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Leveraging complexity for ecosystemic innovation

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ABSTRACT

This paper looks at innovation ecosystems through the lens of complexity science, considering them as open non-linear entities that are characterized by changing multi-faceted motivations of networked actors, high receptivity to feedback, and persistent structural transformations. In the context of the growing organizational complexity of economies, driven by their adaptation to high uncertainty, and the central role of collaboration, we differentiate the innovation capacity of various types of business networks by the complexity of their internal interactions, thus identifying the place of innovation ecosystems in the world of business networks, as well as the place of innovation clusters among other innovation ecosystems. We observe how innovation ecosystems have been viewed in four different research streams: management literature; the inter-firm and business network stream of economic and sociological literature; the innovation policy and competitiveness agenda in economic literature; and the dichotomy of localized and economy-wide innovation ecosystems in policy studies (in economic literature, evolutionary geography, and regional research). We then describe generic properties of innovation ecosystems in terms of complexity science, viewing them as complex adaptive systems, paying special attention to the complexity of innovation clusters. We compare complexity thinking of modern economies, deriving from their emerging ecosystem design, with traditional thinking conceived for industrial era, drawing insights for a better transition to innovation-led growth. We conclude with a summary of key findings, practical and policy implications and recommendations for further study.

1. Introduction

1.1. Non-linear innovation and the emergence of innovation ecosystems

Under enhanced global competition and global proliferation of information communications technologies (ICT), economic activities have become more knowledge-intensive, and industrial economies have accelerated their transition to knowledge-based systems.

In various sectors, the linear model of innovation (a downstream cascade of knowledge flows from fundamental science to applied research, and further to application) is giving way to a non-linear model, in which ideas for innovation come from many sources and stages of economic activity, and a growing number of institutions have become involved in the production and diffusion of knowledge (OECD, 1999). This implies that innovation is becoming highly interactive and collaborative, often multidisciplinary and multidirectional (National Research Council, 2012).

Driven by global forces of non-linear innovation, the modern systems of production and economic governance are also obtaining a non-linear nature to become decentralized, diffused and dispersed along

network nodes (Elsner, 2015; Nieto and Santamaría, 2007; Smorodinskaya, 2015; Todeva, 2013). Their development is increasingly characterized by uneven leaps, multi-vector fluctuations and other manifestations of nondeterministic behavior. In contrast to linear systems, non-linear ones evolve disproportionately: in some cases, minor behavioral changes in a system's separate elements may lead to large-scale changes in its state, while in other cases, major changes in the state of elements may produce weak or even no impacts on the system as a whole (OECD, 2009).

The objective paradigm shift from linearity to non-linearity brings about a non-equilibrium, constantly changing global environment, which generates a situation of unprecedented high uncertainty, unlike has been witnessed ever before (Kidd, 2008). Facing this challenging situation, businesses and economies in different parts of the world are searching for new ways to enhance their innovativeness, strengthen their competitiveness and adapt themselves to non-linear global realities.

In particular, to maintain sustainable growth under high uncertainty and manage the growing complexity of technological systems, economies of all levels are simultaneously enhancing their social and

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organizational complexity, tending to assume agile network-based designs (Smorodinskaya and Katukov, 2015). In fact, since 2000s, the creation of new goods and values is seldom singularly producer-led or user-driven; instead, today's technological, service and social innovations are increasingly co-created interactively by participants of collaborative networks. Individuals and companies, as well as regions and nations are more and more engaged in the formation of multifold network partnerships, in which actors develop multilateral cooperation and create new values together, thus jointly responding to continuing technological and market changes. Economic advantage now accrues to those entities that can quickly transit from their traditional hierarchic model to a horizontal network structure and start participating in collaborative activities with similar network entities (Friedman, 2005; Seppä and Tanev, 2011; Smorodinskaya, 2015). The emergence of manifold social networks and innovative business milieus is accompanied by the development of shared perceptions and systems for value co-creation (Russell et al., 2011). Network of affiliations bridge social worlds, which were formerly less or not well-connected (Powell et al., 2013).

This organizational transformation of businesses and economies toward a higher complexity and more agility catalyzes the emanation and proliferation of innovation ecosystems. Not just networks as such but rather heterarchical ecosystems formed by interactive activities and collaboration of networked partners are shaping the dynamic industrial landscape of knowledge-based economies. Taking various scales, configurations and profiles, such ecosystems are seen in literature as a new typical way for producing goods and values in the twenty first century (MacGregor and Carleton, 2012).

