Technological Forecasting & Social Change 82 (2014) 115–131

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

Collaborative networks and technology clusters — The case of nanowire

Sercan Ozcan *, Nazrul Islam

School of Management and Business, Aberystwyth University, Penglais, Aberystwyth SY23 3DD, UK

ARTICLE INFO

Article history:
Received 23 July 2012
Received in revised form 19 June 2013
Accepted 16 August 2013
Available online 17 September 2013

Keywords:
Nanotechnology
Systems of innovation
Patent analysis
Collaborative networks
Clusters
Linkages
Nanowire

ABSTRACT

Patenting activities and technology diffusion in high-tech sectors are being increasingly driven by collaborative, international and technology-based new entrants. In the realm of nanotechnology, one of the most mature structures is nanowire. This paper is concerned with the technology transfer process in the nanowire field; in particular it examines how patent collaborations occur and how the key actors interact with each other to support this process. This study uses a different methodology than previous studies in terms of patent data extraction. The methodology offers a new taxonomy that could make a significant impact on accurate patent data quests and increase the reliability of patent analyses in emerging fields such as nanotechnology. As patent data are valuable sources of technology innovation data and for forecasting technical change, this study utilises patent network analysis to visualise the actors, clusters and their relationships at the organisational, national and international levels. Overall, this study proposes a new collaborative network model to assist with analysing patenting activities between actors in regard to types of linkages. Different types of linkages between countries and organisations can be found for nanowire-related patenting activities by following the proposed network model. Findings indicate that some nations have highly centralised networks where large organisations dominate most linkages, as in the case of South Korea with regard to Samsung. Nations such as the US and Japan have a more distributed network where academic and industrial players are linked with each other. In the case of China, there were mono-linkages between large organisations such as Foxconn and Tsinghua University, which was the key with regard to collaborative innovation there.

1. Introduction

Nanotechnology is the process of understanding, manipulation and production of materials and devices at the level of atomic and molecular precision [1], particularly at dimensions of roughly 1 to 100 nm, where unique phenomena enable novel applications. This field is highly interdisciplinary [2–4], as it depends on the knowledge and expertise found in conventional disciplines such as chemistry, physics, biology, material sciences and medicine [5]. For this reason, there is much varied research being conducted in order to gain insights into this field and to forecast its possible outcomes. The wide range of studies in this field may increase the rate of nanotechnology diffusion and shorten the pre-commercialised era, and so help it to move on to its highly commercialised era. However, the outcomes of current nanotechnology innovation systems, with their commercial progress, their possible positive and negative effects on the environment and existing industries (e.g. whether they are disruptive innovations or the extent of their market penetration) are uncertain [1,6–8].

The uncertainty of nanotechnology in a business context is even higher when the subcategories of this field are considered. Nanomaterials, nanomedicine and nanoelectronics are some of these subcategories of nanotechnology. However, the applications of these subcategories have differences; there are common nanostructures and nanoparticles that are used in these different fields of research such as nanotubes, nanowires and nanocrystals. All these nanostructures have different

* Corresponding author at: Office S15, Cledwyn Building, Penglais Campus, Aberystwyth, SY23 3DD, Wales, UK.
E-mail addresses: seo5@aber.ac.uk (S. Ozcan), mni@aber.ac.uk (N. Islam).

0040-1625/$ – see front matter © 2013 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.techfore.2013.08.008

characteristics and their own particular novelties [9]. For this study, the nanowire field was chosen for analysis, there being two main justifications for this. Firstly, nanotechnology is not a clearly defined sector, so the scope of this study requires specifying linkages between countries or organisations for a specific field. Secondly, the field of nanowires is one of great interest for researchers and industry, when the number of granted/applied patents for this technology is considered. According to the collected patent data, 4484 patents out of 49,544 nanotechnology patents are for nanowire, which represents almost 10% of all nanotechnology patents.

