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Technological innovation systems in contexts: Conceptualizing contextual structures and interaction dynamics☆

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ABSTRACT

This paper addresses interactions between technological innovation systems (TIS) and wider "context structures". While TIS studies have always considered various kinds of contextual influences, we suggest that the TIS framework can be further strengthened by a more elaborated conceptualization of TIS context structures and TIS–context interactions. For that purpose, we identify and discuss four especially important types of context structures: technological, sectorial, geographical and political. For each of these, we provide examples of different ways in which context structures can interact with a focal TIS and how our understanding of TIS dynamics is enhanced by considering them explicitly. Lessons for analysts are given and a research agenda is outlined.

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1. Introduction

Over the past three decades, system concepts have gained prominence in the academic literature on innovation processes and in associated policy-making (Chang and Chen, 2004; Sharif, 2006). These approaches have proven to be instrumental for informing a wide range of pressing public policy problems, such as national economic competitiveness, regional industrial revival and global environmental sustainability.

The specific variant of technological innovation systems (TIS) focuses on understanding how the innovation system around a particular technology functions. The focus can be on mature technological fields or on the emergence and diffusion of new and radical innovations (Bergek et al., 2008b; Carlsson and Stankiewicz, 1991; Hekkert et al., 2007; Markard and

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Truffer, 2008). A large part of the studies applying the TIS framework have focused on studying the emergence of clean-tech sectors and, by this, it has become a major building block of sustainability transitions research (Markard et al., 2012). In the field of transition studies, TIS contributes with an analytical framework for understanding the complex nature of the emergence and growth of new industries and a focus on analyzing obstacles to this process (labelled blocking mechanisms, system weaknesses or systemic problems). The framework also contributes to the subsequent translation of obstacles into intervention and policy strategies, which has led to concepts such as systemic instruments and policy mixes (Alkemade et al., 2011; Jacobsson and Karltorp, 2013; Smits et al., 2010; Weber and Rohracher, 2012; Wieczorek and Hekkert, 2012).

As a technology-centred framework, there has always been a focus on technology-specific factors in TIS research. However, since it is a systems approach analysts have from its inception tried to find ways to take into account interactions with other types of systems encompassing or transcending the TIS, such as sectoral and national systems of innovation. Indeed, the 'functions approach' was developed as a methodological tool to handle this complexity by aggregating various influences (of different origins) on the dynamics of a TIS into a set of key processes (Hekkert et al., 2007; Jacobsson and Bergek, 2006; Johnson and Jacobsson, 2001). This has allowed for a large number of detailed empirical analyses of how the dynamics of various TISs have been influenced by internal and external pushes and pulls (for reviews, see Bergek, 2012; Truffer et al., 2012).

At the same time, the functions framework does not give much explicit attention to the dynamics of surrounding contexts. In recent years, TIS scholars have therefore returned to the relationship between TISs and contextual systems. Scholars have developed the geographical dimension further (e.g. Binz et al., 2014; Coenen et al., 2012; Gosens et al., 2015; Schmidt and Dabur, 2014), studied the parallel development and competition of several technologies (Johnson and Jacobsson, 2001; Sandén and Hillman, 2011; Suurs and Hekkert, 2009a; Wirth and Markard, 2011) and linked TISs to wider policy settings (Kivimaa and Virkamäki, 2014; Markard et al., 2015; McDowall et al., 2013). Some have also made a plea to combine the TIS framework with the Multi-Level Perspective to better capture the relationship between technology evolution and sectoral change (Markard and Truffer, 2008; Meelen and Farla, 2013).

While these studies have all contributed to a better understanding of how a TIS relates to various context structures we still lack a coherent framework that makes explicit how the interactions between a TIS and its contexts can be conceptualized. Such a framework would have at least four clear benefits. First, it would improve the TIS framework as a policy tool in that an improved contextual understanding would guide analysts in their search for central interactions between a focal TIS and its context. Second, it would increase the awareness among analysts and policy-makers that contexts vary widely and that technologies develop differently in different contexts. Explicit consideration of contexts would, thus, increase our understanding of the particularities of individual case studies and, at the same time, provide a basis for a classification, generalization and transfer of findings, which is of key importance for TIS-based policy-making. Third, by acknowledging that context structures are not static but change over time, it would allow analysts to identify particularly favourable (or unfavourable) opportunities for development of new technologies. Fourth, a coherent framework incorporating context structures would facilitate further analytical work with a focus on how a given TIS (or set of TISs) impacts on different contexts. Hence, an additional benefit may be to pave the way for the development of a TIS-based framework which is helpful for analyzing larger transitions involving the growth and decline of several technologies and associated sectoral transformation processes.

The aim of this paper is to take a step towards a more explicit framework for analysis of TIS–context interactions by addressing the relation between a TIS and four different context structures. We also formulate a set of questions that may form the backbone of a research agenda. The selected contexts include other TISs, industrial sectors, geographical territories and political systems.

In Section 2, we discuss some general aspects of system delineation and interaction and motivate the choice of the four analyzed context structures, while Section 3 provides examples of how technological, sectoral, geographical and political structures interact with TIS dynamics and identifies a set of research questions. Section 4 concludes the paper by discussing some general lessons for analysts.

2. Understanding TIS context structures and interactions

A technological innovation system is defined as a set of elements, including technologies, actors, networks and institutions, which actively contribute to the development of a particular technology field (e.g. a specific technical knowledge field or a product and its applications) (cf., e.g. Bergek et al., 2008c; Markard and Truffer, 2008). The TIS perspective emphasizes systemic interdependencies between these elements, which give rise to various forms of synergies, such as collective assets on which the different actors can draw but which they could not produce if they worked in isolation.

The existence of system-level assets (or resources, see Musiolik et al., 2012) implies that system boundaries have to be carefully chosen. The boundary separates the TIS (i.e. the realm where systemic interdependencies in a specific technological field play out) and its "context" (all other structures and relevant factors outside of the TIS). In the literature, the setting of system boundaries is largely considered to be an analytical problem, i.e. system boundaries can be set in many different ways depending on the research interest of the analyst and often have to be adjusted as the analysis proceeds (Bergek et al., 2008a; Carlsson et al., 2002). In principle, the aim of boundary setting is to determine what technology and what level of analysis (a knowledge field, a product or one or more applications of the technology) is in focus (Carlsson et al., 2002). It is also common in empirical analyses to use some kind of geographical delimitation, e.g. a region or a country, but it should

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