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Maturity of knowledge inputs and innovation value: The moderating effect of firm age and size

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ABSTRACT

This paper investigates whether and how the relationship between knowledge maturity and innovation value depends on firm age and size. Thus, we seek to advance the search and recombinant perspective of innovation by revealing that the successful recombination of knowledge inputs of different ages is strictly related to structural characteristics of innovating firms. Specifically, we contend that older firms outperform younger ones when they employ mature knowledge; conversely, younger firms are more able to exploit nascent and middle-aged knowledge. Regarding firm size, we expect that larger firms present a greater capability to innovate by using both nascent and very-well mature knowledge, while smaller firms develop more valuable innovative solutions when they build upon knowledge with a moderate level of maturity. These ideas are empirically tested on a sample of 5575 patented inventions registered by 298 biotechnology firms at the U.S.PTO., and our results offer support for the proposed conjectures.

1. Introduction

Innovation is often the result of a novel combination of knowledge inputs (Savino, Messeni Petruzzelli, & Albino, 2017; Schumpeter, 1934), defined as the fundamental bits of knowledge constituting innovative ideas (Fleming, 2001). By following this line of inquiry, extant research has paid noteworthy attention to study the main characteristics of the knowledge inputs searched and combined in the innovation process (e.g., the degree of relatedness and their origins) (Ahuja & Katila, 2004; Kogut & Zander, 1992; Phene, Fladmoe-Lindquist, & Marsh, 2006; Rosenkopf & Nerkar, 2001). Notably, knowledge characteristics have been deemed to be as important predictors of the innovation value, which relates to the impact that an innovation has on subsequent innovation efforts (Phene et al., 2006; Sorenson, Rivkin, & Fleming, 2006); stated differently, innovation value reflects the extent to which an innovation is considered as especially important, hence spurring subsequent innovations.

In the recent years, scholars have also underlined the key role played by the age of knowledge inputs (Katila, 2002; Vimalnath, Gurtoo, & Mathew, 2017). Innovation activities, in fact, may build upon knowledge developed in different points in time as nascent inputs, which stay in the forefront, and mature ones, which exist from a long time and whose features are well known (Heeley & Jacobson, 2008). Up until the last two decades, based on the assumption that the value of knowledge decreases over time, the conventional view of innovation studies suggested that valuable innovations origin form the adoption of nascent knowledge inputs (e.g., Adner & Snow, 2010; Ahuja & Lampert, 2001; Huarng & Mas-Tur, 2016). This view has led to the so-named recency bias. That is, an adverse vision of old knowledge and, hence, an undervaluation of its potential benefits (e.g., Katila, 2002). However, more recently, past knowledge is increasingly being recognized as a unique source of innovation (e.g., De Massis, Frattini, Kotlar, Petruzzelli, & Wright, 2016; Messeni Petruzzelli, Rotolo, & Albino, 2012), thus proving the unsuitability of previous theories that support the recency bias and demanding a thorough comprehension of the temporal dimension of innovation search and recombination processes. Specifically, it has been called for a deeper understanding of the degree of the knowledge maturity level - deriving from the combination of nascent and old knowledge inputs - that firms should adopt in innovation activities. In fact, for example, Heeley and Jacobson (2008) noted that Ciena and Canon patented innovations vary with regard to the mean difference between a focal patent filing date and the filing dates of the cited patents, hence showing different levels of the overall knowledge maturity of each patent. In turn, this difference has been revealed to affect innovation performance. Among existing studies, there is now consensus that the relationship between knowledge maturity and innovation value has an inverted u-shaped form (e.g., Capaldo, Lavie, & Messeni Petruzzelli, 2017; Katila, 2002), which prompts firms to strike a balance between the adoption of nascent and more mature knowledge inputs.

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Despite the relevance of this finding, the actual relationship between knowledge maturity and innovation value is yet to be fully unveiled. More recent research acknowledges that there are circumstances under which this relationship changes. Therefore, a contingency approach is deemed to be necessary (Capaldo et al., 2017). The present paper addresses this issue. It adopts a contingency approach to further examine the influence of knowledge maturity on innovation value. Recalling previous studies on this topic, to capture knowledge maturity, we examine the time elapsed, on average, between the original discovery of knowledge inputs and when they are incorporated in the respective innovation (e.g., Capaldo et al., 2017; Heeley & Jacobson, 2008).

Following the structural contingency theory (Zona, Zattoni, & Minichilli, 2013), we focus on structural characteristics of firms. Structural contingency theory advocates that the value of firm resources (e.g., knowledge resources) depends on the context within which they are deployed. Notably, structural characteristics may make firms more (or less) able to engage in learning activities and, hence, leverage knowledge to effectively innovate (e.g., Savino et al., 2017). Notwithstanding, scant attention has been devoted to the structural moderators that may influence the relationship between knowledge maturity and innovation value. In detail, since the pioneer work by Schumpeter (1934), age and size are among the most debated firm-level structural factors influencing innovation activities (see also Balasubramanian & Lee, 2008; Leal-Rodríguez, Eldridge, Roldán, Leal-Millán, & Ortega-Gutiérrez, 2015; Sørensen & Stuart, 2000), especially because of their effects on knowledge search and recombination processes (Laursen & Salter, 2004; Zona et al., 2013). For instance, it has been shown that firm size indirectly affects innovation performance because it is related to internal knowledge creation capability and absorptive capacity (Forés & Camisón, 2016), how the board of directors manage knowledge (Zona et al., 2013), and organizational unlearning (Leal-Rodríguez et al., 2015). Likewise, firm age affects learning speed (Gopalakrishnan & Bierly, 2006), the ability to recognize knowledge value (Hill & Rothaermel, 2003), and the ability to take advantage of external knowledge (Naldi & Davidsson, 2014). Therefore, by influencing how firms use knowledge resources, firm age can also explain innovation performance. In line with this reasoning, we may assume that firm age and size affect the temporal dimension of knowledge search and recombination processes, thus being important structural moderators in the relationship between knowledge maturity and innovation value. Eventually, firm age and size are considered in this study.

