ECONOMIC STATISTICS AND INDICATORS OF NANOTECHNOLOGY

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ABSTRACT

Economic indicators and statistics are the baseline of any measurement, but when it comes to measuring innovation, the schools of thoughts are divided on what are the most relevant and reliable indicators and metrics to assess the development of a specific technology not only within its wide range of applications, but also against another technology? The younger the technology in question, the more difficult it is to find the right indicators for the measurement of its innovative power at a time when such measurement is most needed, in order to evaluate the efficiency of policy making regarding this technology.

The measurement of the innovative power of a General Purpose Technology (GPT), like nanotechnology, can benefit from adoption of commonly accepted economic indicators, such as intellectual property creation, creation of enterprises, manufacture of value-added products and supply of relevant services, but new indicators need to be proposed, in order to specifically grasp the disruptive and revolutionary power of the GPT.

This study aims to stress-test the use of traditional indicators for the measurement of nanotechnology innovation, in order to specifically allow for comparison with other technological developments and between economic markets, while gaining insight into the shortcomings of these traditional indicators and aiming to identify needs for better suited future indicators to be created.

Keywords: Nanotechnology, Economic Statistics, Economic Indicators, Commercialisation.
1. INTRODUCTION

Various definitions of nanotechnology exist. The definition of “nanotechnology”, which was accepted across the world is as follows:

Nanotechnology - The purposeful engineering of matter at scales of less than 100 nanometres (nm) to achieve size-dependent properties and functions.

To understand the scale, 10 hydrogen atoms in a row side by side measures about one nanometre in width. A strand of DNA is about two nanometres wide.

Nanotechnology is an enabled technology which has affected a wide range of industries. It has an impact of $254 billion worth of products across the globe in 2009 and this effect is expected to grow to $2.5 trillion in 2015.

Nanotechnology is multidisciplinary thus extracting information from science and technology data is difficult and uncertain. There is no exact clarity in the definition of nanotechnology. Exact and clear definition forms the base to gather effective indicators on the data on investment. All definitions utilised by a number of selected national and global organisations broadly cover similar aspects in terms of materials within a size range of 1 to 100 nanometres (nm) that exhibit novel properties as a function of this size.

Defining nanotechnology products and processes

Due to lack of a stable definition it is difficult to assess the contribution of nanotechnology to specific processes and products. In this paper, we will use following definitions that align with those being used by the Working Party on Nanotechnology (WPN):

- Nanotechnology product: product based on nanotechnology fundamentals. The product would not exist without it. e.g. novel batteries.
- Nano-enabled product: products whose functions is based on utilising size dependent phenomenon underlying nanotechnology
- Products that utilise nanotechnology: nanotechnology has improved or enabled more efficient or cost effective production or processing due to which finished product may or may not contain nanomaterial. e.g. anti-fouling coatings for food processing equipment.

Therefore in terms of economic impact assessment it is relatively simple to determine nanotechnology product and material. However, in later stages the definition stated above make assessment more complex.

2. LACK OF NANOTECHNOLOGY SPECIFIC ECONOMIC INDICATORS

The large number of application of nanotechnologies across all sectors and their enabling nature creates a complex and difficult situation for analysis. Due to these difficulties and short time span of investments in nanotechnology, the development of consistent and widely accepted nanotechnology specific economic indicators has been quite slow.

This challenge exists on both national as well as international front to ensure that indicators developed or revised can be compared on global WPN has been considering the need for nanotechnology related statistics and indicators since 2007. In 2009 WPN published Nanotechnology: An Overview Based on Indicators and Statistics (STI Working Paper 2009/7) addressing the policy considerations of moving towards a statistical framework for nanotechnology, and report findings from a pilot survey of business activity in nanotechnology.
In addition, the OECD’s National Experts on Science and Technology Indicators (NESTI) is currently developing a conceptual and methodological framework for statistics on the development, application and impact of technologies. NESTI target to design a conceptual and methodological framework which can be utilised for other technologies like biotech etc.

Selection of such indicators (that measure input, output, and impact) which are currently used in assessing nanotechnology are described further in terms of performance and challenges faced. Reliable assessments of nanotechnology development and its potential impact could not be measured as there is no worldwide accepted definition of nanotechnology and its assessment methods. This has affected data collection and analysis and hampered the development of reliable indicators and statistics. While we acknowledges the need for further work on nanotechnology metrics and its existing data limitations, it draws on available statistics, indicators and other sources in order to provide a useful overview of emerging developments related to nanotechnology innovation and commercialization and to support a more informed policy discussion.

3. TRENDS IN R&D, PUBLICATIONS AND PATENTING

Public-Sector Investment — The growth of nanotechnology has been benefited from rapidly increasing public R & D investment over a short span of time. In terms of total investments, the United States, the European Union and Japan are the primary locations for nanotechnology R&D. However investments on a per capita basis in some smaller countries like Ireland, Israel, Taiwan, New Zealand, the Netherlands, Finland and Australia are also remarkable.

Private-Sector Investment — 2006 data on private-sector investments which were compiled by the European Commission indicate that the United States and Japan have a higher percentage of total R&D, originating from the private sector (54 percent and 63 percent, respectively) when compared to the European Union (33 percent).

