Title

Building a Multi-Perspective Scientometric Approach on Tentative Governance in Emerging Technologies

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EXTENDED ABSTRACT

Emerging technologies have the potential to generate profound - both positive and negative - social changes such as creating new industries as well as reconfiguring/destroying existing ones. Defining governing arrangements for emerging technologies is however a complex activity given the uncertainties and dynamics that feature in their emergence process. The development of novel technologies may follow some directions rather than others as a result of a variety of factors. These including the visions, goals and expectations the constellation of involved actors have on them (e.g. Geels, 2002; Wick et al., 2007; Stirling, 2009). These actors of the innovation dynamics, are at the same time being regulated, and actively influencing (i.e. actually regulating) the emergence process by attempting to steer the intentional government arrangements (Braithwaite and Drahos, 2000). Rip (2010) refers in this sense to concept of de facto governance.

In this configuration, traditional forms of governance are unsuitable because of their highly routinized and structured nature, which in times of more incremental change gives them legitimacy. Novel governance approaches instead aiming to address the complexity, interdependencies, and contingencies characterizing the process of emergence have started to appear. The main characteristic distinguishing these novel approaches to the traditional ones is their ‘tentative’ nature (e.g. Hagendijk and Irwin, 2006; Boon et al., 2011). Forms of governance that are tentative aim to create a space where the generation of a number of options for the development of emerging technologies is desired and supported. Our understanding of this phenomenon is however limited. Policy makers and researchers need tools that are capable of capturing, in a timely and informative manner, the dynamics of the emergence process.

In this regard, scientometrics represents a valuable source. We propose a multi-perspective scientometric approach that has the potential to identify connections between structure and dynamics, and the governance, which in turn is a scarcely investigated area of research. The approach builds on several data sources (e.g. publications, patents, inter-organisational alliances) that portray different analytical lenses at various levels of aggregation (e.g. individual, organisation, discipline). The intersection between data sources and units of analysis defines perspectives (Figure 1) that can be observed across time to
capture evolutionary dynamics. By using scientometric techniques the different perspectives may serve as informative and interpretative tool of de facto governance across three distinct but interdependent dimensions of the emergence process, i.e. cognitive, social, and geographical ones.

Firstly, scientometrics has developed robust mapping techniques to dynamically and timely trace the structure of the cognitive dimension. These techniques mainly use two types of data, i.e. publications and patents. Until recently, scholars’ efforts in using publication data have been focused on the development of maps of science circumscribed only to the publications of the topics (e.g. co-citation, co-words maps). In the last decade, an important development has been the creation of so-called global maps of science, which represent all science in one map in terms of disciplines, journals, or research topics (e.g. Klavans and Boyack, 2009; Rafols et al., 2010). Overlay techniques can be applied to this map in order to project an entity’s (e.g. individual, organisation) publishing activity. Among these maps it is worth mentioning the global map of science (Klavans and Boyack, 2009; Rafols et al., 2010)—based on the ISI Web of Science subject categories—and the Medical Subject Headings (MeSH) map (Leydesdorff et al., 2012)—based on the PubMed/MEDLINE MeSH terms, which provide the practitioners’ view on the use of

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1 The multi-perspective approach is flexible, i.e. it does not limit to the perspectives reported in Figure 1. Yet, it can be extended by including additional data sources and units of analysis.
medical knowledge. Efforts have been also undertaken to build maps based patent technological classes (e.g. Leydesdorff et al., Forthcoming). Secondly, the structure of the relationships between actors surrounding novel technologies and its dynamics play a critical role in the emergence process (e.g. Latour, 1993; Klijn and Koppenjan, 2000). These connections are channels through which actors gain access to and mobilise knowledge, resources, and power. The use of co-authorship data in publications to trace network and social dynamics has a long tradition in scientometrics (Crane, 1972). Co-invention activities and inter-organisational alliances data represent also valuable sources to build additional perspectives. Thirdly, the geographical diffusion of emerging technologies can also be traced. Scientometricians have developed also in this case a number of applications to localise the production of publications and patents (e.g. Leydesdorff and Bornmann, 2012).

The paper will discuss the multi-perspective scientometric approach across three illustrative case studies in the life science: (i) RNA interferences (RNAi), (ii) Human Papillomavirus (HPV) diagnostics and (iii) Thiopurine Methyltransferase (TPMT) testing.

