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Is there a first mover advantage in science? Pioneering behavior and scientific production in nanotechnology

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ABSTRACT

This article investigates whether pioneers in a research field have a sustainable first mover advantage in publications. Combining bibliometric (publications, citations, co-authorship) with survey data on 495 nanotechnology researchers, we analyzed career attributes, professional context and production over-time. Our econometric estimates highlight two main results. First, pioneering behavior is not exogenous: it is more probable among scientists who are already established in their "mother-discipline" (before entering nanotechnology), have a strong collaboration network, and have easy access to field-specific resources. Second, even after controlling for the endogeneity of entry timing, we find a strong first mover advantage: pioneers in the emerging field exhibit significantly higher scientific production in that field in the long run.

1. Introduction

A key feature of the sciences is their constant evolution (Bonaccorsi, 2008). Scientific fields emerge and evolve as a function of new discoveries, which yield new questions. Similarly, the appearance of ground breaking technologies opens new possibilities for solving unanswered scientific puzzles, leading to new categories in Science. The disparity in their emergence processes notwithstanding, new fields always confront scientists with fundamental dilemmas about their research trail and career (Debackere and Rappa, 1994): should they invest time and energy in this emerging field? Should they act as pioneers? Or should they wait and see? What are the long term consequences of such a decision?

The notion that some scientists take a pioneering role is inherent to Kuhn's (1962) description of scientific revolutions. Pioneers contribute to the adoption of a new paradigm, involving new "beliefs, values and techniques, shared by the members of a given community" (Kuhn, 1970). Even in approaches more evolutionary than Kuhn's, pioneering works are thought to produce major changes in how scientific problems are solved (Laudan, 1977). They have an impact in the long run on how an emerging field is structured. However, as high as their impact may be at the collective level, it isn't clear yet whether the pioneers get any individual benefit from their early entrance. Although the first articles published in a given topic tend to be much more cited (Price, 1965; Newman, 2009), occasionally some "sleeping beauties" gain impact only long after their publication (Van Raan, 2004). More importantly, that an early paper gets more cited than later ones does not inform whether its author gets an advantage in terms of subsequent production in the field.

This question of entry timing is surprisingly absent from the burgeoning research exploring the factors of individual scientific productivity. The latter includes a wide range of factors from age (Bonaccorsi and Daraio, 2003; Diamond, 1986; Stephan and Levin, 1997), to gender (Hunter and Leahey, 2010), to institutional affiliations (Stephan 1996), to collaboration strategies (Jonkers and Cruz-Castro, 2013; Pezzoni et al., 2012) or international mobility (Jonkers and Cruz-Castro, 2013) to cite just a few. Performance in these cases is analyzed within the scope of a community which is considered as a given, one piece of a larger scientific nomenclature assumed to be stable for the study, therefore making entry timing a non-issue. Perhaps an important explanation for this gap is that

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this array of factors influences not only a scientist's productivity, but also entry timing itself. That is, pioneering behavior needs to be considered as partly endogenous (Lieberman and Montgomery, 1988). Support for this notion is provided by Debackere and Rappa's (1993, 1994) studies comparing early entrants in a scientific field with their followers. They found that early entrants indeed have specific profiles. Thus, the question of what is the reward of pioneering behaviors (i.e. is there a first mover advantage) is tightly coupled to another one: what drives such behaviors (i.e. who are the first-movers)?

Both questions have important implications for research policy. They entail specific scientific strategies for laboratories, in terms of recruitment and incentives to encourage (or discourage) pioneering behaviors. Through the identification of the typical profile of early entrants in a field, policy makers can be informed on the type of researchers they need to enable in order to promote knowledge breakthrough. At an individual level, it sheds light on how researchers need to strategize about entry timing.

Our objective in this paper is two-fold. First, it is to test whether first-movers do have an advantage in terms of further scientific production in an emerging field. Second, it is to investigate what specific characteristics increase the chances that a scientist engages in it. For this double purpose we rely on the extended literature in marketing and strategic management discussing first mover advantages and disadvantages (Kerin et al., 1992; Gomez-Villanueva and Ramírez-Solís, 2013; Lieberman and Montgomery, 1988; Suarez and Gianvito, 2007). We translate these debates to the context of scientific publication and test their applicability to the case of nanotechnology, which emerged in the mid-1990s and strongly appealed to scientists from a variety of disciplines, from physics to life science. We exploit a rich data set that combines bibliometric data (dates of publication, publication counts, citation counts, co-authorship relationships) and a survey on the scientific careers and professional context of French nanotechnology researchers. This dataset allows estimating the effect of pioneering behavior on future scientific production, accounting meanwhile for the potential endogeneity of entry timing.

