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Does it pay to stand on the shoulders of giants? An analysis of the inventions of star inventors in the biotechnology sector

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ABSTRACT

Previous research has highlighted the importance of star inventors for invention success and firm performance. However, we have limited knowledge regarding the indirect influence of star inventors on knowledge generation and how the ideas of star inventors influence subsequent invention performance. Therefore, this study uses biotechnology patents to investigate the extent to which star inventors influence the value of subsequent inventions. It explores whether non-star inventors can build, just as successfully, on the ideas of star inventors as star inventors. The results show that having a star directly involved in the generation of an invention, and building upon other star invention/s, is positively related to invention performance. However, stars are not better than non-stars at building upon earlier star inventions, and in fact, stars building upon their own, previous, inventions negatively affects the outcome/s of their future inventions. Furthermore, these results hold true for both general and high-value inventions. Overall, this study highlights the importance of stars in cumulative knowledge generation, but also shows the limits of self-referencing and individual path-dependency.

1. Introduction

The phrase "standing on the shoulders of giants" is often used by economists, sociologists and historians to describe progress in science and technology (Caballero and Jaffe, 1993; Dosi and Nelson, 2013; Furman and Stern, 2011; Kuhn, 1962; Merton, 1973). At the core of this statement lies the notion of a process in which inventors and scientists develop ideas, based upon the discoveries of other inventors or scientists, and where new ideas add to an existing stock of knowledge. However, there may be a second 'truth' within the statement. Research in science and innovation has demonstrated that a small group of individuals, often called 'star scientists' or 'star inventors', is associated with generating a disproportionately large amount of scientific and technological ideas (Lotka, 1926; Narin and Breitzman, 1995; Zucker et al., 2002). Therefore, 'stars' might be the 'giants' in knowledge development on whose 'shoulders' we stand.

While research has demonstrated the importance of stars in various areas, e.g. their positive influence on peers and firm invention (Almeida et al., 2011; Azoulay et al., 2010; Grigoriou and Rothaermel, 2014; Oettl, 2012), there are still many questions related to the indirect role of stars in the process of knowledge generation. For example, we have limited knowledge as to whether building on the inventions of stars relates to invention success or if inventors can build upon the ideas of stars in order to build successful inventions in their own right. These are important considerations because while previous research has shown how influential stars are on inventions – that is, that stars generate important ideas, which positively affect the invention outcomes of their peers – it is not clear to what extent other inventors can benefit from the ideas of stars without actually collaborating with them. The fact that knowledge is often sticky and difficult to copy is widely discussed (Brown and Duguid, 2001; von Hippel, 1994) and previous research has shown that even stars' employees have difficulties in replicating success in other organizations (Groysberg et al., 2008).

However, most of the earlier research focused on the influence of an inventor and his/her research output, as well as the benefits of collaborating with a star inventor. In contrast, the current study is mainly concerned with the nature of knowledge created by an inventor and discerning who can benefit from such knowledge. In order to explore these issues, this study investigates three specific questions. First, *is building inventions, based on the ideas of star inventors, associated with the development of new and successful inventions?* This question examines the cumulativeness of technology in the case of star inventors and, thus, is at the heart of

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modern knowledge generating processes (Dosi and Nelson, 2013; Powell and Snellman, 2004). Second, *are star inventors more likely than non-star inventors to successfully build ideas based on the ideas of other stars?* As there are multiple explanations for why it might be particularly difficult or easy to build upon the ideas of stars (e.g. skill differences between inventors and signaling), this question explores the boundary conditions for the cumulativeness of ideas. Finally, this study asks, *are star inventors more likely to be successful when building upon their own ideas, rather than those of other stars?* This question focuses on the individual path-dependency of inventors, and explores specific reasons for why knowledge, as well as building upon one's own knowledge, may be dis/advantageous for star inventors and firms. While previous research has shown that invention activities and knowledge search patterns often produce different effects along the distribution of invention outcomes (Arts and Veugelers, 2014; Kaplan and Vakili, 2014; Phene et al., 2006; Singh and Fleming, 2010)[1] the current study presents the analysis that was conducted on both the performance of general and high-value inventions, in order to provide a more detailed picture of invention activities.

