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International research networks in pharmaceuticals: Structure and dynamics

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ABSTRACT

Knowledge production and scientific research have become increasingly more collaborative and international, particularly in pharmaceuticals. We analyze this tendency in general and tie formation in international research networks on the country level in particular. Based on a unique dataset of scientific publications related to pharmaceutical research and applying social network analysis, we find that both the number of countries and their connectivity increase in almost all disease group specific networks. The cores of the networks consist of high income OECD countries and remain rather stable over time. Using network regression techniques to analyze the network dynamics our results indicate that accumulative advantages based on connectedness and multi-connectivity are positively related to changes in the countries' collaboration intensity whereas various indicators on similarity between countries do not allow for unambiguous conclusions.

1. Introduction

Collaboration between different actors has become an increasingly more important mode of knowledge generation in almost all scientific disciplines (Wuchty et al., 2007). Particularly in science-based fields and research areas with rapidly developing and widely distributed knowledge bases, no single actor has the ability to keep pace with the scientific and technological advances in all areas. Consequently, increasing collaboration within collaboration networks have been found to be a means by which actors can pool, exchange and develop ideas, knowledge and other resources (Powell and Grodal, 2005; Powell et al., 1996; Powell and Brantley, 1992). In this paper we are interested in the dynamics of collaboration networks in general and tie formation herein in particular.

We pursue our analysis for pharmaceuticals, where innovation is based on scientific advances and thus clearly connected to basic and applied research (Lim, 2004). Pharmaceutical innovation can be seen the result of interaction and collaboration between a broad set of different types of agents endowed with complementary knowledge, competencies and other resources (e.g. Pisano, 1991; Orsenigo, 1989). Since this field is characterized by a complex, expanding and dispersed knowledge base, the locus of innovation, and thus the appropriate level of analysis, is no longer the individual actor, but rather the entire network (Powell et al., 1996). Its structure and the actors' positions therein determine the actors' access to relevant sources of knowledge and may therefore have consequences for their innovative activities and performance (Powell et al., 1999; Walker et al., 1997; Kogut et al., 1994).

Against this background of a specific research area, pharmaceuticals, and following the analytical design of Wagner and Leydesdorff (2005a), we pursue an analysis on the country level, implying that the collaborating actors within the network are countries. Our deviation from an analysis on the level of individual actors is justified by the presumption that for the dynamics of international collaboration networks in pharmaceutical research the country level embraces an additional and important influence on the formation of and the changes in those networks. Looking at the research and collaboration activities in pharmaceuticals worldwide as measured by publications and co-authored publications we, first, find the OECD countries to be the main actors in both categories. Secondly, these countries show a continuous reinforcement of the co-authorship ties among each other over time combined with a slightly but steadily increasing widening out of collaborative

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activities to other countries. For OECD countries this, third, is evidenced by a growth of the number of internationally collaborated publications exceeding the growth of the number of non-collaborated ones: their growth rates of the number of internationally collaborated publications are about 37% which is almost twice as high as their growth rates of non-collaborated publications. Fourth, for non-OECD countries, starting from a much lower number of publications, the growth rates of publications are much higher, between 60% and 95%, with only a minor difference between the growth of the number internationally collaborated and non-collaborated publications for this group.[1] This, fifth, leads to a share of collaborative in all publications which increases for OECD countries from almost 17% to 22% and which remains nearly stable for non-OECD countries between 20% and 21%. Taken these five observations for worldwide research in pharmaceuticals together, OECD countries are dominant in these activities, show a higher inclination for, and put more emphasis on international scientific collaboration. Hence, from a research network perspective, OECD countries tend to be at the core of those networks and should be considered the main drivers of network dynamics. We consider these patterns as an indication for country level factors having a prominent effect on the structure and dynamics of the international pharmaceutical research network.

Among the country level factors, in our context, the national innovative capacity matters most. It is considered as the binding frame for research as well as innovation activities and their very structures influence the long-term ability of a country to generate and commercialize innovative technologies (Furman et al., 2002). Countries differ in their national innovative capacity. Hence, the exchange of knowledge and approaches for problem solving among organizations embedded in national contexts with country-specific scientific and technological advantages can be seen as a driver for international collaborations (Bartholomew, 1997; Shan and Hamilton, 1991; Dosi et al., 1990). Although the national innovation systems are connected among each other, the development of the pharmaceutical industry in general and the development of the related research networks in particular are closely connected to the structure of national institutions (Henderson et al., 1999). Differences in the national institutional setting and the national innovative capacity may at least partly explain the considerable differences of research activities in different disease groups on the country level (cf. Furman et al., 2006).

