of infectious diseases in a macro-financial agent-based model: A methodological proposal. *Working paper*.

Bodin, Ö. (2017). Collaborative environmental governance: achieving collective action in social-ecological systems. *Science 357*(6352), eaan1114.

Brodeur, A., D. Gray, A. Islam, and S. Bhuiyan (2021). A literature review of the economics of covid-19. *Journal of Economic Surveys 35*(4), 1007–1044.

Castro, J., S. Drews, F. Exadaktylos, J. Foramitti, F. Klein, T. Konc, I. Savin, and J. van den Bergh (2020). A review of agent-based modeling of climate-energy policy. *Wiley Interdisciplinary Reviews: Climate Change 11*(4), e647.

Chappin, E. J., L. J. de Vries, J. C. Richstein, P. Bhagwat, K. Iychettira, and S. Khan (2017). Simulating climate and energy policy with agent-based modelling: The energy modelling laboratory (emlab). *Environmental modelling & software 96*, 421–431.

Currie, C. S., J. W. Fowler, K. Kotiadis, T. Monks, B. S. Onggo, D. A. Robertson, and A. A. Tako (2020). How simulation modelling can help reduce the impact of covid-19. *Journal of Simulation 14*(2), 83–97.

References II

Davis, S. J., Z. Liu, Z. Deng, B. Zhu, P. Ke, T. Sun, R. Guo, C. Hong, B. Zheng, Y. Wang, et al. (2022). Emissions rebound from the covid-19 pandemic. *Nature Climate Change 12*(5), 412–414.

Diesendorf, M. (2020). Covid-19 and economic recovery in compliance with climate targets. *Global Sustainability 3*.

Diffenbaugh, N. S. (2022). Covid-19 and the environment: Short-run and potential long-run impacts. *Annual Review of Environment and Resources 47*, 65–90.

Dunz, N., A. Mazzocchetti, I. Monasterolo, A. Hrast Essenfelder, and M. Raberto (2021). Macroeconomic and financial impacts of compounding pandemics and climate risks. *Available at SSRN 3827853*.

D'Orazio, P. (2021). Towards a post-pandemic policy framework to manage climate-related financial risks and resilience. *Climate Policy 21*(10), 1368–1382.

D'Orazio, P. (2023). Climate change and macro-financial risks: financial policy responses for an orderly low-carbon transition. *Environmental Research: Climate 2*(1), 013002.

Epstein, J. M. (2009). Modelling to contain pandemics. *Nature 460*(7256), 687–687.

Farmer, J. D., C. Hepburn, P. Mealy, and A. Teytelboym (2015). A third wave in the economics of climate change. *Environmental and Resource Economics 62*(2), 329–357.

References III

Forster, P. M., H. I. Forster, M. J. Evans, M. J. Gidden, C. D. Jones, C. A. Keller, R. D. Lamboll, C. L. Quéré, J. Rogelj, D. Rosen, et al. (2020). Current and future global climate impacts resulting from covid-19. *Nature Climate Change 10*(10), 913–919.

Gerst, M. D., P. Wang, A. Roventini, G. Fagiolo, G. Dosi, R. B. Howarth, and M. E. Borsuk (2013). Agent-based modeling of climate policy: An introduction to the engage multi-level model framework. *Environmental modelling & software 44*, 62–75.

Gnanvi, J. E., K. V. Salako, G. B. Kotanmi, and R. G. Kakaï (2021). On the reliability of predictions on covid-19 dynamics: a systematic and critical review of modelling techniques. *Infectious Disease Modelling 6*, 258–272.

Gog, J. R. (2020). How you can help with covid-19 modelling. *Nature Reviews Physics 2*(6), 274–275.

Hepburn, C., B. O'Callaghan, N. Stern, J. Stiglitz, and D. Zenghelis (2020). Will covid-19 fiscal recovery packages accelerate or retard progress on climate change? *Oxford Review of Economic Policy 36*(Supplement_1), S359–S381.

