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Promoting Future Sustainable Transition by Overcoming the Openness Paradox in KIE Firms

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Abstract: A key issue for transition to a more sustainable future is how to promote collaboration for innovation amongst multiple diverse partners. However, collaborating for innovation requires that firms overcome the paradox of openness, i.e., they need to be open to collaboration to innovate and at the same time protect their internal knowledge and intellectual assets to appropriate value from their innovations. The aim of this paper is to investigate how knowledge-intensive entrepreneurial (KIE) firms can overcome this paradox—which is an important barrier to future transitions—by choosing a combination of collaborative partners and appropriability strategies that support their ability to create more radical innovations. We analyze a sample of over 2450 KIE firms, drawing from a cross-European survey. Our results indicate how different partners, and different appropriability strategies, are more, or less, relevant to the generation of the radical innovations needed to transform society into one with a sustainable future; university collaboration and the use of formal protection mechanisms seem especially important for such new-to-the-world innovations. Our study includes important policy implications for how to support and promote future sustainable transitions and also establishes a foundation for future lines of research regarding entrepreneurship and sustainable transition.

Keywords: sustainable transition; knowledge-intensive entrepreneurship; innovativeness; collaboration; appropriability strategies; openness paradox

1. Introduction

Firms are central for transforming our societies and economies towards systems of sustainable production and consumption, i.e., accomplishing sustainable transition. Firms create and diffuse innovations in the form of new technologies, products, services and business models and contribute to the creation of new markets and industries, all of which is necessary for sustainable transitions to take place [1]. Smaller innovative entrepreneurial firms—not least knowledge-intensive innovative entrepreneurial firms [2–4]—are especially important for sustainable transitions; this type of firm often pursues radically novel solutions and attempts to drastically change markets and industries [5,6], thereby making important contributions to technological development [7]. Entrepreneurs are also often driven by larger goals than just profits, including sustainable value creation [8].

Transition to a sustainable future moreover relies upon collaboration amongst multiple diverse partners and has increasingly become recognized as a focal goal [1]. In order to innovate, firms need to collaborate with external actors to augment their internal resources and knowledge base with external inputs; smaller entrepreneurial firms especially need collaboration to overcome the resource constraints resulting from their limited age and size [9–11]. The broad notion of transition to a sustainable future is often divided into subproblems, such as the sustainable development goals (SDGs) outlined by the UN, but is also conceptualized as grand challenges (GCs). Grand challenges “by

their very nature, require coordinated and sustained effort from multiple and diverse stakeholders towards a clearly articulated problem or goal" [12] (p. 1881). Similarly, in the innovation public policy literature, Schot and Steinmuller [13] (p. 1563) described transition as the third framing of policy, requiring focus on "emerging and open-ended coordination in the process of working together towards transformative change", including experimentation in niches. A more specific line of literature, which we follow here, has analyzed how knowledge-intensive entrepreneurship and collective actions are needed in order to promote transition through collaboration [4]. These authors argue that sustainability requires knowledge-intensive entrepreneurship (KIE) firms, as these firms are needed to commercialize and diffuse the novel solutions and innovations developed by specialized knowledge generated through collective action.

Being able to develop and introduce new innovative solutions is, however, not sufficient for either firms in general or for KIE firms; they must also be able to appropriate value from their innovations in order to recover their investments [14]. The ability of these firms to appropriate value from their innovations therefore becomes important in order to successfully promote innovative solutions to transition problems. Specifically, KIE firms need to capture value from innovations sold on the market, where KIE firms translate ideas and specialized knowledge into innovations by taking risks and acting through market forces. To do so, firms need to invest in and establish suitable appropriability strategies by choosing and implementing different appropriability mechanisms for protecting both the innovation itself and the increased rents due to research and development [15]. However, developing appropriability strategies may be particularly difficult for small, young firms, such as KIE firms, due to their lack of financial resources and relevant complementary assets that could be used to protect their assets [7,15,16].

There is a tension between collaboration for innovation and the need to make profits within a market economy, commonly referred to as the openness paradox. The paradox is that firms need collaboration to innovate but at the same time also need to protect their internal knowledge and intellectual assets from imitation to safeguard their ability to appropriate value from those innovations [17]. Thus, understanding how KIE firms combine collaboration with appropriability strategies is critical for innovation in light of this paradox between the simultaneous need for openness and protection. We expect that the openness paradox is especially pronounced for KIE firms since their aforementioned resource constraints lead to an inherent need for external collaboration in order to access such assets [9,10,18] and also because of their limited ability to use formal and resource-demanding protection mechanisms, such as patents [7,15].

