



The mechanisms of collaboration in inventive teams: Composition, social networks, and geography

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ARTICLE INFO

Article history:

Available online 11 November 2010

Keywords:

Invention teams
Academic scientists
Team performance

ABSTRACT

This paper investigates the composition of creative teams of academic scientists engaged in inventive activity. Our data provides a unique opportunity to explore the links between team composition and commercialization outcomes. We find that there are coordination costs associated with reaching across academic departments and organizational boundaries to build teams. However, we also find evidence of benefits due to knowledge diversity, particularly in the cases of truly novel combinations. In support of internal cohesion arguments, we find that performance improves with the experience of the team. In line with arguments regarding the value of diverse external networks, we find that teams that are composed of members from multiple institutions – focal university, other research institution, and/or industry – are more successful in generating patents, licenses, and royalties. Finally, we find that the presence of prior social ties supporting links with external team members positively influences commercial outcomes. We find that there is no benefit to proximity in team configuration.

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“Rita, you and I are good, but together we are wonderful.”

Stanley Cohen to Rita Levi Montalcini talking about their work on Nerve Growth Factor, which was awarded the 1986 Nobel Prize in Medicine¹

1. Introduction

Invention, in spite of the romantic image of lone genius, has increasingly become a team endeavor. Problem-focused creative teams involving individuals with varied backgrounds are a staple across organizations, including academic institutions, small entrepreneurial ventures, and large corporations (Reagans and Zuckerman, 2001; Roberts, 1991). Creative teams have become especially important in research and development, inventive efforts, and new product development as scientific activity is becoming more specialized (Wuchty et al., 2007). Creating valuable and novel solutions requires melding multiple types of individual expertise. One notable fact is that team size among American inventors, as witnessed by the number of inventors on U.S. patents, has

been increasing at the rate of 17% per decade (Jones, 2009). Technical innovation is increasingly at the intersection of traditional domains of knowledge calling for greater use of interdisciplinary creative teams. Simultaneously with the growth in team size, there is also a trend towards including individuals from outside the focal organization in order to tap external expertise (Chesbrough, 2003).

Despite the pervasiveness and importance of teams, many open questions remain as to how to successfully configure effective teams. Issues of team configuration become even more salient when the task is complex and requires creativity and problem solving (Amabile, 1988). The desired outcome for commercially oriented R&D teams is the generation of an invention that is novel, valuable and non-obvious. While organizations have an interest in finding team configurations that increase the probability that scientific and economic value result, the relationships between combinations of individual expertise, expertise diversity and team performance have proven difficult to disentangle (Williams and O'Reilly, 1998). In addition, greater understanding of the social networks that underlie these combinations is needed as team learning capacity, and hence team performance, may be influenced by these social ties (Reagans et al., 2005). One vexing problem in evaluating team configuration is lack of systematic data on team performance outcomes.

The objective of this paper is to enhance our understanding of the links between team structure and outcomes. Our subject is academic teams of university scientists and other external members who engage in inventive activity. In the context we

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¹ <http://www.hypothesis.it/nobel/ita/bio/montalcini.ext.htm>, referenced December 27, 2005. As referenced in Stephan and Levin (1992, p. 15).

study, team composition is internally managed rather than externally assigned or determined. This means that teams are able to self-organize, providing an ability to experiment with different configurations of individuals, including adding members from different departments or even other organizations. We have detailed data on the individuals that comprise the invention team. We are able to follow inventive teams from the initial reporting or disclosure of their invention and the progress the idea makes towards realizing commercial value. In this process there are a variety of outcome measures such as the granting of a patent based on the invention, the subsequent licensing of that intellectual property to a commercial firm, and finally, the generation of royalties from the license. Thus, we can test how different constructs of team composition affect team performance using econometric methods. This provides a unique opportunity to study how team composition affects outcomes and productivity.

The paper is organized as follows. Section 2 provides a review of the literature and develops hypotheses about creative team composition and effectiveness. Section 3 introduces our data and study context and develops our empirical measures. Section 4 presents results and Section 5 concludes.

