1. Introduction

A large body of literature emphasizes in recent years the utter importance of external knowledge search and efficient knowledge recombination in order to innovate (Chesbrough and Bogers, 2014; Mina et al., 2014; Martini et al., 2015). The openness to collaborate with external actors across the innovation process does however not come without challenges: recent studies also suggest that opening up for innovation significantly increases imitation risks and that such risks are present across all stages of the innovation process (Veer et al., 2016). This might further relate to the ‘fundamental paradox’ described by Arrow (1962: 615), as pointed out by Laursen and Salter (2014).

Indeed, innovation management literature provides ample evidence of how external search may influence firm performance (Chiang and Hung, 2010; Laursen and Salter, 2006; Spithoven, 2013; Tsai and Wang, 2009; Un et al., 2010). However, there are still unanswered questions regarding firms’ appropriability strategies across organizational boundaries and concerning the way companies manage to innovate in external collaborations while also capturing benefits from their innovations. For instance, Zobel et al. (2017) specifically call for further research investigating the use of formal and informal appropriability mechanisms in various phases of the innovation process. Cooperation with different types of partners and appropriability strategies has also been suggested as avenue for further research by recent studies (see Veer et al., 2016). Furthermore, while the intricate and often tense relationship between openness and appropriability is studied by scholars (see e.g. Laursen and Salter, 2014; Veer et al., 2016; Zobel et al., 2017) there is to date scarce evidence about openness and appropriability in relation with performance, as pointed out by Laursen and Salter (2014).

The previously suggested imitation risks that are more acute for companies that collaborate in R&D (Veer et al., 2016) may give rise to the so-called paradox of disclosure (see Arrow, 1962; Laursen and Salter, 2014). This study thus aims to address the above-signalled gaps in research (Laursen and Salter, 2014; Zobel et al., 2017) and investigate the effects of three groups of intellectual property protection mechanisms (IPPMs), i.e. formal (patents, trademarks, designs and...
2. Theoretical background and hypotheses development

The search for new knowledge is an essential element of innovation endeavors and investing in search generates capabilities to produce, apply and mix new knowledge, which in turn increases innovation performance (Laursen and Salter, 2006). In recent years, a growing body of literature massively investigates linkages between openness and performance (Chiang and Hung, 2010; Faems et al., 2010; Kang and Kang, 2009; Laursen and Salter, 2006; Santamaría and Surroca, 2011; Spithoven, 2013; Tsai and Wang, 2009; Un et al., 2010). Many uncover the effects of openness on innovative performance of firms (see Hwang and Lee, 2010; Inaüen and Schenker-Wicki, 2011; Li and Tang, 2010; Nieto and Rodriguez, 2011; Wang et al., 2012), while some focus particularly on radical innovation performance (e.g. Chang et al., 2012). Furthermore, scholars explore the interplay between internal practices and external knowledge sourcing and their effects on performance (see Berchicci et al., 2015; Cassiman and Veugelers, 2006; Cheng and Huizingh, 2014; George et al., 2001; Grimpe and Kaiser, 2010; Hung and Chiang, 2010; Martini et al., 2015; Salge et al., 2012; Svetina and Prodan, 2008; Tsai et al., 2011). Many studies remain focused on manufacturing industries (e.g. Vega-Jurado et al., 2009; Wadhwa and Kotha, 2006) but several also investigate the linkages between open innovation and performance in services (Love and Mansury, 2007; Menten and Asikainen, 2012). Further areas of interest that stem from the investigation of open innovation practices and firm performance notably include investigation of SMEs (e.g. Gronø et al., 2012; Huang and Rice, 2009; Kim and Park, 2010; Lasagni, 2012; Parida et al., 2012) and several longitudinal studies (see Tsai and Wang, 2007a, 2007b). Various types of boundaries or proximity may be linked to different external search modes. Previous literature points out that when engaging in external search and collaboration firms cross spatial (geographical), as well as organizational and technological boundaries (Knoebel and Oerlemans, 2006). However, it remains unclear how firms effectively bridge multiple boundaries (represented by e.g. distinct types of partners, providing different types of technological contributions to the innovation process) and how this affects the outcomes of the external search, in terms of value creation and appropriation.

Inter-organizational knowledge flows specifically require management in order to avoid either excessive disclosure (leading to unwanted spillovers) or extreme concealment (possibly leading to missed collaboration opportunities with valuable partners). Still, literature concerned with search for external resources widely neglects the potential misappropriation risks, as pointed out by e.g. Katila et al. (2008). Thus, in parallel with the extensive investigations of the openness-performance relationship, a related literature stream pursues the intricate linkage between openness and appropriability (see Henttonen et al., 2016; Zobel et al., 2016, 2017). It is further emphasized that in some circumstances appropriability-openness tensions may lead to a paradox, as pointed out by Laursen and Salter (2014) paraphrasing Arrow (1962). This potential paradox manifests due to the need for openness when engaging in external search for knowledge or resources on one hand, and the challenge to protect internal knowledge in order to avoid misappropriation on the other hand (also see Arrow, 1962; Laursen and Salter, 2014). Hence the tense relationship between openness and appropriability may have severe impact on the performance outcomes of external search. Even though appropriability is a widely researched topic, the interconnections between appropriability, openness and performance are seldom investigated jointly in previous studies (Laursen and Salter, 2014). The few studies that investigate openness-performance linkages and also consider an appropriability component often restrict appropriability measures to, for instance, patents (see e.g. Faems et al., 2005). One notable exception is the study by Hurmelinna-Laukkanen et al. (2012) who analyze the effects of absorptive capacity, network stability and appropriability on firm innovative performance as well as on alliance outcome. Furthermore, recent studies signal the need for further investigation of appropriability and openness in regards to performance (Laursen and Salter, 2014), as well as specific inquiry into the use of different types of IPPMs in various stages of the innovation process (Zobel et al., 2017). The present study addresses these gaps by investigating effects of three groups of IPPMs and openness (in terms of depth of collaboration with eight types of partners) on efficiency and novelty performance in three different phases of the innovation process. In the following sections hypotheses concerning the associations between the use of IPPMs, openness and performance across different innovation stages are formulated. Since previous studies do not provide very conclusive evidence regarding the effects of use of different types of IPPMs or of the openness towards distinct types of partners on performance in specific stages across the innovation process, the hypotheses included in this study make the rather raw distinction between early, i.e. idea phases, and later, i.e. engineering, as well as commercialization phases, though in the analysis a clearer distinction is made between three stages: idea, engineering and commercialization.

1.2. Openness depth and firm performance across stages in the innovation process

As described in the previous section there are numerous studies that investigate linkages between openness and performance. The partly mixed results from previous studies, where some show clear positive results while others show partly negative outcomes (e.g. Laursen and Salter, 2006), imply that the fallout is contingent upon several factors. The need to investigate such contingencies has also been stressed in recent studies, for instance Rogers et al. (2016) or Cassiman and Valenti (2016). One factor of interest is how the involvement of different kinds of partners affects innovation performance. When searching for external knowledge, organizations make strategic choices concerning the type of partner they could source new knowledge and technologies from (see Katila et al., 2008). This choice in turn might affect the innovation performance of the firm (Fabrizio, 2009; Savino et al., 2015). Laursen and Salter (2006) propose various search channels and, following Scott and Brown (1999) and Brown and Duguid (2000), they suggest that every search channel is an individual search arena, which consequently requires distinct norms, rules and practices in order for the search efforts to become productive. According to Ebersberger et al. (2012), “firms search among customers, clients and competitors to...”

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