An AB-SFC model of finance, technological diffusion, and the low-carbon transition

Alessandro Caiani[a], Teresa Felici[a], Jessica Reale[a,b,*]

[a] *University School of Advanced Studies (IUSS) Pavia*
[b] *Computational and Quantitative Methods, School of Business and Management, Queen Mary University of London*

Abstract

The rapid adoption of new green technologies is necessary to address the climate crisis (IPCC, 2011; IPCC, 2023). New technologies typically come alongside other innovations, leading to the emergence of "techno-economic paradigms" that drive new markets, transform production and institutional procedures, and impact the governance of economic systems (Freeman and Louçã, 2001; Perez, 2003; Hall, 2006). Promoting a green transition may thus represent an attempt to foster a new techno-economic paradigm rooted in low-carbon technologies. However, unlike past techno-economic paradigms that naturally evolved through extensive exploration of alternatives and market selection processes, the urgent climate threat demands ways to expedite this process. Reallocating financial capital towards zero and negative emission technologies could accelerate the transition (Mazzucato and Penna, 2015; Schmidt, 2014). However, the evolution of eco-friendly technologies is often unpredictable and marked by significant fluctuations in returns, leading investors to favor fossil-fuel-based technologies and ultimately hindering the transition to green ones (Demirel and Parris, 2015; Polzin, 2017). While recent contributions account for the accumulation of technology-specific knowledge and its role in green innovation (Hötte, 2020, 2021), they do not focus on the drivers of financial investment in the green energy sector. As such, the complex interplay between the diffusion of green technologies and investment decisions is still understudied.

Against this backdrop, we develop a macroeconomic agent-based model of technological diffusion featuring green vs. dirty techno-economic paradigms which interact with and are affected by investors' capital allocation. We focus on the feedback relations among technological innovation, demand and finance (Caiani et al., 2014) and use this model to study how the position in the technological landscape may affect investors' portfolio decisions, firms' access to finance, and ultimately the speed of the transition.

The adoption of new technologies typically follows an S-shaped pattern, which includes phases of emergence, diffusion and exhaustion (Arthur, 1989; Geroski, 2000; Hall, 2006; Mercure, 2015). The same pattern also characterizes energy technologies (Wilson, 2012). To capture this, we consider various types of technologies that differ in (i) the level of diffusion – i.e., whether they are already mature or in development or an exploratory phase – (ii) the inputs of production (labor and/or energy sources), and (iii) the variability of production, smooth vs. cyclical. These factors then impact the expected returns of a specific plant over its lifetime and thus the rate of adoption of alternative technologies (Mercure and Salas, 2012). In our model, energy firms can adopt multiple technologies and issue both green and dirty stocks accordingly. Households then invest in the energy sector and manage their portfolio à la Tobin (Brainard and Tobin, 1968; Backus et al., 1980; Godley and Lavoie, 2016; Caiani et al., 2014). They thus distribute their financial wealth across different assets - such as bonds and green vs. dirty equities - after comparing their relative expected returns. While a traditional "dirty" technology may be mature and produce relatively predictable future returns, a "green" one may still be in its exploratory-incubation stage, with low diffusion, high unpredictability of future trajectories, and thus higher volatility of returns. However, the flow of investment towards green technologies and their adoption rate is anchored to investors' expectations – influenced by uncertainty in technology and climate policies – and their ex-ante preferences for different financial stocks.

Our agent-based model features heterogeneous investors with diverse expectation formation (rational, adaptive, naive) and multiple energy firms with heterogeneous technologies. This dual level of heterogeneity may result in intertwined feedback mechanisms, potentially yielding outcomes that are unforeseen within aggregate macroeconomic models.

We plan to simulate the model across various policy scenarios to assess how investors react to policy changes, while also accounting for the uncertainty faced by climate policy-makers, the credibility of policy claims and its implications for investment decision-makers (Mercure et al., 2016). These scenarios include implementing a carbon tax and other industrial and innovation policies identified as contributors to cost reductions in renewable

*Corresponding author. University School of Advanced Studies (IUSS) Pavia, Piazza della Vittoria 15, Pavia 27100, Italy. *Email address*: jessica.reale@iusspavia.it

energy (IPCC, 2023). We expect the simulations to provide insights into the theoretical conditions supporting the rapid development and diffusion of green technologies.

