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Driving sustainability transitions through financial tipping points

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Abstract

Achieving a net-zero carbon economy requires significant structural changes in the financial system, including a substantial shift in investment towards low-carbon assets. Through the alignment of expectations, promotion of herding behavior, utilization of public finance, reduction of capital costs and attainment of low-carbon investment thresholds in developing nations, and implementation of robust financial regulations and policies, the financial system can assume a central role in re-orienting economies onto a net-zero course. Taken together, such mechanisms highlight the positive tipping points that can be triggered within sustainable finance and emphasize the necessity of policy interventions to activate and capitalize on these dynamics. The identification and activation of critical and positive tipping points can lead to the amplification of sustainable investments and foster transformative changes in the practices of the financial sector.

Keywords

Sustainable finance, tipping point, expectations alignment, feedback loop, path-dependency, investment threshold and dynamics, herding behavior, financial regulation and policies

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1. Introduction

The transition to a net-zero carbon economy entails a large-scale structural change where investment in low-carbon (zero and negative emission) assets would need to scale up, while shifting away from carbon-intensive activities (Kreibiehl et al. 2022; Pauw et al. 2022). Financial markets have a critically important role to play in this shift as providers of the needed capital. They would need to move beyond their focus solely on risk and return opportunities and incorporate sustainability considerations across relevant aspects of central banking, supervision, regulation, and market practices (Chenet 2023).

In the late 2000s the financial sector was largely absent from the climate change discussion. Back in 2005, the most proactive banks were proudly reporting on the efficiency of their light bulbs and reducing business trips, without mentioning the detrimental consequences of their increasing lending to fossil fuels companies.[1] An important milestone was the 2015 Paris Agreement (PA), which explicitly acknowledged the role of finance in addressing climate change through Article 2.1(c) (Zamarioli et al. 2021). Although its full implementation is still pending, it triggered a new institutional regime and narrative related to finance and climate change. In the same year, Mark Carney's speech on financial stability and the risks associated with climate change (Carney, 2015) spurred the 'financial risk' side of the story. By highlighting the urgency for financial institutions to adopt climate risk management and reporting measures 'before it's too late', Carney catalyzed an unprecedented move in finance. Fully establishing transparency across the financial system became a prime goal of policy, financial regulation and industry efforts in the climate finance arena (Ameli et al 2021a).

In the more recent years, the establishment of initiatives like the Glasgow Financial Alliance for Net Zero (GFANZ) and the Network for Greening the Financial System (NGFS), demonstrates the growing commitment of financial institutions and central banks to align themselves with climate targets, beyond their traditional remit. GFANZ signatories committed to reach net-zero carbon emissions by 2050, in a manner that is in line with the 1.5°C target (e.g., with limited temperature overshoot and using existing technologies). This marked the first instance in which financial institutions committed and pledged to a real alignment with climate targets. NGFS opened a new governance framework to better coordinate and regulate the role of finance in addressing climate change. However, it also raises the question of whether monetary and supervisory authorities (which are primarily non-democratically elected bodies) should interfere on economic orientation, technological and societal choices, as well as the articulation with governments and their (lack of) decisions on the matter.

This sequence of events can be viewed as the initial catalyst for challenging current practices in the financial system, prompting financial actors to embark on a different path in terms of changing their investment outlays (Farmer et al. 2019). These initial shifts have the potential to cross critical thresholds (e.g. "tipping points"), where a relatively small alteration can trigger a larger and systemic change, and where nonlinear feedback effects act as amplifiers (Lenton et al. 2022). By influencing the allocation of capital to different sectors or activities, the financial system has the power to affect the evolution and composition of the real economy.