By conducting an extensive study on a sample of 5575 patented inventions registered by 298 biotechnology firms at the United States Patent and Trademark Office (U.S·PTO.), we confirm the existence of an inverted U-shaped relationship between knowledge maturity and the value of the resulting innovations, which stands for our baseline hypothesis. Furthermore, we advance the existing literature by showing that older firms outperform younger ones when employing mature knowledge, while larger firms present a greater capability to innovate by using both nascent and very-well mature knowledge. These results let us contribute to the literature on the search and recombinant perspective of innovation by jointly investigating the influence of the age of knowledge and firms' structural characteristics on the value of resulting innovative solutions. More in general, we not only corroborate that differences in the knowledge targeted by the search process (e.g., older vs. newer) is relevant to predict innovation value (e.g., Jung & Lee, 2016), but also reveal that diverse firms, e.g., in terms of age and size, may benefit differently from mature knowledge.

The remainder of the paper is organized as follows. Next section presents the theoretical background and develops hypotheses. Then, we present the research methodology and the empirical results. Finally, we discuss our findings, outline their implications for both theory and practice, and acknowledge the limitations of the study.

2. Theory and hypotheses

2.1. Knowledge maturity and innovation value

Recently, the temporal dimension of knowledge search and recombination processes has received an increasing attention, as revealed by the number of empirical studies discussing the relationship between innovation and the maturity of knowledge upon which it is built (Katila, 2002; Nerkar, 2003). Irrespective of the industries under analysis, previous studies have found that the reliance upon mature and nascent knowledge presents both costs and benefits (e.g., Capaldo et al., 2017; Heeley & Jacobson, 2008).

On the one hand, novel knowledge may reduce the risks to fall into competency traps (Levinthal & March, 1993) and open avenues for new commercial applications, hence sustaining the development of valuable innovations (Ahuja & Lampert, 2001). Yet, as knowledge ages, it tends to become more reliable (Fleming, 2001), so it reduces uncertainty and utilization costs (Heeley & Jacobson, 2008; Messeni Petruzzelli & Savino, 2014) that suffer new knowledge. Notably, as compared to novel knowledge, more mature knowledge has passed a validation process over time and does not require a drastic change in firms' modus operandi, thus decreasing the likelihood of technical errors and improper applications (e.g., Turner, Mitchell, & Bettis, 2013). Moreover, a certain level of knowledge maturity is needed to make innovation accepted by customers and is, hence, more valuable (Messeni Petruzzelli et al., 2012). Indeed, customers are often reluctant towards extremely novel solutions that do not have connections with their existing values and experiences (Story, Daniels, Zolkiewski, & Dainty, 2014). Finally, using aged knowledge may allow discovering valuable applications whose time has not yet come due to a lack of enabling technologies or complementary assets (Cattani, 2006; Nerkar, 2003). For instance, as pointed out by Vinton Cerf, the Internet co-inventor, “Leonardo da Vinci had many inventions that really could not be built effectively in the 15th or 16th century because of a lack of suitable materials...The latest technologies often produce opportunities to reapply earlier ideas more effectively” (Standage, 2005, p. 131). This phenomenon has been also explained by Hughes, a historian of technology, in terms of “reverse salients”, which refers to solutions that have fallen behind or are out of phase with the others.

However, as knowledge continues to mature, its marginal contribution to innovation value may decline. First, embedding mature knowledge may result into obsolete innovative solutions that do not fit with customers' current needs and expectations (Alnuaimi & George, 2016; Tushman & Anderson, 1986). Second, very-well mature knowledge may hamper organizational learning, as reflected in the complexity of its interpretation and application, which is associated with the decay of organizational memory (Katila, 2002). Third, in contrast to recent and middle-aged knowledge (i.e., knowledge with a maturity level between very high and very low), more mature knowledge comes with a lack of recombinant opportunities (Heeley & Jacobson, 2008) since many of the potential combinations may be already employed, hence leaving less room for the development of valuable solutions, while enhancing the risk of imitation. Finally, firms combining aged knowledge may fail in the race towards scarce resources, so lagging behind their competitors (Lieberman & Montgomery, 1988). In fact, if resources related to a specific technology are scarce, first adopters may capture these resources at the expenses of the followers, which may fall into a disadvantaged position. Overall, the above reasoning suggests a non-monotonic relationship between knowledge maturity and the value of the resulting innovations. Specifically:

Hypothesis 1 (baseline). *Knowledge maturity has an inverted U-shaped effect on innovation value.*