Today, the idea of promoting the persistent emergence of localized innovation ecosystems and of creating an economy-wide ecosystemic landscape, typical for systems with innovation-led growth, stands high on the policy agenda of many developed and developing nations (Bramwell et al., 2012; Warwick, 2013; WEDC, 2009). The World Economic Forum now directly associates the new model of industrial policy, as introduced recently in different countries for developing advanced manufacturing, with the prospect of building powerful innovation ecosystems in the manufacturing sector (WEF, 2013).

1.2. Motivating questions, focus and logic of analysis

In this paper, we explore organizational foundations and generic features of innovation ecosystems, including innovation clusters as their sophisticated sub-variety, in concert with non-linear development, collaborative mode of production, and the ongoing transition of entities and economies to innovation-led growth. Our aims are to more precisely define the notion of the term "ecosystem" versus "system", to disclose the origin of synergy effects that make innovation ecosystems and particularly innovation clusters "the new face" of the industrial landscape in the twenty first century, as well as to highlight the emerging ecosystem-based design of modern economies and its key role in facilitating their innovation dynamics. We associate the emergence and evolution of innovation ecosystems with the proliferation of collaborative networks aiming to produce innovation interactively, through a collective action of legally independent actors (Bramwell et al., 2012; Russell et al., 2015).

The quest motivating this analysis is to better understand the organizational setup of emerging knowledge-based systems as compared to the traditional industrial landscape conceived for the linear world, as well as to conceive a supposed interplay between the growing complexity of modern economies and their innovation capacity.

We look at innovation ecosystems through the lens of complexity science, considering them as *open non-linear systems* that are characterized by changing multi-faceted motivations of networked actors, high receptivity to feedback, and persistent structural transformations, induced both endogenously and exogenously. Such ecosystems rely on the agility of network relationships (Adner, 2017) and the

collaborative, non-hierarchic models of governance, which enables their *self-adaptability to rapid change*. Their further proliferation demands decision-makers of all levels to provide and support a favorable context (social, economic, institutional, etc.) for continual networking, more horizontal linkages, and the enhancement of *collaborative cohesive milieu within and among entities and economies*.

We situate the analysis of ecosystems in the context of the non-linear world of networks and the central role of collaboration in producing innovation. We then differentiate the innovation capacity of various types of business networks by the complexity of their internal interactions, thus identifying the place of innovation ecosystems in the world of business networks, as well as the place of innovation clusters among other innovation ecosystems. Next, we observe how innovation ecosystems have been viewed in four different research streams: management literature; the inter-firm and business network stream of economic and sociological literature; the innovation policy and competitiveness agenda in economic literature; and the dichotomy of localized and economy-wide innovation ecosystems in policy studies (in economic literature, evolutionary geography, and regional research). We then describe generic properties of innovation ecosystems in terms of complexity science, viewing them as complex adaptive systems, paying special attention to the complexity of innovation clusters. We compare complexity thinking of modern economies, deriving from their emerging ecosystem design, with traditional thinking conceived for industrial era, drawing insights for a better transition to innovation-led growth. We conclude with a summary of key findings, practical and policy implications and recommendations for further study.

2. The world of business networks and the appreciation of innovation ecosystems

2.1. The concept of collaboration and its role in producing innovations

An interpretation of non-linear innovation in modern literature points to its direct connection with the development and proliferation of networks. One of the first descriptions of networks as innovative entities appeared in the early 1990s in the "New Society of Organizations" by P. Drucker (Drucker, 1993), in which he underlined the ability of such organizations for continual "creative destruction" and predicted their future global domination. According to Chesbrough (2003) and Tassey (2008), in order to sustain their competitive advantages, firms move to collective creation of innovation. According to Powell and Grodal (2005), the most effective way to produce innovation involves network interactions of firms with other firms, research institutes and other organizations. The ongoing further proliferation of networks worldwide implies that *innovative goods, technologies and values will be increasingly co-created by networked actors that collaborate with each other to form a certain, relatively sustainable ecosystem of actors, assets and linkages* (Gloor, 2006; Russell et al., 2016; Wessner, 2005).

The term "collaboration" (from Latin 'working together') has no universal definition in literature: this term is used both in a broad and in a narrow meaning by different lines of research, each of which applies its own language. For example, some experts argue (MacGregor and Carleton, 2012) that collaboration is important for both R&D and non-R&D innovation but each type uses different networks. Others admit that collaboration involves active and interactive exchange of ideas between two or more people who acknowledge that such exchanges can result in the joint production of co-constructed ideas, some of which may be novel (WEF, 2015). Taken in a loose definition, collaboration denotes various forms of interactive communication between networked actors.

By a more exact definition, accepted in economic literature, collaboration is described as "the process of formal and informal negotiations between autonomous actors, during which they create common rules and organizations to regulate their interactions and fields of activity, or tackle common issues cohesively, with these common rules

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