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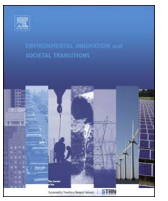

Established industries as foundations for emerging technological innovation systems: The case of solar photovoltaics in Norway

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ABSTRACT

This paper follows up on recent debates on relations between technological innovation systems (TISs) and context. Particular focus is placed on the role of established industries, which possess important resources for TIS formation. The paper contributes in two ways. First, the paper builds and expands upon the TIS framework to encompass beneficial relations between a TIS and its sectoral and technological context. Second, the framework is applied to the analysis of the emergence of a solar photovoltaic (PV) industry in Norway. The analysis first illustrates how an emerging TIS can benefit from an overlap with an established industry, which serves as a structural foundation and impacts key TIS processes. Second, the paper shows how relations between TIS and context change over time and range from supply chain interaction to more profound overlaps of system elements.

1. Introduction

Established industries harbour much-needed resources for the development of new industries and technologies that are part of sustainability transitions. The transfer of resources would require a beneficial relation between established and emerging industries. While the relation between established and emerging industries has been at the heart of sustainability transitions research, much of this attention has been directed at instances characterised by conflict and antagonism (Geels, 2002). Positive relations and cases where established industries show higher degrees of adaptability to new technological opportunities have received less attention (Dolata, 2009). Both qualitative studies and suggestive theories that explain industry emergence and relations to factors prior in time have been called for (Forbes and Kirsch, 2011; Krafft et al., 2014). Recent contributions have opened to the inquiry of whether there is more to the relations between established and emerging industries than conflict (Berggren et al., 2015; Geels et al., 2016). The paper engages with this line of research with the purpose of analysing how processes of new industry formation can benefit from established industries and its associated actors and resources.

The paper applies the technological innovation system (TIS) framework, which has become a useful tool for analysing emerging industries (Markard et al., 2012). Recent contributions call for conceptual strengthening and more empirical analyses of relations between TIS and context. This includes the context of established industries. In most studies, the context of a TIS is seen as a source of competition or suffering from lock-in, but in some cases, established industries can be beneficial for emerging industries (Frenken and Boschma, 2007 Garud and Karnøe, 2001). Arguably, strong relations to existing context structures could play a decisive role in new TIS formation (Bergek et al., 2015). Few studies focus explicitly on the conditions under which beneficial relations between mature industries and newly forming TISs emerge. We miss insights into how such relations are established and unfold. The paper contributes to the TIS field by analysing how such relations are created by exploring the following research question: *how, and under which conditions, can an established industry contribute to TIS formation*?

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To explore this question, the paper extends the TIS framework and applies it to the analysis of the solar photovoltaic (PV) industry (PV-TIS) in Norway. The analysis focuses on how PV-TIS formation benefited from relations to the metallurgical silicon industry and the broader electrometallurgical industry sector. This case is useful for gaining insights into how established industries can play a beneficial role by acting as a structural foundation for new TIS formation, and affecting key TIS processes.

The following section introduces the analytical framework and methods employed in this article. Section 3 presents and analyses the case, while Section 4 provides a discussion. Conclusions and suggestions for future research are provided in section 5.

2. Analytical framework

2.1. Relations between a technological innovation system and context

A TIS consists of elements (actors, networks and institutions) that are engaged in generation, diffusion and utilisation of a specific technology (Bergek et al., 2008; Hekkert et al., 2007; Markard and Truffer, 2008). However, given its technology specific focus, the TIS approach has been criticised for being myopic with lacking attention to how TISs relate to their broader contexts (Markard and Truffer, 2008). This critique has been met by Bergek et al. (2015) who suggest a scheme for TIS context analysis, based on how TISs relate to geographic, political, sectoral and technological contexts. This paper engages with this recent development and explores the circumstances under which these relations to context are established. Specifically, the paper explores the context of established industries, and how it can contribute to TIS formation processes.

2.1.1. Specifying context

As a starting point, the context must be specified. Established industries are here seen to provide context for the focal TIS along two dimensions − sectoral and technological. These contexts can overlap, but the paper distinguishes between them for analytical purposes to single out technology-specific resources from more general ones embedded in broader sectoral contexts.

Sectors are stable, institutionalised and regulated sociotechnical systems that follow particular technological trajectories and organisational patterns, in part depending on the technologies developed and used (Dolata, 2009). A sector thus can be seen as serving a particular function, such as the supply of energy or other products and goods, while multiple technologies are integrated with the sector to various degrees (Bergek et al., 2015). Sectors are built up of the same elements as a TIS noted above.

Previous studies have shown that established sectors can influence emerging TISs. Wirth and Markard (2011), for instance, show how the emerging biomass TIS in Switzerland depends on its connections with several sectoral contexts, both in terms of inputs (forestry and sawmill) and outputs (electricity and gas supply).

To discuss a beneficial sectoral impact on TIS formation, factors that enable the development of a positive relation between a sector and an emerging technology must be accounted for. Although much focus has been put on relations characterised by conflict and separation, emerging technologies and established sectors can also be tightly connected (Dolata, 2009). The main focus of this paper is on the creation of connections that involve the engagement of sectoral focal actors or transfer of resources from the sector. It has been empirically shown that new opportunities presented by emerging technologies can trigger actor entry from established sectors to newly forming TISs (Erlinghagen and Markard, 2012; Wirth and Markard, 2011). The exploration of these new opportunities can be triggered by changes in actors' selection environments. These include pressures and opportunities presented by new technologies (Dolata, 2009), firm-level pressures (i.e., pricing and competition) or broader pressures emanating from institutional change (Smith et al., 2005).

Whether established sectors can connect with, and positively influence an emerging technology through actor entry or transfer of resources, depends on the sectors' institutionalised patterns of experimentation, openness and ability to interpret opportunities linked to new technologies. Furthermore, this openness and experimentation with emerging technologies not only depends on intra-organisational capabilities. Firms also rely on other firms, universities and research institutes to create an environment that is conducive to anticipation and interpretation of new technological opportunities (Dolata, 2009).

Since sectors are comprised of several technologies, and thus several TISs, we could expect that the opportunities to interpret and link up with emerging technologies would differ across the technological fields present in the sector (Bergek et al., 2015).

A proposition explored in this paper is whether search and experimentation in a technological field already integrated with an established sector helps to enable a relation that is beneficial for the focal TIS. This would entail the presence of a context TIS integrated with the sector, which has the potential to form a positive relation to the focal TIS. Much of TIS–TIS interaction occurs in supply chains, where one TIS supplies materials or technologies to another TIS (Bergek et al., 2015). Instances of more profound relations would entail overlap between the innovation system elements discussed in Section 2.2.

This thus leads to specifying the technological context as the second context dimension provided by established industries. The paper thus distinguishes between two relevant contexts: the particular technological context (TIS) and the broader sectoral context to which these TISs relate. The inclusion of a technologically related context TIS provides the opportunity to analytically distinguish a particular technological context that enables a relation between the sector and focal TIS to materialise.

2.1.2. Type of relation

With regards to the potential types of relations between TIS and context, Sandén and Hillman (2011) develop a framework, which suggests that emerging technologies may enjoy a range of relations to established ones, ranging from pure conflict to pure symbiosis. The locus of interaction can be observed at the value-chain level, where two technologies may overlap in different forms at different levels of the value chain. Sandén and Hillman (2011) further suggest six patterns of relations, differentiated in terms of whether a technology has a positive, negative or neutral impact on the old technology and vice versa. All six dimensions are not explored here,