Hoffart, F. M., P. D'Orazio, F. Holz, and C. Kemfert (2023). Uncovering the nexus between fossil-based energy security, financial policies, and climate and energy transition risks: Insights from a german economic case study. *working paper*.

References IV

Hoffart, F. M., P. D'Orazio, and C. Kemfert (2022). Geopolitical and climate risks threaten financial stability and energy transitions. *Energy 2004*, 2965.

Le Quéré, C., G. P. Peters, P. Friedlingstein, R. M. Andrew, J. G. Canadell, S. J. Davis, R. B. Jackson, and M. W. Jones (2021). Fossil co2 emissions in the post-covid-19 era. *Nature Climate Change 11*(3), 197–199.

Lorig, F., E. Johansson, and P. Davidsson (2021). Agent-based social simulation of the covid-19 pandemic: A systematic review. *JASSS: Journal of Artificial Societies and Social Simulation 24*(3).

Mahul, O. and B. Signer (2020). The perfect storm: How to prepare against climate risk and disaster shocks in the time of covid-19. *One Earth 2*(6), 500–502.

Martin, M. A., O. A. Sendra, A. Bastos, N. Bauer, C. Bertram, T. Blenckner, K. Bowen, P. M. Brando, T. B. Rudolph, M. Büchs, et al. (2021). Ten new insights in climate science 2021: a horizon scan. *Global Sustainability 4*.

Mofijur, M., I. R. Fattah, M. A. Alam, A. S. Islam, H. C. Ong, S. A. Rahman, G. Najafi, S. F. Ahmed, M. A. Uddin, and T. M. I. Mahlia (2021). Impact of covid-19 on the social, economic, environmental and energy domains: Lessons learnt from a global pandemic. *Sustainable production and consumption 26*, 343–359.

References V

Phillips, C. A., A. Caldas, R. Cleetus, K. A. Dahl, J. Declet-Barreto, R. Licker, L. Merner, J. P. Ortiz-Partida, A. L. Phelan, E. Spanger-Siegfried, et al. (2020). Compound climate risks in the covid-19 pandemic. *Nature Climate Change 10*(7), 586–588.

Ranger, N., O. Mahul, and I. Monasterolo (2021). Managing the financial risks of climate change and pandemics: What we know (and don't know). *One Earth 4*(10), 1375–1385.

Rockett, R. J., A. Arnott, C. Lam, R. Sadsad, V. Timms, K.-A. Gray, J.-S. Eden, S. Chang, M. Gall, J. Draper, et al. (2020). Revealing covid-19 transmission in australia by sars-cov-2 genome sequencing and agent-based modeling. *Nature medicine 26*(9), 1398–1404.

Savin, I., F. Creutzig, T. Filatova, J. Foramitti, T. Konc, L. Niamir, K. Safarzynska, and J. van den Bergh (2023). Agent-based modeling to integrate elements from different disciplines for ambitious climate policy. *Wiley Interdisciplinary Reviews: Climate Change 14*(2), e811.

Shakil, M. H., Z. H. Munim, M. Tasnia, and S. Sarowar (2020). Covid-19 and the environment: A critical review and research agenda. *Science of the Total Environment 745*, 141022.

References VI

Shan, Y., J. Ou, D. Wang, Z. Zeng, S. Zhang, D. Guan, and K. Hubacek (2021).
Impacts of covid-19 and fiscal stimuli on global emissions and the paris agreement.
Nature Climate Change 11(3), 200–206.

Simonovic, S. P., Z. W. Kundzewicz, and N. Wright (2021). Floods and the covid-19
pandemic—a new double hazard problem. *Wiley Interdisciplinary Reviews:
Water 8*(2), e1509.

Squazzoni, F., J. G. Polhill, B. Edmonds, P. Ahrweiler, P. Antosz, G. Scholz, É. Chappin,
M. Borit, H. Verhagen, F. Giardini, et al. (2020). Computational models that matter
during a global pandemic outbreak: A call to action. *Journal of Artificial Societies and
Social Simulation 23*(2).