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Beyond standard economic approaches: complex networks in climate finance

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Beyond standard economic approaches: complex networks in climate finance

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Abstract
The financial system is a key tool to enable the shift towards a climate-smart economy: by reallocating capital to low-carbon assets, it internalizes the climate externality. However, the financial sector operates as an ecosystem of evolving agents continuously shaping the outcomes they jointly generate. Hence, the consequences of global warming and the climate impacts are potentially amplified by the micro and meso dynamics of agents interacting with each other and with technologies and institutions in the space they operate. In this working paper, we present a concise but exhaustive review about complex networks models and methods applied to climate finance. We show where networks can overcome the limitations of standard economic models in both macroprudential regulation and capital allocation. We present the main challenges ahead and we discuss the importance of a renewed research-policy dialogue to advance the discipline.

Keywords
Complex networks, climate finance, complexity economics, energy transition, climate change

JEL Codes
F21, F64, F65, O13, O16, P18

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Introduction

Climate represents a major challenge for both current and future generations. It imposes economic costs beyond the standard operation time of traditional actors. As such, it is "the tragedy of the horizon" (Carney 2015). The international and scientific community recognized the urgency to tackle climate change since long time. The Intergovernmental Panel on Climate Change (IPCC) collected the physical evidence and flagged some of the most prominent solutions in its Working Group III report. Since 2015, finance has gained a prominent role in academic and policy discussions. In particular, finance has been identified as an effective tool to promote a progressive, fast and coordinated transition towards a low-carbon global economy (UNFCCC, 2015; United Nations, 2015). On one hand, financial supervisors and financial institutions recognized that the sustainability transition requires a system-wide structural change (Financial Stability Board (FSB) 2015; Visco 2020). On the other, the transition can only be realized through the deployment of an unprecedented amount of financial resources. It has been shown that simply doubling the share of renewables in the global energy mix by 2030 will require an annual investment of $770 billion between 2016 to 2030 and this amount could double or treble for pathways consistent with a global warming target of 1.5°C (McCollum et al. 2018).

Traditional economic approaches have typically ignored or underrepresented the role of financial markets in decarbonization pathways failing to capture the economy and society in their full complexity. Speaking at the ECBs flagship annual Central Banking Conference in 2010, Governor Jean-Claude Trichet highlighted that "available models are of limited help" in designing the strategy to overcome the financial crisis. Evidence of how "complex and chaotic […] systems had become" require empirical understanding of "how things can cascade" (interview with Ben Bernarke, the IHT May 2010). Climate change introduces many more complexity layers and – beyond that – an important inter-generational mechanism, which further enhances the challenge in the present to meet uncertain future needs. Identifying dynamic real-world solutions that can be translated to effective policy impose new ways of thinking about economic and financial systems and how order from such systems emerges from the interactions of their adaptive components (Arthur 2010, 2021). Complexity-driven approaches augment standard economic analysis with perspectives from behavioral, institutional, and evolutionary economics to identify how macro trends at system level arise as a result of behavior of individual actors (Beinhocker 2006). Emergent investment patterns are the result of the combination of such elements, which would be hard to predict when analysing the various elements in isolation.

When it comes to the study of the financial system for climate action, complexity is a paradigm shift in two major areas: macroprudential policies, and optimal capital allocation in both mitigation and adaptation options. The former involves the quantitative identification of the systemic risks that may harm globalized and interlinked economic activities (Battiston et al. 2017, 2021b). The latter studies the size and the direction of financial flows to understand how different actors, market channels and conditions lead to a just, quick and effective transition towards a climate-resilient economy (Naran et al. 2020). Analyses accounting for existing spillovers among different economic sectors, their players and interactions, are vital for policy design to monitor and influence the way financial markets could pool long-term financial assets to boost the low-carbon transition.