There are a few studies of small young firms that investigate, on the one hand, the association between appropriability strategies and broader collaboration patterns [16,19] and, on the other hand, appropriability strategies and innovativeness [7,19]. There is, however, a general lack of studies that analyze these three dimensions together [17,20]. To the best of our knowledge, there are no existing studies of the relationship between collaboration, appropriability strategies and innovation performance, neither for small, young firms in general nor for KIE firms specifically. It is therefore important to further investigate how the openness paradox affects KIE firms, as this will shed additional light on how innovation with external partners is organized in such firms and how this together with their appropriability strategies impact, positively or negatively, innovation performance.

The aim of this paper is to investigate how knowledge-intensive entrepreneurial firms can overcome the openness paradox by choosing a combination of collaborative partners and appropriability strategies that support their innovativeness. This is an important problem since stimulating and supporting the creation of radical innovations is a vital necessity for sustainable transition to take place [1,11]. We explore the explicit considerations of KIE firms in relation to their choice of collaborative partners and the different types of appropriability strategies, ranging from formal appropriability mechanisms protected by law to informal appropriability mechanisms, such as secrecy, lead time and complexity. Thus, we explore the relationship between openness, appropriability strategies and innovation performance in KIE firms.

We first empirically study how KIE firms' choice of collaboration partners and their assessment of their importance are associated with their choice of appropriability strategy. These strategies range from formal (such as patents and confidentiality agreements) to informal protection mechanisms (such as lead-time advantages and secrecy). We then investigate how the combination of the above two choices is associated with the innovativeness of KIE firms. Here, we focus on collaboration with three specific types of external collaborators—suppliers, universities and competitors—since the choice of partner type can significantly impact the nature of the innovation generated [21], as well as influence the choice of appropriability strategy [22]. Thus, we expect that collaborations with suppliers, universities and competitors will be associated with different appropriability strategies as well as different degree of innovativeness. We empirically analyze a sample of more than 2450 young and small KIE firms, drawing on data from a cross-European survey [23]. KIE firms constitute an appropriate empirical phenomenon for our purpose since they base their competitiveness on the development and application of new knowledge to innovations [2,3], implying that this type of firm has a specific need for both collaboration and appropriability strategies in order to innovate and profit.

This paper contributes to our understanding of how transition to a more sustainable future can be achieved by investigating the key issue of how to promote collaboration for innovation amongst multiple, diverse partners [1,12,13], from the perspective of KIE firms [4]. While the literature on sustainable transitions assumes and highlights the need for collaboration [1], there are currently few insights on how to stimulate collaboration that support appropriation of innovation. We investigate how KIE firms can overcome the openness paradox [17,24] by choosing a combination of collaborative partners and appropriability strategies that supports their ability to create more radical innovations, an approach for which there is currently little evidence in the literature [17,20]. Supporting the creation of radical innovations is fundamental for achieving sustainable transitions through entrepreneurship [1,5,13]; the openness paradox is therefore an important barrier to sustainable transitions [1]. Our study thus provides important policy implications for how to promote future sustainable transition, as well as a foundation for future lines of research regarding entrepreneurship and sustainable transition [5]. By focusing upon knowledge-intensive entrepreneurship, collaboration and appropriability, this paper also contributes to the interesting, but broader, question of the role of market forces in terms of appropriability in public policy in relation to transition [13].

2. The Paradox of Openness in Knowledge-Intensive Entrepreneurship (KIE) Firms: Openness, Appropriability Strategies and Innovation Performance

2.1. Openness through Collaboration with External Actors in Young and Small Firms

In order to innovative and remain competitive, firms need to be open and collaborate with external actors to augment their internal resources and knowledge base with external inputs [25,26]. Indeed, innovation performance has been shown to be positively associated with the number of external sources firms draw on in their innovations [27].

Firms can collaborate with different types of external partners, such as suppliers and customers, as well as draw on other types of external sources, such as trade fairs, conferences and scientific publications [27]. We focus on collaboration with external partners, since collaboration exposes the firms' internal know-how and innovations to increased risk of spillovers to and imitation by their partners [16]; in other words, collaboration enhances the need to establish appropriability strategies. Firms can collaborate vertically with suppliers and customers; horizontally with competitors; and/or with research organizations, such as universities [16,21].

Openness and collaboration are important in general for entrepreneurial firms—likely even more so than for larger and more established firms—in order to overcome the barriers provided by the resource constraints and limited legitimacy associated with newness and smallness [9,10,18]. In the KIE literature, there is evidence that the extent to which these firms draw on external knowledge sources positively influences innovation performance [2,10,28].

