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Author(s): Hamdy Abdelaty and Daniel Weiss

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Title:

**R&D Capacity and the Innovation Collaboration Paradox: The Moderating
Role of the Appropriation Strategy**

Authors:

Hamdy Abdelaty^{a,b*} and Daniel Weiss^b

^aBusiness Administration Department, Cairo University, Egypt, Orcid:

<https://orcid.org/0000-0002-4520-4926>

^bChair of Innovation Management, Free University Berlin, Germany, Orcid:

<https://orcid.org/0000-0003-2851-1040>

*corresponding author, hamdy.abdelaty@fu-berlin.de

Abstract

R&D capacity is claimed to be a stimulant for open innovation. We argue that after a specific level of R&D investment, firms diminish their external innovation collaboration due to the risk of knowledge imitation and unwanted spillovers, which generates a concave relationship between the two variables. This concave relationship can be flattened if an appropriation strategy is applied. Using 3815 firm observations from the German Mannheim Innovation Panel (MIP) in 2013 and 2017, our regression results support our hypotheses. Theoretically, our study suggests that the absorptive capacity literature should consider the potential negative impact of internal R&D capacity on openness. Similarly, economists should approach knowledge spillovers as a manageable issue if an appropriation strategy is present. Specifically, appropriation stimulates openness by playing a double role in protecting internal knowledge against imitation while also sending a quality signal for external partners to collaborate. This effect is driven by the presence of an appropriation strategy regardless of its form or strength.

Keywords: R&D capacity, innovation collaboration, appropriation, open innovation, knowledge spillover

Introduction

This paper explores how the presence of an appropriation strategy moderates the influence of internal R&D capacity on firms' external innovation collaboration. Generally, firms innovate when they find commercially exploitable knowledge. However, such knowledge does not exclusively exist within the firm's boundaries, but rather it is distributed throughout a broad range of internal and external sources (Chesbrough & Bogers, 2014). Therefore, many scholars affirmed the essential role of collaborating with external sources of knowledge in enhancing a firm's innovation performance (Fu et al., 2019; Laursen & Salter, 2006). Innovation practitioners admit, more than before, the importance of openness for innovation and for tackling social challenges (McGahan et al., 2021). One recent example is the COVID-19 pandemic, where both governments and big companies opened their boundaries towards individual inventors, universities, private research labs, and SMEs to accelerate innovation processes and stop the virus from spreading (Bergami et al., 2021). In this regard, innovation openness can take different forms, such as external search or external collaboration (Laursen & Salter, 2014) or relational or transactional openness (Grimpe & Sofka, 2016). In this study, we focus on innovation collaboration as a hard form of openness where the interaction between R&D capacity and appropriation strategy is essential in determining firms' external collaboration strategy.

Against this background, external innovation collaboration is not a substitution for investing in internal R&D capacity (Bogers et al., 2019). Building a firm's absorptive capacity through investing in in-house R&D is an essential prerequisite for acquiring and transmitting knowledge from external sources and integrating it into the internal knowledge base (Cohen & Levinthal, 1990). Prior evolutionary economics studies affirmed that both in-house R&D and external innovation collaboration are complementary, meaning that adopting one strategy improves innovation performance provided that the other one is present (Cassiman & Veugelers, 2006).

On the other hand, economists underscored the negative impact of intensive R&D investment on firms' innovation collaboration, which occurs when firms fall into the 'Not Invented Here' (NIH) trap (Katz & Allen, 1982). Particularly, external innovation collaboration requires the focal firm to reveal internal knowledge to attract and convince promising innovation partners to join forces (Henkel, 2006). This disclosure encompasses the danger of knowledge leaking out or being imitated in terms of unwanted spillovers (Miozzo et al., 2016). We argue that such a risk might diminish the firm's engagement in external innovation collaborations after a specific level of internal R&D intensity, with a tipping point that constitutes a concave relationship (H1).

In contrast to the economics literature, the open innovation model approaches knowledge spillovers as a manageable challenge by emphasising the importance of intellectual property (IP) (Chesbrough & Bogers, 2014; Grimaldi et al., 2021). Given open innovation, firms have to keep their knowledge protected against unwanted spillovers and also seize the outcomes of collaboration (Sofka et al., 2018). Hence, many scholars highlighted the importance of the appropriation strategy in facilitating collaboration and dissolving it (Granstrand & Holgersson, 2013; Hagedoorn & Zobel, 2015). For instance, using the french innovation data, Lhuillery and Pfister (2009) found that 14% of R&D collaborating firms had to abandon or delay their innovation projects. Only big firms with a strong appropriation strategy were less likely to face these cooperation failures.

Before this background, we assume that having an appropriation strategy mitigates the inherent risk of knowledge being stolen during collaboration, which then encourages R&D investing firms to engage more in external innovation collaborations. In other words, it flattens the concavity and shifts the tipping point (H2).