Reliable and valid information about a particular technology or innovation system can be gathered if the patent data is analysed systematically [10,11]. Some of the reasons why patent analyses are pursued include the discovery of promising technologies, assessment of technological advances and new trends, or helping organisations in their strategic decision-making [12]. Patent analysis can benefit various individuals and organisations such as inventors, R&D departments, policy-makers, academics and managers. Generally, looking at various patent analyses, the most commonly used methods are bibliometric and quantitative analysis; if some of these studies are clustered under various categories, these can then be subjected to network analysis, citation analysis, trend extrapolation/impact analysis, life cycle analysis, innovation system modelling, road mapping studies and economic base analysis [13–17].

Relevant studies conducted by Huang et al. [18] present a longitudinal patent analysis on nanotechnology patents between 1976 and 2002, focusing on content map analysis and citation network analysis. Accordingly, they showed how countries, institutions, and technology fields are linked with each other in terms of cited and citing actors by visualising linkages of the largest patent citation centre, institutional patent citation centres and dominating technologies that are cited most. Another similar study by Li et al. [19] identified key influential players and subfields, knowledge transfer patterns, and overall knowledge transfer efficiency. Porter and Youtie [20] examined nanotechnology positions in relation to other disciplines by considering their multidisciplinary nature, and linkages of these disciplines amongst each other. Similar work was conducted by Miyazaki and Islam [17], focusing on cross-country comparisons, actors and institutions by using similar quantitative methods (bibliometrics and tech mining) to understand the sectorial innovation systems in nanotechnology from a global perspective. Shapira et al. [21] observed the influence of cross-border international invention linkages by using patent data. Our study differs from the previous studies, as the focus of this work is to examine the types of linkages by focusing on co-ownership of patent documents rather than citation linkages. Patent co-ownership analysis is a better model for this study since our objective is to study collaboration linkages between actors, while citation analysis is a more appropriate method for studying knowledge flow between actors.

The objective of this paper is to analyse various linkages by examining granted and applied nanowire patents until the present time. To assist with the investigation process of types of linkages within a network, a new collaborative network model is proposed. This model is tried with the nanowire case bearing in mind the international and organisational contexts that assist gathering information on collaboration trends, linkages and the key players. The case of Samsung is analysed to examine a cluster and to support the findings further.

Considering the limited number of studies in this field in terms of collaborations in patenting activities, this study contributes to the field with a specific case of nanowire patent analysis. There are few studies that examine how nano-patents are linked to each other and in what form they are interconnected. In any event, there is a need for up-to-date studies in various areas of nanotechnology, as it is an emerging field undergoing rapid development. In this study, the patent collection method and the search query are well defined and the patent database was the best among those available for use. The accuracy of the patent database was increased by using lexical queries with a combination of patent classification codes.

2. Theoretical background

In the course of time, innovation management theories have evolved and the perspective on how innovation processes work has changed. After Schumpeter's identification of innovation and his studies [22], there were various theories that have been used by technology or innovation management specialists. The first theories that received attention and were implicit in the work of many innovation specialists were the technology push [23–26] and market pull theories [26–30]. These models were widely accepted in the technology management field but until the 1990s, they failed to take account of other influences that were affecting the innovation process. Lundvall [31] introduced a more comprehensive model to explain systems of innovation. In this model, linkages of various actors were taken into account in the innovation process and included many actors under a single system. Various important aspects are highlighted such as the functions of actors, linkages of actors, and knowledge flow between them. As the focal point of this study is the collaboration mechanisms within an innovation system, the relevant literature is thoroughly reviewed in the following section.

2.1. Systems of innovation approach

The system of innovation (SI) concept has captured the attention of a growing number of researchers involved in the fundamentals of SI as it explains the system in terms of actors, processes and flow of information. The SI comprises the linkages and flow of information among actors such as inventors and organisations in terms of innovative processes [31–35] and describes the processes of interactions among the actors to facilitate the innovation value chain [35,36]. Various SI studies are described in the literature, including national systems of innovation [31,37,38], regional innovation systems [39,40], sectoral systems of innovation [41], technological innovation systems [42], and functions in innovation systems [43].

Looking at these different models, the notion common to all of them is to explain how an innovation system develops, diffuses, and utilises innovations within different contexts. However, the focal point of each study varies at some level and these studies emphasise different aspects of innovation