Environmental Innovation and Societal Transitions 36 (2020) 270–290

Contents lists available at ScienceDirect

Environmental Innovation and Societal Transitions

journal homepage: www.elsevier.com/locate/eist

Original research paper

Relating financial systems to sustainability transitions: Challenges, demands and design features

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ARTICLE INFO

Keywords:
Sustainability transitions
Financial systems
Climate breakdown
Characteristics of sustainability transitions
Transition demand framework

ABSTRACT

The Paris Climate Agreement, Sustainable Development Goals and Addis Ababa Action Agenda call for the financial system to be "consistent and integrated" in its response to the sustainability and climate breakdown. Sustainability transitions research (STR) and orthodox finance literature are failing to engage with these calls. This paper offers three contributions to address this issue. Firstly, it scopes the sustainability-related finance literature and finds broad but fragmented research strands with limited critical analysis and little cross-engagement with STR. Secondly, the paper draws on insights from STR and international climate and sustainable development agreements to propose a transition demand framework that characterises the explicit demands that sustainability transitions place on the financial system (understood as intermediaries, markets and infrastructure). Thirdly, the paper considers essential design features for financial systems to meet the specific demands of sustainability transitions and identifies critical questions for broadening research in this area.

1. Introduction

The Paris Climate Agreement (PCA) and the 2030 Agenda for Sustainable Development and its 2015 Sustainable Development Goals (SDGs) represent a turning point in sustainability and climate action (Nerini et al., 2019). These critical agenda-setting and interdependent multilateral commitments draw attention to the urgency and scale of the sustainability and climate breakdown, which affects every nation, every sector and every aspect of modern existence,[1,2] (Nerini et al., 2019). Some also frame the climate breakdown, in particular, as an existential crisis (Spratt and Dunlop, 2019) or as a super wicked problem (Lazarus, 2008). The Intergovernmental Panel on Climate Change Special Report on Global Warming of 1.5 °C (IPCC Special Report) amplifies the urgency of effectively responding to the sustainability and climate breakdown (IPCC, 2018). Responding to the breakdown requires radical and urgent actions between 2018–2030 to limit the global temperature rise to no more than 1.5 degrees Celsius and build resilience to the increasing impacts of climate change (IPCC, 2018). The global commitment context suggests grand-scale responses to shift economic development towards sustainability, which extends beyond incremental or quick-fix solutions (Spratt, 2015; Loorbach et al., 2017). Grand-scale responses require finance. The financial system, therefore, has an indisputable role in responding to the sustainability and climate breakdown.

The financial system, on the one hand, and social and environmental challenges, on the other, have long been associated. For

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[1] The Paris Climate Agreement and SDGs are interdependent in so far as achieving the PCA's climate goals must happen within the context of the SDGs, not to the exclusion of any of the goals.

[2] The paper adopts the term "climate breakdown" as the preferred reference to the generally used term "climate change". Climate breakdown was first used by Monbiot (2013) to convey the urgency and intensity of response required.

https://doi.org/10.1016/j.eist.2019.10.004
Received 27 November 2018; Received in revised form 3 October 2019; Accepted 14 October 2019
Available online 01 November 2019
2210-4224/

example, in the early 1970s, US and UK banks were the subject of social campaigns that lobbied against their support of South Africa's apartheid regime at that time (Fullwiller, 2016). Around the same time, recommendations relating finance to sustainability emerged in the 1972 Stockholm Declaration (UN, 1972) and, 15 years later, the Brundlandt Report (WCED, 1987). The recommendations proposed that financial institutions such as the World Bank introduce environmental and social risk into project design and investment appraisal processes (UN, 1972; WCED, 1987). Further, the UN proposed that countries should work together on integrating sustainability into global trade, development and finance systems (WCED, 1987). The multilateral commitments of 2015 re-emphasise the centrality of the financial system in responding to the sustainability and climate breakdown. They also mark a shift in emphasis. Specifically, the Paris Climate Agreement sets as one of its three *main* objectives to make finance flows *consistent* with low emission and climate-resilient development (UN, 2015a), while the SDGs and the Addis Ababa Action Agenda on Financing for Development (Addis Action Agenda) call for *integrating* sustainability into trade and finance flows (UN, 2015b, c). The shift in emphasis appears evident in the focus on finance flows having to be consistent and integrated, which implies both a quantitative *and* a qualitative role for the financial system in the shift to a new sustainable economic system.

With over US$112.1 trillion global assets under management predicted by 2020 (PwC, 2017), it is unlikely that there is any scarcity of finance to address the sustainability and climate breakdown. The financial system is, therefore, capable of driving radical and transformative changes in the economy through large-scale infrastructure investment (Schumpeter, 1942; Demirgüç-Kunt and Levine, 2009 cited in Mohamed (2014). However, recurrent financial crises also show that the financial system is capable of creating significant economic and social losses (Reinhardt and Rogoff, 2009; Griffith-Jones et al., 2010). This suggests that the financial system is unlikely to sustain and maintain the radical and transformative changes that are necessary to respond to the sustainability and climate breakdown unless it is disciplined to do so. Further, the response required from the financial system in the context of the Paris Climate Agreement, the SDGs and Addis Action Agenda resides within an interconnected global financial system attempting to keep pace with the digital economy, big data and having to build resilience to new risks (Carney, 2018; Carney, 2019). This global policy context and broader financial system challenges is the backdrop for this paper.

The paper examines the possibilities for relating financial systems to sustainability transitions. The sustainability transitions field represents the primary research domain for this paper. It is an interdisciplinary field within the social sciences, studying the process of transforming systems over the long term due to grand societal challenges and examining the influence and role of different actors within such change processes (Geels, 2004; Smith et al., 2010; Loorbach et al., 2017). Extensive academic research over the last 50 years connects finance and sustainability, with many framings for finance emerging in response, such as climate, green, sustainable, and environmental finance. However, research on finance within the sustainability transition field remains nascent (Köhler et al., 2019), and its conception of finance remains limited.

The paper is organised as follows: Section describes the research approach for this paper. Section 3 presents the results of a scoping review of sustainability-related finance literature and sustainability transitions research (STR), including relevant research on financial crisis, sustainability-related financial practices, and critical research on these subjects. Section 4 presents a tentative framework for identifying the demands that sustainability transitions place on the financial system. Section 5 proposes design features for responding to such demands, including further research possibilities. Conclusions are presented in Section 6.

2. Research approach

The paper applies a scoping review to relate sustainability-related finance literature and STR. The methodology is valid because relating finance to STR is a new area of research and scoping reviews provide insights on the prevailing themes and state of conceptual development (Peterson et al., 2016). The scoping of sustainability transitions literature commences with reviewing the 12 papers published in the 2013 Special Issue of Environmental Innovation and Sustainability Transitions (2013 EIST Special Issue). These papers represent the first effort by scholars in the field to engage on finance and the implications of the 2008 financial crisis on sustainability transitions. The supplemental information annexed to this paper further describes the content of these papers. Additional literature was identified through Scopus for the period 2013–2019, based on the co-occurrence of the keywords, "sustainability transitions" and "finance".

The scoping of finance literature combined keyword searches using Scopus for the co-occurrence of "finance" and "sustainability", which yielded over 35,000 results. Filtering these results with key phrases such as "environmental finance" and "sustainable finance" reduced the search results to 2787 papers. These results were later reduced to 14 papers by searching for the co-occurrence of the phrase "sustainability transitions". Because the literature on finance and sustainability is extensive, the author prioritised papers offering systematic and scoping literature reviews on finance and sustainability. Some of these were identified applying a snowballing approach.

The results of the scoping review suggest that an alternate entry point for relating financial systems and sustainability transitions is required. The paper therefore draws insight from STR to deduce the demands that sustainability transitions place on the financial system and the design features necessary for responding to such demands.

2.1. Assumptions

The paper adopts the view that sustainability transitions concerns the normative goal of achieving reduced greenhouse gas (GHG) emissions and increased resilience through socially just and inclusive means (Swilling and Annecke, 2006; Silveira, 2015), and the process to achieve such normative goals. This means sustainability transitions aim to address the goals of the Paris Climate Agreement and the SDGs.

The dominant approach for framing systems in STR is that transitions refer to changes in the socio-technical system. However, transitions also refer to changes in other systems, namely techno-economic, socio-ecological, technological innovation systems, social practices, resilience, and human geography (Silveira, 2015). References in this paper to systems change in the context of sustainability transitions applies a broader approach than just socio-technical systems.

This paper applies the description of the financial system as the "central nervous system of the economy" (Crockett, 2011, 3)[3] . Three interdependent components exist within the financial system, namely: i) *intermediaries* (public and private banks and insurance companies) directly engaging with households and businesses, ii) *markets* exchanging debt, equity, foreign currencies and commodities such as gold and platinum; and iii) *infrastructure* managing the regulation, supervision, legal and administrative systems that support intermediaries and markets (Crockett, 2011).

References in this paper to "finance" are aligned with Perez's classification of financial capital as the agent for reallocating and redistributing wealth in the form of money or other paper assets, through banks and other intermediaries (Perez, 2002, 71).

3. Challenges

This section presents the results of the scoping review of finance and sustainability transitions literature and STR related aspects of financial crisis, practice-based, and critical emergent literature.

3.1. Finance literature

3.1.1. Conceptual framing

Finance is a subset of economic studies, which defines the role of finance in the economy as facilitating the exchange and transfer of funds from households with excess funds to those in need of funds. A key point of this literature is that banks create new money (out of the deposits of savers) through lending, rather than just recycling deposits of savers into loans (Werner, 2014). The orthodox theories study how finance fulfils its role in the economy based on the assumptions that markets are efficient, and investors behave rationally. These include the efficient market hypothesis and capital asset pricing model theory, which assign variables on the basis of financial risks (Spratt, 2009; Sun et al., 2011; Urban and Wójcik, 2019).

The research methods used in orthodox finance studies apply algebraic, mathematical and econometric approaches, and treat environmental and social factors as externalities (Lagoarde-Segot, 2015; Ansart et al., 2017). The quantitative bias of orthodox finance is incompatible with the qualitative focus of sustainability transitions on environmental and social goals. This incompatibility creates challenges for establishing interdisciplinary linkages. Critical finance researchers are recognising the incompatibility of orthodox finance approaches to sustainability through new collaborations that aim to embed sustainability and climate breakdown in orthodox theories[4] .