We based our quantitative regression analysis on a large pooled sample of 3815 innovative manufacturing and service firms to test this study's hypotheses. The data is extracted from the Mannheim Innovation Panel (MIP), conducted in 2013 and 2017. This data is collected by the European Centre of Economic Studies (ZEW) and represents the German contribution to the European Community Innovation Survey (CIS). The findings of our regression analysis and several robustness tests demonstrate full support for our hypotheses. R&D capacity is a driver of adopting an innovation collaboration strategy. However, external collaboration decreases if R&D investments exceeded a certain threshold. Complementing R&D investment with an appropriation strategy fosters the firms' external innovation collaboration. In this case, appropriation protects the focal firm against unwanted knowledge spillovers and sends a quality signal to external partners. Notably, our additional findings suggest that this moderating role does depend on the presence of an appropriation strategy regardless of its form (i.e. legal and strategic) or strength (i.e. the number of the used protection mechanisms).

This study contributes to the absorptive capacity literature by underscoring that R&D is not an ultimate stimulant of innovation collaboration and asserting the positive role of appropriation in stimulating openness through managing the knowledge spillover issue. Practically, innovation managers should complement their firm's R&D investment with an appropriation strategy to guard their collaborative innovation projects against being abandoned or terminated due to the undesired opportunistic behaviour of external partners.

The rest of the paper is structured as follows: the second section covers the theoretical background and hypotheses development. The third section encompasses the research methods, while the fourth section presents the results. Finally, we end our study by discussing the results, including the implications, limitations, and outlook on future research.

Theoretical Background and Hypotheses Development

Towards Openness: External Innovation Collaboration Strategy

In today's global market competition, firms face the challenge of developing new products or services more quickly and economically while also considering the market's needs (Gesing et al., 2015). Introducing new products to the market was traditionally happening in a linear pattern based on firms' in-house R&D activities (West & Bogers, 2014). Over time, R&D activities became overwhelmingly costly and too risky to be practised by a single company. In the era of digital communication, characterised by data-driven innovation and knowledge diffusion, unique knowledge is now distributed throughout a broad spectrum of external sources (Bogers et al., 2019). In such a dynamic business world, no single firm has a monopoly over knowledge. Thus, firms cannot stay abreast of these changes in their business environment by only depending on their internal capabilities. Hence, firms become increasingly forced to augment their internal resource bundle by accessing external ideas and resources as part of their innovation strategy (Teece, 2018). Accordingly, innovation becomes a result of an interactive process between various actors located inside and outside the firm. The open innovation model suggests that firms have to reach knowledge beyond their boundaries through collaborations with customers, suppliers, competitors, universities, and other research organisations (Chesbrough, 2003).

While cooperation for innovation has long been a norm in business practices, the inauguration of the open innovation concept in 2003 by Henry Chesbrough fuelled the discussion around the phenomenon (Chesbrough, 2003). Over the last decade, a growing body of literature sought to understand open innovation's contingency perspective (Gesing et al., 2015; Wikhamn & Styhre, 2020). Prior studies distinguished between different forms of openness that fit the specifications of external sources and the types of knowledge they provide (Sofka & Grimpe, 2010). For

instance, Laursen and Salter (2014) differentiated between the soft external search strategy and the hard collaboration strategy with external partners. The former strategy is informal and does not include contractual agreements. The latter is labelled as hard because it is formal and based on a contractual agreement between two innovation partners. On the one hand, the soft search strategy is more effective for a firm's innovation novelty when the firm deploys it to draw knowledge from market-based sources (e.g., customers). On the other hand, only using a hard collaboration strategy with science-based knowledge sources (e.g., universities) generates a positive impact on innovation novelty (Abdelaty, 2020). Whereas an external search strategy represents only the inbound aspect of openness, the collaboration strategy represents openness as a coupled process. This process involves two parties who share their experiences, reveal their knowledge, and jointly use their capabilities in the collaborative innovation project (Enkel et al., 2009). Hence, for our research objectives, we focus on external innovation collaboration strategy as the hard form of openness.

In external innovation collaboration, firms use their R&D capacity to activate external sources of knowledge for their innovation success (Rosenberg, 1990). Accordingly, firms have to reveal their internal knowledge to attract and convince an external innovation partner (Henkel, 2006). Simultaneously, firms must keep their internal knowledge protected against being copied, i.e., with an appropriation strategy. Both the R&D capacity and appropriation strategy are expected to influence the firm's innovation collaboration strategy. In the next two subsections, we delve into the theoretical background of the relationship between R&D capacity, appropriation, and innovation collaboration strategy to develop our research hypotheses.