**RNA interference.** RNAi is a technique for gene silencing that has the potential to stop the progression of a given disease. This gene silencing mechanism was discovered in 1998 (Fire et al., 1998) and its discovery reshaped the landscape of research on therapies based on control of gene expression creating important expectations on the therapeutic applications (e.g. Sung and Hopkins, 2006). One of the main characteristics of RNAi is that it can be conceived as a “general purpose technology” for research in labs (Youtie et al., 2008). In this regard, by mapping the publication activity with overlay techniques applied to the global map of science (Leydesdorff and Rafols, 2011) the diffusion and impact of RNAi across a number of diverse fields of science is revealed, thus informing on the cognitive dynamics of *de facto* governance. Figure 2a depicts the disciplinary overlay map for the 2007-2011 period. The social dimension can be also traced by using collaboration networks as reported in Figure 2b. This informs on the structure of the inter-organisational alliances networks of companies involved in the development of RNAi revealing that the two key players, i.e. Alnylam Pharmaceuticals and ISIS Pharmaceuticals (grey nodes), are strongly connected and positioned at the centre of the network. Finally, publishing and patenting activities can be projected on Google Maps to investigate the geographical dimension (e.g. Leydesdorff and Bornmann, 2012). The collaboration activity (co-authorships) across different cities on Google Maps (Figure 2c) (Leydesdorff and Rafols, 2011) the diffusion and impact of RNAi across a number of diverse fields of science is revealed, thus informing on the cognitive dynamics of *de facto* governance. Figure 2a depicts the disciplinary overlay map for the 2007-2011 period. The social dimension can be also traced by using collaboration networks as reported in Figure 2b. This informs on the structure of the inter-organisational alliances networks of companies involved in the development of RNAi revealing that the two key players, i.e. Alnylam Pharmaceuticals and ISIS Pharmaceuticals (grey nodes), are strongly connected and positioned at the centre of the network. Finally, publishing and patenting activities can be projected on Google Maps to investigate the geographical dimension (e.g. Leydesdorff and Bornmann, 2012). The collaboration activity (co-authorships) across different cities on Google Maps (Figure 2c) (Leydesdorff and Rafols, 2011).

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2 ISI subject categories are grouped in 19 macro-areas. A different colour is assigned to each macro-area (for further details see Rafols et al., 2010).
2011) allows identifying locations of and interactions among the constellation of actors involved in *de facto* governance.

**HPV diagnostics.** The second case study is related to the development of a diagnostic technology for the detection of HPV. In the 1980s, HPV viruses were discovered strongly associated with cervical cancer in women, which has a significant impact on population—about 500,000 new cervical cancers and 250,000 deaths each year. This has led to the development of a large screening program with 100+ million tests performed annually. While this screening has been mainly performed by using the Pap-test, the discovery on the association between HPV and cervical cancer opened the space for the development of a competing and more sensitive technology for the detection of the HPV and then of the cervical cancer based on molecular diagnostics technology, namely the HPV testing (Casper and Clarke, 1998; Hogarth et al., 2012). In this process, Digene Corp. played a crucial role in establishing the HPV-test as gold standard. (Hogarth et al., 2012). We reported in Figure 2d the inter-organisational network (co-authorships from 1997 to 2001).³ Digene and the organisations to which the company was directly connected are represented with yellow and red nodes, respectively. The network reveals the social structure of the *de facto* governance since a detailed analysis shows Digene collaborating with main institutions in the field (e.g. National Cancer Institute, Kaiser Permanente) involved in the regulation of the cervical cancer screening. In other words, while Digene’s activity was ‘regulated’ (e.g. FDA approval), Digene was affecting the developments and dynamics in cervical cancer screening.

**TPMT testing.** The third case study is focused on an emerging class of Pharmacogenetic tests (which predict adverse events affecting patient’s health) (Hopkins et al., 2006), i.e. the TPMT testing. TPMT is an enzyme in the human body responsible for metabolising thiopurine drugs. Cytotoxic Thiopurine drugs are used to treat a range of conditions including leukaemia, and autoimmune diseases. However, where a patient has mutations in the gene encoding TPMT, they may be at increased risk of toxicity from a build up of thiopurines. Therefore, several types of TPMT test started to emerge across a number of clinical fields of use. Some of the tests are based on patented technology (with an IP holder that seeks to aggressively exploit their exclusivity in certain markets such as the USA, but not in others such as the UK). The relatively small market for the (off-patent) thiopurine drugs represents a small ‘niche’ made up of other niches such as transplantation,

³ We reported only the giant component and the nodes’ size is proportional to organisations' degree centrality.
gastroenterology, and rheumatology. In these different niches, evidence of clinical utility of the test is highly contested. In this case, tentative governance occurs through medical guidelines which report significant differences in the use of TPMT testing. Investigating the cognitive structure of the emergence process can reveal for instance different translations and interpretations of basic knowledge on TPMT.

While the present extended abstract has reported only some key examples of the application of the multi-perspective scientometric approach, the full paper will comprehensively discuss this approach across the three case studies. Particular attention will be paid in integrating the outputs of the approach under the lens of *de facto* governance and the extent to which these outputs can inform, in a timely manner, policy makers and researchers.
Figure 2. The multi-perspective scientometric approach, techniques, and examples.
REFERENCES


