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Systemic complementarities and transformative change: A tentative methodology to examine bidirectionality effects across connected systems

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Achieving energy-sustainable goals involves large-scale production and social changes necessary to fulfil societal functions (Geels, 2004; Markard, 2011). These long-term goals imply a transformative change requiring multiple transitions involving multiple socio-technical systems and their interplay (Raven and Verbong, 2007; Geels, 2007; Papachristos, 2013; Rosenbloom, 2020). To fully address system change, it is necessary to consider that changes in one system affect the other (Geels, 2007; Papachristos, 2013), i.e., the presence of bidirectionality in system interactions. However, bidirectionality has only recently started being tackled and remains under-conceptualized.

Unravelling the complex interrelationships that underlie systems change has attracted attention from different streams of the literature. The technological innovation systems (TIS) approach argues that a new system needs to establish connections with the context from which it emerges to gain access to key actors and resources and proposes the notion of structural couplings linking “context structures” with the new system (Bergek et al., 2015; Markard, 2020). While these links are assumed to be bidirectional, the goal has been to understand their effects on the emerging system, and thus the focus has primarily been on one-directional change (Ulmanen & Bergek, 2021). Also missing is a process view, e.g., conceptualising how these interactions occur. This limits our ability to understand the change processes resulting from the interactions between the systems involved (Rosenbloom, 2020; Andersen & Geels, 2023; Breitschopf et al., 2023). In particular, there is limited understanding of the potentially transformative effects in the existing systems with which the new system connects (Andersen et al., 2020; Fontes et al., 2021).

Nevertheless, the notion of overlaps or “structural couplings” between an emerging system and other connected systems still appears to be a productive route to investigate how bidirectional effects take place in this case. For this, it is helpful to bring in the concept of complementarities between socio-technical systems (Markard & Hoffman, 2016; Mäkitie et al., 2022; Leitch, 2019). However, there is still a gap to be addressed, as overlaps do not automatically lead to interactions, so the problem of system failure in setting up complementarities is raised (Leitch, 2019). This leads us to two research questions:

- How do complementarities enable the construction of interactions between systems?

- To what extent do complementarities support transformative effects in emerging systems and in established ones?

To deal with these questions, we build on and extend the TIS approach (Bergek et al., 2015). The fact that “context structures” is a very abstract concept makes it difficult to examine bidirectional flows.

Drawing on the literature on multi-system interactions, we propose that the emerging “focal system” effectively connects with a set of other systems, and, therefore, structural couplings exist with elements of these systems. We are looking at system/system interactions. Considering that structural couplings imply shared elements, namely shared actors and resources, we build on the premise that complementarities are formed through these interactions between systems (Markard & Hoffman, 2016; Leitch, 2019), leading to a “shared space”.

However, shared resources formed in the “shared space” need to be “contextualized” by each system, in order to be used by them. We call this process transformation of resources that "by definition are anything useful or available to achieve a goal" (Shostak & Dmitry, 2019) into assets that are defined as "anything owned or controlled that has economic value (Shostak &Dmitry, 2019), and thus are resources that can be appropriated. This process of “contextualization” (Teece, 2010) is conducted through feedback mechanisms (Mäkitie et al., 2022) that enable adjustments (Forrester, 1971) in both the emerging and the existing systems. These transformative effects can be more or less broad, affecting a few or several elements of a system, and one or various systems simultaneously.

This study proposes a methodology—centred around the notions of "shared space," systemic complementarities, and the contextualization of resources (e.g., their transformation into assets)—that enables an examination of the processes supporting the bidirectionality of flows across connected systems and, tentatively, their transformative effects