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Global Innovation Systems—A conceptual framework for innovation dynamics in transnational contexts

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ABSTRACT

This paper proposes a framework for the analysis of technological innovation processes in transnational contexts. By drawing on existing innovation system concepts and recent elaborations on the globalization of innovation, we develop a multi-scalar conceptualization of innovation systems. Two key mechanisms are introduced and elaborated: the generation of resources in multi-locational subsystems and the establishment of structural couplings among them in a global innovation system (GIS). Based on this conceptualization, we introduce a typology of four generic GIS configurations, building on the innovation mode and valuation system in different industry types. The analytical framework is illustrated with insights from four emerging clean-tech industries. We state that a comprehensive GIS perspective is instrumental for developing a more explanatory stance in the innovation system literature and developing policy interventions that reflect the increasing spatial complexity in the innovation process.

1. Introduction

In a globalizing knowledge economy, the mobility and circulation of people, knowledge, and capital increasingly interrelates innovation processes in distant places (Corpataux et al., 2009). The increased spatial complexity of innovation processes raises the question whether a territorial (local, regional, or national) *system* perspective is still a valid one as system boundaries get increasingly blurred and porous. More fundamentally, some argue that the innovation system (IS) perspective, on a more general level, is no longer a promising line of research and should be left on the shelves of the history of innovation studies, as concluded in a plenary debate at the 2013 DRUID conference.[1]

In the present paper, we argue against this view and maintain that a systemic perspective still holds considerable explanatory potential, not the least when adapted to increasingly internationalized innovation processes. However, to realize this potential, a number of conceptual improvements are required. The strong focus on actor networks and institutions that condition innovation in regional and national systems needs to be combined with greater emphasis on the role of multi-scalar networks and systematic differences between the innovation processes in various industries. This calls for a more integrative view in which various innovation system perspectives and related literatures on the globalization of innovation stop living parallel lives and start talking to each other in more engaged and reciprocal ways (Martin, 2016; Weber and Truffer, 2017).

To elaborate on this proposition, we take a closer look at the challenge of international interdependencies in the innovation process. Over the last decade, authors have argued that the spatial configuration of innovation systems is getting more complex, spanning actor networks and institutional contexts from various places and across spatial scales (Bunnell and Coe, 2001; Carlsson and Stankiewicz, 1991; Coe and Bunnell, 2003). While various analytical approaches have started to conceptualize the increasing importance of international linkages between regional and national innovation systems (for an overview see e.g. Carlsson, 2006; Grillitsch and Trippl, 2013), a comprehensive and operable analytical framework for global innovation systems is still missing. In particular, existing concepts were criticized for remaining rather vague in their conceptualization of interdependencies between various territorial subsystems at an international level (Binz et al., 2014; Coenen et al., 2012; Grillitsch and Trippl, 2013; Wieczorek et al., 2015a).

The present paper aims to address this challenge by reinterpreting

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the overlaps between various innovation system approaches. In particular, we aim at specifying how key system resources for innovation get created and integrated at a global level. In this venture we build on existing multi-scalar perspectives on innovation from various IS traditions, but elaborate two new conceptual dimensions. First, we define subsystems of a GIS not based on pre-defined territorial boundaries, but based on the actor networks and institutions that are involved in creating specific system resources (knowledge, market access, financial investment and technology legitimacy (see Binz et al., 2016b)). Whether or not the actor networks and institutions in each of these dimensions fall within territorial boundaries, is treated as an empirical question. Second, we argue that the performance of a system in developing and diffusing innovation depends not only on the existence of coherent subsystems, but also on the availability of structural couplings between them. Structural coupling is attained if specific actors, actor networks or institutions span across or overlap between various subsystems, be this in a specific region or country, in a global non-governmental organization or a transnational corporation.

Second, we draw on recent insights from the sectorial systems literature to explain differences in the spatial configuration of GIS in various industry types. Our framework differentiates between an industry's dominant innovation mode – STI (science-technology and innovation) vs. DUI (doing, using and interacting) (Jensen et al., 2007) – and the economic system of valuation in which markets for the innovation are constructed – standardized products for global mass markets vs. customized products depending on symbolic valuation in local contexts (Huenteler et al., 2016a; Jeannerat and Kebir, 2016). Based on empirical illustrations from recently emerging clean-tech sectors, we discuss how the spatial configuration of GIS differ between industries that produce standardized commodities with an STI innovation mode (i.e. consumer electronics, solar photovoltaic modules) and industries with a DUI innovation mode that depend on a valuation process that is customized to specific territorial contexts (i.e. luxury watchmaking, wind power). This heuristic creates new hypotheses on why in some industries national and regional innovation system boundaries remain relevant, while in others territorial boundaries are increasingly transcended by international interdependencies. Policy interventions that target specific national or regional subsystems will accordingly lead to different spatial spillovers depending on the overall GIS configuration.