3.1.2. Research themes

Finance research shapes the understanding of the financial system, influences investors and market behaviour, educates future finance and business practitioners, and facilitates policymaking (Diaz-Rianey et al., 2016). The research trends in orthodox finance are therefore important to reflect upon. Several systematic reviews of highly ranked accounting and finance journals show that finance research focuses mainly on the post-2008 financial crisis, covering topics such as asset pricing, bankruptcy, credit issues, governance, and risk management (Lagoarde-Segot, 2015; Aspinall et al., 2018; Diaz-Rianey et al., 2016; Brooks et al., 2018). Despite the climate breakdown and related events being classified as the top three global risks facing the economic system (WEF, 2019), it seems that finance researchers are not engaging on these issues adequately, according to four systematic reviews: Goodall, 2008; Patenaude, 2011; Aspinall et al., 2018; and Diaz-Rianey et al., 2016.

While orthodox finance journals may be failing to address finance and sustainability adequately, a Scopus search identifies at least 35,000 papers connecting these terms. The search was further narrowed by identifying terms associating finance with environmental and social concerns from textbooks on sustainable finance, sustainable banking, social finance and environmental finance (Bouma et al., 2001; Labatt and White, 2002; Ramiah and Gregoriou, 2016; Lehner, 2016), which yielded 2787 papers (see Table 1).

After applying "sustainability transitions" and "finance" as an additional filter, only fourteen out of these 2787 papers show the co-occurrence of such keywords. Google searches to supplement the Scopus results identified a solitary paper in the accounting and finance field. That paper applies the MLP lens in arguing that niche innovations such as sustainable, climate and green finance potentially destabilise the old regime of finance (Ryszawska, 2016). The low rate of co-occurrence shows that academic associations between the sustainability transitions and finance fields are nascent.

Outside of the Scopus results, the open access Journal of Sustainable Finance and Investment (JSFI) is dedicated to sustainable finance-related issues. According to a systematic review by De Carvalho Ferreira et al. (2016), between 2011 and 2014, the research themes prominent in the JSFI were: i) broadening the definition of investors; ii) building the business case for climate change and

[3] A recent paper by Urban and Wójcik (2019) applies the sustainability transitions terminology of "socio-technical system" and the multi-level perspective (MLP) framework to reforms in the financial system. For the treatment in this paper, the author chose not to adopt this definition due to the emergent nature of the research. A more general definition of the financial system is used here.

[4] In September 2019, the Global Research Alliance for Sustainable Finance and Investment hosted a pioneering event at its 2nd Annual Conference in Oxford, UK entitled "Purpose-Driven Finance: The Manual". The event aimed to launch an introductory sustainable finance curriculum.

Table 1
Results of keyword searches on finance and environmental and social outcomes.
Source: Author search via Scopus (the numbers in brackets next to each year refers to the number of papers in that year, if there was a broken period of publications bearing the keyword).

Terms linking finance and sustainability	Scopus results	Publication period	# Co-occurrence of "sustainability transitions"
Social finance	99	1988, 1999, 2008–2019	0
Environmental finance	88	1989–2019	1
Responsible investment	800	1991–1994, 1996–2019	3
Socially responsible investment	609	1991–1994, 1996, 1998–2019	2
Sustainable investment	300	1992–1995, 1998–2019	6
Sustainable finance	129	1992, 2004–2019	1
Green finance	80	1997, 2005, 2011–2019	1
Impact finance	18	2000–2019	0
Carbon finance	200	2002–2019	0
Climate finance	323	2004–2019	0
Impact investing	141	2011–2019	0
Total papers	2,787		**14**

socially responsible investment; iii) generating impacts through investment decisions; and iv) mechanisms to institutionally embed environmental and social factors over the long term in financial systems. The systematic review identifies the following research gaps: i) a lack of research on developing countries' contexts; ii) a lack of common terminologies on finance, investment and sustainability; iii) a need for engaging in theoretical debates to facilitate financial innovations; iv) a need to engage more deeply on the public sector role in finance and sustainability; and v) a question about whether finance and investment tools are suited to the sustainability challenge (De Carvalho Ferreira et al., 2016). The critical emergent approaches are promising, though they appear to be developing outside the orthodox finance research arena.

The wide range of terms represents interpretations of financing aspects of sustainability, be they social, environmental or climate-specific, and emerge from conceptual and empirical approaches that are beyond the scope of this paper. Relating finance to sustainability in this way may have validity in terms of specific aspects of sustainability, e.g. governance, environmental, and social approaches. However, the finance literature does not yet appear to be drawing on the insights from sustainability transitions literature which addresses system-level approaches to sustainability.

3.2. Sustainability transitions literature

3.2.1. Conceptual framing

The sustainability transitions field is a subset of innovation studies, which classifies finance as a resource and function within innovation systems. As a resource, finance is necessary for systems change, along with other resources such as equipment, skills, supportive infrastructures and institutional support (Clayton et al., 1999) and is essential for achieving strategies enabling long-term systems change (Farla et al., 2012). Seen as a function, finance is one of seven functions required when building systems (Hekkert et al., 2007). The multi-level perspective (MLP), a widely used qualitative field heuristic for studying socio-technical changes, theorises that transitions occur due to interactions between micro (niche), meso (regime) and macro (landscape) levels of individual agency, and based on rules (Silveira, 2015). The MLP adopts the framing of finance as a resource and function from innovation studies by including financiers in the additional social groups that influence technical trajectories and embedding them, at the regime level, in user practices and application domains (markets) (Geels, 2002, 1259).

The framing of finance in sustainability transitions within the market domain aligns with the orthodox economic view of finance, which is later reinforced by classifying transition processes as creating market, infrastructure and transformative failures (Weber and Rohracher, 2012). The failures view is a useful entry point in the short term for developing policies for sustainability transitions (Weber and Rohracher, 2012; Foxon, 2015). For example, a failures view facilitates the selection of financial instruments that lowers project risk (Naidoo et al., 2014; Mathews, 2015; Volz et al., 2015), identifies public and private sources of finance as the ones best suited to absorb such project risk (Spratt, 2015; Mazzucato and Semieneuk, 2018), and considers market and finance instruments as climate policy tools (Gevorkyan et al., 2016). Justifying policy actions over the long term, however, requires moving beyond the failures view (Weber and Rohracher, 2012; Foxon, 2015). The failures view limits the role of policy to fixing market failures instead of promoting the transformative role policy can play in creating new economic pathways (Mazzucato, 2014).

3.2.2. Research themes

The 2013 EIST Special Issue entitled "Economic-financial crisis and sustainability transitions" published the initial papers discussing finance within the newly established sustainability transitions field[5] . Five themes associating finance and sustainability transitions are interpreted from reviewing these papers. These themes are: i) the recurrence of financial crises which are endemic to system dynamics (Perez, 2013; Geels, 2013; Swilling, 2013; van der Ploeg and Withagen, 2013); ii) divided opinions on the

[5] Refer to the supplemental information section of this paper for a summary of these papers.

dominance of a green growth narrative (Antal and van den Bergh, 2013; Loorbach and Huffenreuter, 2013; Vergragt, 2013; Witt, 2013; Geels, 2013; Swilling, 2013); iii) the inevitability of poor policymaking due to societal concerns not being reflected in orthodox approaches (Foxon, 2013b; Perez, 2013; O'Riordan, 2013; Swilling, 2013; Geels, 2013); iv) the structural compatibility of the financial system with sustainability transitions (Perez, 2013; Foxon, 2013b; Antal and van den Bergh, 2013; Swilling, 2013; O'Riordan, 2013); and v) policy competition between financial crisis and sustainability challenges (Geels, 2013; Antal and van den Bergh, 2013; Loorbach and Huffenreuter, 2013; Vergragt, 2013; Witt, 2013; Swilling, 2013; O'Riordan, 2013; Perez, 2013).

Subsequent research between 2013 and 2019 identifies eight papers with the co-occurrence of the keywords "sustainability transitions" and "finance" within STR. The research themes evident in these papers are: i) applying the MLP to understand the financial reforms in the retail banking sector of the UK (Seyfang and Gilbert-Squires, 2019), the emerging storyline of green finance as niche innovation in Italy (Falcone et al., 2018), and the contribution of development banks to the energy transition in the UK, Australia and Germany (Geddes et al., 2018); ii) demonstrating the financial policy challenges that the ecological crisis presents for sustainability transitions and the energy sector (Röpke, 2017; Safarzyńska and van den Bergh, 2017); iii) illustrating the structural challenges and financial innovations for achieving a just transition in South Africa (Mohamed, 2019; Naidoo, 2019); and iv) categorising the financial system as a socio-technical system and the adoption of sustainable finance as a business opportunity (Urban and Wójcik, 2019).

The 2013 EIST Special Issue mainly highlights the narrative of green growth as a response to the post-2008 financial crisis and the critique that such framing masks the underlying systemic problems of unsustainable production and consumption patterns. The concerns raised by authors in the 2013 Special Issue centre around how green growth narratives affect policymaking and finance innovations. Concerns raised include whether the financial system is fit for the purpose of supporting sustainability transition processes. Subsequent research between 2013 and 2019 that explicitly applies sustainability transition concepts to finance at a systems level mainly use the MLP in different geographies (predominantly Global North countries), and at the level of private, state-owned and retail banks. There is no apparent cross-referencing to arguments made in the 2013 EIST Special Issue.

The section shows that research on finance within the sustainability transitions field is embryonic, and researchers generally agree that further conceptual and empirical research is needed to understand the role of finance at a systems level.

3.3. Financial crisis research

STR scholars writing about the 2008 economic-financial crisis in the 2013 EIST Special Issue describe finance as being ill-disciplined, speculative and blocking the global transition (Antal and van den Bergh, 2013; Perez, 2013; Swilling, 2013). The remedies to avert future financial crises over time are familiar, suggesting more regulation, separation of investment and deposit-taking functions, and calls for global action led mainly by the G20 and other multilateral processes (Griffith-Jones et al., 2010). Critics argue that multilateral processes are relatively weak in enforcing fundamental changes in the financial system - for example, proposals for fundamental shifts in the banking sector that are initially broad and far-reaching immediately after the financial crises are generally set aside once the financial system stabilises (Griffith-Jones et al., 2010; Turner, 2016). The behaviour of financial institutions leading up to the financial crises and afterwards shows that regulation has limited effects on curbing unhelpful and embedded investment behaviours of bankers and other actors in the financial system (Spratt, 2009; Griffith-Jones et al., 2010). The concerns raised by these scholars are valid, as they suggest financial crisis may slow down sustainability transitions processes.