R&D Capacity and External Innovation Collaboration Strategy

Empirical studies show contradicting views regarding the relationship between R&D capacity and innovation collaboration strategy. This paradoxical relationship goes back to the economic studies of both absorptive capacity (Cohen & Levinthal, 1989) and knowledge spillovers

(Arrow, 1969). Cohen and Levinthal (1989) wrote about the importance of investing in internal R&D to deploy external technology, i.e., the ability coined as absorptive capacity. They defined absorptive capacity as '*firms' ability to recognise the value of new, external information, assimilate it, and apply it to commercial ends*' (p. 1). Later, Zahra and George (2002) revisited absorptive capacity literature and redefined it as a process of acquiring, assimilating, transforming, and exploiting knowledge to create dynamic organisational capability. Their work differentiates between the potential absorptive capacity, i.e., acquiring and assimilating and realised absorptive capacity, i.e., transforming and exploiting. The notion is that the firm's absorptive capacity means not only drawing knowledge from its external sources but also the ability to integrate this knowledge into the internal innovation system to enhance the overall innovation performance (Cassiman & Veugelers, 2006).

Similarly, Rosenberg (1990) raised the question of why private firms do basic research with their own money and suggested that internal research activities enhance the firm's ability to create unique knowledge and absorb external knowledge for innovation. Hence, without internal R&D activities, the focal firm cannot evaluate the quality of externally acquired knowledge. This absorptive capacity emerges as a by-product of investing in internal R&D capacity through in-house research activities and sending staff to advanced technical training (Zahra & George, 2002). Thus, the firms' absorptive capacity also relies on the competencies of their boundary spanners and gatekeepers, who stand at the crossroad between the firm and the external environment (Filho et al., 2021; Whelan et al., 2010). These various nuances of absorptive capacity drove prior studies to R&D expenditure as a proxy for firms' absorptive capacity (Cassiman & Veugelers, 2006), while others used the internal number of Ph.D. holders, experts, R&D managers, or engineers as a measurement for firms' absorptive capacity (Bogers et al., 2018).

Prior studies, therefore, defined R&D capacity as a major prerequisite and determinant for adopting an innovation collaboration strategy (Benhayoun et al., 2020; Spithoven et al., 2013). By doing so, firms seize advantages of the complementarity between external and internal knowledge (Cassiman & Veugelers, 2006; Grimpe & Sofka, 2016). For instance, Becker and Dietz (2004) examined the German manufacturing industry and found that internal R&D capacity complements external R&D collaboration in enhancing product innovations. The reason is that firms with a high R&D capacity can recognise and reap the value of external collaborations better than firms with low R&D capacity.

Another group of studies considered the potential negative impact of internal R&D capacity on the firm's decision to practice a collaborative innovation strategy. Laursen and Salter (2006) argued that having a high R&D capacity and opening up the innovation process towards external sources negatively influences innovation performance due to a substitution effect. Prior studies also suggested that firms with superior R&D capacity find no further value in adding external linkages after a specific level (Asimakopoulos et al., 2020). Several studies underscored the NIH syndrome as a psychological resistance behaviour against moving towards external knowledge sources (Katz & Allen, 1982). Firms that have highly skilled creative people might believe that they have the smartest innovative mentalities. Hence, firms with such strong innovative competencies might find it unnecessary to search for technological support outside the firm's boundaries (Lichtenthaler & Ernst, 2006). In contrast to this psychological closeness attitude, the open innovation mindset and spirit rely on the idea that no matter how smart you are, most of the smartest people work for someone else, popularised as Joy's Law (Chesbrough & Bogers, 2014; Engelsberger et al., 2021).

On the other hand, from the spillover research viewpoint, we argue that firms with a substantial investment in their R&D capacity might prefer to practice less external collaborative innovation activities. Generally, knowledge is a public good by nature, and it is challenging to keep it

secured from being imitated or stolen (Grimpe & Sofka, 2016). R&D investing firms cannot estimate the ex-ante outcomes of their investments, and R&D investment inevitably produces outcomes not expected beforehand (Chesbrough, 2020). We argue that knowledge imitation as a free-riding behaviour is more likely to occur during openness. As we mentioned, collaborative innovation projects require the focal firm to disclose their knowledge to external partners, which, in return, creates information asymmetry problems (Laursen & Salter, 2014). These risks might push R&D intensive firms to decrease their external innovation collaborations to not lose their knowledge to competitors through customers, suppliers, or any other external collaborators.

In sum, from the absorptive capacity viewpoint, R&D capacity should stimulate a firm's decision to collaborate with external partners. However, from the spillover viewpoint, the firm might decrease its external collaborative linkages if the R&D capacity exceeds a certain threshold. Therefore, we hypothesise that:

H1: There is a concave relationship between R&D capacity and external innovation collaboration strategy.

