Commercialization of Nanotechnology Products & Services: A case study from the United Kingdom

Prof. Pir Roshan Shah Rashdi[a], Qazi Moinuddin Abro[b]

[a]*Mehran University Institute of Science and Technology Development*
Mehran University of Engineering and Technology, Jamshoro Sindh Pakistan
Tel: 022-2772431, Fax: 022-2772432
E-mail: pirrashdi@yahoo.com

[b]*PhD Research Student, Nottingham University Business School*
University of Nottingham, Nottingham NG7 1BB, U.K
E-mail: lixmq@ nottingham.ac.uk

ABSTRACT

This article aims to provide an insight into the commercialization process of new technologies. Nanotechnology is being heralded as a new technological paradigm that will profoundly influence all aspects of our lives over the coming decades. This research effort attempts to unravel the first signs of commercialization of this new technology in the United Kingdom and to highlight some important aspects of the commercialization process of nano-scale products and services. The commercialization process is poorly understood because of the embryonic state and loose definition of the technology (Libaers, et al, 2005), and previous studies have been based upon surveys and consultant reports only. In this paper, a number of important features and characteristics of the commercialization process are highlighted through organizational typology and the technological bases of the firms. The research includes a quantitative analysis of empirical data collected through bibliometric and patent data bases.

Keywords

Commercialization, Nanoscience, Nanotechnology,

1.0 INTRODUCTION

1.1 Nano publications

Bibliometric quantification is a way to track the emergence of a new technology. Even more so, bibliometric studies can also point to the emergence of accompanying scientific literature. There are about half a dozen bibliometric published studies that deal explicitly with nanotechnology or nanoscience. Braun et al. (1997), published the first ever study in a bibliometric journal dealing with the nanoscience and technology. In their study, they showed that a new scientific field had emerged on the nano-scale and were able to establish an exponential growth pattern of publications that addressed nano-scale issues, starting in the early 1990s. In another study, Meyer and Pearson (1998) set out to reproduce and confirm the results of Braun and his colleagues. They confirm the observations with respect to the strong increase of publication activity in the 1990s and explored to characterize the field as more interdisciplinary than other areas of science. Porter and Cunningham (1999) carried out a number of different searches in INSPEC[i] and SCI[ii] databases. In particular, they distinguished the following:

- 'Nano-related' - the most encompassing scan
- 'Nanotechnology' - items explicitly including the term
- 'Scanning probe Nanotechnology' - items mentioning STM[iii] or AFM[iv]
- 'Bottom-up' - the most restrictive search seeking bottom-up nanotechnology research.

Comparing the nanotechnology content of INSPEC and the SCI, the authors observe divergent developments. Porter and Cunningham (1999) see substantial and growing differences among researchers in the 'nanosciences'. They concluded that, "In SCI nanotechnology coverage is less applied and more oriented towards basic research, so much so that the word 'nanotechnology' itself is only infrequently used. In SCI, nanotechnology research relates much more closely to the life sciences and most particularly to bio- and organic-chemistry. 'Bottom-up nanotechnology' items in INSPEC share this orientation". So far there seem to be few other studies in the US that address nanotechnology in bibliometric terms. Tolles (2001) uses bibliometric data to compare the international scientific standing of the U.S. in nanostructure science and technology and did a search in the SCI using 'nano*' as the search term. One may argue that this is a much too simplistic approach for defining and limiting the field of nanotechnology. However, often expert in the field cannot agree themselves as to what nanotechnology exactly is ?[v]

'Nano*' appears then as a useful search approach and, as a consequence, was used in several other studies also. ISI presents bibliometric data on their website (www.esi-topics.com/nano/), in this database, papers were compiled based on title and author supplied keywords for nanotechnology. The keywords were extracted using the stem 'nano*'. The time span for this database was 1991-2000; the database contained 32,605 papers, reflecting the contributions of 47,143 authors, 99 countries, 1,840 journals and 6,377 organizations.

1.2 Nano patents

Patents are also a way to represent and track 'technology'. In a study carried out by Meyer and Pearson (1998) by applying a similar search strategy as applied to the bibliometric analysis to United Stated Patents and Trade Mark Office (USPTO), a database of nano-patents was built up. The search strategy that was applied to the US patent data was similar to the one used earlier in the bibliometric search, mostly using the terms chosen by Braun et al. (1997)[vi]. More than 2,000 nano-patents were identified during their search period 1990-1997.