The 2008 financial crisis generated alternative framings of the financial system, which acknowledge the systemic risks to the economy posed by interdependent behaviours of financial intermediaries such as banks. For example, Farmer et al. (2012) and Battiston et al. (2016) categorise the financial system as complex interconnected multi-layered networks rather than single networked systems, recognising the complexities of modern, integrated payment systems within and across global capital markets. While interconnectedness increases competition and improves the way in which resources are allocated by financial intermediaries (Farmer et al., 2012), the interconnectedness also means that instability in one market reverberates in the markets to which it is connected (Aziakpono, 2006). The interconnectedness of the global financial system represents the current context for directing finance to support sustainability transition processes.

The propensity for financial intermediaries to behave in ways that contribute to financial crises is important for understanding the demands being placed on the financial system for three academic reasons. Firstly, for critically evaluating the assumptions underpinning the sustainability-related financial practices and innovations as these may inadvertently contribute towards a future sustainability-related financial crisis and amplify the risk of misdirected and failed transition processes. Secondly, for understanding the influence that finance wields over economic activity, which implies reframing the implicit role of finance (currently, as resource and function) in STR. Thirdly, for evaluating the impact and extent of the financial system's response to sustainability transitions. This suggests having to examine causal linkages between the response and impact of new practices and innovations adopted by financial intermediaries.

3.4. Practice-based research on finance and sustainability

Global initiatives calling the financial system to respond to the sustainability and climate breakdown include a diverse range of convened and lobbying processes.[6] Convened processes, to name a few, include the Climate Action in Financial Institutions, Central

[6] During the 2015 Paris Agreement negotiations, 20 institutions launched the Climate Action in Financial Institutions for mainstreaming climate

Banks and Supervisors Network for Greening the Financial System, the United Nations Environment Finance Initiative, the Task Force on Climate-Related Financial Disclosures, the International Network of Financial Centres for Sustainability, and the G20 Sustainable Finance Study Group. Examples of lobbying processes include Climate Action+, the Global Investor Coalition on Climate Change (CIC), and the Portfolio Decarbonisation Coalition.

An ever-widening range of global initiatives are contributing to mainstreaming the need for the financial system to respond to the global sustainability and climate breakdown. An important example is the Governor of the Bank of England (BoE) recognising that the climate breakdown influences the stability of the financial system. The recognition has led to the BoE engaging with transitions-related risks and designing climate stress tests for the UK financial system (Carney, 2018; Carney, 2019)[7] . The effects of anti-fossil fuel campaigns targeting investors shows trillion-dollar divestment by investors in fossil-fuel companies (Bergman, 2018), which is starting to devalue the investment ratings of the coal sector (McKibben, 2018). Investment flows reflect support for new industries emerging from sustainability challenges, for example, with renewable energy investment in 2017 reaching US$333.5 billion (Louw, 2018) and new asset classes termed "green bonds" reaching a total of US$162.1bn in 2018 (CBI, 2018). To appreciate the contribution of these initiatives and investments to promoting sustainability transitions, contextual factors relative to the amount of overall funds invested would be needed. For example, though multilateral development banks are supporting renewable energy, their investment portfolios do not fully reflect a transformation agenda aligned to addressing the climate breakdown (Wright et al., 2018).

A scoping paper by Hafner et al. (2019) shows that finance initiatives on the sustainability and climate breakdown are rapidly expanding and identifies at least 31 initiatives including the United Nations Inquiry into the Design of a Sustainable Financial System (UNE Inquiry) and the European Commission's High-Level Expert Group on Sustainable Finance (ECHLEG). The UNE Inquiry claims a revolution towards a sustainable financial system is underway (UN, 2018). The ECHLEG says a complete transformation of the "entire financial system, its culture and incentives" is needed (ECHLEG, 2018, 2). Both initiatives separately propose a sustainable finance roadmap for policymakers to consider. Such practice-based research is useful in contributing towards finance-related sustainability policies and is gaining strategic importance among policymakers, for example, the UK and German governments' Green Finance strategies. At the same time, the rapid emergence of practice-based research highlights the need for independent validation of such claims and proposals as academic researchers are failing to engage adequately with such practice-based policy research (Hafner et al., 2019). This means that the context, assumptions, impact and generalisability of such research is not being examined or challenged.

On contextual factors, for example, Falcone et al. (2018) argues out that the UNE Inquiry recommendations primarily focus on financial systems in the Global North. Ahlström (2019) argues that the European Commission's response to the ECHLEG is path-dependent, following the limitations of existing laws and regulations which may undermine achieving a fully sustainable European financial system.

On impact factors, for example, the UNE Inquiry traced over 200 sustainable finance practices between 1980–2015, as illustrated in Fig. 1. The graph shows a rising trend in such practices, but studying the impact of these practices fell outside the scope of the UNE Inquiry. On generalisability of recommendations, for example, the UNE Inquiry offers policymakers a useful financing roadmap towards achieving a sustainability-focused financial system (UN, 2017). However, independently engaging on the roadmap's underlying assumptions would strengthen its usefulness.

The speed at which new sustainability-related financial initiatives are proliferating without critical evaluation can lead to misdirected or failed transitions. For example, on what assumptions are the financial initiatives based? Is there a common understanding of the problems to be solved? Who is defining the problems? Who is proposing the solution? Is policy guidance relevant for the current context? Are practices creating specialist financing areas or enabling wider systems-level reforms?

3.5. Critical emergent research

As the sustainability transitions field matures, criticisms are inevitable, two of which are noteworthy for this paper. Firstly, Sorrell (2018) and Svensson and Nikoleris (2018) call for greater reflection on the implicit assumptions of the MLP, highlighting its limitations in establishing causal linkages. Secondly, Feola (2019) draws attention to the tacit acceptance of capitalism within the sustainability transitions field, which may restrict forward-looking research and applications for research in the Global South. The criticisms are relevant because implicit assumptions about the role of finance (as a resource and function) restricts the ability to conduct empirical research on a more explicit role systems-level role for finance over the long term. Questions that could be asked include, how will new financial practices contribute to long-term systems change? On what and whose assumptions of sustainability transitions are the financial practices based? Will new finance practices create niche areas of finance or create an integrated financial system that is fit-for-purpose? Who directs and who follows the sustainability-related reforms of financial systems? Such questions are presently difficult to respond to if finance is framed only as a resource and function in the sustainability transitions field. This invites more reflexivity on theorising the potential of finance to enable transformative system-level changes.

The sustainability and climate breakdown contribute to the growing movement of rethinking the validity and relevance of orthodox economics, which became heightened during the 2008 global financial crisis. Orthodox economic theories fail to account for sustainability and climate breakdown, as they were relevant for the time, place and circumstances that the world found itself in when

(footnote continued)

change into their operations. https://www.mainstreamingclimate.org/connecting-the-dots/.

[7] The Bank of England classifies climate-related risks as physical (in terms of volatile and unpredicted climate-related events), liability (loss and damage claims among affected parties), and transition (sudden and disorderly adjustment towards low carbon economy).

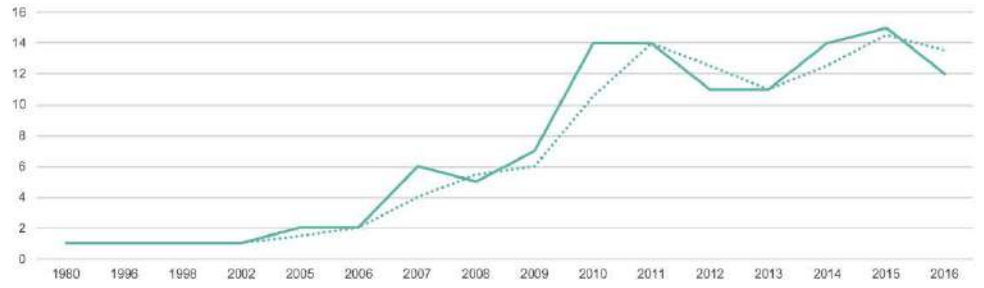

Fig. 1. Sustainability-Related Finance Practices in Middle Income Countries 1980 to 2015.
Source: Adapted by author based on an extract of UNE Inquiry into the Design of a Sustainable Finance System database as at June 2015.

these ideas originated (Orléan, 2014; Raworth, 2017). Such orthodox economic theories position environmental and social concerns as externalities and currently dominate the policy and educational landscape, which is an inappropriate policy basis for responding to 21st-century sustainability concerns (Raworth, 2017). Similar research draws attention to the need for capital to have a public purpose (Jacobs and Mazzucato, 2016), developing economic alternatives such as green industrial strategies (Mathews, 2015), and promoting circular economies to reduce materials waste and create employment (Perez, 2016). Although these emergent conceptual debates and concepts are critical, they are still fragmented and are not yet framed coherently as an alternative to orthodox economics (Foxon, 2018). This suggests that orthodox economic approaches still exert influence over sustainability transitions processes.

Within orthodox finance, rethinking movements are growing too, as scholars question the epistemological assumptions of finance theory and its compatibility with the demands for sustainability (Gray, 2010; Lagoarde-Segot, 2018), raise the need for social rather than economic purpose for finance (Lagoarde-Segot and Paranque, 2017), and reflect on the inadequacy of finance theory to account for climate and social risks (Aspinall et al., 2018; Fullwiller, 2016). New social forms of finance are emerging such as crowdfunding as an alternative to relying upon the formal financial system to promote sustainability objectives (Ansart and Monvoisin, 2017). New approaches are emerging outside of orthodox economics in response, for example, developing climate stress-tests of the financial system (Battiston et al., 2016), and considering the impact of climate change on financial stability (Campiglio et al., 2018). Further, research is emerging that highlights the risks that climate breakdown poses to investors and policy makers, especially since economic models inadequately account for such risks (Monasterolo et al., 2019). Additional examples include the critical work on stranded assets which draws attention to the limited lifespan of fossil fuel assets (Caldecott, 2017). In addition, informal networks such as the Sustainable Finance Lab are bridging theory and practice to study how the financial system can contribution towards averting the sustainability and climate breakdown.

Although coherent theoretical alternatives remain underdeveloped and contested, critical emergent research shows that the sustainability and climate breakdown is questioning the assumptions of orthodox economic and finance theory. The sustainability transitions field is not immune to this agitation. Even though it is a relatively new field, critical reflection on its implicit assumptions is essential for further conceptual and empirical development, particularly for relating financial systems to sustainability transitions where research remains underdeveloped.