Setting the problem

According to the IPCC, climate change is linked to changes in frequency and magnitude of extreme weather and climate events (Seneviratne et al., 2012). Extreme events are "tail risks", which are often ignored by economists (Weitzman 2011). This research gap becomes huge in practice and policy design, since scholars have proved that the economic damages from extreme events have mounted overtime (Coronese et al. 2019). As financial systems are highly interconnected, "based on interdependence of multiple actors and counterparties"[1], extreme events' impacts transmit through these networks, impacting the structure and organization of the overall system (Helbing 2013). Hence, it becomes important to identify the potential channels through which climate risks can affect the financial system, along with their nature and impacts. For instance, financial stability may be threatened by physical and transition risks producing non-linear and discontinuous impacts. Combined with uncertainties concerning timing, location and breadth, the existence of climate-related risks – often acting in tandem – limits the ability of economic agents to price them. Ultimately, this might also amplify the impacts of climate-related risks within the financial system (Mandel 2020).

In addition to assess and manage climate-related risks, achieving a just energy transition will also require the shift towards low-carbon production processes. Renewable energy technologies are crucial to achieve this goal. While their cost-effectiveness is improving (IEA, 2020), the diffusion of low-carbon technologies is uneven and strongly depends on favorable local market conditions (Pohl and Mulder 2013). Finance enables the shift from a fossil-intensive economy to a low-carbon one, and understanding the direction of flows, the pace and related scale, is crucial to make global climate progresses. Knowledge about the architecture of the financial systems and the actors involved becomes even more pressing if we consider that already vulnerable countries may raise their public debt to enact the energy transitions[2]. The type of financial instruments, financing conditions, and actors involved are essential features of a just and fair climate transformation.

New approaches to inform policies and chart a complex landscape

Standard economic models and traditional approaches to finance tend to disregard the complexity generated by the interaction between sectors, agents, countries and policies. The economy is typically represented as a system in equilibrium, where climate becomes an additional constraint to the optimized behaviour of a social planner. These traditional approaches are encapsulated within the Integrated Assessment Models (IAMs) developed by the 2018 Nobel Prize awardee William Nordhaus. IAMs do not include the financial sector as a key variable. Hence, they consider finance as immediately usable and infinite in levels. Furthermore, IAMs structurally consider technology and productivity as exogenous variables and they miss distributional issues of the impacts (Pollitt and Mercure 2018). These motivations lead to new research avenues and approaches capable of providing policy-relevant insights and maximising the efforts to drive a systemic and climate-friendly transformation.

On the finance side, complexity approaches can enhance the role of the financial system to manage climate risks. For instance, the Network for Greening the Financial System (NGFS) elaborated a framework to guide private and public financial institutions in identifying and measuring physical and transition risks. The physical risk refers to the measurable impact of climate on assets and people. The transition risk is associated with the risks arising from the changes required to make the transition towards a low-carbon future (Reisinger et al. 2020). Guidelines of the NGFS prescribe the use of scenario analysis and climate stress-tests to assess the macro-financial impacts of climate change. For instance, climate stress-test helps to quantify the response of the financial system to climate policy risks (Battiston et al. 2017). They account for financial dependencies, acknowledging that linkages between financial institutions can accentuate positive and negative shocks. Such novel models rooted in complexity science offer a new opportunity to detect and evaluate the reaction of global financial chains to extreme events and how they propagate in the system (Otto et al. 2017).

Network models are also helpful in scaling up green finance to support the global energy transition. By signing the Paris Agreement, parties have agreed to a new collective goal to provide climate finance at a floor of USD

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[1] Remarks by Mr Jean-Pierre Landau, Deputy Governor of the Bank of France, at the conference on extreme events jointly organised by the Bank of France and the Toulouse School of Economics (TSE), Paris, 3 September 2008 (here)
[2] As already pointed out by the International Monetary Fund in the 2nd Finance Ministers and Central Bank Governors Meeting, April 7th 2021

100 billion per year and to further provide capacity building and technology transfers to developing nations. While increasing the amount of resources devoted to a climate-friendly systemic transformation is essential, understanding the architecture of the financial system is crucial to understand the distributional effects of aggregate climate finance and reach the most vulnerable areas of the planet. Networks capture, model and ultimately forecast the links between different nations and assess if these transfers are taking place. Examples of their use (Naran et al. 2020) serve to monitor the respect of the Paris Agreement and include policy insights to align global, regional and national priorities to the common goal of a decarbonized economy.