[1] See e.g. BNP Paribas Annual Report 2005 - https://invest.bnpparibas/en/document/annual-report-2005

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In a variety of historical episodes, the financial system has acted as an amplifier of oscillations, both positive and negative. This phenomenon is commonly referred to as the "financial accelerator" (Bernanke et al. 1999; Delli Gatti et al. 2010), which describes how developments in financial markets amplify and propagate the effects of minor changes in the economy. For example, bursts of financial bubbles have triggered uncertainty, instability, contagion among financial actors, and feedback loops with ripple effects on the real economy, even though the initial shock was not particularly severe. The Global Financial Crisis of 2008 is a prominent example of such a negative shock. On the other hand, financial accelerators have the potential to amplify positive shocks through, for example, mechanisms which dampen the financial fragility of firms operating in the real economy, enhancing the effects of innovation and its diffusion, resulting in positive outcomes in the medium and long run (Lamperti et al. 2021). Similarly, favorable financial conditions can magnify the impact of policies aimed at sustaining aggregate demand, creating significant synergies between prudential, fiscal, and monetary measures.

Finance can also have a more direct impact on the real economy. Following Perez (2003), financial actors play a central role in enabling technological revolutions by actively contributing to the advancement and implementation of innovative processes, technologies and services, extending their involvement beyond simply providing funds. In fact, they often take part in the management of the innovation process, assuming the role of financial entrepreneurs and 'picking winners'. On the other hand, financial markets have a tendency to replicate the economy as it is and resist making potentially costly new decisions. Driven by backward looking indicators, financial actors are still allocating capital to fossil fuels assets, thus creating carbon lock-ins (Chenet et al. 2021). Finance thus has the capacity to expedite or impede the dissemination of new products and technologies, particularly those of utmost importance for the transition to a low-carbon future. The next sections will delve into the potential mechanisms behind these dynamics and present current evidence of tipping points in sustainable finance; while the concluding section summarizes the key points.

2.1. Potential for Tipping Points in Sustainable Finance

The financial system's shift towards sustainable orientations is fundamental to scale-up opportunities in the transition to a net-zero carbon economy, avoid risks of carbon-stranded assets, and accelerate emission reduction and nature conservation efforts. While progress thus far has been gradual, there is potential for rapid non-linear changes to enable transformative shifts within and beyond the financial sector.

Theoretical and empirical evidence suggest that public finance has a catalytic role for investments (Mazzucato 2013). Indeed, the ability of public actors (e.g. public investment banks, public governmental agencies) to take on risk induces private investors to follow. This is not only due to the substantial amount of funding provided by public actors, but also because of the quality of financing schemes they offer. Public financing, with its long-term horizons, favorable repayment conditions and ancillary support, resembles the role of financial entrepreneurs. By underwriting risks associated with investments and supporting specific technological trajectories, public finance can mitigate market uncertainty, potentially creating tipping points in the financing of low-carbon projects and assets (Campiglio and Lamperti

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2021; Mazzucato and Semieniuk 2018). However, the emergence of tipping points cannot be easily guaranteed and needs adequate policy support. For example, a mission-oriented industrial policy shaping the behavior of financial actors under direct or indirect public control (e.g. public investment banks, public development banks, public agencies, large public utilities) can increase the likelihood of tipping dynamics (Dosi et al. 2023).

Expectation alignment on the timing and speed of the transition is an additional tipping element that can scale up sustainable investment (Campiglio and Lamperti 2021; Campiglio et al. 2023). Uncertainty about the future prospects of low carbon assets coupled with unclear information about the strength of climate policy may delay substantial portfolio rebalancing decisions. In such cases, investors may adopt a more cautious "wait-and-see" approach, favoring conventional investments whose profitability appears less affected by unclear climate policies. On the contrary, certainty regarding future climate policy schedules can signal the long-term trajectory of the economy, inducing a positive correlation between low-carbon assets' returns and macroeconomic performance. This alignment of beliefs can coordinate and shift the strategies of long-term institutional investors (e.g. pension funds), which are typically influenced by a wide range of subjective beliefs about asset returns (Broeders and Jansen, 2021). Hence, aligning expectations on the timing and speed of the low-carbon transition could mitigate risk and spur momentum towards sustainable investments. This shift in perception may transform sustainable investments from being mere diversification assets into strategic ones. Consequently, reducing the cost of capital for low-carbon firms, facilitating their growth and creating a positive feedback loop that further encourages sustainable investment practices.