Appropriation Strategy and External Innovation Collaboration

Firms secure a competitive advantage over rivals by introducing innovative products or services to the market or reducing production costs by adopting innovative processes (Wernerfelt, 2017). However, firms lose these competitive advantages once the knowledge behind these innovations leaks out to an external competitor. Therefore, firms have rational reasons to keep their knowledge protected by establishing an appropriation strategy (Liebeskind, 1997). In doing so, firms use legal (e.g., patenting) and strategic (e.g., secrecy and complexity) protection mechanisms to secure their innovation profits (Andries & Faems, 2013). In this respect, protection mechanisms aim to make the imitation or copying of knowledge as costly and risky as possible (Sofka et al., 2018). While legal mechanisms achieve protection through the threat

of punishment, the strategic mechanisms achieve the same goal by making imitation impossible or at least very costly.

Against this background, the open innovation model acknowledges the role of IP and suggests it as an effective tool to manage the knowledge spillover problem (Chesbrough & Bogers, 2014). Because of this, firms might use two strategies to solve the paradox of protecting and disclosing knowledge and the pertained risks of information asymmetries: 1) A selective revealing strategy where the focal firms select which knowledge to reveal or keep hidden to the extent that allows an external partner to be convinced with the potential cooperation (Henkel, 2006). 2) A signalling strategy, which means that the focal firm uses the tightness of its appropriation strategy to send quality signals to external partners (Laursen & Salter, 2014). We call these 'cooperation gestures' that induce external partners to cooperate without endangering focal firms to disclose additional internal knowledge and ideas. By emphasising appropriation, the focal firm sends positive signals about its protected valuable assets, which promotes open innovation by motivating external partners to cooperate and officially get access to the protected knowledge. In this vein, empirical studies reveal a positive association between a firm's degree of openness and having formal IP. For instance, Alexy, George, and Salter (2013) argued that IP is the currency of innovation for Procter and Gamble's 'Connect + develop' process. Protection mechanisms can play a role for firms in promoting their internal expertise, which draws attention from potential partners.

In sum, the appropriation strategy plays several roles in sending quality signals for external partners, preventing free riding, and creating new business opportunities. Firms with a strong R&D capacity and fear of losing their knowledge to external partners (i.e., concave relationship in H1) might continue to practice more collaborative innovation activities if they can protect their knowledge from being imitated or stolen. In other words, appropriation moderates the

relationship between the R&D capacity and external innovation collaboration level and flattens the relationship's concave curve. Hence, we add a second hypothesis:

H2: The strength of the concavity between R&D capacity and innovation collaboration will decrease if the firm has an appropriation strategy in place.

Method

Data

Our study uses data from the Mannheim Innovation Panel (MIP), which is part of the European Community Innovation Survey (CIS). The MIP is conducted by the Centre for European Economic Research (ZEW) in Mannheim, Germany, annually since 1993. The survey collects data from the German manufacturing and service sectors regarding companies' innovation activities, sources of innovation, the share of exports, revenues, size, location, and other measurements. Specifically, the MIP follows the questionnaires and methodology provided by Eurostat for the CIS and includes firms with at least five full-time employees. Although the MIP is constructed as a panel survey, with around 5000 firms participating in each wave, the average response rate is only about 25%, resulting in very few observations when using a balanced panel structure (Peters, 2009). Thus, we follow the related empirical studies relying on the MIP (Grimpe & Kaiser, 2010; Ganter & Hecker, 2013) and use a pooled data set consisting of both the MIP 2013 and MIP 2017 to gather enough observations to test our research hypotheses. We chose these two survey waves since they provide unique information about external collaboration activities and appropriation mechanisms and also include all other variables of interest. Each wave covers the three years before the respective survey year, i.e., the MIP 2013 survey covers the period 2010-2012, and the MIP 2017 covers the period from 2014-2016.

The resulting pooled data set consists of 11,397 firm observations (Ganter & Hecker, 2013; Grimpe & Kaiser, 2010). After selecting our variables of interest and removing the

corresponding non-response cases, we end up with 3,815 firm observations in the final estimation sample with a relatively equal distribution across 21 industrial sectors (see Appendix Table A1). Nevertheless, while the selected data is adequate to test our hypotheses, it is subject to the drawbacks like self-reporting bias, misinterpretation of the survey questions, and administration difficulties (for a discussion, see Cirera & Muzi, 2020)

Variables and Measurements

We created our main variables (external innovation collaboration strategy, appropriation, and R&D capacity) based on the existing literature. Our dependent variable, the external innovation collaboration strategy, is adopted from Laursen and Salter (2014) and refers to the number of external knowledge sources with which the focal firm establishes collaborative innovation activities (Laursen & Salter, 2014). We believe that the paradox between R&D capacity, openness, and the associated moderating role of the appropriation strategy is only a matter during collaborative innovation activities and not external search activities. A list of seven external sources of knowledge is provided in the survey, including clients or customers, suppliers, competitors, consultants and private R&D institutes, universities, public research institutes, and private research institutes., Each of the seven sources is coded as a binary variable, scoring zero if the firm does not collaborate with the source and one if it does. The seven sources are then summed up, scoring zero if the firm does not collaborate with any external sources of knowledge and seven if the firm collaborates with all external sources of knowledge.

