Journal of Informetrics 10 (2016) 1025–1036

Contents lists available at ScienceDirect

Journal of Informetrics

journal homepage: www.elsevier.com/locate/joi

The world network of scientific collaborations between cities: domestic or international dynamics?

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ARTICLE INFO

Article history:
Received 14 March 2016
Accepted 16 June 2016

Keywords:
Scientific publications
Co-authorship
Research collaboration
Network of cities
Geography of sciences

ABSTRACT

An earlier publication (Grossetti et al., 2014) has established that we are attending a decreasing concentration of scientific activities within "world-cities". Given that more and more cities and countries are contributing to the world production of knowledge, this article analyses the evolution of the world collaboration network both at the domestic and international levels during the 2000s. Using data from the *Science Citation Index Expanded*, scientific authors' addresses are geo-localized and grouped by urban areas. Our data suggests that interurban collaborations within countries increased together with international linkages. In most countries, domestic collaborations increased faster than international collaborations. Even among the top collaborating cities, sometimes referred to as "world cities", the share of domestic collaborations has gained momentum. Our results suggest that, contrary to common beliefs about the globalization process, national systems of research have been strengthening during the 2000s.

1. Introduction

The global "growth of science", world-wide access to transportation, information, and communication technologies, as well as collaborative research policies, have encouraged international scientific cooperation. Together with the continuing spatial diffusion of scientific activities at the world level (Grossetti, Eckert, Gingras, Jégou, & Larivière, 2014; Inhaber, 1977), the increase of scientific collaboration is often described as one of the main features of globalization (Royal Society, 2011; Schott, 1993; Sexton 2012; Wagner, 2008). However, certain scholars using measures based on scientific publications show that the lion's share of scientific collaboration has remained domestic, that is to say intra-national (Frame & Carpenter, 1979; Georghiou, 1998; Hennemann, Rybski, & Liefner, 2012). Measuring the growth of scientific collaboration both within and across countries during the 2000s, and taking into account the share of intercity co-authorships, this article provides new evidence regarding the evolution of the world collaboration network. Showing that science is performed from a growing number of connected places, our work confirms the necessity to adopt a comprehensive approach of scientific activity.

Previous works used to focus only on the top publishing or cited urban areas in the world (Bornmann, Leydesdorff, Walch-Solimena, & Ettl, 2011; Matthiessen, Schwarz, & Find, 2010). They also used to limit their scope to certain macro regions such as Europe (Hoekman, Frenken, & Oort, 2009; Zitt, Barré, Sigogneau, & Laville, 1999). Here, we perform a spatial analysis

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http://dx.doi.org/10.1016/j.joi.2016.06.002
1751-1577/

of the co-authored articles, reviews, and letters extracted from the *Science Citation Index Expanded* with the much sharper spatial resolution of the urban level. We want to answer the question: what are the territorial dynamics underlying the world growth of interurban collaborations during the last decade?

After a review of existing literature on scientific collaboration focusing on the spatial dimension of world science, we present our spatial bibliometrics method based on the geocoding of publications and their assignment to urban areas. At the global scale, even if the overall production was still furnished by groups from one city in 2007, we demonstrate that there has been an increase in collaboration, both at the domestic and international scales. Country-to-country as well as city-to-city differences are discussed. It appears that the more developing is a country, the more scientists located in this country have favored domestic collaborations. To finish, we demonstrate that national systems have remained highly structuring, even when considering only the position of the top world cities.

2. The spatial stakes of scientific collaboration

Exiting literature on the geography of scientific collaborations has provided three different approaches within the spatial scientometrics framework (Frenken, Hoekman et al., 2009): the reasons for scientific collaboration, the proximity and size effects on the propensity to collaborate, and longitudinal tendencies of the world collaboration network.

Observing the increasing number of authors per publication, several scientists have tried to provide explanations. Following Gingras (2002) and Katz and Martin (1997), certain key results deserve to be highlighted. Alongside their historical bibliometric analysis, Beaver and Rosen demonstrated that co-authorship practices improved the world scientific productivity and visibility of the French elite (Beaver & Rosen, 1978, 1979). Focusing on international collaborations alone, Frame and Carpenter (1979) were the first to discuss country-to-country differences at a global scale and during the contemporary era. Their lead was followed by several authors, including Luukkonen, Persson, & Siverstsen (1992), who distinguished between internal (scientific) and external factors; the latter consisting of political incentives and the role of cheaper access to transportation and electronic communication. Apart from these "structural" reasons, Melin carried out a qualitative study showing that, above all, there are individual reasons for collaboration (Melin, 2000). Focusing on scientists' careers, it has also been shown that collaborations are sustained by interpersonal relationships (Cabanac, Hubert, & Milard, 2015). Bozeman and Corley (2004) have highlighted the role of research policies on collaborative practices and identified that research grants have a positive effect on more distant collaborations, even if "most researchers tend to work with the people in their own work group".

At the global scale, there are two ways of analyzing the spatial determinants of scientific collaborations: the first is investigating the role of invariant factors such as geographical distance and scientific weight on the propensity to collaborate, the second is considering geo-historical factors leading to special affinities between territories.

To our knowledge, the first scientists who adapted the gravity model to co-authorship data in order to identify the spatial constraints for scientific collaborations were members of the "Swedish Regional Science Mafia" (Andersson & Persson, 1993). The explanatory variables they identified for scientific collaborations were, in order of importance: scientific size (the publication weight per country), travel time, language similarity, and political unionization. One year later and independently, Katz (1994) was the first to measure the negative impact of geographical distance on university–university co-authorship links within (but not across) several countries. In his study, *Ceteris Paribus*, he showed that "the frequency of research collaboration between domestic universities in the United Kingdom, Canada and Australia decreases exponentially with the distance separating the research partners".

During the 2000s, efforts have been made to enrich the quantitative analysis of scientific collaborations' spatial determinants. In particular, institutional effects were taken into account together with those of geographical distance within a proximity framework. Thus, using a pseudo-regression model, Nagpaul (2003) separately considered the geographical, the thematic, and the socio-economic proximities between countries to explain the international collaboration rate per country. In 2009, Frenken et al. showed at several geographical scales that the "death of distance" theory (Morgan, 2001) did not hold true for scientific collaboration practices. Using gravity equations on three datasets, they demonstrated that in addition to scientific outputs (size effects), both the geographic distance (in kilometers or travel time) and the institutional proximity (boundary effects) are significant to explain the intensity of scientific collaboration measured during the 2000s: first between 36 countries in the world, second between 1316 regions in Europe, and third between 40 regions in the Netherlands (Frenken, Hardeman, & Hoekman, 2009; Frenken, Hoekman et al., 2009). Further, they found that the effect of distances has increased while that of boundaries has decreased between European regions suggesting a better integration of nations within Europe (Hoekman, Frenken, & Tijssen, 2010).

Since the 2010s, much progress has been made in processing the spatial information of bibliometric data at a higher level of resolution (Leydesdorff & Persson, 2010). Performing a bibliometric analysis of urban production has been worthwhile to find that the world scientific production is realized by an increasing number of cities (Grossetti et al., 2014). What is happening is that the previous monopoly of capital cities or historical university/research centers is, little by little, diminishing in almost every country in the world. Also exploiting geolocalization tools, Tijssen et al. have proven that the mean kilometric collaboration distance has increased globally during the 2000s whereas the share of international collaborations has leveled off (Tijssen, Waltman, & van Eck, 2012).

Drawing upon this last family of collaboration studies, the multi-level analysis approach we propose can be used to describe the evolution of the world collaboration network at an unprecedented level of geographical resolution: the urban