Tipping points in financial markets can also emerge through herding behavior, wherein a critical mass adopts a particular trend, ultimately influencing the broader population to follow suit (Bikhchandani and Sharma, 2000). Herding behavior refers to the tendency of investors to mimic others, especially during periods of uncertainty or when faced with limited information, resulting in the amplification of market movements. In the context of financial tipping points, herding behavior can have both positive and negative impacts. On one hand, it can exacerbate market instability and contribute to the formation of speculative bubbles. When investors flock towards certain assets or sectors, it may lead to an unsustainable surge in prices and valuations. However, on the other hand, herding behavior can also be channeled positively to drive sustainable investments and foster the transition towards a low-carbon economy. Critical mass comes into play when a sufficient number of investors adopt sustainable practices (e.g. GFANZ) or allocate funds to sustainable investments. This creates a self-reinforcing cycle, attracting more capital and generating increased demand for sustainable products and services.

The significance of herding and critical mass lies in their potential to facilitate the scaling up of sustainable investments. Herding behavior can rapidly accelerate the adoption of sustainable investments until a critical mass is reached. Once this tipping point is achieved, it becomes easier for sustainable investments to attract more funding and support from a widening pool of investors. This positive feedback loop can lead to a transformative shift in the financial landscape, where sustainability becomes the new norm rather than the exception.

These tipping elements in financial markets signal the existence of sensitive intervention points (SIPs) that can be leveraged by policy interventions. SIPs can either be small 'kicks'

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that trigger positive feedback cycles in a system, or shifts in the inherent dynamics of a system, that lead to transformative changes even without external triggers (Sharpe and Lenton 2021; Farmer et al. 2019). Activating an SIP initiates tipping dynamics, causing significant shifts in the market. Policy intervention can serve as the catalyst for such changes directly, by providing the initial "kick", or indirectly, by shifting the underlying dynamics that bring about the transformation. Beyond those tipping elements described above, Farmer at al. 2019 identified two finance-related SIPs. The first involves financial disclosure and falls into the 'kick' type of SIP. Indeed, a change in accounting standards or disclosure guidelines could trigger a substantial repricing of fossil assets, such as fossil fuel reserves and securities valuations. Consequently, this would limit the ability of the oil and gas sector to invest in new fields, thereby reducing committed emissions. Preventing such investments lowers the economic, social, and political costs of transforming the energy industry, as it levels the playing field for renewables, reduces the risk of stranded assets, and enhances the credibility of climate targets. The second pertains to technology selection and a targeted 'shift' towards low-carbon investment. Contrary to traditional portfolio theory, diversification of investments can be detrimental, especially when it comes to developing novel and uncertain technologies where spreading resources too thin can hinder significant progress. Instead, rapid progress requires concentrating resources on specific technologies (Farmer et al. 2019). For example, solar PV has achieved remarkable progress due to targeted support, becoming cheaper than most alternatives. The next step is to similarly focus on developing technologies that can accelerate the deployment of solar PV, such as energy storage. In essence, inducing tipping behavior in this context involves not attempting to invest across a broad range of options with hopes of developing each of them but concentrating efforts on technological complementarities that synergistically support research, development, and actual deployment. Further, identifying these technological complementarities dramatically reduces technological uncertainty, which would amply the diffusion dynamics even further.

2.2. Empirical and modelling evidence of tipping points in sustainable finance

In terms of empirical and modeling evidence, a variety of examples show how the financial system can play a pivotal role in activating tipping points to accelerate the transition to a net-zero carbon economy.