In Europe, Bachmann (1999) presents some results of a patent search in the World Patent Index using a broad search approach of 'nano*' and some additional search terms, he has also given a general overview where and to what extent nanotechnological developments have already been taken place .

In the above discussion, some studies have been pointed out which postulate a close relationship between scientific research and technological development at the nano scale. The available data shows that there is an activity to be traced in both science and technology. The bibliometric analysis of nano publications in journals indicates that there is a substantial amount of scientific exploration going on. The analysis of nano related patents points towards the substantial technological activity. As a basis for further discussion, this paper will examine the linkage between nanoscience and technology in the UK, because to our knowledge no study has been conducted so far from the UK's context. To assess the strength and nature of the linkage between nano science and nano technology another important indicator, that of co-publications, will also be explained in this paper, which has been ignored in the previous studies. This is because it is very useful to look at the co-publications patterns if one also wishes to assess the linkage between science bases at the universities and technology base at the commercial organizations (Patel and Calvert 2003). After examining the linkage between nanoscience and technology, the results of a web survey has also been presented which classified all the identified nanoscience and technology organizations into their organizational typology and technological background.

2.0 DATABASES AND THEIR GENERATION

2.1 Publication Database

As a first step, a database of all 'nano' related co-published academic articles, papers, letters and reviews by the UK authors was generated. The data collection was started in December, 2005 and was completed in December, 2006. The search key word (nano*) [vii] at Science Citation Index, SCI Extended database on the Web of Science, covering the period 1997-2006 was used. The database contained around 11000 nano-related papers published during 1997-2006. It is expected that a fraction of the 2006 nano papers are not yet available but this will not affect the overall results of this analysis. A number of terms, such as nanosecond, nanoampere, nanogram, nanoplankton, nano4 were excluded, as irrelevant to the topic.

2.2 Patent data base

A database of all 'nano' related patents granted to UK assignees during the period (1997-2006) was generated. This was done by using the online database of the United Stated Patents and Trade Mark Office (USPTO) and European Patent Office (EPO). Huang, et al, (2004), argued that, in the absence of a unified global patent system, the USPTO database is the most representative because usually the claims submitted in other countries are simultaneously submitted to USPTO. Both the databases were used to get the most comprehensive results.

In order to provide the broadest possible basis for the matching procedure, the search for the term 'nano*' was included not only in the title of the patent but in the abstract also. A total of 330 patents were found and downloaded manually.

3.0 LINKAGE BETWEEN NANOSCIOENCE AND NANOTECHNOLOGY

A technological field that is generally acknowledged as science-based should have a substantial number of patents granted (Meyer, 2001). This might not necessarily be the case, as this analysis yields. There are 11,000 nano-publications identified, with a total number of 330 patents granted to the UK based assignees during the same period of time. This results in **3%** linkage between the two, which also confirms the results of Meyer (2001), who revealed that there is a weak linkage between the nanoscience and nanotechnology.

3.1 Patent Citation Analysis

Nanotechnology patents do not cite nano-science publications as frequently as one might expect. Matching the 11,000 nano publications identified in the Science Citation Index at the Web of Science during 1997-2006 with the 330 nano patents downloaded from the USPTO and EPO databases during the same period of time resulted only in 240 matches. This leads to a ratio of 'nanoscience papers cited in nanotechnology patents per total nanoscience papers' of approximately 2.2% [viii]. A report compared the number of US papers published in 1993-95 that were cited in 1997 US invented patents with the total number of US papers published in 1993-95 by field and research type (Hicks, et al, 2000). Applied physics papers were a group of publications that were cited in patents the most with 2.4%. Also, 2.3% of the basic biomedical research papers were cited followed by 1.5% of the basic research clinical medical papers.

These findings suggest that, in absolute numbers many fields of science and technology do not interact at a very high rate. However, comparing the present findings with the Hicks results, it can be concluded that nanoscience and nanotechnology are not poorly interlinked in comparison to other fields of science and technology, particularly given that it is new and emerging field of science and technology.