International scientific collaboration between countries can be seen as a self-organizing network as suggested in Wagner and Leydesdorff (2005a). The position of each country within the network is determined by economic, social, political, and cultural factors. These factors include the priorities of scientists and policy makers to conduct research in particular fields and to collaborate with different partners (Miquel and Okubo, 1994). They can be considered as part of the national innovative capacity of a country that influences by itself scientific collaboration in lower order subsystems, such as pharmaceuticals, and induces the dynamics of the cross-country network. These subsystems contribute to the dynamics on the international level while they are at the same time affected by the dynamics on the international level (Wagner and Leydesdorff, 2005a). Within this analytical context, we explore the structure and the dynamics of international research collaboration networks for different disease groups in pharmaceutical research.

We use social network analysis to investigate collaboration networks and to calculate network statistics for different disease groups. Moreover, we analyze endogenous network dynamics, i.e. mechanisms within the network that are responsible for new connections being build up or existing ones being cut off. Therefore, we test whether the connectedness of countries, the similarity of countries or their degree of multi-connectivity are the driving factors of tie formation within the networks. In order to investigate the network dynamics, we draw upon multiple regression analysis for dyadic data (Butts and Carley, 2001; Krackhardt, 1988). More precisely, we apply the multiple regression quadratic assignment procedure (MRQAP) with double semi-partialing (DSP) as proposed by Dekker et al. (2007), which is particularly robust against multicollinearity and network-autocorrelation.

Our empirical analysis is performed on a unique dataset of publications in scientific journals related to pharmaceutical research. We analyze three periods, 1998–2000, 2002–2004, and 2006–2008. A first inspection reveals that high income OECD countries are located in the center of the network in all periods and disease areas. Although often connected to countries in the core, only a few non-OECD countries have managed to become part of the center of the international research community. Our descriptive network statistics indicate increasing cross-county collaboration in almost all disease groups.

Our regression results reveal that dyadic tie formation and break-up is positively related to the amount of previous collaboration. This finding may indicate an accumulative advantage based on the degree of connectedness of a country in a network. We do not find a clear-cut association between differences in the visibility of two countries, as another proxy for connectedness, and the change in the number of research collaborations. Moreover, similarity of two countries in terms of income groups and language has no unambiguous association with the changes in the number of collaborations. Country differences in the strength of their research sectors are negatively related to the change of their bilateral collaborations. Multi-connectivity, in terms of other countries connecting two countries, is positively related to changes in the number of collaborations between them, whereas we find a negative association for the number of shortest paths between two countries. From a policy perspective, our results suggest that supporting international research collaborations and investments strengthening countries' scientific systems may help countries located at peripheral positions in the network to get access to the relevant sources of knowledge and to overcome liabilities of unconnectedness.

The remainder of the paper is structured as follows: Section 2 presents related literature on research networks and its dynamics. In Section 3, we present the methods and the data used in this paper. Descriptive network statistics can be found in Section 4. Results of our regression analysis are presented in Section 5. Finally, Section 6 concludes.

2. Related literature

2.1. Internationalization of research networks

Research and innovation activities worldwide appear to be performed more and more in collaboration. With respect to scientific collaboration, there is a large body of evidence for an increasing amount of co-authored research. This trend towards scientific collaboration has been found in a broad set of disciplines and across different periods (Wuchty et al., 2007; Wagner-Döbler, 2001; de Solla Price, 1963). These studies suggest that the interconnectedness of authors and institutions has considerably increased during the last decades. This growth in scientific collaboration activities is not bound within national boundaries but shows an international outreach. As Adams et al. (2005) show, on a large sample of publications originating in U.S research universities, the rate of

[1] This trend is prevalent for the comparison of all three sub-periods analyzed in this study, 1998–2000, 2002–2004, and 2006–2008. We obtain qualitatively similar results if we look at the biggest contributors in the number of publications in the sample instead of OECD countries.