In developing countries, policy support can help to overcome climate investment traps created by the high costs of accessing finance (Ameli et al 2021a). Access to finance, understood as the costs of raising funding for a specific project from different sources, varies significantly across countries. For instance, in some African nations, such as the Democratic Republic of the Congo, Madagascar and Zimbabwe, the cost of capital can soar to 30%, while in developed countries such as Germany and Japan, it can be as low as 3% (Ameli et al 2021a). The high cost of accessing capital is preventing developing countries from decarbonizing their economies, and levelling the finance playing field could help poorer nations to steer their economies onto a net-zero course.

While energy system transitions in developing economies require particularly high investment, these parts of the world are also particularly financially constrained. They are characterised domestically by under-developed capital markets and lack of capital stock (Ameli et al 2021a). Furthermore, international finance is restricted due to high sovereign and local currency risks.

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Projects funded with foreign currency while generating returns in local currencies lead to volatile economic fundamentals (Ameli et al 2021b, Bilir et al 2019), resulting in restricted access to external funding sources. This leads to a chronic lack of available finance to support low-carbon investments, creating a climate investment trap which occurs when climate-related investments remain chronically insufficient, with dynamics similar to those of the poverty trap (Ameli et al 2021a). A self-reinforcing cycle takes place where high risk perceptions lead to increased capital costs, delaying the transition to cleaner energy systems and carbon emission reductions. Climate change impacts exacerbate the situation (IPCC 2022), causing adverse impacts on production systems, economic output, unemployment, and political stability (figure 1).

To address this challenge, potential policies that reduce capital costs can act as tipping elements in facilitating the low-carbon transition. Policies, such as credit guarantee schemes, can shift risk away from private investors resulting in lower cost of capital and allow developing economies to achieve a much higher level of low-carbon electricity deployment and faster emissions reduction. In the case of Africa, reducing the cost of capital by 2050 would allow the continent to reach net-zero emissions approximately 10 years earlier than when reduction is not considered.

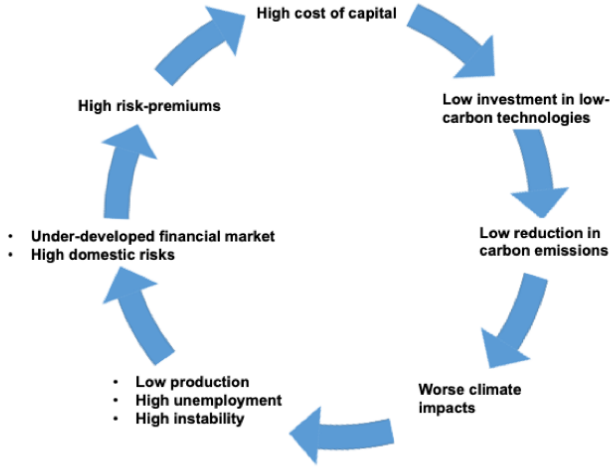

Figure 1: A climate investment trap. The figure shows the set of self-reinforcing mechanisms and related links occurring in developing economies characterised by high cost of capital. The strength of these links is strongly linked to local conditions implying that the set of self-reinforcing mechanisms could be exacerbated (or less relevant) in some economies.

Additionally, the flow of international capital into renewable projects in developing countries is influenced by path-dependency, creating a tipping element in the scaling up of renewable investments (Rickman et al. 2023a). Countries with a track record of renewable investments are more likely to attract future investments leading to positive feedback loops within renewable energy markets. As countries build a track record in renewables, market confidence

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grows bringing down financing costs and attracting further investments in a virtuous cycle (Egli et al 2018). Climate investment thus evolves through the strengthening of historical investment and capital stock, rather than new investment. However, this also results in an "investment lock-in" across countries as well as income groups, with only a small fraction of countries receiving the majority of investment. Between 2010 and 2019, 76% of private capital and 67% of public funds went to the top eight recipient countries (Rickman et al. 2023a).