Following Laursen and Salter (2014), appropriation, as our first main independent variable, refers to the number of protection mechanisms a firm uses to keep its IP protected against imitation or theft. The MIP survey in Germany listed eight protection mechanisms, including the application for (utility) patents, registering of industrial designs, trademarks, copyright, secrecy, complex design of goods or services, and lead time advantage over competitors. In the

first step, the variable is recorded similarly to our external innovation collaboration strategy variable. In a second step, we binarise the final variable, giving it the value one if the respective firm uses more than one appropriation mechanism and zero otherwise. Notably, this serves as a simple indication of whether a firm applies an appropriation strategy or not. We assume that IP protection's moderating role is a matter of presence regardless of the form or the strength of the applied appropriation strategy. However, we will further elaborate on this notion in the following sections and try to decompose the binarisation by differentiating between different levels and types of appropriation in the additional findings section. In line with related empirical studies, our second main independent variable, R&D capacity, is measured as the firm's ratio of R&D expenditure to total sales (Teirlinck & Spithoven, 2013).

Following the related literature, our study considers other variables that might affect a firm's innovation collaboration strategy. We include firm size as an essential determinant of openness. Prior studies argued that large firms depend on their financial capabilities to build up a strong network of partners around their business (Narula, 2004). Large firms can also take on more risk of openness because they have a broad portfolio of partnerships. If one collaboration fails, it is likely to be compensated by other successful cases. Therefore, the larger the firm, the broader the collaboration strategy will be. In addition, because of the higher risks and costs of managing such partnerships, SMEs are more careful when they practice open innovation because they have limited opportunities to fail (Parida et al., 2012). Here, the liability of smallness restrains SMEs' orientation towards an external innovation collaboration strategy. However, SMEs are less bureaucratic, more flexible, and focus only on one product. Therefore, they might benefit more from external collaboration in filling out their internal technological gaps (Grimpe & Kaiser, 2010). Hence, SMEs might use the positive side of smallness to practice a more collaborative innovation strategy. We capture firm size as the natural logarithm of the number of full-time employees (Grimpe & Sofka, 2016). Also, we control for a firm's

degree of internationalisation by incorporating the ratio of exports to total turnover. Firms that work on the international level face a high competition level and interact with different actors. International competition might facilitate openness on the national level to be more innovative and differentiate themselves globally. On the other hand, focusing on the global market through exporting might also cause fewer collaboration activities with domestic actors (Grimpe & Sofka, 2016). Following many empirical studies from Germany using the MIP, we control for regional differences by including a dummy variable, location, which captures whether a firm is located in East or West Germany, with West being coded as zero. This regional control is necessary as most parts of East Germany are still lagging behind West Germany in terms of infrastructure and economic growth, which potentially influences the performance and propensity to collaborate (Becker & Dietz, 2004; Gesing et al., 2015; Robin & Schubert, 2013). Last, we include sector and year fixed effects to control for unobserved heterogeneity (Laursen & Salter, 2006)

Results

Descriptive Results

The descriptive statistics in Table 1 show that firms, on average, collaborate with 0.5 external sources of knowledge, which is in line with prior studies of Laursen and Salter (2006) and Grimpe and Kaiser (2010). This low level of external innovation collaboration can be attributed to our reliance on the actual collaborative innovation activities to capture the real openness level rather than using external search activities. The results also indicate that the firms in our sample spend around 1.3 per cent of their sales on R&D activities on average. We have this relatively high level of R&D capacity since our analysis only includes innovative firms. At the commencing section of the survey, these firms stated that they introduced either new or significantly enhanced products or processes during the questioned period. Notably, the other non-innovative firms did not answer the questions of interest, as they were reoriented to answer

further questions in the survey. Regarding the appropriation strategy variable, results indicate that around 67% of the firms are employing protection mechanisms. In our sample, the average firm size equals 103 employees, with 2,220 small firms, 1,145 medium firms, and 450 large firms using the SME definition of the European Commission (European Commission, 2020). Our sample firms stated that, on average, 17 per cent of their revenue is gained from exports to regional or international markets. Around 30 per cent of firms in the sample operate in East Germany, while the rest are in West Germany.

insert Table 1 here

Econometric Model

For comparability, we follow Laursen and Salter (2006) and employ an ordered probit model to explain a firm's collaboration strategy since the latter is measured as an ordered discrete multinomial choice variable. The three regression models are estimated on the pooled data set. We make sure there is no issue of collinearity between our explanatory variables by checking if the variance inflation factor is below 4 (O'Brien, 2007). Model 1 includes the control variables and the base terms of R&D capacity and appropriation. In model 2, we add the squared R&D capacity (H1). Model 3 considers the hypothesis that the appropriation strategy moderates the concave relationship between R&D capacity and external innovation collaboration (H2). This moderation effect is tested by interacting the appropriation variable with the squared R&D capacity.

