The Emergence of Inter-organisational Networks in Emerging Technologies: The Case of Microneedles

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The study aims at increasing our understanding of how inter-organisational collaborative networks form, evolve, and are configured when new technologies emerge. Emerging technologies are conceived as radically novel technologies capable of exerting a considerable impact on the socio-economic domains in which they are observed (e.g. Rotolo et al., 2015). However, the high levels of uncertainty and ambiguity that feature in the emergence process – in terms of potential applications, technical challenges, financial support, production cost, and adoption, as well as unintended or undesirable consequences – pose major policy and management challenges for what concerns value creation, commercialisation, governance, and regulation (Kuhlmann et al., 2019; Kapoor and Klueter, 2021). The development of technological innovation is distributed across a large variety of organisations, often led by different institutional logics that contribute to create path-dependency and shape the directionality of the emergence process (Powell et al., 1996; Garud and Karnøe, 2003; Sauermann and Stephan, 2013). Networks represent critical conduits for the exchange of knowledge, ideas, and resources among the different organisations (Padgett and Powell, 2012), as well as loci of power distribution among these. The architecture of the relationships among the variety of organisational actors involved in the emergence process therefore exerts a significant influence in shaping technological change in certain directions rather than others (Geels, 2002). On this basis, we argue that understanding the formation of inter-organisational networks in the case of emerging technologies is crucial to shed light on how uncertainty and ambiguities reduce as a new technology emerges, as well as how an expert community of practice forms around the technology (Rotolo et al., 2015). Accordingly, we examine the interorganisational network associated with the case of microneedles technology from 1990 to 2019, using publication co-authorship data. In particular, we examine the extent to which different incentives and institutional logics that lead the action of various organisational actors contribute to the formation of inter-organisational relationships as the microneedles technology emerges. To do so, we distinguish organisations among five institutional groups: Research and Higher Education (RHE), Healthcare Provider (HC), Government (GOV), Industry (IND), and Non-Governmental Organisation (NGO). We also examine whether contributing to publications on prominent themes in the emergence process generates signals about an organisation's research that attract future partners. In order to do so, we assess the emergence score of the terms extracted from the titles and abstracts of the microneedlesrelated publications (see Carley et al., 2018; Porter et al., 2019) – the emergence score distinguishes those natural language processing (NLP) phrases that match the traits of emerging technologies as identified by Rotolo et al. (2015). We examine to what extent these two variables – institutional groups and

emerging terms – contribute to explain the network dynamics by estimating an Exponential Random Graph Model (ERGM) (see Robins et al., 2007).

Our analysis focuses on the case of emerging "microneedles" technology. Microneedles are needles the size of which (e.g. diameter, length) is on the micrometre length scale. These are combined in patch-

like structures that, when applied to the skin, create painlessly micro-holes through which macromolecular drugs (e.g. vaccines, insulin) can be delivered. This radically novel approach was proposed in the 1970s, but demonstrated in the 1990s, thanks to advancements in the microelectronic industry. To collect data for our research, we identified and retrieved all publications records related to microneedles technology by querying the Web of Science (WoS) Core Collection using a purposely developed query. This query returned an initial sample of 3,207 records from 1991 to 2019. We relied on co-authorship data to build a longitudinal network of inter-organisational relationships. We identified an initial set of 2,246 affiliation names, that we subsequently harmonised into 1,807 organisations names – the harmonisation process was undertaken combining algorithms of string similarity as available in OpenRefine and desktop searches. From this list, we removed more peripherical actors that we defined as those that contributed to one publication only during the observation period, and this publication did not involve other organisation co-authors. This led to a final sample of 1,710 organisations. We then constructed the corresponding inter-organisational networks. We apply ERGM modelling to examine how our variables of theoretical interest contribute to predict the formation of new inter-organisational links, as the new technology emerges. ERGMs make it possible to make statistical inferences about the configuration of a network, allowing for statements on whether a given configuration occurs more than could be expected by chance (Robins et al., 2012). The ERGM approach thus enables us to test how the likelihood of two organisations establishing an inter-organisational link depends on the variables of main theoretical interest. In our study, we analyse how the likelihood of establishing an interorganisational link depends upon the institutional homophily of organisations and the emergent nature of organisations' research, based on the emergence score of the terms used in their publications. We also included in the ERGMs a number of exogenous control variables that can contribute to the formation of inter-organisational (co-authorship) links between two organisations. Furthermore, endogenous control variables have been added to the models, to account for networks' characteristics. Preliminary results of the ERGM estimation suggest that institutional homophily between organisational actors is positively associated with the formation of new inter-organisational ties. However, the models suggest that this varies with the type of institutional group (e.g., HC organisations are more likely to co-author publications, while this pattern does not strongly emerge for other institutional groups such as RHE) and with the process of emergence (e.g., IND organisations are more likely to establish co-authorship ties in the early and middle period of emergence, possibly suggesting the need for recombining different expertise as new technical challenges arise). These preliminary results further support the need of a more holistic approach (beyond the focus on the firm) to understand the process of technological emergence and to devise effective managerial and policy implications.

References

Available upon request.