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The dynamic role of universities in developing an emerging sector: a case study of the biotechnology sector

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ABSTRACT

Literature maintains that the role of universities has shifted from pure knowledge dissemination organisations into the key intermediaries of technology commercialisation, especially in the case of the developing emerging high-tech sector (Etzkowitz, Webster, Gebhardt, & Terra, 2000; Vallas & Kleinman, 2008). To further explore the dynamic role of the universities interacting with the other actors in the innovation system, this paper examines the changing roles of the universities that have actively interacted with the biotechnology industry in Taiwan from 2000 to 2012. Combining social network analysis and interview data on a longitudinal dataset gathered from 125 IPO biotechnology firms, this paper aims to explore the R&D collaboration networks between the universities and the other actors in the biotechnology sectoral innovation system to understand how universities make use of knowledge exchanged with other parties to shape society while developing emerging industries. The involvement rate of academia in the knowledge transfer networks appears to have increased since 2000 but more can be done to spur scalable action after 2008, and therefore association with other similar evolving areas. Moreover, the participation of foreign collaboration is one which needs some attention. The finding of this paper sheds light on the changing role of academia in developing emerging technologies in technology followers, while the innovation ecosystem is ready for academia-industry collaboration, universities not only take charge of disseminating knowledge but also serve as the major intermediaries in the process of commercialising science and technologies developed through the universities. Future policies may need to boost more partaking between the universities and industries by motivating the transmission of knowledge capital through encouraging technology commercialisation in academia.

1. Introduction

Innovation is an interactive process in which the creation and flow of knowledge between firms, and access to externally-generated knowledge from non-firm sources, are particularly important. In the recent literature on innovation, the positive association between firms' networking activities and their long-term innovation performance has been recognised (Breschi & Malerba, 2005; Edquist, 2011; Malerba & Vonortas, 2009), especially in science-based industries (Edquist, 2011). The central role of knowledge transfer in the inter-organisational innovation process, particularly in emerging technologies such as biotechnology, has also been well established in the literature (W. W. Powell & Grodal, 2005).

Biotechnology has been widely expected in the existing literature to stimulate a shift in the industrial structure of the pharmaceutical industry from large drug companies to networks of biotech firms agglomerated in innovation systems (Hopkins, Martin, Nightingale, Kraft, & Mahdi, 2007; Nightingale & Martin, 2004; Rafols et al., 2014). The innovation network literature has reinforced that innovation is embedded in the networks instead of any single actor (such as a firm), especially in the biotech sector. Literature also maintains that the biotechnology industry has been characterised by a set of production techniques with application across a broad range of industrial sectors (Bartholomew, 1997). As Malerba (2002) defined,

> A sectoral system is a set of products and the set of agents carrying out market and non-market interactions for the creation.

In fact, the biotechnology industry has been widely considered as a high-tech sector which can be traded in various stages of the R&D process. Moreover, during the innovation process, the young start-up biotech firms rely heavily on the interdependence with the universities and large multinational firms. As W. Powell et al. (2005) indicated,

> In the early years of the industry, from 1975-87, most dedicated biotech firms (DBFs) in the US were very small start-ups, and deeply

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reliant on external support out of necessity. Thus, they became involved in an elaborate lattice-like structure of relationships with universities and large multinational firms.

DBF is defined as "a biotech active firm whose predominant activity involves the application of biotech techniques to produce goods or services and/or the performance of biotech R&D" (OECD, 2005). According to the observation by Powell et al., the interdependence between firms and the non-firm actors is not only because of the associations of their technologies and development experiences, but also because of the accumulations of interpersonal connections (Chen et al., 2015) . Hence, how interaction occurs in local networks to develop linkages between diverse actors has become an interesting question to be further explored. In particular, how universities make use of knowledge exchange with other parties to shape the process of developing emerging industries would be another interesting question to study. Therefore, the main research question this paper attempts to answer is: how do interactions occur in the biotechnology networks to develop linkages between actors and what role do universities play in the emergence of emerging networks? Analytically, this paper firstly analyses the R&D collaboration networks of the biotechnology sector in Taiwan in 2000, 2006 and 2012 as an example to explore the R&D collaboration networks changing over time. A dynamic perspective is employed using data from the above-mentioned three periods. This permits the analysis of the structural and functional evolution of the entire innovation system, particularly in relation to the knowledge transfer network between academia and industry. Consequently, this paper analyses in greater detail about the roles that universities play.

This paper is anticipated to contribute to the literature in several ways. Firstly, it will provide a deep empirical study of how universities network with other actors while developing an emerging high-tech sector. Secondly, this study attempts to conduct in-depth analysis regarding the dynamic roles that universities play while developing an emerging sector. Finally, this study contributes an innovative approach of empirical longitudinal data collection and analysis to map the knowledge transfer and innovation networks in a complete sectoral innovation system (Malerba, 2002).