Regression Results

The regression results are shown in Table 2.

insert Table 2 here

Model 1 presents our baseline model. As expected, R&D capacity and appropriation strategy positively affect the external innovation collaboration strategy, and they are highly significant at the 1% level. Model 2 includes the squared R&D capacity. The coefficient of the squared term is negative, which, together with the base term's positive coefficient, suggests a concave relationship between the R&D capacity and the external innovation collaboration strategy. Again, the coefficient is significant at the 1% level. Hence, hypothesis 1 receives full support. Model 3 adds the interaction term between the appropriation strategy and the squared term of R&D capacity. We find a positive coefficient for this interaction term with significance on the 5% level. Moreover, the base term for appropriation is positive and highly significant at the 1% level. Hypothesis 2, therefore, receives empirical support as well. The moderation effect of the appropriation strategy on the concave relationship between R&D capacity and external innovation collaboration can also be depicted graphically.

insert Figure 1 here

Figure 1 shows how an increasing R&D capacity is concavely related to external innovation collaboration. The blue curve depicts the cumulated impact of R&D intensity on external innovation collaboration for firms whose appropriation score is zero. Similar to model 2, the concave relation suggests that the positive effect of R&D capacity on collaboration is increasing until a tipping point at the value of 5,4%. After his tipping point, the positive effect gets weaker and even turns negative for high values of R&D capacity. Most interestingly, this relationship is substantially altered for firms that employ appropriation measures. The dashed red curve shows that using an appropriation strategy increases the overall cumulative impact on practising external innovation collaboration (curve is shifted up). Additionally, appropriation moderates the relationship by flattening the curve and shifting the tipping point to an R&D intensity of 7,9%. In contrast to the blue curve, we do not observe that the effect is getting negative for the

highest R&D values in our dataset. The negative effect of the squared term for R&D capacity on external innovation collaboration is considerably reduced if a firm uses appropriation.

Additional Findings

To provide further insights, we differentiate between two types of external innovation collaboration: market-based collaboration with clients, customers, suppliers, or competitors and science-based collaboration with consultants, universities, and research institutes. Our results align with the main model when using collaboration with science-based sources of knowledge as the dependent variable. On the contrary, we do not find significant evidence for the moderating role of appropriation using market-based knowledge sources as a dependent variable. We attribute this to the novelty of knowledge provided by science-based sources that require firms to adopt a hard form of openness, i.e., a collaborative innovation strategy to absorb such type of knowledge (Abdelaty, 2020; Grimpe & Kaiser, 2010; Laursen & Salter, 2014). In this collaboration, researchers at universities and research institutes, as well as their counterparts at private firms, can absorb the unprotected technical knowledge facing no negative consequences. This inherent knowledge imitation hazard raises the importance of knowledge appropriation in keeping this collaboration on. But market sources provide less novel knowledge, which firms can draw by adopting a soft form of openness, i.e. search strategy (Sofka & Grimpe, 2010). In this line, firms do not have to disclose much of their internal knowledge to external partners, which diminishes the role of appropriation in keeping this form of openness (Abdelaty, 2020). We also considered the differentiation between two forms of appropriation, namely the legal form, i.e., patents, trademarks, copyrights, and the strategic form, i.e., secrecy, design complexity, and time lead. These two forms were used to examine whether a specific protection mechanism drives the results of our main model. Moreover, we created a proxy for the appropriation strategy's strength by summing up the number of used protection mechanisms. However, after extensive testing of these specifications, no conclusive

picture of a robust relationship emerged. Therefore, we conclude that the moderating impact of the appropriation exists regardless of the form or strength of the applied appropriation strategy.

Robustness Check

The results of the main model stay valid while using different coding schemes for the binary appropriation variable and using the depth of the external search as an alternative dependent variable. Considering that appropriation might be less relevant for small firms, we test our models using firms with over five full-time employees. Again, our results stay robust. The additional findings for collaboration with science and market-based sources are robust to the same alterations. The results for the additional findings and our robustness testing are available upon request.