Keywords: Climate finance, Innovation, Technological change, Low carbon transition, Complex systems

---

References

Arthur, W. B. (1989). Competing Technologies, Increasing Returns, and Lock-In by Historical Events. *The Economic Journal 99*(394), 116–31.

Backus, D., W. C. Brainard, G. Smith, and J. Tobin (1980). A model of US financial and nonfinancial economic behavior. *Journal of Money, Credit and Banking 12*(2), 259–293.

Brainard, W. C. and J. Tobin (1968). Pitfalls in financial model building. *The American economic review 58*(2), 99–122.

Caiani, A., A. Godin, and S. Lucarelli (2014). Innovation and finance: a stock flow consistent analysis of great surges of development. *Journal of Evolutionary Economics 24*(2), 421–448.

Demirel, P. and S. Parris (2015). Access to finance for innovators in the UK's environmental sector. *Technology Analysis & Strategic Management 27*(7), 782–808.

Freeman, C. and F. Louçã (2001). *As Time Goes By: From the Industrial Revolutions to the Information Revolution.* Oxford University Press.

Geroski, P. (2000). Models of technology diffusion. *Research Policy 29*(4), 603–625.

Godley, W. and M. Lavoie (2016). *Monetary Economics: An Integrated Approach to Credit, Money, Income, Production and Wealth.* Springer.

Hall, B. H. (2006). Innovation and Diffusion. In *The Oxford Handbook of Innovation*, pp. 459–484. Oxford University Press.

Hötte, K. (2020). How to accelerate green technology diffusion? Directed technological change in the presence of coevolving absorptive capacity. *Energy Economics 85*, 104565.

Hötte, K. (2021). Skill transferability and the stability of transition pathways. A learning-based explanation for patterns of diffusion. *Journal of Evolutionary Economics 31*, 959–993.

IPCC (2011). *IPCC Report on Renewable Energy Sources and Climate Change Mitigation.* Cambridge University Press. Ottmar Edenhofer, Ramón Pichs-Madruga, Youba Sokona, Kristin Seyboth, Patrick Matschoss, Susanne Kadner, Timm Zwickel, Patrick Eickemeier, Gerrit Hansen, Steffen Schloemer, Christoph von Stechow (Eds.).

IPCC (2023). *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* IPCC. Core Writing Team, H. Lee and J. Romero (eds.).

Mazzucato, M. and C. Penna (2015). The Rise of Mission-Oriented State Investment Banks: The Cases of Germany's KfW and Brazil's BNDES. SPRU Working Paper Series, 2015–26.

Mercure, J.-F. (2015). An age structured demographic theory of technological change. *Journal of Evolutionary Economics 25*(4), 787–820.

Mercure, J.-F., H. Pollitt, A. M. Bassi, J. E. Viñuales, and N. R. Edwards (2016). Modelling complex systems of heterogeneous agents to better design sustainability transitions policy. *Global Environmental Change 37*, 102–115.

Mercure, J.-F. and P. Salas (2012). An assessement of global energy resource economic potentials. *Energy 46*(1), 322–336.

Perez, C. (2003). *Technological Revolutions and Financial Capital.* Edward Elgar Publishing.

Polzin, F. (2017). Mobilizing private finance for low-carbon innovation – A systematic review of barriers and solutions. *Renewable and Sustainable Energy Reviews 77*, 525–535.

Schmidt, T. S. (2014). Low-carbon investment risks and de-risking. *Nature Climate Change 4*(4), 237–239.

Wilson, C. (2012). Up-scaling, formative phases, and learning in the historical diffusion of energy technologies. *Energy Policy 50*, 81–94. Special Section: Past and Prospective Energy Transitions - Insights from History.