Research Policy 43 (2014) 349–366

Contents lists available at ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

Balancing breadth and depth of expertise for innovation: A 3M story☆

Wai Fong Boh[a,*], Roberto Evaristo[b], Andrew Ouderkirk[b]

[a] Nanyang Technological University, Nanyang Business School, S3-B2A-14, Nanyang Avenue, Singapore 639798, Singapore
[b] 3M, 3M Corporate Headquarters, 3M Center, St. Paul, MN 55144-1000, United States

ARTICLE INFO

Article history:
Received 5 March 2012
Received in revised form
12 September 2013
Accepted 20 October 2013
Available online 23 November 2013

Keywords:
Innovation
Expertise and knowledge
Research and development

ABSTRACT

This study examines how inventors' breadth and depth of expertise influence innovation in 3M, a company renowned for sustained innovation for over a century. While prior research tends to examine a single indicator – the technical success achieved by the inventor – our study differentiates between three indicators of a successful inventor: (1) the number of inventions generated; (2) the extent to which the inventor has a significant impact in his or her technical domain; and (3) the inventor's career success, in terms of the commercial value they have brought by converting their inventions into products that generate sales for commercial organizations. We found that breadth of inventor expertise relates to the generation of many inventions, but not necessarily to those that are technically influential. Depth of inventor expertise enables individuals to generate technically influential inventions, as measured by patents granted. However, both breadth and depth of expertise are required for innovators to be deemed highly valuable, based on their records of effectively converting inventions into commercially successful products. Our study extends prior research on innovation in two ways. We provide a comprehensive view of how inventors' expertise influences innovation and also show how inventors with different expertise profiles can contribute in unique ways to their organization.

1. Introduction

Management scholars have extensively examined what affects innovation in organizations, especially in research and development (R&D) departments, whom companies depend on for inventions that can be translated into new products for the firm (e.g., Collinson and Wang, 2012; den Hond, 1998; Schmickl and Kieser, 2008). There are, however, still many fundamental questions for which we do not have answers. Our study focuses on two of these questions: (1) How does the breadth and depth of expertise of individual inventors influence their approach toward innovation; and (2) How does that, in turn, affect the value and contribution that inventors with different expertise profiles bring to the firm.

Innovation has been defined in many ways, with a common theme of building on existing knowledge and recombining past ideas and artifacts (Hargadon, 2002). Schumpeter (1934) defines innovation as the process of generating novel combinations from existing resources and ideas. This Schumpeterian view of innovation emphasizes how new ideas are built from existing ones. An individual's expertise is thus critical in helping individuals to generate new knowledge and to create recombinations based on existing information, as existing ideas are changed and recombined to create innovative applications (Glynn, 1996; Mumford, 2000).

Even though many inventions are created when individuals work in teams (Jones et al., 2008), studies allude to the observation that individuals are effective in combining existing knowledge to generate new knowledge and innovations (Gupta et al., 2006; Taylor and Greve, 2006). As highlighted by Crossan et al. (1999), innovative ideas and insights first occur to individuals, before such ideas are subsequently shared at the group levels and institutionalized at the organizational level. Fundamentally, this highlights that individuals are the basic unit in which knowledge integration and knowledge creation takes place, regardless of whether individuals work alone or in teams. Hargadon and Sutton (1997) further make the point that individuals are able to generate innovative creations when they effectively transform and recombine knowledge and information that they obtain from different domains. In their study of teams involved in the creation and publishing of comic books, Taylor and Greve (2006) also found that individuals were able to combine knowledge more effectively than teams.

The notebooks of Thomas Edison, one of the world's greatest inventors, show that he often recombined existing ideas in novel ways (Budline et al., 1995). For example, Edison recombined ideas from both the telegraph and the telephone transmitter to generate

* Corresponding author. Tel.: +65 6790 6196; fax: +65 6792 4217.
E-mail addresses: awfboh@ntu.edu.sg (W.F. Boh), revaristo@mmm.com (R. Evaristo), ajouderkirk@mmm.com (A. Ouderkirk).

0048-7333/$ – see front matter © 2013 The Authors. Published by Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.respol.2013.10.009

a new idea that led to the invention of the phonograph. He realized that a vibrating needle point would leave indentations on a piece of paper (features of a telegraph) – the indentations could then be played back (features of a telephone transmitter) (Woodside, 2007). By changing paper to tin foil, he generated an invention where human voice would vibrate a diaphragm, moving a stylus which leaves grooves on the tin foil. When the machine is returned to the starting point, the grooves cause the diaphragm to vibrate again, reproducing the original sound. As this example shows, transformation and combination of ideas often occur within individual actors, demonstrating that individuals, on their own, transform and add value to ideas.

Despite the important role that individuals play in recombining existing knowledge to generate new ideas and inventions (Glynn, 1996), little research has directly explored how the expertise profiles of inventors influence the way that they approached the innovation process and how that affects the value that inventors bring to the firm (Gruber et al., 2012). Prior research has examined and found that firms and teams that are effective in integrating diverse expertise possessed by individual specialists tend to perform better (Rulke and Galaskiewicz, 2000; Tiwana and McLean, 2005; Wu and Shanley, 2009). There has, however, been limited number of studies directly examining the impact of breadth and depth of inventor expertise at the individual level, on innovation outcomes. Part of the reason for this lack of attention may be an implicit assumption that there is no question to be resolved.