3.6. Implications for relating financial systems and sustainability transitions

Section 3 reveals several research challenges. Firstly, although extensive research on finance and sustainability exists covering a wide range of terminologies and specific dimensions of sustainability, it is not yet organised under a common approach or mainstreamed in economics and finance. Deciding on which sustainability-related finance framing to follow is complex. For example, justifying the choices of either green, climate, impact or social finance requires interrogating the conceptual roots of these framings. Yet each framing may have useful contributions and specific limitations that influences its value for sustainability transition processes. Secondly, the sustainability transition field is maturing, but finance-related research at systems level is underexplored. Moreover, sustainability-related finance research appears to be evolving in a way that is not yet incorporating the system-level insights from STR. Thirdly, critical engagement with practice-based research on policy alternatives that claim alignment with the Paris Climate Agreement, the Addis Action Agenda and SDGs is lacking among academic researchers. Lastly, the scoping results in Section 3 shows that old theories are being challenged, but new theories have not yet fully developed into coherent alternatives.

For these reasons, this paper inverts the research perspective to consider a new starting point as discussed in Section 4 for relating financial systems to sustainability transitions.

4. Demands of sustainability transitions on financial systems

This section presents the rationale and insights that STR offer for relating financial systems to sustainability transitions, which includes an indicative framework for evaluating the response of the financial system to transition processes.

4.1. New starting point

A review of finance and innovation research by O'Sullivan (2005) shows that limited research existed at the time inter-relating these subjects, except for the seminal work by Perez (2002) on technological revolutions and financial capital. Perez (2002), like Schumpeter (1942), positions the financial system at the centre of driving fundamental economic change through technology, in the context of technological revolutions or techno-economic paradigms (Dosi, 1982)[8] . Perez, however, places greater emphasis on the resulting changes in the *"institutions of governance, of society, and even of ideologies and culture"* (Perez, 2002, 24-5), implying radical changes to the systems that support the technological revolutions. Perez makes the elemental point that the characteristics of a specific technological revolution determines the nature of problems to be solved and the method of solving them. O'Sullivan (2005) reaches a similar conclusion – that advancing conceptual and empirical research on finance and innovation begins with first understanding the characteristics of the innovation process, which in turn informs the resource (finance) allocation. Practice-based policy research by Köhn (2012) follows a comparable argument that the characteristics of the environmental finance market represents the demands (need) for financial markets.

This paper distinguishes between the characteristics of sustainability transitions and innovation processes. Perez describes the process of diffusing technological revolutions as a period of profound change that leads to modernising and rejuvenating the economic system, and whose influence stretches beyond the new industries or technologies created (Freeman and Perez, 1988; Perez, 2002). In this way, technological revolutions are a form of transition. However, there are at least five characteristic-related differences. Firstly, sustainability transitions process direct change towards achieving new economic, environmental and societal goals and are connected to existential threats while technological revolutions appear agnostic on these issues. Secondly, sustainability transitions are inherently time-bound processes requiring acceleration to manifest transformative environmental, societal and economic impacts by 2030 beyond fossil fuels (IPCC, 2018) whereas technological revolutions have no specific time constraints. Thirdly, achieving just and equitable sustainability transitions is critical whereas technological revolutions are silent on the social quality of new innovations. Fourthly, sustainability transition processes directly target rejuvenating the entire economic system as the primary goal, placing greater emphasis on the system-level influences that can be achieved through different types of innovations, whereas technological revolutions focus on innovation, with system-level influences positioned as an indirect consequence of diffusion. Finally, the Paris Climate Agreement, the SDGs and the Addis Action Agenda underpin the financial focus of sustainability transitions, both of which require the integration and consistency of finance flows, whereas financing technological revolutions does not prescribe such preconditions.

The arguments of Perez (2002), O'Sullivan (2005) and Köhn (2012) are relevant for this paper because STR and finance research is at a similar juncture of beginning to advance research on finance. This paper, therefore, proposes that the characteristics of sustainability transitions represent an essential starting point to understand the demands that transition processes place on the financial system. Further, for the reasons stated here, the sections that follow focus primarily on the characteristics of sustainability transitions processes.

4.2. Insights from transitions research

Transition scholars acknowledge that sustainability transitions are complex processes displaying differentiated characteristics across transitions contexts (Berkhout et al., 2004), transition typologies (Geels and Schot, 2007) and transition pathways (Foxon, 2013a). The heterogeneity of transition processes notwithstanding, certain core characteristics of transition processes are evident. Specifically, transition processes are non-linear and disruptive, targeting the goal of achieving a new sustainable economic state (Loorbach et al., 2017). Further, multi-level and contested interactions are typical in transition processes, which result in the co-evolution and emergence of new systems; such systems display variation and selection in achieving the new sustainable state (Loorbach et al., 2017).

Drawing on Loorbach et al. (2017) and the objectives of the Paris Climate Agreement, the Addis Action Agenda and SDGs, this section reinterprets the characteristics of sustainability transitions and then deduces the consequential demands that the sustainability transition place on the financial system. The analysis results in five specific demands as illustrated in Table 2, which may be useful as an initial framework for evaluating how the response of the financial system meets such demands.

4.2.1. Directional changes

Transitions can emerge through evolutionary changes within an economy (Smith et al., 2010; Silveira, 2015). However, sustainability transitions are different in that they represent a normative goal with a predetermined outcome, being low emission, climate-resilient development that is socially just and inclusive (Swilling and Annecke, 2006). Setting new directions and goals for development are political and contested processes. At a multilateral level, the Paris Climate Agreement, the Addis Action Agenda and SDGs signal these directional changes, although countries will apply varied ambitions in achieving such goals in the midst of competing and contested national processes (Spratt, 2015).

Loorbach et al. (2017) describes sustainability transitions processes as targeting a new sustainable state, which implies two directional shifts – directing *and* redirecting economic systems towards responding to the sustainability and climate breakdown.

[8] Perez (2002, 8) defines a technological revolution as a "powerful and highly visible cluster of new and dynamic technologies, products and industries, capable of bringing about an upheaval in the whole fabric of the economy and of propelling a long-term upsurge of development".

Table 2
Transition demand on financial systems.
Source: Author interpretation.

Transition Characteristics	Consequential demands placed on the financial system
Directional changes	The intermediaries, markets and infrastructure of the financial system consistently direct themselves toward achieving a new sustainable economic system.
Temporal dynamics	The financial system responds across short-, medium- and longer-term timeframes to address the systemic needs of transition processes.
Co-existent system impact	The financial system generates environmental and social system-level impacts by creating new socially inclusive, environmentally sustainable economic systems *and simultaneously* destabilising old environmentally unsustainable, socially unequal economic systems.
Contested social context	The financial system engages with a broad base of stakeholders in developing its response to support the transition process.
Contextual experimentation	The financial system experiments and applies adaptive approaches to address the contextual needs of sustainability transition processes.

Firstly, directing transition processes means such processes are purposive and objective-oriented with some ability to be controlled or directed (Smith et al., 2010; Raven and Verbong, 2009; Geels, 2011; Kemp and van Lente, 2011). Secondly, redirecting means shifting from unsustainable to sustainable practices in production and consumption patterns, structures, sub-systems, cultures and behaviours (Mersmann et al., 2014; Köhler et al., 2019), to meet societal needs in fundamentally different ways (Rotmans et al., 2001).

The demands on the financial system relate to deploying large amounts of resources towards investment that addresses the sustainability and climate breakdown (Geels, 2013). The nature of this demand is not unusual, in that large amounts of finance inevitably flow towards new investment opportunities arising during periods of rapid change (Perez, 2002). However, the directional shifts for sustainability transitions also require ensuring finance flows are consistent and integrated (UN, 2015a, 2015b, 2015c). This means that the role of the financial system has a qualitative aspect. Maintaining a consistent investment direction implies, for example, divesting from existing investments in unsustainable industries (such as fossil-fuel investments) and terminating any new investment in unsustainable industries. New approaches to project development and investment appraisal criteria that prioritise environmental and social outcomes may be needed (Spratt, 2009). For the infrastructure of the financial system, consistent and integrated finance flows may mean reflecting on the fundamental changes needed within the financial system that address incentives and behaviours. For example, misdirected intermediaries, ill-disciplined markets and poor infrastructure within the financial systems poses a risk to transition processes. The risk of misdirection and short-term profit-seeking is shown by the recurrence of financial crises (Perez, 2013; Geels, 2013; Swilling, 2013). The directional changes implied by sustainability transitions requires assessing whether the financial system is fit for the purpose of directing *and* sustaining such processes.

Financial-economic relationships are biased towards debt, financial returns and resource exploitation and the short-termism of markets (Geels, 2013; O'Riordan, 2013). Therefore, directing the financial system towards sustainability transitions can only occur by dislodging the power of finance (Perez, 2013; Foxon, 2013b; Antal and van den Bergh, 2013; Swilling, 2013). This suggests that measures are required to address investment behaviour and incentives, discipline finance to act in line with societal and environmental interests, and repurpose finance away from its dominant focus on financial gain.

4.2.2. Temporal dynamics

The IPCC Special Report argues that a narrow window remains for implementing targeted interventions by 2030, which means the context for sustainability transitions is inherently urgent. Therefore, intertemporal values and issues should be at the core of policy responses to the climate breakdown to avert the mounting societal challenges and address the doubling of infrastructure demands over the next 20 years (Bhattacharya et al., 2016; Stern, 2018)[9] . Transition processes generally unfold over long periods of time and in a non-linear manner (Geels, 2011; Alkemade et al., 2011; Loorbach et al., 2017), as do technological revolutions (Perez, 2002). The longer durations associated with transition processes are problematic for the sustainability and climate breakdown because of the temporal dynamics underpinning the Paris Climate Agreement, the Addis Action Agenda and SDGs. However, accelerating sustainability transitions is possible (Sovacool and Geels, 2016; Sovacool, 2016).