The ability of network approaches to capture transmission of shocks and direction of financial flows represents a valuable asset for both research and policy in climate finance, while also accounting for the relevant variables that make the transition to a sustainable economy possible.

Structuring the research-policy dialogue to build up on progresses

Despite their relevance, network and complexity-derived models suffer from limitations that have to be considered. First, the relationship between climate-related risks, the economy and finance is still poorly understood. Networks help in uncovering the amplification of impacts and support a better understanding of the systemic nature of risks (Acemoglu et al. 2015). However, there is still little empirical evidence about the channels that may prevent these amplified loops from becoming chaotic, especially under a changing climate.

Second, financial and investment data gaps due to confidentiality issues hamper the possibility to truly capture the heterogeneity of investors' preferences for different technologies and projects, the dynamism of their behaviour in the context of an evolving technological and economic environment, their inter-connections and relationships, and their overall influence in the financial system. These aspects of the financial system determine the quantum of financing, the sources and channels of investments, the direction of technological change and technology selection, as well as the overall speed of low-carbon transition. This is why it is essential to incorporate them in economic analyses and models of low-carbon transition that inform policy design.

Finally, climate finance policies and regulations are still "in progress" and more time is needed before a full assessment of current efforts and conduct rigorous modelling analyses to explore whether specific architectures of finance systems have significant impact on the effectiveness of climate public policies.

There is a pressing need for new frameworks dealing with the inherent complexity of the financial system. When it comes to climate change, the challenge is even bigger, posing structural modification to the status quo. The use of complexity-driven approaches which integrate the aspects of evolutionary path-dependence, non-linear system dynamics, heterogeneity, network structures, role of institutions, social forces and technological change in a single encompassing paradigm, offers more scope to reflect the reality than standard economic models. They help in reconsidering the interplay between technological progress, finance and energy systems in the context of heterogenous agents.

These approaches call for improved models and increased transdisciplinarity. The advancements in computational power, the progresses in machine learning and artificial intelligence expand the range of opportunities researchers can explore. At the same time, diverse approaches that belong to different disciplines and research communities can join forces to tackle a common problem. This is why a tighter collaboration between natural scientists and economists can "broaden economists' horizons" (Carney 2015).

Conclusions

As we move towards committed action to stop global warming and meet the Paris targets, new approaches to inform science-based policies are needed. Finance is a tool to accelerate the transition towards a transformed and climate-neutral economy and to make it just and inclusive for all.

While research has acknowledged the complexity behind the human-nature relationship, more must be done to fully represent systemic consequences of our actions. Climate finance is no different: economic agents, sectors and countries impact and are impacted by climate-related risks. Networks and complexity-rooted approaches help describing these dynamics by fully accounting for the interactions that lead to emerging properties of the system. Climate is a systemic challenge to the humankind and represents a structural discontinuity with previous times. Both macro (such as financial stability) and micro economic implications should be better represented by research efforts.

Complexity-driven approaches will provide new insights on the direction of investments in low-carbon technologies, hence pushing for improved monitoring and assessment methods of the progresses. Furthermore, by accounting for the interlinkage of heterogenous investors in the market, we will be able to better represent disruptive cascade effects of climate-related shocks. Afterall, the economy is nothing but the outcome of a set of strictly connected set of local choices with potentially harmful global effects. It is the case of the global chip industry[3], currently under stress due to a prolonged drought in the champion producer country, Taiwan. Crises like this one force countries to rethink about their production chains and priority sectors hampering the benefits derived from trade and competitive advantages.

Across the frontiers of science, complex systems approaches can help us in charting the challenges we are asked to face. Quoting Stephen Hawking, this is “the century of complexity”. Beyond complicated problems and apparently chaotic dynamics, embracing complexity – rather than disregarding it – should be the way.

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[3] See https://www.bloomberg.com/opinion/articles/2021-02-25/making-chips-requires-lots-of-water-and-gulp-taiwan-has-a-drought

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