Publications — as in most of cases of emerging technology number of publication are much higher than number of patent so far. This holds true for nanotechnology. Recently the rate of growth of nanotechnology related publication and patent is much higher compared to total publication and patent. Publication activity is dominated by the United States, Japan and the large countries of the European Union where R&D investments are largely located (around 51 percent of total publications identified). However, the number of Chinese publications has grown rapidly in recent years, including several highly cited publications. Other "newcomer" countries, such as Korea, India, Taiwan, and Singapore, show impressive growth rates, although from low starting levels. Publications indicate a broad range of disciplines, including materials science, applied/condensed matter physics, polymer science, chemistry, pharmacology and biochemistry.

Patents —The United States is a world leader in nanotechnology patenting. Few states accounting for a significant share of United States are California, Massachusetts and New York. The other major leaders in patenting are France, the United Kingdom, Japan, Germany and Korea. It is estimated that patenting activity has increased comparatively last 12–13 years after key enabling inventions were made in instrumentation (for example, similar to patenting trends observed in biotechnology).

4. PATENTING — APPLICATION AREAS AND INSTITUTIONAL INVOLVEMENT

Most of patent has been issued in nanomaterials and nanoelectronics. Nanomaterials application has enabled broad range of patents in various fields. Nanoelectronics are confined mainly to electronics, machinery and consumer goods applications.
Nanotechnology patenting in the fields of electronics, chemicals and instruments has grown the most while sub-fields with above-average growth rates include machines and tools, materials and metallurgy, materials processing, information technology and semiconductors.

Majority of nanotechnology patent are assigned to companies. Ownership of patent by universities is frequent in nanotechnology than other general patent. This suggests that technology transfer to companies may be a key issue in the commercialization of nanotechnology.

The ranking of assignees of nanotechnology patents is largely dominated by multinational enterprises located in the United States, Japan and Europe; many of which are major players in the electronics industry. However, a few smaller European companies also rank high, along with several American and Japanese universities and public research institutes.

5. COMPETITIVENESS INDICATORS

Competitiveness Indicators are a source to count or benchmark a geographical regions impact in innovation to commercialization cycle. Indicators are available for both inputs to competitiveness (the presence, strength and funding available to support development) and outputs (means to measure or benchmark). Typical economic indicators used for new technology are market share, revenue or trade but these are not available for nanotechnology. Therefore, the output indicators for measurement of nanotechnology development are basically non economic and focus on means to gauge spill over potential in areas such as knowledge generation and human capital. Alternatives available for nanotechnology are listed in the table below and are measurable on an absolute or a per capita basis. Several benchmarking strategies using different combinations of the competitiveness indicators below currently exist for nanotechnology economic development.

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<th>Economic Inputs</th>
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<td>Economic Inputs: Public and private investment Support for Nanotechnology Activities</td>
<td>Non-Economic Outputs: Publications, Patents, People, &amp; Participants as proxies to measure knowledge generation, innovation, human capital, and participation.</td>
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<td>Quantity: Number of patents</td>
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<td>Number of supporting organizations (federal and university nanotechnology centers): presence and strength of supporting environment</td>
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6. SOME INSIGHTS INTO BUSINESS ACTIVITIES AND COMMERCIALIZATION CHALLENGES

Small/Large Companies — surveys conducted in few countries revealed that a relatively large number of small companies involved in nanotechnology. The surveys, however, suggest that the larger companies may be better placed to manage nanotechnology developments due to their critical mass in R&D, production and marketing.

Company Specialization — the companies surveyed is distributed across a broad range of manufacturing industries, reflecting the general purpose nature of nanotechnology. In terms of nanotechnology sub-areas, the majority of companies are involved in nanomaterials, nanobiotechnology or nanoelectronics.

Opportunities and Challenges — Nanotechnology is considered to provide opportunity for new markets as well as enhance competition in traditional market.

Company Trends — The surveys figure out towards increasing number of companies involved in nanotechnology related production over a period of time as well as growth of R&D investments and demand of skilled worker in field of nanotechnology. The surveys highlight the problem faced by companies in recruiting skilled workers in the field of nanotechnology. All major companies expect commercialization of their R&D in coming next 2 years.

Challenges for Commercialization — various surveys focuses on challenges being faced by commercialization of nanotechnology, although it is still not clear whether these challenges are unique for nanotechnology. High processing costs, problems in the scalability of R&D towards prototypes and industrial production, the basic research orientation of the field and concerns about health and safety issues (especially public perceptions of these issues) have emerged as key challenges. High investment costs and lack of funding are also highlighted in the survey.

While company surveys provide valuable insights, further qualitative analysis of company challenges is important, particularly with regards to commercialization. Company challenges may also differ significantly according to company size, nanotechnology sub-area and application field.

7. CONCLUSION

Nanotechnology supports both unparalleled opportunity and unprecedented challenge for commercialisation. As nanotechnology has moved from laboratory to industrial manufacturing and commercialisation taking place through distribution network ,huge potential for human and environmental exposure exists hence commercialization of nanotechnology have become an priority and reality of today’s world economic statistics and indicators of nanotechnology is further challenged by the broad range of technologies and products encompassed within the term “nanotechnology,” both in terms of current products and applications and even more in terms of future generations of products.

This paper analyzes the applicability of economic statistics and indicators and the approach towards nanotechnology, and finds these available approaches to be inadequate and unworkable. Nanotechnology will therefore require and force the development of new economic statistics and indicators. As we look to other technology revolutions looming in the future, including emerging developments in telecommunication technologies, surveillance technologies, genetic enhancement, cognitive sciences, and many others, the need to develop new, better models for risk management (starting with nanotechnology) becomes all the more urgent.
8. REFERENCES