The temporal dynamics cause tensions where the sustainability and climate breakdown compete for policy and political attention with the risk of a re-emergent financial-economic crisis, as each emerge over different timeframes with specific causes and solutions (Geels, 2013; Antal and van den Bergh, 2013; Loorbach and Huffenreuter, 2013; Vergragt, 2013; Witt, 2013; Swilling, 2013; O'Riordan, 2013; Perez, 2013). For example, the policy concerns over the course of a transition process differ, with immediate challenges that include how to mobilise large sums of money, initiate policy and institutional changes, and how governments can gain public support and legitimacy during such a time (Geels, 2013). Accelerated transition processes are a necessity, but they also compete with having to regulate the speed of the transition to maintain financial stability (Campiglio et al., 2018; Carney, 2018; Carney, 2019). Greater support for accelerated action may emerge from initiatives such as the Bank of England's stress-testing of the climate risk of the UK's financial system (Carney, 2018; Carney, 2019).

The demands on the financial system mean addressing the temporal needs of transition processes within the narrow window for

[9] The term "inter-temporal" relates to past, present and future events and conditions. In this paper, it refers to the time-sensitive nature of climate breakdown and how, for example, choices are made between current and future benefits.

action identified in the IPCC Special Report and the longer-term impacts of such processes. The needs primarily focus on instilling a sense of urgency among intermediaries, markets and infrastructure to orient resources towards financing interventions that lower emissions and build resilience to the escalating effects of the sustainability and climate breakdown. For intermediaries and markets, the temporal needs may mean programming investment priorities across different time scales and providing access to resources when this is needed. For example, in the short term, this could mean investing in rebuilding and repurposing critical infrastructure damaged by climate events without locking in high-carbon options, and facilitating access to emergency reconstruction efforts[10] . Over the medium term, this could be allocating resources towards sustainable production, consumption and other system-level changes. Over the longer term, this could be maintaining the new sustainable economic state through the quantity and quality of investment. For infrastructure, the temporal context means ensuring that the legal and administrative processes and funding partnerships are in place so that resources are matched with the temporal needs. This may include having to understand the capabilities and limitations of the national finance system and its interdependence with the global financial system. These factors are relevant especially for the Global South, where access to international development support may be necessary. To facilitate the temporal dynamics, institutional innovations may be necessary for fast-tracking implementation and resource deployment, for example, accelerated lending practices, special purpose vehicles for project implementation, and alternative funding platforms to provide access to resources.

4.2.3. *Co-existent system impact*

Sustainability transitions processes allow the co-evolution and emergence of new economic systems, address unsustainable practices in economic systems which incremental solutions cannot shift, and facilitate transformational systems-level impacts (Raven and Verbong, 2009; Geels, 2011; Kemp and van Lente, 2011; Mersmann et al., 2014; Loorbach et al., 2017). Unsustainable practices, in this context, refers to the expanding global influence of economic systems which are destructive to the social, biological and geological processes of the earth (Mathews, 2015). Industrial development, in particular, is resource-intensive and directly linked to high carbon emissions and far-reaching system transitions (IPCC, 2018). Spratt (2015) argues that transition processes focused on technology-focused fixes such as carbon emissions trading may implicitly assume that once the environmental impacts are achieved, the underlying systems may continue as before.

Sustainability transitions therefore require broader impacts in the economic system, which go beyond technology-directed solutions (Perez, 2002; Swilling and Annecke, 2006; Gower et al., 2012; Mathews, 2015; Spratt, 2015). This means the systems impact should address environmental *and* social dimensions. The social systems impact raises the risk that the sustainability transitions exacerbate existing and unsustainable social inequalities by favouring those with access to resources (Swilling and Annecke, 2006). The environmental systems-level impact requires shifting the incumbent economic system away from its lock-in of high-emission infrastructure (Unruh, 2002; Foxon, 2011) and resource-intensive production and consumption processes (Antal and van den Bergh, 2013).

Addressing the dual environment and social dimensions of system-level impacts requires two kinds of policies to be implemented simultaneously: firstly, policies that cause the new system to emerge, and, secondly, policies that destabilise the old system until it eventually fades over time (Kivimaa and Kern, 2016). The simultaneous creation-destruction process is difficult to achieve in practice due to the lock-in and inertia of incumbent economic, social and political systems and vested interests (Unruh, 2002; Stirling, 2006; Voß et al., 2009; Newell, 2014). As the "old" and "new" development pathways co-exist, tensions between the two may lead to what Gramsci (1971) called "morbid symptoms" such as inertia and an inability to act, actions that are too late to achieve any benefit for those affected, a struggle for survival by incumbent institutions and practices, the risk of further social inequality, and fear of job losses.

A potential morbid symptom is the dominance of green growth imperatives for creating the new economic system, which reflects the high-growth expectations of governments, business and citizens and increases the risk of financial crises (Antal and van den Bergh, 2013; Loorbach and Huffenreuter, 2013; Vergragt, 2013; Witt, 2013; Geels, 2013; Swilling, 2013). The new sustainable economic path is framed as green growth (Jacobs, 2012) and the new industries that emerge represent opportunities for entrepreneurs and venture capitalists (Perez, 2013; van der Ploeg and Withagen, 2013; Swilling, 2013). Such framing potentially masks the deep systemic and cultural problems of unsustainable production and consumption, and ignores the need to address social inequalities. Bringing a new economic system to the fore requires social activism and engagement (Voß et al., 2009; Witt, 2013; Vergragt, 2013), as well as the willingness to experiment (O'Riordan, 2013; Mathews, 2015; Kivimaa and Kern, 2016). Navigating these tensions therefore requires political efforts to destabilise old systems towards the point of crisis and nurturing the new economic system so that it can become dominant.

The demands placed on the financial system to deliver systems-level impact relate to accepting the inherent duality of the co-existence of old and new economic systems. Firstly, the financial system needs to evaluate its rationale for supporting sustainability transitions, potentially shifting the dominant investment framing of *opportunity* (which incentivises the pursuit of high growth and implies there is an option about whether or not to support sustainability transitions) towards environmental and social imperative of *necessity*, which conveys the existential imperative of creating a new economic system. The opportunity rationale for transitions contributes to mobilising resources in the short term. This is useful, but it fails to address inappropriate behaviours and incentives among financial intermediaries and markets. The necessity rationale requires financial systems to identify and address upfront

[10] Cyclone Idai, for example, resulted in Mozambique having to take out a US$118.2 million emergency loan from the International Monetary Fund because there was no external funding available for reconstruction. The loan was heavily criticised by civil society and climate activists. See, for example, Suffee (2019).

unsustainable practices within the intermediaries, markets and infrastructure to mitigate the risk that they will resurface in the new economic system, potentially creating a green finance or transitions-related financial crisis.

Meeting the social demand requires, for example, ensuring resources are made available to vulnerable and marginalised groups, such as rural communities, indigenous people, women and youth, which requires reflecting on investment appraisal and lending practices. Meeting the environmental demand means prioritising and incentivising finance to establish a dominant new economic system (Geels, 2013), by investing in environment-focused innovations that reduce harmful emissions such as renewable energy and alternative transport systems, and build resilience to climate breakdown, such as improving port infrastructure for rising sea levels. The financial system should also actively promote practices and policies that destabilise the old economic system through disincentives for investing and maintaining harmful, high carbon-emitting industries and offer financial innovations to assist such industries to transition[11] . Disruption to the old system is therefore inevitable and necessary, which is problematic for the financial system. Therefore, as the Bank of England has reported, stress-testing and disclosure of climate-related risks is useful for managing the pace and scale the speed of the transition process as it impacts on the stability of the financial system (Carney, 2018; Carney, 2019).

4.2.4. *Contested social context*

Sustainability transition processes result in multi-level and contested interactions among new social drivers of sustainability transitions, which contributes towards different long-term visions of the new sustainable pathway emerging typified by iterative and non-linear policy-making (Loorbach et al., 2017).

Transition processes bring forth new pioneers of change such as communities, youth and civil society who are promoting visions of the new sustainable economic pathway and demonstrating its desirability, legitimacy, and feasibility (Stirling, 2006; Scoones et al., 2015). These new pioneers show that governments are not the sole architects of sustainability transition processes. Networks form among these pioneers, bringing together actors that have not worked together before to harness their collective potential to challenge the development status quo (Stirling, 2006). Broad coalitions emerge from among the networks of different social actors that build support and maintain public pressure until the new economic pathways emerge over time (Stirling, 2006; Foxon, 2013a; Scoones et al., 2015). For example, the School Strike for Climate and the Extinction Rebellion activists draw attention to the immediacy of the sustainability and climate breakdown and the need for accelerated responses by government and business. Social movements such as 350.org lobby for divestment from fossil fuels and maintain pressure on the financial system to prioritise the necessary directional changes.

The social dynamics of sustainability transitions means that policy-making is challenging. Framing the long-term vision for the new sustainable economy requires clear and transparent goals. Such goals should reflect behavioural and institutional shifts, the uncertainties of different pathways, social and other costs, and the barriers and opportunities for implementation (Stirling, 2006; Scoones et al., 2015). The escalating levels of deprivation, degradation and inequality that are a result of sustainability and climate breakdown means framing such long-term vision becomes even more complicated (Gower et al., 2012). The policy-making process is, therefore, marked by competing and uncertain policy options and demands (Loorbach et al., 2017).

Bridging the social and policy context of sustainability transitions requires inclusive, participatory policy processes that draw together broad coalitions and includes flexible feedback loops that allow for learning through failures and successes (Stirling, 2006; Smith and Stirling, 2007). All of these are difficult to navigate in practice. Open, dynamic and reflexive policy options are therefore necessary (Foxon, 2013b). More precisely, policies that challenge the roles of government and acknowledge the bias of human actions recognise the institutional complexities of banks and financial regulation and acknowledge the dynamic processes shaping technological and institutional changes (Foxon, 2013b; Perez, 2013; O'Riordan, 2013; Swilling, 2013; Geels, 2013). Different policy mixes which allow for studying the feedback effects of transition processes are also necessary (Edmondson et al., 2018).

The financial system is located within a contested social and policy context in which it may be subjected to questions about the legitimacy of its response to the sustainability and climate breakdown. The Paris Climate Agreement, the SDGs and the Addis Action Agenda require consistent and integrated finance flows to achieve the new sustainable economy. In this context, the demand on the financial system is a willingness to transparently engage in inclusive and participatory processes that collectively frame a shared vision for a new sustainable economy. This would require the financial system to open itself to insights from broad coalitions on its necessary contribution to transition processes through providing the consistent and integrated finance flows envisaged in the Paris Climate Agreement and the Addis Action Agenda. Further, the financial system may need to develop inclusive approaches for designing new projects that prioritise environmental and social outcomes and support the transition process. Non-traditional business models and new financing arrangements that accommodate different social partners' project development and implementation needs may be useful (Brown, 2018; Bidmon and Knab, 2018).