3.2 Linkage of NST companies with the science base in UK

From the publication database, 218 companies have been identified which are publishing their nanoscience research in the UK. To gauge the strength of the linkage of each type of company engaged in nanoscience and technology with the UK science base, the publication database across all the companies identified has been closely examined.

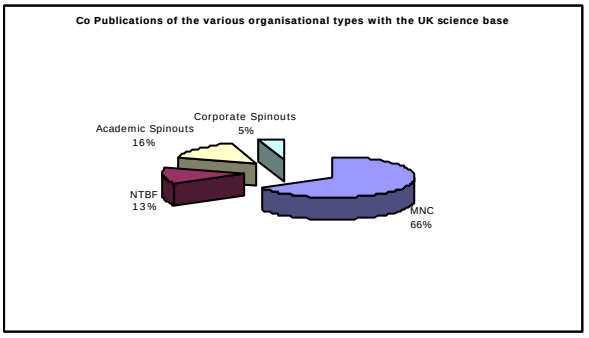

Figure 1:Co-Publications of the various organisational types with the UK science base

The results as presented in the figure 1, it is noted that multinational companies which are involved in the creation, development, and commercialization of NST products and services are very close to the UK science base with an aggregate 180 co-publications over the stated 10 years period of time. Academic spinouts co-publish a relatively low number of peer-reviewed academic articles with UK universities: only 42 publications were observed. It is also noted that the bulk of these publications are concentrated in a handful of academic spinouts mostly from Oxford and Cambridge universities.
High technology or new technology based firms co-publish slightly less than the academic spinouts and corporate spinouts have co-published a marginal amount of the papers with UK academia over the 10 years period studied.
Epigem and Epichem among the corporate spinouts and Teer Coatings and Telecom are the companies among the NTBFs, which co-publish with UK academia.

4.0 WEB SURVEY

The publication and patents databases have been generated for the dual purposes:

1. To provide the data required to study the linkage between the science bases of UK academia with the business world and;
2. To assist in the identification of nanotechnology companies in the UK.

From the analysis of the publication and patent databases and with the help of some other resources available (for example: reports published by the Institute of Nanotechnology in 2003 and 2005, keywords search on Google search engine, etc) a total number of 399 companies have been identified which are engaged in the nanoscience and technology in the UK. After having a comprehensive list of nanotechnology companies, a web survey of all these companies have been conducted in order to get the in depth information about their organizational typology and technology specialization of all these companies.

4.1 Organizational Typology

This classifies all the 399 identified UK based companies into 4 distinct categories:

- Academic spinouts that have been spun off from university departments or research centers that are part of a university
- Corporate spinouts that are typically spun off large, established companies and that are funded by the parent organization
- NTBF, high technology based companies established by independent entrepreneurs
- MNC companies

In the figure 2, it is concluded that the corporate nanoscience and technology community in the UK is predominantly populated by roughly equal proportions of MNC, academic spinouts, and NTBF companies. Corporate spinouts play a marginal role.

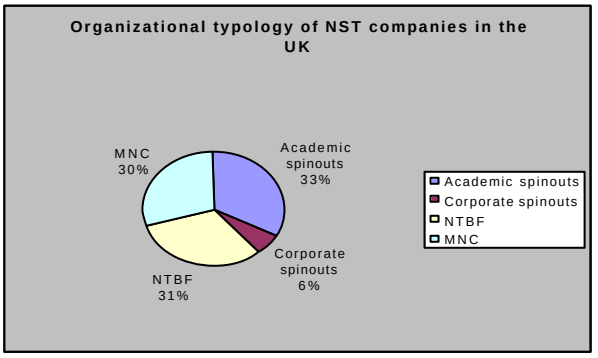

Figure 2: Organizational typology of NST companies in the UK

4.2 Technological specialization

Another aspect to classify these companies is to elucidate how technological specialization is distributed across the companies commercializing nanoscience and technology scale products/services in the UK.
Technological specialization in the UK is distributed as depicted in the pie chart (Figure 3) below:

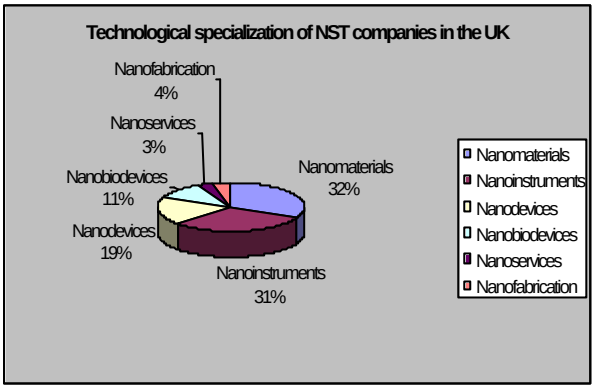

Figure 3: Technological specialization of NST companies

It is concluded that 63 percent of all NST companies in the UK are specialized in only two technologies i.e. nanoinstruments and nanomaterials. The observations made by Rosenberg (1994) that scientific instruments play an enabling role in further discoveries is supporting our findings as well.

The various technologies have been identified in the course of the research are:

- *Nanomaterials*: includes nanopowders, nanoparticles, nanocomposites, nanocoatings, etc.
- *Nanoinstruments*: includes Scanning Probe Microscopes, Atomic Force Microscopes, and a whole range of characterization, imaging, and manipulation instruments
- *Nanodevices*: includes nanoscale electronic, photonic devices, nanomembranes, etc.
- *Nanobiodevices and Nanobiotechnology*: nanobiomolecules, nanobodies, etc.
- *Nanoservices*: Analytical and characterization measurement services, software for simulation of nanoscale phenomena.
- *Nanofabrication*: Facilities for manufacturing nanoscale structures and devices in medium to large quantities.

5.0 CONCLUSIONS

Comparing the 11,000 nano-publications identified, with a total number of 330 patents granted to the UK based assignees during the 1997-2006, resulted in 3% linkage between nanoscience and technology in the UK, which also confirms the results of Meyer (2001), who revealed that there is a weak linkage between the nanoscience and nanotechnology (Meyer, 2001). After matching the 11,000 nano publications with the 330 nano patents resulted only in 240 matches. This leads to a ratio of 'nanoscience papers cited in nanotechnology patents per total nanoscience papers' of approximately 2.2%. However, comparing the present findings with the Hicks results, it can be concluded that nanoscience and nanotechnology are not poorly interlinked in comparison to other fields of science and technology, particularly given that it is new and emerging field of science and technology.

After analyzing the entire sample of companies to observe the linkage of nanotechnology companies in the science bases of UK, we observe that MNC's maintain strong research collaborations with the academia. Academic spinouts are coming in a distant second place in terms of publications.

Our study of technological specialization in NST in the UK has revealed that nanomaterials and nanoinstruments are the dominating technologies proportion-wise, trailed by nanodevices, and to a lesser extent nanobiotechnologies/nanobiodevices. Nanofabrication and nanoservice providers make up a small fraction of specializations offered in the UK.

Academic Spinout's in the UK are leaders in developing and/or commercializing nano-related products, followed by NTBF's and MNC's. An other finding is that the nano-instruments market in the UK is dominated by academic spinouts and NTBF's, while MNC's play a marginal role, these results are also confirming Rosenberg's finding that research universities play an important role in the development of scientific instruments (Rosenberg, 1994).

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Foot Notes:

[1] The INSPEC database is the world's largest and most comprehensive English-language bibliographic database, in physics, electronics and computing.

[2] The Science Citation Index (SCI) provides access to current and retrospective bibliographic information, author abstracts, and cited references found in 3,700 of the world's leading scholarly science and technical journals covering more than 100 disciplines.

[3] Scanning Tunneling Microscopy

[4] Atomic Force Microscopy

[5] For instance, Malsch showed in her Delphi study of nanotechnology experts that there are very few areas that all or a majority of participating experts would view as 'nanotechnology'. However, often a strong minority of experts considered a certain area as a nanotechnology subfield (Malsch1997). Within a bibliometric context, Meyer (2002) observed that 'nano*' is the only text string all experts involved could agree on. However, the study also illustrated that applying this search strategy may lead to poor precision and recall rates.

[6] The patent data were retrieved from the US patent data abstract via Dialog based on the keywords used for article retrieval plus a limited number of other relevant expressions. All the search terms starts with the word 'nano', for example: nano crystalline, nano filter, nano lithography, etc.

[7] The * denotes all the words after nano like: nanotechnology, nanosciences, nanopowder, nanofabrics etc.

[8] (240/11000) x100=2.18%, Say 2.2%.