2. The triple helix model and the changing role of the universities in the innovation networks

This section reviews the literature concerning systems of innovation, knowledge production network, the dynamic role of the universities in the network, and knowledge transfer in a triple helix model with the aim of constructing a conceptual framework. This framework will later be applied to analyse the role that actors play in shaping the structure of relationships in the knowledge transfer networks in an emerging high-tech sector, biotechnology sector, in Taiwan – which has the prospect of transforming the industrial structure into a knowledge economy through building up the biotechnology sector.

2.1. Systems of innovation and knowledge production networks

Since the modern concept of innovation systems was proposed in the past three decades, there have been several levels of analyses at which the concept has been applied. These include the national innovation system (NIS) (C. Freeman, 1995; Lundvall, 2010; Nelson, 1993), which was developed from the theory of production development (Lundvall, Johnson, Andersen, & Dalum, 2002), sectoral innovation systems (SIS) (Malerba, 2002), and technological innovation systems (TIS) (Bergek, Jacobsson, Carlsson, Lindmark, & Rickne, 2008) which were developed from evolutionary economic theory (Witt, 2008), as well as the regional innovation system (RIS) (Cooke, 1992, 2001, 2002, 2004), which came from economic geography.

Each of the innovation system approaches has drawn attention to various components, structures, and theoretical issues, and therefore contributing to differentiated analytical approaches. The most straightforward way to distinguish these approaches would be to explore the boundary of the framework (Edquist, 1997, 2005, 2011; Lundvall, 2007; Niosi, 2011; Smith, 2000).

Whilst significant interplay exists between the systems, in particular between the NIS and SIS, these systems have different components (Chaturvedi, 2007; Malerba & Nelson, 2011). For instance, the SIS consists of the knowledge base, institutions and networks, whereas the NIS focuses on the structure of production, regulation, financial system, education policy, innovation policy, and the institutional set-up (Lundvall, 2010). According to Malerba (2009), the SIS is defined as comprising a knowledge base, technologies, networks of actors, and institutions. It therefore offers a framework to examine the systemic processes relating to a particular set of technologies from the global perspective. In the SIS approach, institutions are defined to include norms, routines, common habits, and established practices which shape the behaviour (interactions, communications, exchanges, cooperation, and competition) of agents in the innovation system. These affect the generation and adoption of new technologies or innovation at the sectoral level.

Sectoral systems have a knowledge base, technologies, inputs and a (potential or existing) demand. The agents are individuals and organisations at various levels of aggregation, with specific learning processes, competences, organisational structure, beliefs, objectives and behaviours. They interact through processes of communication, exchange, cooperation, competition and command, and their interactions are shaped by institutions (Malerba, 2002, 2005, 2009). For analysing inter-organisational agent activities in a specific sector, an SIS would be appropriate. The interactions between firms and non-firm actors are one of the key elements of the SIS approach, but the empirical analysis of such interactions in complete sectoral systems is still rare. Although Malerba and Vonortas (2009) take industries and sectors into consideration, the network topologies mainly stayed at the industry level. The topology of networks between firms and non-firm actors in the system has still been rarely touched.

Knowledge production has played a crucial role in the modern economy (Leydesdorff & Zawdie, 2010) for a relatively long period. In the 1990s, the literature moved from the linear model into the interactive model. This shift was marked by analyses of the society's role in shaping the knowledge base and knowledge production in academia (Pavitt, 1998) and the emergence of the innovation systems' literature. OECD (1996) suggested, given the importance of knowledge networks, that "the firm-level innovation study needs to be developed to better characterise innovation processes and interactions among firms and a range of institutional actors in the economy". Vallas and Kleinman (2008) suggested, based on their study of the confluence of academia and commercial biotechnology innovation in the US, that a knowledge regime has begun to emerge across previously distinct institutional domains.

2.2. The triple helix model and the dynamic role of the universities in the network

Etzkowitz and Leydesdorff (2000) referred to the triple helix as the reciprocal relationships among academia, industry and government at different stages for the purpose of knowledge development, diffusion and economic growth. This relationship is also associated with certain shifts, discussed below, due to the cultural differences between the agents involved. This interconnection is based on the need for universities and firms to collaborate in order to enable knowledge transfer that has economic value (Etzkowitz et al., 2000). Mueller (2006) revealed academia's contribution towards penetration of the knowledge filters (especially in aiding entrepreneurs) through increasing absorptive capacity and co-location advantages of knowledge diffusion often spanning informal means. Knowledge filter in this context denotes the mechanism through which knowledge transitions can be substantiated into commercial activities (Acs, Audretsch, Braunerhjelm, & Carlsson,