2. Creative team composition and effectiveness: theory and predictions

A team is a collection of individuals who share responsibility for an outcome. Even within the same organization and performing the same task, different teams produce widely varying outcomes. The difference is believed to be attributable to the configuration of individuals on the team, specifically the blending of their expertise, access to multiple networks, and the experience of the team members learning to communicate and work together. In scientific labs, the context we study, the lead professor directs the team but the implementation of experiments requires a mix of graduate students, lab assistants and may include additional professors and external partners from other academic institutions, industries, government labs or other organizations. Each individual brings specific human capital and social capital to the task at hand. In the case of research teams, the expertise embodied in human capital is largely due to formal training or background domain knowledge. Social capital is largely derived from the team members' organizational affiliations and the associated network. Ideally, a creative team is more than the sum of its individual parts. However, delineating the precise configuration of the team needed to create high quality outcomes has proven elusive. In the discussion below, we draw on the theoretical literature to provide insights into team configuration and develop empirically testable hypotheses.

2.1. Knowledge combination novelty

Inventive teams differ in composition and level of heterogeneity. While there are multiple sources of heterogeneity, most salient is the combination of different types of expertise that individual team members bring to the creative task. More heterogeneous teams have greater opportunity to leverage the expertise of each individual team member and apply a wider range of information to the creative process (Cohen and Levinthal, 1990; Dahlin et al., 2005). When the members of the team draw on similar common knowledge their search space is circumscribed and together they run the risk of technological exhaustion and a lower chance of significant breakthroughs (Fleming, 2001, p. 120). When teams combine different types of knowledge and expertise, they are likely to approach problems from distinct perspectives prompting a broader search

for possible solutions (Wiersema and Bantel, 1992; Rivkin and Siggelkow, 2003).

Innovation, at its core, is a process of recombination of different types of knowledge. Innovations arise from new combinations of previously unassociated components or from the development of new relationships between previously combined components (Schumpeter, 1939; Henderson and Clark, 1990). For example, Jones (2009) considers the invention of the microprocessor, which was the inspiration of Ted Hoff, an electrical engineer. However, the inventive team combined knowledge from physics (Frederico Faggin), and computer programming (Stan Mazer). The complexity of the invention required a blending of the inventors' different expertises to ultimately transform the design of computers. The cross-fertilization of ideas is associated with more creative outcomes (Perry-Smith and Shalley, 2003).

In configuring a team, the combined knowledge of the individuals may range from homogeneous where all members are grounded in a single common knowledge area, differentiated but with members drawn from multiple knowledge areas that are frequently deployed together, to very novel combinations with a high degree of differentiation with members drawn from multiple knowledge areas with little history of interaction between their source knowledge domains. In the first case, recombination possibilities are constrained. When individual team members have similar backgrounds and are in the same academic department, their performance as a team may be dampened by a tendency to search for solutions along the existing technology trajectory using a discipline-specific frame (Henderson, 1995). Moving along the continuum, producing a more significant advance requires a team with individuals who represent somewhat different perspectives that reflect different domains of knowledge. Expanding the team to incorporate multiple, but commonly coupled, knowledge components allows for greater *exploitation* (March, 1991) [which] "occurs when an inventor recombines from a familiar set of technology components or refines a previously used combination" (Fleming, 2001, p. 119). At the most creative end of the continuum is *exploration*, which requires delving into untried combinations. This third type of team embodies novel combinations of individual team members' heterogeneous knowledge components.

When a task requires creativity and novelty, as in the case of explorative R&D, the potential benefits of novel combinations of expertise are particularly salient (Hambrick et al., 1996; Hamilton et al., 2003; Koestler, 1989; Nooteboom et al., 2007). Consider the team that discovered the Krebs Cycle. Hans Krebs was a medical doctor trained in biology, and his collaborator, Frederic Lawrence Holmes, was a conventionally trained chemist. Holmes notes that Krebs' lack of expert knowledge of organic compounds freed him from the biases that limited the inquiries of contemporary biochemists searching for plausible explanations for cellular respiration, an important and vexing scientific problem at the time. This unique grouping, the team's degree of knowledge combination novelty, conferred an advantage to their joint research (as noted by Kulkarni and Simon, 1988, p. 142).

A significant degree of novelty generates a wide-ranging search over a greater knowledge space to solve more complex problems. The commitment to search for more challenging adaptations and integration of knowledge from one discipline to another suggests a higher probability of generating real breakthroughs (Fleming, 2001; Taylor and Greve, 2006). Creative teams aim to achieve novelty sufficient to result in an invention that will yield intellectual property rights that provide a more marketable idea. Thus, we hypothesize

H1. Creative teams with more knowledge combination novelty will have a higher probability of commercialization success.

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