Discussion

In the current literature on open innovation, two conflicting views prevail. First, the absorptive capacity view argues that having intensive internal R&D activities is a predeterminant of practising external collaborative innovation activities, particularly with institutional links/science-based knowledge sources. Second, economic spillover studies emphasise the risk of knowledge being stolen or imitated during external collaboration. The latter argue that firms, which intensively practice R&D, might prefer to reduce their engagement in external collaborative innovation activities. We argue that the orientation towards openness cannot be comprehensively understood by just adopting these dichotomous viewpoints. In this paper, we show that those two perspectives, which were deemed as conflicting, could complement each other if the presence of an appropriation strategy is considered.

In line with both of these perspectives, our results support our first hypothesis that firms, which invest more in building their internal R&D capacity, become more inclined to reduce their external innovation collaboration after a certain level. These results are in line with previous

studies arguing that companies with a high R&D intensity are prone to limit their external collaboration due to the hazard of knowledge spillovers or imitation by innovation partners (Sofka et al., 2018). We supplement this notion by confirming our second hypothesis. Our results show that the presence of an appropriation strategy helps firms with high R&D investments to engage more in collaborative innovation activities. We interpret this as evidence that deploying protection mechanisms mitigates a firm's risk of losing knowledge in terms of unwanted spillovers. Our additional findings and robustness tests support our argument that the presence of an appropriation strategy, rather than its form or strength, is the decisive factor. In other words, the main component of this moderating role is the signalling effect of using knowledge protection mechanisms. Furthermore, we found robust evidence that the moderating role of appropriation seems more conclusive for collaboration with science-based sources of knowledge. This positive impact of the appropriation strategy on external innovation collaboration is a critical theoretical distinction made by the open innovation concept. In hard innovation collaboration activities with external partners, open innovation acknowledges the importance of IP protection as a mechanism for the purposive management of knowledge in- and outflows (Chesbrough & Bogers, 2014). In this regard, the outbound dimension of the open innovation model encourages firms to develop channels to move unutilised knowledge from inside the firm to other organisations in the surrounding environment. In this vein, prior studies argued that large firms use IP to boost innovation in their ecosystem (Alexy et al., 2013). For instance, in 2005, IBM opened up around 500 patents to the software community to increase the flow of innovation to its ecosystem (Chesbrough & Appleyard, 2007). Similarly, Masucci et al. (2020) suggest that a firm uses outbound open innovation to remove technological bottlenecks in their ecosystem by enhancing the innovation performance of their service providers in the energy sector. Firms can develop many pecuniary (e.g., out-licensing, spin-offs) and non-pecuniary mechanisms (e.g., free revealing) to appropriate value from spillovers.

Thus, instead of considering spillovers as an external cost for firms doing R&D, spillovers could be managed as a motivation for firms to move toward more open innovation processes.

Theoretical and Practical Implications

This paper has three main theoretical implications. First, absorptive capacity researchers have to rethink the role of internal R&D as a stimulant for openness, as a negative impact emerges after passing a specific threshold. Second, the economic spillover literature should revisit the problem of knowledge spillovers by considering the case when R&D investment and collaboration are combined with an appropriation strategy. Our results suggest that appropriation strategies foster, not impede, open innovation activities in high R&D firms due to the positive signalling effect. Third, in contrast to the open sources approach where IPs are lifted, our results affirm that the open innovation strategy relies on IP protection as an initial prerequisite of openness (Chesbrough & Bogers, 2014). A recent example of this subtle distinction between the open innovation and open sources approaches is the ongoing socio-economic discussion about waving COVID-19 vaccine patents. From an open innovation perspective, such patents should not be waived to preserve positive outcomes of collaboration (e.g., the collaboration between Pfizer and BioNTech) and encourage firms to scale up production and distribution while continue investing in innovation projects.

Our paper also provides practical implications for innovation managers. Building a competitive advantage based on knowledge is a classic challenge since knowledge is known as a public good with spillovers (Sofka et al., 2018). This challenge becomes even harder when firms seek to build a competitive advantage using open innovation, where knowledge is more likely to leak out of the firm through collaboration with external innovation partners. We described this as the paradox between R&D capacity and openness. To solve this paradox and allow firms to capture the value of investing in internal R&D and the potential advantage of openness, we suggest that the focal firm has to complement its innovation strategy by implementing an

internal appropriation strategy. We impose IP as an enabler of collaborative innovation instead of using it as a defensive strategy to block or exclude others. Therefore, we suggest that having an appropriation strategy in place plays a double role. First, it sends a positive quality signal to external partners about the potential value the firm can bring to the projected collaboration. Second, it mitigates the risk of knowledge being stolen or imitated by external collaborators and prevents unwanted spillovers. Thus, on the one hand, the firm can find and convince R&D partners to work together. On the other hand, the firm enters into a collaboration with limited risks of getting its intangible assets exploited by external partners. Overall, IP should not be seen as a barrier to collaboration but rather as a stimulant of open innovation. Accordingly, innovation managers should deploy IP to address knowledge spillover and treat it as a business opportunity, not as a cost of openness.