The policy mixes supporting the new sustainable economy may be costly to implement in the short term due to low tax bases, immature technologies, insufficient technical capacities, or other barriers (Granoff et al., 2016). Short-term policy objectives may therefore take priority over policies focused on achieving longer-term structural shifts. The policy context of transition processes contrasts starkly with the financial system's preference for clear policy signals before it risks engaging in new and untested economic initiatives. Since policy uncertainty is inevitable in transition processes, the financial system may need to focus attention on contributing to sustainability transitions within the prevailing policy context.

[11] A practice-related example is the transition bonds recently proposed by AXA Investment Managers (2019) to support carbon-intensive companies to finance the transition away from reliance on fossil fuels.

4.2.5. Contextual experimentation

The IPCC Special Report shows the contextual reality of the sustainability and climate breakdown – a higher incidence of droughts, famine and wildfires, species and biodiversity loss, increased risks of disease, job losses, food and water shortages, and social conflicts (IPCC, 2018). Designing the range of new sustainable economic possibilities varies with the scientific evidence and requires iterative, non-linear, learn-by-doing, innovative processes (Rip, 2006), which requires experimentation and the testing of different approaches in different contexts. Such approaches could relate to new technology shifts, new concepts of welfare, new social innovations and alternative forms of international and national cooperation (Mersmann et al., 2014). The Paris Climate Agreement recognises the need for experimentation in that countries are required to generate increasingly ambitious climate actions over time (UN, 2015a).

Experimentation and iterative learning that consider a variety of stakeholder views is therefore necessary to develop appropriate context-specific responses to the sustainability and climate breakdown (Loorbach et al., 2017; Foxon et al., 2008). Experimental approaches also require enabling policy interventions to guide and induce innovations that shape future economic states, are transformative, and are designed to trigger deep levels of systems change (Voß et al., 2009; Schot and Steinmueller, 2018).

The demands placed on the financial system may depend on the intensity of the sustainability transition process adopted at a country level. For example, less intense and localised ambitions for addressing the environmental and social aspects of the sustainability and climate breakdown may be more easily financed than more ambitious environmental and social goals (Spratt, 2015). Experimental and adaptive approaches should therefore be applied across the financial system, which requires lengthy gestation periods that allow for transition processes to unfold and facilitates an ongoing process of learning by doing (Avelino, 2009; Voß et al., 2009). Such an approach is incompatible with the current financial imperative to demonstrate immediate and predictable results. Investment by intermediaries and the markets may currently be contingent on proven approaches and a given range of certainty regarding return on investment, neither of which may be present in a transition context. Investment may therefore fail to materialise or be made at a high cost to projects. The investment shortfall may be bridged by public institutions and international development organisations (in the case of the Global South). However, the quantum of investment that is required to address the sustainability and climate breakdown means that the financial system may need to re-evaluate its return-on-investment criteria to incorporate environmental and social returns in a sustainable transition context.

4.3. Implications for relating financial systems and sustainability transitions

This section shows that the characteristics of sustainability transitions can inform the consequential demands placed on the financial system, as summarised in Table 2. The value of this perspective is that the demands on the financial system serve as basis for defining the scope of their response, which may aid in the design of appropriate solutions and serve as a framework to evaluate the extent to which the financial system can meet such demands (Minsky, 1986; Perez, 2002; O'Sullivan, 2005; Köhn, 2012).

Having established the potential scope of the demands placed on the financial system by sustainability transitions, the question now arises as to the extent and breadth of its response. The next section, therefore, discusses potential design features for such response.

5. Design features for financial systems' response

The sustainability and climate breakdown as framed by the Paris Climate Agreement, the Addis Action Agenda, SDGs and the IPCC Special Report requires a systems-level response to manifest new sustainable economic systems – in every country, every sector, and every household. The indicative demands that sustainability transitions place on the financial system discussed in Section 4 and summarised in Table 2 set the tone for the potential depth and breadth of the response required.

This section proposes vital design features for the financial system to respond to such demands, as illustrated in Fig. 2[12] . Given the underexplored research agenda on finance within the sustainability transitions field, this section also identifies potential research questions to broaden further empirical and conceptual work in this area.

5.1. Political: address behaviours and incentives within systems

The demands placed on the financial system by sustainability transitions show that it needs to direct and generate both environmental and social system-level impacts while simultaneously destabilising unsustainable economic systems. While finance is a fluid and adaptable resource, it is not a neutral participant in the economy. This lack of neutrality means there is a political dimension to the financial system's responses, raising questions about the scale and nature of the response to achieve the systems-level, directional and other demands inherent in transition processes.

The sustainability and climate breakdown offer many investment opportunities that can drive radical shifts, for example, shifting towards clean energy systems – opportunities framed as contributing to green growth. The directional changes and systems-level impacts that characterise sustainability transition processes and the implications of the IPCC Special Report carry *temporal necessities*, which extend beyond new investment opportunities. Finance is likely to flow towards the new sustainable technologies, based on the

[12] The uneven, overlapping and differentiated shapes and lines with the open spaces that merge at centre represent the interdependent, non-linear and iterative nature of transition processes described in Section 4.

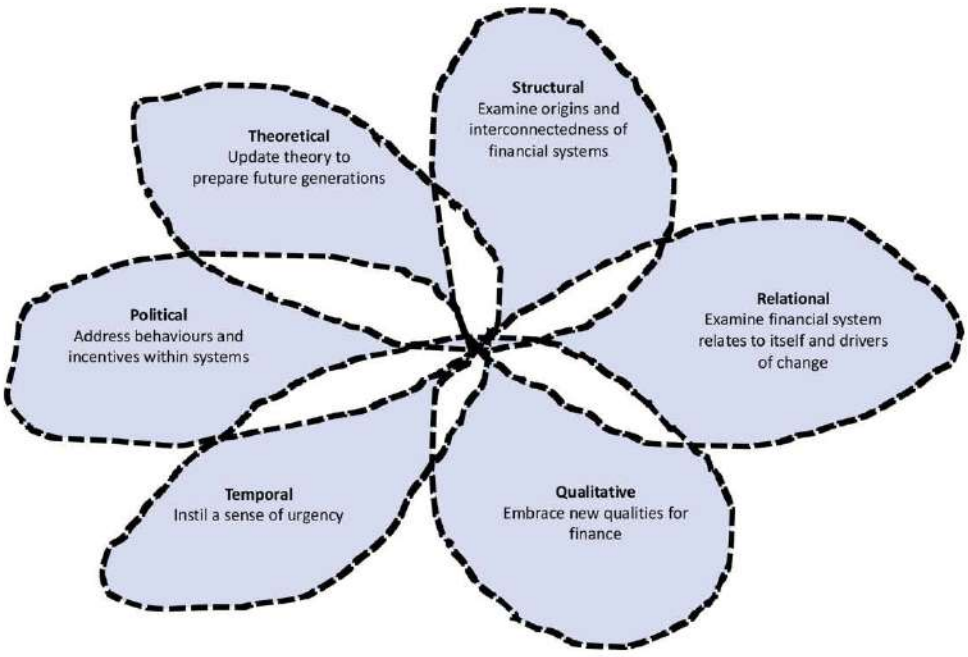

Fig. 2. Design features for financial systems response to sustainability transitions.

natural ebb and flow that accompanies new opportunities (Perez, 2002). While new reorientations in investment management such as impact investing, sustainable and green finance exist, pursuing optimal risk-return investments remains the dominant preoccupation of bankers (Spratt, 2015; Lagoarde-Segot, 2015; Brooks et al., 2018). The call of the Paris Agreement and the Addis Action Agenda for consistent and integrated finance flows show a deeper response is required, beyond making funds available for the new economic path. The type of response required from the financial system to create and direct the new economic state raises questions, for example, how does framing the sustainability and climate breakdown as an *opportunity* for green growth affect the *necessity* of what needs to be done to achieve the new economic state? Who controls the flow of funds?

Schumpeter (1942) characterised bankers' as actors that cause radical changes through their investment behaviours. At the same time, significant economic losses over recurrent financial crises are directly attributed to such behaviours (Reinhardt and Rogoff, 2009; Griffith-Jones et al., 2010). Therefore, the ability to effect radical changes depends on the influences acting on bankers, which relates to the mandate, reward incentives and risk tolerance levels of finance intermediaries and the markets. These influences are formulated into investment positions, which are determined by investment committees, deal-makers and risk managers. The problem-solving processes of the individuals in these structures are influenced by their personal and institutional values, their training, and their prior experiences in different cultural contexts (Bronfenbrenner, 1979). This suggests that the political dimension of the sustainability and climate breakdown may need to be promoted so that it has the potential to influence the funding decisions of bankers, asset managers and others who can make funding available (Knafo et al., 2018).

The response of the financial system to the demands of transition processes depends on how it frames the sustainability and climate breakdown. Is it about new financial innovations, managing climate or sustainability risks, or pursuing new investment opportunities? What should happen in the short term that has long-term implications for sustaining the new economic system? Is more required? For example, practice-based research calls for a transformation of the entire financial system (ECHLEG, 2018; UN, 2018). Why is that the case? What informs the transformation process? Who will direct the transformation process? What does consistency and integration mean to the financial system relative to policymakers and social drivers of change?

Directing the institutions and individuals in the finance system towards the sustainability imperative will be an inherently political and contested process, leading to tensions between the changes the finance system is *willing* to make, and the changes it *should* make. The political dimension requires going beyond discussing the quantum of finance available for investing in the new sustainable economic path. It should recognise that finance may only flow under certain conditions to achieve the new sustainable economic state. Key questions to ask would be, what are those conditions, and what informs those conditions? The political dimension also draws attention to how the financial system relates to itself, and the social drivers of change, as examined in the next section.

5.2. Relational: examine how the financial system relates to itself and drivers of change

The financial system comprises intermediaries, markets, and infrastructure. The intermediaries are banks, institutional investors and national development banks, among others. They serve as the point of access and exchange of finance between those seeking money, and those offering finance, represented by the intermediaries. The relational dimension relates to how different components of the financial system regard their individual and collective role in responding to the sustainability and climate breakdown and their

contribution towards building a consistent and integrated financial system that responds to the demands of transition processes. Meeting the demands of sustainability transitions requires engaging on social issues of inclusivity, with new social drivers, to contribute towards shared visions of change, applying experimental approaches to achieve the new sustainable economic state. To what extent is the financial system able to meet these demands?

