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Collaborative diversity in a nanotechnology innovation system: Evidence from the EU Framework Programme

Krsto Pandza [a,*], Terry A. Wilkins [b], Eva A. Alfoldi [c]

[a] Leeds University Business School, The University of Leeds, Maurice Keyworth Building, Leeds LS2 9JT, UK
[b] NanoManufacturing Institute, The University of Leeds, Houldsworth Building, Leeds LS2 9JT, UK
[c] Manchester Business School, The University of Manchester, Booth Street West, Manchester M15 6PB, UK

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ABSTRACT

Collaborative diversity is, arguably, an intrinsic characteristic of research networks built on the emergence of general-purpose technologies such as nanotechnology. European research policy, epitomised in Framework Programmes, creates arrangements that institutionalise the development of internationally and institutionally diverse research networks. Motivated by concerns that a high degree of collaborative diversity may create managerial challenges for network members in sharing knowledge across national and institutional borders, we study the configurations of collaborative research networks and consider their international and institutional diversity. We also explore the influence of European policy mechanisms on the international and institutional diversity of collaborative research networks. We conclude that nanotechnology research networks are indeed characterised by a significant degree of collaborative diversity, which in turn exposes a need for participating members to develop strategic capabilities to manage research within diverse networks.

1. Introduction

The emergence of nanotechnology as a general-purpose technology (Bresnahan and Trajtenberg, 1995), characterised by its pervasiveness and inherent potential for opening new opportunities, provides fresh challenges for policy-makers, entrepreneurs, managers, engineers and scientists. Policy-makers from different national and transnational innovation systems strive to design policies to realise often highly ambitious promises resulting from the emergence of nanotechnology (Bhat, 2005; Romig et al., 2007). Previous work suggests that entrepreneurs face considerable challenges when venturing to commercialise general-purpose technologies (Thoma, 2008), which is particularly evident in commercialising emergent nano-technologies from an upstream position within a variety of industrial value chains (Maine and Garnsey, 2006). Managers of established companies wrestle with the discontinuous nature of an emergent technological trajectory (Dosi, 1982) that changes dynamics of intra-firm innovation processes (Linton and Walsh, 2008). Engineers and scientists are forced to navigate an interdisciplinary landscape of nanoscience and nanotechnology (Islam and Miyazaki, 2009, 2010).

In this paper, we argue that the emergent and general-purpose nature of nanotechnology demands collaborative research efforts, and that nanotechnology innovation networks are therefore highly likely to be characterised by a degree of international and institutional diversity. We introduce European Union Framework Programmes (FP) as an institutional arrangement that sets norms, rules and values for creating internationally and institutionally diverse research networks. Within this context, we explore the international and institutional configurations of nanotechnology research projects and the characteristic roles of partners within collaborative projects, and analyse the mitigating role of different policy instruments for structuring the international and institutional diversity of collaborative networks in nanotechnology.

Existing definitions of nanotechnology provide an insight into the multifaceted nature of this emergent technology and highlight the numerous challenges faced by different members of a nanotechnology innovation system. Authors are largely consistent in defining nanotechnology as the investigation of bottom-up *and* top-down structural arrangements at a physical size below 100 nm (nanometres), where the properties of materials, systems and devices differ significantly from those at a larger scale (Kostoff et al., 2007). There is also general agreement that nanotechnology is a platform technology with a potential to transform many industrial sectors, in particular by fostering the convergence between previously separate technology-driven industries (Alencar et al., 2007; Bozeman et al., 2007). The interdisciplinary nature of nanotechnology that spans scientific developments across disciplines is also consistently highlighted (Salerno et al., 2008). Romig et al. (2007) additionally emphasise that nanotechnology may have different impacts on

* Corresponding author. Tel.: +44 113 343 4509; fax: +44 113 343 4885.
E-mail address: kp@lubs.leeds.ac.uk (K. Pandza).

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different industrial sectors and members of value chains. While nanotechnology is potentially discontinuous and radical, it often provides incremental improvements within existent technological trajectories.

The combination of newness and often asymmetric dispersion of knowledge about nanotechnology (Pandza and Holt, 2007) suggests that relevant knowledge will most likely reside in networks of organisations, rather than in individual members of a technology innovation system (Powell et al., 1996). Such networks can include individuals, firms, universities, research institutes, venture capitalists and public policy agencies (or parts or groups of each). As a technological innovation system is likely to extend beyond a particular national innovation system and institutional environment, international and institutional diversity become its intrinsic properties. Integrating knowledge across national and institutional borders and creating diverse research networks along these two dimensions represent the basic tenet of European Union (EU) research policy embodied in Framework Programmes (FPs). The history of FPs is characterised by a series of institutional changes (Hargrave and Van de Ven, 2006), by which the European Commission (EC) creates institutional arrangements that determine the nature and structure of research collaboration networks funded from EU sources.