Limitations and Future Research

This study is subject to several limitations that provide opportunities for future research. First, the study only controlled for sectoral heterogeneity within one country. Additional studies should look deeper into the function of appropriation by considering potential differences across sectors, regions, or countries. The effect of appropriation could depend on the maturity of the technological regime or the surrounding institutional arrangements. For instance, unlike the IT sector, where appropriation is not a big issue due to the fast-paced technological development, the pharmaceutical sector is an optimal context for open innovation where appropriation matters. Future research might also use a larger sample to figure out which form or strength of appropriation governs the relationship between R&D and innovation collaboration across different industrial sectors. Thus, repeating this study using different datasets and contexts would improve the reliability and generalizability of our findings. Second, additional research should rely on a larger sample to cluster firms into typologies based on their firm size, mode of innovation, R&D capacity, appropriation strategy, and level of openness.

For instance, we might find that the relation between R&D capacity, external innovation collaboration, and appropriation is influenced by specific firm characteristics, e.g., firm size, supplier relations, innovation strategies, or financialisation. Following empirical work could investigate the role of appropriation strategies for collaboration of non-R&D performing firms, using a different measure for the internal absorptive capacity. Third, using panel data would improve our findings' credibility and might also reveal time-dependent relationships between the main variables. For example, the positive effect of appropriation might last longer for legal forms of protection than for strategic ones. Last but not least, using secondary data limited our ability to deepen this study. Future research would improve our findings by creating a dedicated survey for testing the relation between R&D capacity, appropriation strategy, and external innovation collaboration.

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Appendix

insert Table A1 here

Table A1 Sample breakdown across industrial sectors

Industry	Classification according to NACE Code (Rev 2.)	Freq.	Percent
<i>Manufacturing</i>			
Mining	5-9, 19, 35	114	2,99
Food/Tobacco	10-12	190	4,98
Textiles	13-15	140	3,67
Wood/Paper	16-17	137	3,59
Chemical	20-21	160	4,19
Plastics	22	157	4,12
Glass/Ceramics	23	103	2,7
Metals	24-25	307	8,05
Electrical equipment	26-27	318	8,34
Machinery	28	240	6,29
Retail/Automobile	29-30	122	3,2
Furniture/Toys/Medical technology/Maintenance	31-33	273	7,16
<i>Services</i>			
Energy/Water	36-39	151	3,96
Wholesale	46	119	3,12
Transport equipment/Postal Service	49-53, 79	228	5,98
Media services	18, 58-60	187	4,9
IT/Telecommunications	61-63	192	5,03
Banking/Insurance	64-66	145	3,8
Technical services/R&D services	71-72	200	5,24
Consulting/Advertisement	69, 70.2, 73	172	4,51
Firm-related services	74, 78, 80-82	160	4,19
Total		3815	100%

Table 1 Descriptive results of all included variables

<i>Variable</i>	<i>Obs</i>	<i>Mean</i>	<i>Std.Dev.</i>	<i>Min</i>	<i>Max</i>
External Collaboration Strategy	3.815	0.497	1.110	0	7
Appropriation Strategy	3.815	0.673	0.469	0	1
R&D capacity	3.815	1.330	2.690	0	15
Ln (Firm Size)	3.815	3.585	1.509	0.0136	7.191
Location	3.815	0.306	0.461	0	1
Internationalisation	3.815	0.166	0.247	0	0.850

Table 2 Results of the ordered probit regression model

Dependent Variable: External Collaboration Strategy	Model (1)	Model (2)	Model (3)
VARIABLES			
Ln(Firm Size)	0.202*** (0.0173)	0.201*** (0.0174)	0.202*** (0.0174)
Location	0.343*** (0.0502)	0.334*** (0.0504)	0.332*** (0.0505)
Internationalisation	0.216** (0.105)	0.163 (0.106)	0.170 (0.107)
Appropriation strategy	0.368*** (0.0603)	0.322*** (0.0609)	0.341*** (0.0692)
R&D capacity	0.0940*** (0.00791)	0.235*** (0.0222)	0.374*** (0.0742)
Appropriation strategy x R&D capacity			-0.146* (0.0767)
R&D capacity squared		-0.0131*** (0.00194)	-0.0345*** (0.00943)
Appropriation strategy x R&D capacity squared			0.0225** (0.00961)
Observations	3,815	3,815	3,815
Sector fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Standard errors in parentheses			
*** p<0.01, ** p<0.05, * p<0.1			
Fixed effects and constants not displayed but included in the estimations			

Figure 1 Predicted relationship between R&D intensity and external collaboration

