Available online at www.sciencedirect.com
ScienceDirect
Research Policy 36 (2007) 832–849
research policy
www.elsevier.com/locate/respol

The nanotech versus the biotech revolution: Sources of productivity in incumbent firm research

Frank T. Rothaermel [a,*], Marie Thursby [b,1]

[a] College of Management, Georgia Institute of Technology, Atlanta, GA 30308-1149, USA
[b] College of Management, Georgia Institute of Technology, Atlanta, GA 30308-1149, and NBER, USA

Available online 19 March 2007

Abstract

Does the adaptation of incumbent firms to new methods of inventing follow similar patterns across industries and inventions? We investigate this question in the context of the revolutionary scientific advances enabling biotechnology and nanotechnology, both of which represent inventions of methods of inventing for incumbent firms. We hypothesize that an incumbent firm's ability to exploit these new methods of invention depends initially on access to tacit knowledge on how to employ the new methods. Over time, however, as firms learn and/or the knowledge becomes codified in routine procedures or commercially available equipment, inventive output is more highly dependent on traditional R&D investments. We empirically test these hypotheses on two longitudinal samples over the 21-year time period between 1980 and 2000: 80 incumbent pharmaceutical firms generating 15,607 biotechnology patents, and 249 firms across a diverse set of industries that were granted a total of 3236 nanotechnology patents. We find broad support for our conjectures.

Keywords: Capability development; Research productivity; R&D investments; Alliances and acquisitions; Tacit knowledge

1. Introduction

Research and development (R&D) at atomic, molecular, or macromolecular levels, i.e., nanotechnology, by allowing the manipulation and creation of new organic and inorganic materials, processes, and products, provides enormous technological opportunities in all sectors of the economy. Such scientific breakthroughs present both opportunities and challenges to existing firms, as newly emerging firms face the same opportunities as incumbents without their organizational rigidities (Henderson and Clark, 1990; Hill and Rothaermel, 2003; Reinganum, 1989; Rothaermel and Hill, 2005; Zucker and Darby, 1997). This, of course, underlies the Schumpeterian hypothesis that radical technological change sets in motion a process of creative destruction by which new firms, whose technological identities are aligned with the new technology, can replace incumbent firms' market position (Schumpeter, 1942).

Prior research in biotechnology has challenged this view by showing that while new biotechnology enterprises played a critical role in the biotechnology revolution, their emergence did not displace the major pharmaceutical firms. As discussed by Gans and Stern (2000) as well as in Gans et al. (2002), over half of the top 10 pharmaceutical firms had well established market positions in the seventies, before the biotechnology revolution. They show that a well functioning market for ideas (through licensing, strategic alliances, and acquisitions) allowed a cooperative equilibrium to emerge

* Corresponding author. Tel.: +1 404 385 5108; fax: +1 404 894 6030.
E-mail addresses: frank.rothaermel@mgt.gatech.edu (F.T. Rothaermel), marie.thursby@mgt.gatech.edu (M. Thursby).
[1] Tel.: +1 404 385 6249; fax: +1 404 894 6030.

0048-7333/$ – see front matter
doi:10.1016/j.respol.2007.02.008

in which biotechnology firms formed alliances with larger pharmaceutical firms rather than competing in the market for downstream products (see also Rothaermel, 2000, 2001). For the new biotechnology firms, alliances with pharmaceutical companies provided complementary assets for commercialization of products; and for the pharmaceutical firms, the new enterprises provided critical expertise in new techniques for discovery as well as manufacturing and process development, bolstering their fledging product pipelines (Galambos and Sturchio, 1998; Henderson et al., 1999; Hoang and Rothaermel, 2005). Similar arguments can be made for R&D sourcing by pharmaceutical firms through acquisitions of research-intensive small biotech firms (Higgins and Rodriguez, 2006). By drawing on the expertise of the new biotech enterprises, incumbent firms were able to adapt to the revolutionary changes in molecular biology of the 1970s rather than becoming victims of a Schumpeterian gale of creative destruction (Gans and Stern, 2000; Hill and Rothaermel, 2003; Rothaermel and Hill, 2005).

Existing firms across a wide variety of industries have faced similar challenges with the dramatic avenues for scientific discovery in nanotechnology enabled by the invention of the scanning tunneling microscope (STM) in IBM's Zürich laboratory in the early 1980s. Although the sources of the enabling inventions in nanotechnology and biotechnology differ, with the latter coming from university labs, both were revolutionary in that they were entirely *new methods of inventing* (Darby and Zucker, in press; Griliches, 1957), and thus posing substantial threats to incumbent firms.

The question we therefore address is whether the emergence of nanotechnology created a "gale of creative destruction" or whether incumbent firms have weathered the storm with similar strategies to those of incumbents in the biotech revolution? This question is of paramount importance as nanotechnology potentially affects many more sectors than did the biotechnology revolution. While biotechnology allowed the creation of new organic materials, nanotech allows the creation of new materials, both organic and inorganic. Despite the surge of papers predicting great economic and social value of nanotechnology, there has been little systematic empirical research on these issues (Roco and Bainbridge, 2001). Notable exceptions are Lemley (2005) and Sampat (2005) which examine patent quality, and Darby and Zucker (in press) which examine patenting, coauthoring patterns, and entry of new nanotechnology enterprises. The dearth of rigorous academic research on economic and social issues pertaining to nanotechnology motivated the special issue in which this article is included.

We examine whether the evolution of existing or incumbent firm adjustment to nanotechnology is following similar patterns to those in biotechnology. To empirically test if nanotechnology is following biotechnology in leveraging R&D alliances and R&D acquisitions, we use samples of 80 incumbent pharmaceutical firms attempting to patent in biotechnology and 249 incumbent firms across different industries that have been assigned at least one nanotechnology patent by the U.S. Patent and Trademark Office (PTO) since 1980.

2. Revolutionary inventions: new *methods* of inventing

Because the scientific discoveries underlying both nanotechnology and biotechnology represent inventions of methods of inventing (Darby and Zucker, in press), one might expect to observe similar development patterns in the strategies of incumbent firms when attempting to build an innovative presence in the new technologies. Indeed, Darby and Zucker's analysis of nanotech publishing, patenting, and the entry of nanotech start-ups near academic centers of excellence shows similar patterns to those in their earlier work on the biotechnology revolution (Darby and Zucker, in press; Zucker et al., 1998). The argument is that new methods of inventing create intellectual human capital that is naturally excludable. The inventors possess tacit knowledge that while often critical to further development is not easily transferred to others. This knowledge may well involve memory of avenues for development that were tried and failed, as well as those that look promising. This natural excludability provides a window of opportunity for inventors to earn above normal profits if they choose to form new enterprises to develop their discovery. Moreover, in the more than two decades since both the biotech and nanotech enabling inventions, universities have adopted liberal policies regarding faculty entrepreneurship which have facilitated the formation of new enterprises around university inventions (Thursby et al., 2001). Such firms are typically more nimble than larger, established firms and hence better suited to develop revolutionary inventions (Holmstrom, 1989).

More importantly for our purposes, the significance of tacit knowledge for further development means that, even if inventions developed are patented (as was the case with both recombinant DNA and the STM), other firms have a disadvantage in exploiting new methods of inventing. Thus, the ability of incumbent firms to adopt these new methods depends on close collabora-