Evidence of path-dependency thus implies a new mechanism of the “climate investment trap” whereby historical inequalities in financing are locked-in across countries and income groups and perpetuate over time. To escape this investment lock-in, developing countries must mobilize sustained investment to build a renewables track record that creates market confidence and attracts private finance. Indeed, there is a non-linear relationship between the probability of private investment in developing countries and their track record in renewables investment, as measured by installed capacity. Once a significant capacity base of around 1GW (of wind or solar) is installed a tipping point is reached and the probability of private investment increases sharply. Crucially, low-income developing countries (e.g. in Sub-Saharan Africa) fall far below this threshold, highlighting the inefficiency of opening finance channels into poorer nations without sustained investment which can mobilize private finance at scale. Investment decisions by public actors should thus move beyond project-specific inducements to support more holistic renewable roadmaps and unlock developmental co-benefits (Schwerhoff and Sy, 2017). Innovative financial and policy mechanisms should similarly target the evolution of the sector and build networks of relationships to initiate path-dependent flows from private sources (Ameli et al 2021b) and leverage tipping elements in the renewable finance ecosystem.

Inducement effects between investors are another example of tipping points that can be leveraged in sustainable finance. Financing in renewables markets is driven by a heterogeneous set of actors spanning energy, financial, utilities and diversified sectors (Mazzucato and Semieniuk 2018), who invest according to their investment remits, preferences and capacities, as well as technological maturity and the market environment. They collaborate across the development and operational stages of a project based on their risk appetite and expected return, contributing different types of capital to the project in the form of equity and loan investments. Their interaction and relationships drive the market growth and technological maturity of renewable technologies within the energy system resulting in unique emergent characteristics of the renewables sector across countries based on their enabling investment environments.

In solar finance markets, co-investment relationships between different actors are established at different stages of the market’s development and evolve with the continued growth of the sector (Kothari et al 2023). Actors exercise influence over their peers by inducing them into the market and leveraging their investments alongside their own. The strength of these relationships can be measured in terms of the intensity of influence that determines the timing of investments and the leverage ratio which measures the amount of induced investment. These facets of relationships differ between different actors in the solar sector based on existing co-investments, market position of actors and the alignment of their interests. For instance, the strongest influence exerted by government investments in solar projects is on investments by international institutions whereas renewable energy companies exercise strong influence on state-owned and private utilities. Similarly, institutional investors attract a

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high leverage from the private banking sector who are their natural debt partners in renewable projects and state-owned utilities correspondingly leverage investments from state-owned banks.

Country context also determines the structure of solar finance markets and the strength of relationships between different actors. The influencing power of different actors differs significantly across countries. For example, in the United States, private bank lending induces investments from a range of energy and diversified sectors, whereas in China, government agencies and state-owned banks are major influencers and in Germany, renewable energy companies and state-owned utilities exert a strong influence (Kothari et al 2023). From a policy standpoint, therefore, it is important to consider the impact of individual elements of energy policy on prominent actors in solar financing and the relationships that are driving the markets. Leveraging existing and new relationships with government agencies and state-owned actors can induce other actors into the markets and trigger a non-linear growth of investment, particularly from the private sector.

Theoretical modeling also reveals tipping elements in the global network of banks which supply debt to the fossil fuel industry (Rickman et al. 2023b). A sharp decline in fossil fuel use is necessary to achieve the Paris Agreement target of keeping global temperature rise below 1.5°C (Tong et al. 2019) and this will require a corresponding decline in bank lending to the fossil fuel sector (Kirsch et al. 2021). However, mainstream financial theory holds that debt flows to the fossil fuel sector will be resilient to the phase-out of lending by climate-friendly banks, as their capital can simply be substituted by banks with a neutral stance on the climate transition (Ansar et al. 2013). Capital substitution thus poses a challenge to a system-wide decline in fossil fuel lending in an unregulated market.