It is critical to reflect on how intermediaries, markets and infrastructure of the financial system relate to each other, and how they define their purpose in the economy. The relational dimension is addressed directly in the call of the Paris Climate Agreement and the Addis Action Agenda for consistency and integrated finance flows within the financial system against the background of the urgent action demanded by the IPCC Special Report. The extent to which this call is met will have a direct impact on the degree to which the financial demands of transition processes are met. Further, the financial system's response to the sustainability and climate breakdown depends on the openly stated commitments of individual countries to meet the goals of the Paris Climate Agreement and the SDGs[13] . The demands placed on the financial system and its ability to meet them also depends on the intensity of the environmental and social aspects of the breakdown in specific localities (Spratt, 2015). Sector-specific changes may be less demanding for the financial system than shifts that address economy-wide transformations (Spratt, 2015). The intensity of these economic shifts will influence the type of financial innovations that emerge, the inclusion of new social players, and how relations between intermediaries evolve.

For example, at the level of designing new financial products and business models, each intermediary offers a range of financial instruments such as loans, shares, guarantees to reduce risk, and grants based on its investment mandates and priorities. Public and private intermediaries relate to each other in country context-specific ways. The relationship determines their investment decisions, collaborations, and support of specific interventions. For example, public intermediaries such as state-owned banks are expected to invest in economic development objectives such as health, social welfare and infrastructure, and support high-risk investment where other forms of finance fail (Mazzucato and Penna, 2016). By contrast, private intermediaries such as banks and institutional investors mainly focus on investment opportunities that minimise risk and maximise returns on investment for their shareholders (Spratt, 2009). Incentives are required to attract finance flows towards alternative investments (Spratt, 2009). However, public institutions can also create and shape new markets to promote new investment opportunities (Mazzucato, 2013; Mazzucato and Semienuek, 2018). Each intermediary offers different types of finance, depending on where they engage in the transition process. For example, in the renewable energy sector innovation cycle, different financiers engage differently, based on their investment mandate and preferences (Mazzucato and Semieniuk, 2018). The relational dimension within and between different institutions affects the temporal dynamics of sustainability transitions, as short-term interventions are required to deliver long-term impacts. Several questions arise. How much finance flows? How accessible is such funding? Will finance flow organically over time to support the transition process? Moreover, who holds the financial system accountable for its response?

Relating to the social drivers of change requires the financial system to engage in the design interventions that will drive the new sustainable economic path. Since systems impact is a demand placed on the financial system, the scale of interventions implies going beyond the traditional approach of financing single projects and shifting towards portfolio approaches (i.e. recurring combinations of projects and programmes) that support scaled-up interventions. The interventions also require experimental and adaptive approaches as future impacts may be uncertain, and the policy context may change. An example of an experimental financial innovation is the Green Fund managed since 2012 by the Development Bank of Southern Africa. Designed for learning-by-doing, the Green Fund provides evidence of the developmental needs of green projects and their environmental, social, and financial returns (Naidoo, 2019).

Evaluating the traditional roles and mandates of the components of the financial system relative to their purpose in creating and sustaining a new sustainable economic path may be helpful for understanding to what degree the system should transform itself. Addressing these relational issues among the intermediaries, markets and infrastructure of the financial system also depends on the structure of the financial system as the next section shows.

5.3. *Structural: examine origins and interconnectedness of financial systems*

The structural dimension relates to a country's national financial system. Why this focus? The evolution of a country's financial system influences its ability to drive radical economic shifts and determines the pace and scale of future development (Schumpeter, 1942; Gerschenkron, 1962). The structural dimension incorporates the degree to which the national finance system is interconnected with the global financial system, which determines its vulnerability to financial crises originating in other jurisdictions (Aziakpono, 2006). The structural dimension also requires consideration of the cultural influences from which financial systems originate and the forces that shape their evolution (Naidoo, 2019; Urban and Wójcik, 2019). For example, the dominant model for financial systems are British or American banking systems, with differentiated approaches in the Middle East and Asian countries (Urban and Wójcik, 2019). Given these factors, the structural dimension significantly influences how the financial system responds to sustainability transition processes. This means that any structural impediments or advantages of a country's financial system may either inhibit or promote transition processes.

The impediments or advantages of the financial system in question affect the diversity of financial innovations available for structuring and financing projects and programmes (Pathania and Bose, 2014; Polzin et al., 2017; Naidoo, 2019; Urban and Wójcik, 2019). Financial innovations can arise in two ways. Firstly, existing intermediaries in the financial system may collaborate to create

[13] For example, the Nationally Determined Contributions for reductions in greenhouse gas emissions under the United Nations Framework Convention on Climate Change.

new financial instruments. Secondly, new government policies may encourage the creation of new financial innovations (Pathania and Bose, 2014). For example, financial instruments with the longer durations needed for renewable energy investment may not be available due to the structure of the national financial system (Polzin et al., 2017), but this may change. Financial innovations in current systems are biased towards debt (Turner, 2016; Polzin et al., 2017), which influences how investment decisions are made, what is financed, and by whom (both public and private). The debt bias amplifies the need for new innovative non-debt-based instruments and models for exchanging and deploying financial resources, such as crowdfunding platforms (Ansart and Monvoisin, 2017). The Paris Climate Agreement and SDGs are interdependent, requiring responses to both the environmental and social dimensions of sustainability. This requires consistent and integrated financial systems to support the shift to new sustainable paths, which influences how the financial system supports this process. For example, as mentioned in Section 4, the narrative related to green growth and its associated reward expectations requires reflection. Since transition processes require contextual experimentation, alternative learning-by-doing mechanisms, digital platforms and community finance arrangements may be within the realm of possibility for creating a diverse financial system that is both accessible to, and relevant for, the demands of transition processes.

Structural limitations further influence the extent to which there is equitable access to finance for the transition process. This has an impact on how the directional changes unfold, whether the desired systems impact is achieved, and the level of social contestation. For example, structural limitations in Ghana's finance system inhibit access to finance for renewable energy project developers; project development and entrepreneurial finance is limited (Beggs, 2018). Poor access to finance for vulnerable groups and small to medium-sized firms place may inhibit a just and equitable transition from materialising in South Africa (Naidoo, 2019). The structural limitations, therefore, require open engagement between the drivers of change to consider openly how the financial system can be reoriented to the purpose of sustaining the new sustainable economic path. While practice-based research through the UNEP Inquiry, the UK Green Finance Strategy and ECHLEG is promising, it has not yet been subjected to independent academic consideration. Falcone et al. (2018) observe that the financial system reforms are mainly led by developed countries with limited evidence of developing country engagement. Whose vision of a sustainable financial system is emerging? How is the vision constructed to include broader social dimensions? How does the vision relate to the demands of sustainability transition processes? What dimensions are being included or excluded, and why?

Systems innovation and co-evolution are inherent parts of sustainability transitions processes (Geels, 2010), suggesting that stagnant and rigid financial systems should be reviewed. This has broad implications. Importantly, it sets a new challenge for finance, including and going beyond the Schumpetarian goal of achieving radical changes in the economy. The challenge is to direct the financial system towards supporting environmental and social sustainability, which requires consistent and integrated approaches to maintaining this direction. An added challenge for the financial system is a lack of time.

5.4. *Temporal: instil a sense of action*

The rate of past energy transitions provokes debates about the temporal dynamics of transitions: need they be lengthy and protracted processes, or should we be asking what it will take to accelerate them? (Sovacool, 2016). Further, accelerated transitions require increasing the pace and scale of public policies that respond to the sustainability and climate breakdown (Stern, 2018). The emerging debate on the temporality of transitions is relevant because transitions depend on a series of actors and forces to forge new pathways (Fouquet (2016). The realities of the sustainability and climate breakdown drive sustainability transitions processes and the temporal timeframes of responses, which suggests that the slow pace of sustainability transitions is concerning (Schmitz, 2015; Brown and Granoff, 2018). It therefore becomes important to ask: how does a focus on the longer term shift the debate on financing sustainability transitions?

These debates are timely. The IPCC Special Report puts forward the real-world drivers and arguments for accelerated transitions, offering evidence of environmental and social crises that will eventuate unless urgent actions are taken (IPCC, 2018). These debates need to be extended into academic and empirical research on relating the financial system to sustainability transitions. What will it take to deliver finance urgently and at scale? What type of funding and governance models are needed to do so? What does this imply for public and private investment strategies? What type of governance arrangements and financing models can support accelerated transitions? What role can central banks play in ensuring that the financial system moves at the required pace and scale?

The temporality of the sustainability and climate breakdown adds a sense of urgency to the dimensions discussed so far in this section, which leads to questions about the qualitative dimensions of developing the response of the financial system. This is explored in the next section.

5.5. *Qualitative: embrace new qualities for finance*

References to the quality of finance relate to the reluctance of investment managers to invest over the longer term (Knafo and Dutta, 2016). Calls for reorienting finance towards qualitative dimensions first emerged in the aftermath of the 2008 financial crisis with calls for "patient capital". Such patient capital enables a shift away from the short-termism of investment allocations and financialisation (finance investing in finance), and a move towards long-term gains (Mazzucato, 2013). Since transition processes are iterative and experimental, patient capital is essential for learning by doing, which is identified in Section 4 as the contextual experimental characteristic. While patient capital is a useful starting point for more qualitative dimensions for finance, the demands placed on the financial system require new qualities for finance. This paper, therefore, proposes additional qualities for the financial system to support sustainability transitions processes: consistency, pragmatism, responsiveness, inclusivity and adaptability.

a) *Consistency*: Consistency is necessary to address the directional shift of finance towards sustainability and away from unsustainable options. This quality is linked to the Paris Climate Agreement (UN, 2015a) call for finance flows to be consistent with sustainability transition processes and for integration per the SDGs and the Addis Action Agenda (UN, 2015b, 2015c). The tensions associated with contextual experimentation described in Section 4 also lend support for this quality which acknowledges that, while difficult choices will have to be made, responding to the sustainability and climate breakdown should always be the top priority.
b) *Pragmatism*: Pragmatism is necessary to address the real-world temporal dimensions through developing new business and funding models for accelerated access to finance for sustainability transitions. This includes reducing the lag effects associated with governance delays that slow down the development and implementation of projects. This quality is derived from the real-world context of transitions highlighted by various authors (Stern, 2018; Sovacool, 2016; Geels et al., 2017).
c) *Responsiveness*: Many of the temporal-related responses to the need for accelerated transition processes, including reducing greenhouse gas emissions, increasing resilience and addressing crises such as habitat destruction and displaced people change may be linked to uncertainty and significant variability. This requires the financial sector to be responsive and willing to provide access to resources that permits experimentation and learning by doing.
d) *Inclusivity*: Inclusivity is necessary to ensure that new coalitions participate equitably in the transition process to address social inequalities in the economy so that, for example, a sustainability transition does not exacerbate social inequalities (Vergragt, 2013; Witt, 2013).
e) *Adaptability*: This quality argues for more adaptive approaches to investment decision-making that depend on a social mechanism that influences the behaviour of financiers (Hall et al., 2016). Such a mechanism would accommodate experimentation, learning by doing and iterative decision processes. The quality of adaptability also addresses the co-existence of creative and destructive processes. Central banks and regulators are concerned about maintaining stable and secure financial systems to facilitate economic development and avert financial crises. This means a specific role for central banks and regulators on information disclosures and risk management strategies to reduce and manage the uncertainties linked to sustainability transition processes and the climate breakdown (Campiglio et al., 2018; Battiston et al., 2016; Stolbova et al., 2018). Alternative debates are emerging that hold that focusing on stability and managing financial risks is a defensive approach; instead, central banks should offer incentives to the financial system to support green investment (Tooze, 2019).