One often assumes that specialization is a requirement for inventions to happen. For example, studies have regarded inventors to be knowledgeable in a domain area as long as inventors have filed at least one patent in the area (Melero and Palomeras, 2013). This implies that a certain depth of knowledge is required before someone can generate an invention. On the other hand, studies have also highlighted that breadth of expertise is useful in providing the ability to integrate diverse ideas to generate new ones. The literature on network analysis, for example, has studied how individuals' position in the social and/or knowledge structure influence their access to diverse information and thus their ability to generate new ideas (Burt, 2004; Fleming et al., 2007; Obstfeld, 2005). This literature suggests that individuals who have access to diverse information are able to generate more good ideas by combining diverse information.

Hence, one can conclude from prior research that depth and breadth of expertise are important in different ways. Yet past research has only examined breadth and depth of expertise as a single dimension at the individual level, when examining its impact. For example, Leahey and Hunter (2012) examined the impact of specialization on lawyers' earnings, and found that lawyers who specialized earned more. Leahey et al. (2010) found that specialization increased the propensity of academics in the sociology domain to obtain tenure, due to the improved productivity and visibility. Recent research appears to recognize that breadth and depth of expertise can have different impact, but has chosen to examine how the diversity and depth of knowledge drawn upon at the patent level influenced the impact of the patent (measured in terms of the number of forward citations) (Lettl et al., 2009).

In this study, we explicitly examine how the breadth and depth of inventor expertise influence their approach toward the innovation process, and how that influences different outcomes. We focus on the examination of the breadth and depth of R&D inventor's technical expertise. Depth of expertise refers to the level of knowledge and skills (e.g. novice or expert) that an individual holds in a technical domain area. Specialization cultivates profound knowledge of an area, creating efficiency in generating repeated combinations of a narrow range of knowledge elements and deep understanding of the interconnections between them (Katila and Ahuja, 2002; Yayavaram and Ahuja, 2008). Breadth of expertise refers to the diversity in knowledge, know-how and experiences that an individual has accumulated (Fleming et al., 2007). Diversity of knowledge often generates exposure to new ideas, creating opportunities to experiment with new forms of knowledge (Katila and Ahuja, 2002; Yayavaram and Ahuja, 2008). We explicitly examine how inventors with different expertise profiles – generalists with broad expertise, specialists with deep expertise and polymaths with broad *and* deep expertise, if they exist – tend to be associated with different innovation outcomes, and how they contribute to a firm in different ways.

Examining how the breadth and depth of inventor expertise influence the value that they bring to the firm require researchers to consider the role of the organization. The organizational context – the practices of the firm, and the ways that an organization support inventors with different expertise profile – would influence the firm's ability to leverage inventors with different expertise profiles. Lettl et al. (2009, p. 244), for example, found that independent and corporate inventors benefit from their expertise differently. They argued that independent inventors are less likely than corporate inventors to be able to bridge diverse technological fields because "they lack the corporate intelligence systems and organizational resources to cope with the corresponding information overload and complexity". They highlight that an organizational setting provides complementary resources that would help the corporate inventors to deal with the negative aspects of and reap the benefits of diverse knowledge. We thus conduct our study of individual inventors within a single company, as a case study of an organization with significant emphasis and investment in R&D, to examine how inventors with different expertise profiles bring value to the organization.

By focusing on inventors within a single firm, we are also able to expand the definition and conceptualization of "value" that inventors bring to firm, by considering not only outcomes that can be determined by publicly available patent data, but also outcomes that are more reflective of the commercial value that inventors actually bring to the firm with their inventions. Prior research used patent data to examine the impact of inventions, usually using forward citations to provide an indication of the value and usefulness of an invention (e.g., Fleming et al., 2007; Nerkar and Paruchuri, 2005). However, other researchers have pointed out that patent citations, while providing a proxy measure that has some correlation with the value of patents (Trajtenberg, 1990), is a rather noisy indicator for the economic value of a patent (Harhoff et al., 1999; Sampat and Ziedonis, 2005). While forward citations provide a good assessment of how the invention influences future research in a domain (Carpenter et al., 1981), they do not capture the extent to which the invention has had a practical impact, e.g., by changing actual products. Little research, so far, has made an explicit link between patent citations and the social and private value of patents (Sampat and Ziedonis, 2005).

We thus argue that while a patent with higher forward citations shows a higher level of technical advancement and signifies a greater influence on a technical domain, it is indicative of the value of the invention rather than its innovative value. The process of innovation is defined as the "development and implementation of new ideas by people" (Van de Ven, 1986, p. 590). In other words, there are two parts to innovation: (1) generating an idea or invention, and (2) converting that invention into a useful application that is implemented and used by others (Roberts, 2007). An invention is a new idea, which may be a recombination of old ideas; it may or may not have economic value. Ideas and inventions have to be moved into a usable form to qualify as an innovation (King et al., 1994; Taylor and Greve, 2006), and this process involves the conversion of an invention into a product, to bring about eventual broad-based utilization of the idea and reap sales for an