By investigating how innovators build on the work of others, and how this influences subsequent invention performance, the current study helps to develop a more detailed picture of inventions and technological progress. Detailed knowledge on how inventions are formed is beneficial for inventors, firms and the society as whole. In general innovation is a driver of economic development (Fagerberg and Srholec, 2008; Romer, 1990; Schumpeter, 1939) and it is related to firm performance and survival (Audretsch, 1995; Cefis and Marsili, 2006; DeCarolis and Deeds, 1999). The potential benefits are even stronger for high value inventions, which have been linked in particular to economic progress, firm survival and business growth (Ahuja and Lampert, 2001; Anderson and Tushman, 1990; Christensen, 1997). However, particularly high value inventions suffer from a limited understanding among practitioners and scholars (Conti et al., 2013). Developing a better understanding of how inventors build on the ideas of others, and how their knowledge contributes to technological advances, is important because the cumulative nature of the innovative process lies at the heart of economic growth and progress (Dosi and Nelson, 2013) and organizations grow increasingly dependent on the production, refinement and accumulation of ideas (Powell and Snellman, 2004). More specifically, to know if inventors are equally able to build on the ideas of star inventors is relevant for firms and inventors alike. Inventors might be able to adjust their research projects to their own benefits and decide to which extend they follow research trajectories of stars. Firm can use this knowledge for hiring and project allocation decision as they gain a better understanding, if the inclusion of stars is beneficial for a specific research endeavor.

The results show that having a star directly involved in the generation of an invention, and building upon other star invention/s, is positively related to invention performance, and the likelihood of developing particularly high-value inventions. However, stars are no better than non-stars at building upon previous star inventions. In fact, stars building upon their own, previous, inventions negatively impact the outcome/s of their future inventions and this results hold for both general and high-value inventions. Therefore, while star output is generally important for cumulative knowledge generation invention performance is limited by self-referencing and individual path-dependency.

[1] Frequently the term "breakthroughsï̈s used to describe high-value inventions (e.g. Kaplan and Vakili, 2014; Phene et al., 2006; Singh and Fleming, 2010).

2. Theory section

2.1. Literature on stars[2]

Early research on scientific developments, and the importance of individual inventors, found that progress is concentrated around a limited number of people. Almost a century ago, Lotka (1926) observed that a small percentage of physicists produced more than half of the published papers, and similar skewed distributions across academic contributions has subsequently been found in a number of related studies (Sutter and Kochner, 2001). For example, studies on technological and commercial advances have echoed the results of studies in the realm of science. Narin and Breitzman (1995) found a distribution, similar to Lotka's Law, for patenting inventors in US and Japanese semiconductor firms, and Ernst et al. (2000) show that only a small group of inventors are responsible for the technological output in German industrial sectors. Additionally, recent developments in patent databases have allowed the examination of inventors and their patenting output across a wide set of industries (Jaffe and Trajtenberg, 2002; Lai et al., 2011). An analysis of the US patent system (1975–1999) shows that out of 1600,000 inventors only 60% created one patent; 30% between two and five patents, and only 2402 (0.15%) were responsible for more than 50 patents (Menon, 2009).

The high concentration of research output from star scientists, and their influence on organizational-level innovation, has also been shown in commercial settings (Almeida et al., 2011; Beaudry and Schiffauerova, 2011; Hess and Rothaermel, 2014). In a study by Rothaermel and Hess (2007), 0.65% of all corporate scientists produced 15.2% of publications and represented 27.3% of citations. In the work of Almeida et al. (2011), these numbers only slightly differ, that is 1.04% of scientists were found to be involved in 30.9% of all publications, and these publications represented 30.8% of all citations. Furthermore, Almeida et al. (2011), and Beaudry and Schiffauerova (2011), found a positive relationship between star scientists and innovation performance measures. However, Rothaermel and Hess (2007) argue that the positive influence of stars is mediated by non-stars, and that stars alone do not influence patent output. The impact of stars on productivity, via knowledge spillover to their peers, is directly investigated by Azoulay et al. (2010) and Oettl (2012), who report significant star-specific effects on academic collaborators, in the sense that collaboration with stars can be beneficial for non-star scientists. In this context, Grigoriou and Rothaermel (2014) coined the term 'relational stars' to describe the relevance of embedded relationships between inventors. Finally, in a series of papers, Zucker et al. (2002) showed that star scientists were central to the birth of the biotechnology sector, and also influence firm location, time to initial public offering and IPO success.

2.2. Is it beneficial to build on the ideas of stars?

The above research has advanced our understanding of the invention process, and demonstrated that star inventors do indeed influence invention outcomes. However, the extent to which inventors can successfully build upon the previous ideas of star inventors has, for the most part, remained unexplored.

[2] While there are notable differences between 'stars' in academic and applied invention settings, theoretical concepts regarding stars are often transferable from one setting to another. For this reason previous research on 'star inventors' references frequently research of 'star scientist' (e.g. Beaudry and Schiffauerova, 2011; Goetze, 2010). However, in order to reduce confusion this study largely refers to 'star inventors' and only in cases where the paper draws explicitly on earlier studies in the realm of science it use the term 'star scientist'.