Reorienting the financial system's focus to include the qualitative issues described above requires deep reflection on the underlying theories and assumptions that drive the investment behaviours, cultures and incentives of financial institutions (Lagoarde-Segot, 2015; Diaz-Rianey et al., 2016), as discussed in the next section.

5.6. Theoretical: update theory to prepare future generations

The theoretical dimension refers to investing in the education of future generations who will be the bankers and policymakers leading the transformed systems of the future. They will need to maintain the direction of sustainability transitions and sustain systems transformations when they make their decisions in the future.

Finance as an academic discipline resides within economic studies, a field in which scholars and students are questioning the ability of the field to address real-world challenges of sustainability and climate breakdown (Orléan, 2014; Lagoarde-Segot, 2015; Raworth, 2017). Early conceptions of finance connect to real economic growth and human well-being, but finance evolved mainly using quantitative approaches (Raworth, 2017). Further, the emergence of sustainable finance requires qualitative approaches are incompatible with orthodox financial models (Lagoarde-Segot, 2018). These mismatched approaches create an epistemological challenge for conceptual and empirical research. Further, some authors argue that the theories on which financial models are based have no theoretical basis for embedding environmental and social objectives, despite existing framings of what sustainable finance should entail (Lagoarde-Segot and Paranque, 2017). These epistemological challenges lend urgency to evaluating and interrogating the underlying assumptions of financial innovations and initiatives that claim to support sustainability transitions.

This lack of appropriate theoretical conceptualisation between the sustainability transitions and finance fields raises questions for both the pace and depth of sustainability transitions in the short term. For example, how do financial theories lock in changes that the financial system is *prepared* to make, rather than the changes it is *required* to make? The poor conceptual development of finance and sustainability transitions also means empirical research on financial innovations and reforms is limited by current framings of finance and sustainability transitions. The short-term risk is that sustainability transition processes may be constrained by a financial system that is guided by financial theories incompatible with sustainability transitions. Rethinking the field of finance is therefore essential for long-term systems transformation aligned with responding in a consistent and integrated manner to the sustainability and climate breakdown.

The sustainability transitions field positions finance neutrally. It assigns a background role to finance as a function inherent in user practices and as one of the resources critical for advancing transition processes. This neutral positioning masks the broader and multi-layered complexity of the political dimensions of the financial system. It is therefore critical to develop new framings for finance in the sustainability transitions field. Such framings should focus on developing heuristics that can examine causal linkages, for example how financial system responses to sustainability transitions inhibit or promote such transitions. Research on finance in the sustainability transitions field tends to apply the MLP as a core heuristic, which frames finance as a resource and function. While the MLP is useful for reflecting the *process* of transitions, its ability to explain the causality of transition processes is limited (Svensson and Nikoleris, 2018; Sorrell, 2018). Causal explanations are essential for answering questions such as that posed by Köhler et al.

(2019) about how financial capital restricts or promotes sustainability transitions.

Independently evaluating practice-based policy research that claims to advance transition processes is also essential because the seeds of the financial system's responses are planted through these initiatives. While there are no guarantees of success, the future generation of policymakers and bankers will either benefit from what they learn, or have to unravel misdirected and poorly-conceived approaches.

Although new reorientations and conceptual developments may only take effect over time, efforts in the theoretical dimension are critical for educating and laying good foundations for future generations of bankers, policymakers, entrepreneurs and consumers. Sustainability transitions research is not only about creating the new economic path. It relates to sustaining such a path by putting in place measures that ensure no reversion to unsustainable economic options or investment behaviours. Academia has an important role to play through the power of ideas and education.

5.7. *Implications for future research*

The discussion in this Section 5 invites interdisciplinary approaches to further relate financial systems and sustainability transition. The implications for future research extend beyond the subject matter of this paper, which started with identifying possibilities for relating financial systems and sustainability transitions. A recurrent theme stands out in the critical emergent literature on finance and sustainability – the need for explicit assumptions (Section 3.5) and, specifically, the relevance and validity of the assumptions of orthodox economic theories to societal challenges (Orléan, 2014; Raworth, 2017; Mazzucato, 2018), and the epistemological assumptions of finance that make embedding sustainability difficult (Aspinall et al., 2018; Lagoarde-Segot, 2018; Diaz-Rianey, 2016). For STR, the research highlights the limitations of the tacit assumptions informing the sustainability transitions field such as accepting the orthodox view of capitalism (Swilling, 2013; Feola, 2019) and the assumptions underlying the ontological foundations of sustainability transitions and the MLP heuristic (Svensson and Nikoleris, 2018; Sorrell, 2018).

Why focus on assumptions? In any change context, explicit assumptions help to articulate expectations and generate effective responses where possible, which enhances the rate, scale and pace of the change process (Stern, 2018). Assumptions contain the underlying elements of that which we accept unthinkingly (Feola, 2019). This means that the design of solutions is inclined to embody the unquestioned and silent assumptions about the cause and effect of a problem. Solutions influence how future conceptual, empirical and policy-making processes unfold. While theory cannot solve the problems of sustainability and climate breakdown, implicit assumptions informing theory-policy-practice exchanges may have the effect of accelerating the breakdown rather than mitigating its impact. This may lead to misdirected and misaligned transition processes and locking in fault lines that would have to be unravelled in future, if this is still possible.

For these reasons, the paper encourages advancing STR research to openly examine the assumptions about the problem and the emerging solutions. Feola (2019, 7) describes STR scholars as "not only researchers but also change actors in society", i.e. change actors studying the process of responding to sustainability and climate breakdown. This means that the process of theory and policy research and development in STR carries a duty of care and responsibility towards present and future generations. It requires continually reflecting on *what is the nature of the problem(s)? What implicit assumptions underpin our ideas and solutions concerning such problems? How may the assumptions we hold be problematic in future?* By making our assumptions visible, we create space for ourselves, current and future generations of scholars to engage critically. The call to STR scholars for relating financial systems to sustainability transitions is especially important. Current research in this area is limited and conceptually, finance has not been adequately located, so its causal effects cannot be studied. A good understanding of the causal linkages between financial systems and sustainability transitions is essential for understanding how finance and financial systems inhibit or advance transition processes, so that ongoing improvements can be made in the spirit of learning by doing.

6. Conclusions

Sustainability transitions will struggle to materialise without the active engagement of financial systems, however, the role that finance plays extends beyond financing the new sustainable economic state. We know that the availability of finance is not a constraint for sustainability transitions as over US$112 trillion (PwC, 2017) is currently circulating in the global economy that can be potentially address the sustainability and climate breakdown. This suggests that the calls for the financial system to have consistent and integrated finance flows in the Paris Agreement, the SDGs and the Addis Action Agenda relate to a qualitative rather than purely quantitative role for the financial system.

This paper set out to explore possibilities for relating financial systems and sustainability transitions. In Section 3, the paper scopes existing research and finds broad sustainability-related finance literature with limited critical engagement and little cross-engagement with STR. This context together with the underdeveloped conceptualisation of finance at a systems level in STR creates conceptual challenges to connect the current sustainability-related finance literature and STR.

In Section 4, the paper argued that relating financial systems to sustainability transitions begins with understanding the nature of the transition process and identifies a framework of indicative demands for the financial system to respond to. This is akin to asking, what is the nature of the problem being solved? The demands represent explicit assumptions for the financial system to engage with and the framework may be useful for evaluating the extent to which the financial system can meet such demands. Explicit demands also serve as a point of reference for situating and critically evaluating the response of the financial system relative to such demands; such ability to critique the responses of the financial system is presently lacking in sustainability-related finance and STR.

In Section 5, the paper proposes essential design features for responding to the demands of transition processes, which involves

multiple overlapping dimensions. The process is complicated, as it requires reflecting on the implicit assumptions framing finance and the financial system embedded in each of these dimensions. This paper does not presume that the financial system has to transform to be compatible with a new sustainable economy. Rather it argues that if such a transformation is indeed required, then the depth and breadth thereof matter and identifies critical questions to broaden research in this area.

This paper invites scholars and policymakers to reflect further on the explicit demands that transitions place on the financial system, the process of designing solutions, and the underlying assumptions and critique of such solutions. In the words of George Harrison, *"If you don't know where you're going, any road will take you there."*[14] . It is a timely warning: although responding to sustainability and climate breakdown requires accelerating rapid and radical changes - in our haste, we may overlook the dangerous assumptions that created the breakdown in the first place – finding ourselves on a road sometime in the future, where we are right back at the same unsustainable place.

Acknowledgements

I express my deep gratitude to @Lahotar for inspiring my research. The paper benefited from the review of the editor and two anonymous reviewers at EIST, as well as comments from Tim Foxon, Benjamin Sovacool, Karoline Rogge and several colleagues at SPRU on the earlier drafts of this paper. An earlier version of this paper appeared in the SPRU Working Paper Series, August 2019. No financial support was made available for the research from any funding agencies in the public, commercial, or not-for-profit sectors. There are no conflicts of interest to be declared.

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[14] Extract from George Harrison's song "Any Road".

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