These arguments will be elaborated as follows. We first review existing IS literature relative to the role of international linkages. Section 3 integrates these insights to a novel concept of global innovation systems, focusing on subsystems and their structural couplings. Section 4 develops a taxonomy of GIS configurations in different industry types and illustrates them based on recent case studies from the wind power, solar power, carbon capture and storage, and electric car industries. Section 5 discusses methodological challenges and outlines a broader research agenda in the field of global innovation systems. We conclude with policy implications and the framework's contributions to research at the interface of economic geography and innovation studies.

2. Existing perspectives on innovation systems in transnational contexts

2.1. Earlier attempts to conceptualize global innovation systems

Innovation system studies emphasize that innovation emerges from complex interactions between actors with complementary (technological, managerial, investment or regulatory) competencies, which operate under specific institutional settings (Lundvall, 1992). The use of a system metaphor emphasizes the distributed, yet more or less coordinated agency that underpins the innovation process; interaction between firms, universities, policy makers and various intermediaries creates positive externalities that are of key importance in the innovation process, but very difficult to be produced or controlled by any actor on its own (Nelson, 1993).

Over the years, different variants of IS have been formulated and applied empirically, including a national (Lundvall, 1988), regional (Cooke et al., 1997), sectoral (Malerba, 2002) and technological (Carlsson and Stankiewicz, 1991) approach. Superficially, the distinguishing feature of each framework lies in the way system boundaries are set, i.e. in determining which elements contribute to the generation of innovation-related positive externalities and which ones do not (Bergek et al., 2015). Yet, when comparing the approaches more deeply, one finds significant differences in each tradition's epistemology, research objectives, and methodological approach (Coenen and Díaz López, 2010). Given these differences, various streams of IS research have lived largely parallel lives, without much cross-fertilization between their research networks (Coenen and Díaz López, 2010). The existing literature on 'global', 'international' or 'multi-scalar' IS (Anadon et al., 2016; Archibugi and Michie, 1997; Binz et al., 2014; Bunnell and Coe, 2001; Carlsson, 2006; Dewald and Fromhold-Eisebith, 2015; Niosi and Bellon, 1994; Oinas and Malecki, 2002; Pietrobelli and Rabellotti, 2009; Sagar and Holdren, 2002; Spencer, 2003) generally reflects this lack of interaction between varying research traditions.

First and foremost, NIS and RIS scholars departed from a territorial perspective in emphasizing the importance of institutionally embedded face-to-face interaction in the innovation process (Lundvall, 1992). Capability accumulation, interactive learning and capacity building in national and regional contexts became the key focus of research. When conceptualizing the globalization of innovation, NIS and RIS scholars started from the customary assumption that regional/national contexts matter most for innovation and then moved to explain the links between territorially embedded innovation processes (for a comprehensive overview see Carlsson, 2006). Another illustrative example is the work by Oinas and Malecki (2002), who provide a comprehensive conceptual approach on how innovation processes in various RIS complement each other in a global division of labor.

This approach later got criticized for providing a rather static concept of innovation and employing 'spatial fetishism' (Moulaert and Sekia, 2003). By a priori setting national or regional borders as scalar envelopes, NIS and RIS concepts could not fully capture the activities of organizations, networks and institutions evolving at a supranational level and thus lacked a clear understanding of how they influence territorially embedded innovation dynamics (Coenen et al., 2012). GIS concepts in the NIS and RIS tradition thus mostly show that territorial subsystems still matter, even though they get increasingly interconnected at supranational levels. Yet, there is no shared understanding on how these interconnections emerge, how they matter, let alone whether they matter for all industries and markets in the same way (Coenen et al., 2012).

Scholars in the SIS tradition complemented the NIS and RIS concepts by arguing that industry- and technology-related rather than country-related or regional factors mostly affect the (spatial) organization of innovation (Breschi et al., 2000; Malerba, 2005; Spencer, 2003). Comparative empirical work in a broad range of sectors (such as semi-conductors, cars, pharmaceuticals, telecommunications, machine tools, etc.) consistently showed similarities between innovation processes of the same sector in different regions (Jung and Lee, 2010; Malerba, 2005; Malerba and Nelson, 2011; Yu et al., 2016). SIS scholars developed elaborate sector taxonomies, which were grounded in the technological regimes and trajectories that structure the innovation process (Castellacci, 2008). This approach allowed developing rigorous analytical frameworks, which however also attracted strong criticism for their technology bias. In particular, SIS studies increasingly downplayed the importance of more distributed forms of agency, non-firm actors and the influence of informal institutions on the innovation processes (Coenen and Díaz López, 2010). Also, given the concept's roots in evolutionary economics and its reliance on standardized quantitative databases (e.g. NACE codes), it tended to focus on long-term industrial dynamics in existing manufacturing sectors (Castellacci,