The international diversity of collaborative research projects is influenced by two strategic objectives of EU research policy: subsidiarity and cohesion. Under the policy objective of subsidiarity, introduced in FP2 (1987–1991), the EC funds research projects that are most effectively pursued at the EU level by integrating resources from different member states (Kuhlmann, 2001). In practice, this principle is addressed by the condition that research networks funded within a FP must consist of partners from at least three different member states. As such, the EC has effectively institutionalised a degree of international diversity in collaborative research projects. International diversity is further emphasised by the strategic objective of cohesion, which has been central to the introduction of FP6 (2002–2006). By emphasising cohesion, the EC recognises that the technology gap among the EU member states is bigger than the gap between the EU, the USA and Japan (Pavitt, 1998) and is still increasing (Clarysse and Muldur, 2001). Although the EC does not make the participation of so-called 'less favourable countries' a norm for collaborative projects, it certainly favours a balanced international structure (Marin and Siotis, 2008), and applicants for research funding are generally aware that a well-balanced research network makes their application more likely to succeed.

Meanwhile, institutional diversity in EU collaborative research is also influenced by various policy objectives, which include increasing industrial competitiveness, fostering innovation for achieving economic growth and tackling large-scale societal challenges by organising research into strategic thematic priorities. The notion of pre-competitive research, explicitly emphasised in FP4 (1994–1998), highlights the importance of inter-firm collaboration and knowledge sharing (Ahuja, 2000; Luukkonen, 2000), as well as encouraging close and strategic collaboration between industry and university research centres (Santoro and Chakrabarti, 2001). Overall, it is evident that EU policy objectives are aimed at increasing the international and institutional diversity of nanotechnology research networks, which inevitably creates challenges for managing such networks. As Kastrinos (1994) argues, configurations of European research networks determine the ability to shape and control the direction the research projects, calling for more in-depth studies on the configuration of research networks fostered by the FPs.

The remainder of this paper is organised as follows. Section 2 discusses the evolution of EU research policy on nanotechnology. In this section we attempt to depict the policy instruments with the highest impact on international and institutional diversity and position them within the wider context of EU policy development on nanotechnology. In Section 3, we review the issues that may affect the management of international and inter-institutional research collaboration. In Sections 4 and 5, we provide information on our data sources, propose a methodology for exploring collaborative diversity in research projects and present our results. A discussion with policy-relevant conclusions is presented at the end of the paper, in Section 6.

2. Nanotechnology and EU innovation policy

The establishment of nanotechnology as a distinct research priority within Framework Programme 6 (FP6) reflects the spirit of the time at the beginning of the 21st century. The ambitious, coordinated and centralised National Nanotechnology Initiative (NNI) in the USA in 2001 clearly exposed the fragmentation of nanotechnology research in the EU, and strengthened the recognition that the EU cannot remain competitive at a global level without better focusing and coordinating nanotechnology research. FP6 provided a fertile institutional environment for creating a separate research programme dedicated to an emergent technology. It was introduced with ambitious policy objectives to significantly enhance industrial innovation, change the European research landscape through the introduction of the integrated European Research Area (ERA), and create sustainable growth, increased employment and greater social cohesion. This unique confluence of the emergence of a major new technology paradigm, competitive pressures and a new institutional context explains the creation of a focused and integrated EU research policy dedicated to nanotechnology. Table 1 provides a detailed chronology of EU nanotechnology policy and highlights those policy instruments with the greatest impact on diversity and configurations of nanotechnology research networks.

Research policy development in the EU is a highly complex process wherein a myriad of representatives from different EU countries and different institutional environments attempt to shape the structure of the final Work Programme. FP6 introduced European Technology Platforms (ETPs) for providing high-level industrial input into the development of European research policy. At the end of FP6, the number of ETPs was 33, each producing a strategic research agenda that fed into the preparation of a series of annual Work Programmes. ETPs have been a major force for driving industry sector diversity and significantly increasing the range of institutional stakeholders that influence EU research policy development in general and nanotechnology in particular. The EC recognises that some twelve ETPs (e.g. Nano-Medicine, Sustainable Chemistry, Future Manufacturing Technologies) have a direct interest in nanotechnology.

FP6, similarly to its predecessors, consists of *thematic programmes* (TPs) that concentrate on a particular research area and *instruments* for funding and managing research. Typically, TPs and instruments are structured as vertical and cross-cutting activities. Each TP is managed by an EC Research Directorate and builds its annual operational plan (Work Programme) with input from member states' governments via its Programme Committee and a variety of other stakeholders. It is implemented through various instruments, which are the principal mechanisms for realizing the EU's objectives for international and institutional diversity within the annual operating plans and are defined at the start of each FP. We introduce four instruments that have a strong influence on the configuration of nanotechnology research networks.

Strategic Targeted Research Projects (STREPs) are objective-driven research projects focused on a single research issue, with a limited scope of activities. For STREPs, relatively small networks (3–4 participant institutions/firms) may suffice, budgets tend to be moderate and projects may last for up to three years. The EC is