We structure the remainder of this article as follows. Section 2 sets out theoretical foundations for first mover advantages and disadvantages in Science, particularly nanotechnology. Section 3 describes the data and methods. Section 4 presents the econometric results. Section 5 concludes with a discussion of the results and suggestions for further research.

2. Antecedents and outcomes of entry timing in an emerging field

2.1. Outcomes: first mover advantages and disadvantages

2.1.1. First mover advantages

Pioneering behavior has received a lot of attention in the field of firm competitive strategies, resulting in arguments in support for both first mover advantage and disadvantage. Perhaps the most intuitive argument for first mover advantage is that the advance of early entrants ensures technical leadership and creates a technology gap that competitors might never bridge. As they develop knowledge in new research processes and techniques (Kerin et al., 1992), pioneers can maintain this advantage overtime. In the field studied in this paper, nanotechnology research, this argument is made even stronger by the prevailing role infrastructures played in its development. Consistent with Darby and Zucker's (2005) demonstration that research in nanotechnology consists in the "invention of a method of invention" in Griliches' sense (1957), pioneers had to adapt and develop new equipment tailored for the nanoscale. They could capitalize on this experience and gain considerable timing advantage in developing applied research in that field. For example, the history of the scanning tunneling microscope shows that early users were heavily involved in its development and modified it to better match their needs (Mody, 2011). In this example, early exposure to this technology probably provided an advantage for further research.

Another advantage of pioneering behavior is reputational (Lilien and Yoon, 1990). This mechanism is particularly relevant in scientific research, where reputation has a considerable effect on scientists' ability to attract new co-authors and funding (Newman, 2009), resulting in a self-reinforcing dynamic of success known as the Matthew effect (Merton, 1968). High status researchers get better research conditions (in terms of funding, teaching and administrative tasks), therefore enjoying higher chances to be productive and visible in the community (Stephan, 1996). As first movers enter an empty field, it is theoretically easier for their work to gain visibility and serve as a landmark for future entrants (Newman, 2009). With this prominent position they can pre-empt scarce resources (Boulding and Christen, 2008). The latter can be human: early movers can establish international collaborations networks which will be more difficult to join thereafter. Of course there are also financial resources to be preempted. In nanotechnology research, in particular, the dramatic increase in government funding took place around 2000 (i.e. launch of the US National Nano Initiative in 2001, nanotechnology named as a priority in the Sixth Framework Program in 2002 (Palmberg et al., 2009)). Building on their legitimacy, nanotechnology researchers who were already established and had a publication track in the field were in a better position to address those calls, if not to simply take part in their conception and execution as subject-matter experts.

2.1.2. First mover disadvantages

Pioneering behavior, on the other hand, might as well have disadvantages, such as pioneering inflexibility—that is, the inability to change due to investments in fixed assets and switching costs (Lieberman and Montgomery, 1988). For example, nanotechnology research required costly infrastructures, which must have prolonged use to justify costs. This important initial investment may limit the possibility of discovering new fields in the future and quickly adapting to prescribers' needs (e.g., industrial specifications). Later entrants, on the contrary, tend to face lower entry barriers. For example, if in the early years of the scanning tunneling microscope its cost was extremely high, microscopy became cheaper overtime and even small labs came to be able to afford it. Similarly, whereas material characterization would initially systematically need important equipment, research progress opened possibilities to use much cheaper methods such as computer simulation.

Another typical disadvantage relates to free-riding behaviors, whereby followers benefit from the efforts of early entrants (Jensen, 2003). Researchers have an incentive to wait and see, as pioneering work may provide them with valuable knowledge on equipment and research processes, while not partaking in the cost of its development. Especially if returns are uncertain, as is often the case during discovery phases, exploiting the pioneer's experience can be advantageous for followers. In "regular" economic sectors, such free-riding is usually mitigated by first-movers' attempts to erect barriers to imitation (Gal-Or, 1985, 1987), such as patenting. Patents limit competition for a while, during which the firm can consolidate a market position and gain advance down the learning curve. However, in the publication arena, there is scarcely any tool to increase the cost of imitation for later entrants. On the contrary, a large part of the research activity is to disseminate to the scientific community through conferences, workshops and seminars (Stephan, 1996), in order to gain visibility. In nanotechnology, moreover, there has been a clear division of labor, whereby an early

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