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Tech mining to generate indicators of future national technological competitiveness: Nano-Enhanced Drug Delivery (NEDD) in the US and China

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ABSTRACT

"Global technological competitiveness" is widely acknowledged, but the challenge is to go beyond this recognition to develop empirical indicators of important transitions. These may concern particular technologies, the competitive position of particular organizations, or national/regional shifts. For decades, the US has been the world leader in biomedical technologies, with attendant implications for organizational priorities in terms of R&D location and market targeting. Recent years have seen a tremendous acceleration in Asian research in most domains, including biomedical, particularly visible in China. This paper investigates comparative patterns between the US and China in a promising emerging area of biotechnology — Nano-Enhanced Drug Delivery. It then explores indicators of, and implications for, future transitions at the national level — an approach we label "Forecasting Innovation Pathways."

1. Introduction

Nano-enhanced Drug Delivery (NEDD) systems seek to improve the release, distribution, absorption, and elimination of drugs. Traditional methods for administering drugs have relied on absorption in the digestive tract or skin or on injection (with manifold issues). Scientists investigate new delivery methods that use nanoparticles (e.g., lipid-based, polymer-based, proteins, dendrimers, etc.) to target specific organs or cell-types [1]. These may increase drug effectiveness, both via "technical" and "social" effects — e.g., by controlling release one can reduce the size of dose and frequency and improve patient compliance. NEDD offers potential for treating chronic diseases and genetic disorders, and it has also been considered as a suitable substitute for conventional protein therapy.

China is on the rise in the drug delivery technology sector and is becoming an increasingly nimble competitor in the space. Chinese drug delivery companies are seeking to expand their opportunities into Europe and the US. One company, Lepu Medical Technology, uses its nanomaterial technology to make drug-eluting coronary stents, among other interventional cardiology products, and the company captured $120 million in revenue in 2011. Meanwhile, just as for other frontier technologies, the US has been the dominant leader in the area of biotech. Thus, with this context, it is important to underscore to what extent these two countries are progressing in this frontier technology — NEDD.

This NEDD study is part of a project seeking to develop methods to Forecast Innovation Pathways (FIP) for "New and Emerging Science & Technologies" (NESTs) [2]. NESTs have

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great potential for innovation, but at the same time they are associated with great uncertainties. The nurturing of appropriate research avenues is crucial so that NESTs are developed along the most promising pathways, both in technological terms as well as towards addressing societal and economic problems or needs.

The project aims to develop a methodological framework and associated tools for analyzing NESTs to help policy makers and R&D managers to make better-informed decisions regarding innovation pathways. It combines empirical and expert knowledge of an emerging technology. The empirical work mainly seeks to extract intelligence from database search results about R&D activities, technological maturation, key players, and promising prospects for applications. This reflects a combination of bibliometrics and text mining (i.e., "Tech Mining" [3,4]). The case studies in the project (one is NEDD) are to be followed by expert interviews, and a dedicated workshop with stakeholders to explore innovation pathways (planned for March, 2014).

The development of new profiling and mapping techniques to characterize key actors and their interactions is crucial. Our hypothesis supposes that by understanding the various bodies of knowledge involved in a NEST, the key organizations, how they are related, and the visions they have constructed, analysts can grasp the diverse potential innovation pathways. Our approach aims to support the identification of previously hidden possibilities for connections among new ideas, artifacts and actors relating to NEDD [5] — hence trying to preserve diversity in order to avoid technological lock-in towards undesired applications [6].

The content for this paper can be divided into four parts. After this general introduction we follow with a description of the Contextual Framework and Research Approach. The third section presents the results of the bibliometric analysis. The last section sums up and points out promising "next" research opportunities to pursue.

2. Contextual framework & research approach

2.1. Data & search strategy

We started researching NEDD in 2008. After multiple trials and iterations to enhance our search strategy, we have developed a multi-module approach to construct an NEDD dataset from Web of Science (WoS), using the Georgia Tech (GT) "nano" (nanoscience, nanoengineering, nanotechnology, etc.) dataset [7] with additional searches in the full WoS. We assessed an extensive range of candidate search terms, drawn from an earlier study, a doctoral dissertation investigation, a literature review (especially of review and foresight articles about NEDD), and expert opinions. We grouped those terms into seven categories. After further testing and comparison, plus another round of expert review, we set aside three categories ("B" — biological processes; "I" — imaging; and "H" — helpers). We largely set aside "T" (targeting) terms as well. In so doing, we note that their inclusion would greatly expand the dataset, but at the expense of increased search complexity and a greater degree of opacity in terms of what is included, and the resultant NEDD set would be biased in favor of those particular terms. For the base NEDD search, we focused mainly on three categories: P (Pharmaceutical), N (Nano), and D (Delivery), with limited incorporation of "T" terminology. Our colleague Xiao Zhou leads the search strategy analysis and presents the process in detail [8]. The WoS record set generated for 2000–2012 includes 61,465 abstract records in December 2012 (Table 1).

2.2. Framework & research questions

New and Emerging Science & Technologies (NESTs) have some obvious characteristics. First, plenty of scientists believe in the future of any given NEST and apply themselves to advance it; so such technologies often show accelerating R&D activity

Table 1
Nano-Enabled Drug Delivery: related terms.

No.	Category	Keywords
1	B (biological processes)	(Bioavailab*or biodistrib* or biocompatib* or cytotox* or biodegradab*)
2	I (imaging)	Image* or imaging
3	T (target)	(Cancer or tumor* or tumour* or "RNA interference" or RNAi)
4	H (helpers)	("Polyethylene glycol"or pegylate or PEG or molecule* or polymer* or polyethyleneimine or PEI or polyspermine or polyproplyenimine or "poly lactic-co-glycolic acid" or PLGA or cyclodextrin or dendrimer* or chitosan* or atelocollagen* or "hyaluronic acid" or polypeptid* or peptid* or lipid* or ligand* or HPMA or "Hydrolyzed Polymaleic Anhydride" or Micelle* or Liposom* or conjugat* or Viral* OR Virus* or nonvira* or non-vira*)
5	P (pharmaceutical)	(1) (agent* or Drug* or pharmac* or formulation*) (2) (siRNA or "short interfering RNA") (3) microRNA (4) DNA or gene (5) (Dox or Doxorubicin*) (6) actives or adjuvant
6	D (delivery approach)	(1) (deliver* or vehicle* or carrier* or vector*) (2) (treat* or therap*) (3) ("control* releas*" or transduct* or transfect* or transport* or translocat*)
7	N (nano-delivery vehicle)	This category means GT nano-Database or some approximation of its search terms; also consider viral or virus or dendrimer or colloid

Note: we focus on pharmaceutical/cargo (P), nano-delivery-vehicle (N), characteristics of the delivery approach (D), and the target for the drug cargo (T). As for B (biological processes), I (imaging) and H (helpers) categories, since these terms are more complex in terms of searching and for what they reveal about NEDD itself, we set them aside for the time being.