Macroprudential tools, such as capital requirements rules, can counteract capital substitution by setting a limit on the amount of fossil fuel assets a banks' can hold, depending on their capital reserves. While fossil fuel debt markets are resilient to the unregulated phase-out of capital, the introduction of capital requirements rules can trigger a rapid contraction of fossil fuel debt flows. The first banks to exit the fossil fuel debt market have little impact on debt flows, as their capital is substituted by other banks. However, a sudden transition is observed after a certain number of banks have exited the sector, at which point debt flows sharply contract. The tipping point depends critically on the stringency of capital requirements rules; the number of banks that must exit the sector before the tipping point is reached decreases rapidly as capital requirements rules are tightened. Moreover, the tipping point is reached sooner if large banks move first and coordinate their actions.

Suitable capital requirements rules will deliver a managed decline in fossil fuel lending. On the one hand, overly stringent capital requirements rules could precipitate a tipping point too early, leading to a disruptive transition in which the failure of fossil fuel companies is too widespread to be managed sustainably. On the other hand, loose capital requirements rules and a late tipping point could delay the emissions reductions necessary to keep Paris temperature targets within reach. Such rules can be developed by formal standard-setting bodies such as the Basel Committee on Banking Supervision and prudential regulators such as the Financial Stability Board. At the same time, banks should strategically coordinate their transition plans to increase their collective impact on debt markets through voluntary alliances such as the Net

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Zero Banking Alliance (NZBA 2021), to which many of the most influential banks in the sector are signatories.

Finally, the utilization of policy mixes that incorporate a combination of command-and-control and market-based instruments can be likened to "kicks" that yield positive outcomes for the transition to a net-zero carbon economy. Recent advancements in modeling have demonstrated that these policy combinations have the potential to initiate a virtuous cycle, driving technological development, reducing the overall need for public investment, and simultaneously stimulating employment and economic growth (Wieners et al. 2023; Lamperti et al. 2020; Lamperti and Roventini 2022; Stern and Stiglitz 2023). Moreover, such positive feedback loops significantly lessen the reliance on carbon taxes by decreasing their intensity. As a result, this enhances their political acceptability and potentially triggers another tipping element.

Conclusion

As of today, the financial sector is contributing to a projected ~3°C global warming scenario by 2100. The financial system itself is neutral and does not inherently favor any particular climate objectives. To successfully shift the economy towards a net-zero emission path, it becomes crucial to harness the potential of tipping elements embedded within financial markets. These elements can play a pivotal role in redirecting economic activities towards sustainable practices.

Taken together, the mechanisms detailed above highlight the system-wide tipping points' potential within sustainable finance and emphasize the necessity of policy interventions to activate and capitalize on these dynamics. Through the alignment of expectations, promotion of herding behavior, utilization of public finance, reduction of capital costs and attainment of low-carbon investment thresholds in developing nations, and implementation of robust financial regulation and policies, the financial system can assume a central role in expediting the shift towards a net-zero carbon economy.

Regulation has a critical role in driving tipping points within the financial sector and it has become increasingly evident in recent years. Robust monitoring and supervision by entities like central banks and financial regulators are forcing financial institutions to move faster and more decisively than market signals alone would prompt them to do. In this regard, policy makers and financial authorities hold the potential to take a leading role in steering the financial system towards a transformative tipping point, dedicated to financing the transition to a net-zero carbon economy. As these key stakeholders increase their efforts to guide the financial system, leveraging all the available tools and exploring new avenues, they also create a coordinated momentum with industrial policy makers. In this way, financial and economic policies can be more effectively aligned to support sustainable industries and practices.This collaboration further strengthens the potential to tip the financial system into a new regime, where the identification of critical intervention points can lead to the amplification of sustainable investments, mitigate risks, and foster transformative changes in the practices of the financial sector.

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Author contribution

NA, FL and HC conceptualised the structure of the analysis and coordinated the research. NA, FL and HC wrote the manuscript, with support from JR, SK and MF. All authors reviewed the manuscript.

Competing interests

The authors declare that they have no conflict of interest.

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