Relatedly, collaboration can be expected to impact the choice and use of different appropriability strategies [22]. Close collaboration with external organizations can increase the incentive for using formal protection mechanisms, such as patents; reasons for this include the fact that patenting facilitates protecting internal innovations and defining the collaborating partners' rights to resulting innovations, and existing patents can be used in negotiations with partners [15,16]. However, small firms commonly do not have a good bargaining position against larger established firms, suggesting that they may find it difficult to gain ownership of the intellectual assets resulting from collaboration with such firms. Also, young, small firms generally do not have the resources to patent or to legally defend patents [15]. Moreover, secrecy as a protection mechanism is hard to uphold in close collaboration with external organizations [16].

Understanding collaboration with specific types of partners has been highlighted as important in relation to appropriability strategies and performance [20–22]. In this paper, we therefore focus specifically on collaboration with suppliers, competitors and universities, since we have expectations that these different types of collaboration partners will provide different resources to KIE firms. Suppliers can provide important inputs for technological and market knowledge [21,29]. Such inputs can aid the firm in the innovation process, for instance by reducing uncertainty in product development and increasing flexibility and market fit [30]. Cassiman and Veugelers [31] have argued that supplier collaboration negatively affects the ability of firms to appropriate value—no matter which type of protection mechanisms used—due to high likelihood of spillovers of important knowledge in such collaborations. However, the various inputs gained from collaborations with suppliers can also reduce lead times [30], which is itself one type of informal protection mechanism.

Firms collaborate with competitors to, e.g., share and jointly solve exogenous or fundamental problems, share risk or increase market size, which can facilitate innovation. However, collaborating partners are also rivals and collaborations often require the exchange of proprietary knowledge; competitors are therefore commonly viewed as the most uncertain and risky type of partner [21,32]. While this would suggest a need for employing formal protection mechanisms, especially patents, the negotiation over ownership in such collaborations may be difficult, especially for young, small firms with their weaker bargaining power and limited knowledge about and resources for patenting [15,33]. Leiponen and Byma [16], for instance, found that small firms involved in such horizontal collaborations were more likely to perceive speed to market, and not patents, as the most important protection mechanism.

Collaboration with universities is commonly focused on accessing or collaboratively developing fundamental and scientific knowledge, but increasingly also on innovation, often related to exploration of novel solutions and fields [11,21,34]. For instance, Leiponen and Byma [16] found that only those small firms collaborating with universities were associated with perceiving patents as the most important protection mechanism. Since university collaboration commonly does not involve exchange of commercially sensitive information, the risk of imitation is less severe, and it becomes easier in such collaborations to maintain secrecy as a protection mechanism. At the same time, firms in such collaborations commonly transfer jointly developed knowledge for in-house development into innovations [35], which increases the ability to also employ patenting since ownership is then uncontested.

2.2. Appropriability Strategies in Young and Small Firms

The paradox of openness—as well as the need to collaborate for transitions—requires us to consider appropriability strategies. Appropriability refers to the extent to which innovations can be protected from imitation and thereby the capacity of the firm to retain the added value it creates for its own benefit. The firm can do so by employing different appropriability mechanisms, i.e., different means of protecting both the innovation itself and the increased rents due to research and development [15]. Protection mechanisms can be divided into formal appropriability mechanisms, such as patents, trademarks and copyrights [16,36,37], and informal mechanisms, such as secrecy and lead-time

advantages [16,19,38]. Research on appropriability has to a large extent focused on patents and secrecy, finding among other things that patents are on average perceived as a less important protection mechanism than secrecy [39,40].

In general, entrepreneurial firms—due to their lack of experience and to resource constraints—lack (control over) important complementary assets, which makes it crucial for these firms to control their knowledge and innovations [41]. Due to their financial and resource constraints, young, small firms may face difficulties in developing appropriability strategies. For instance, small firms commonly do not have the resources to apply for or legally defend patents and other forms of formal protection mechanisms [15]. Indeed, Arundel [40], who analyzed data from the Community Innovation Survey (CIS) in seven European countries, showed that the perceived importance of patents as an appropriability mechanism, relative to secrecy, increased with firm size. Relatedly, a study of the patent strategies of entrepreneurial SMEs in Sweden found that patent competence was low in these firms [33].

While a seemingly important topic, there are still, however, few studies on the appropriability strategies of small firms [16], and especially with regard to young innovative firms [7]. Leiponen and Byma [16] examined the appropriability strategies of small Finnish firms (<100 employees), focusing on the influence of collaboration types on the perceived importance of specific appropriability mechanisms (patents, speed and secrecy). They found, among other things, that most types of small firm perceived informal mechanisms—secrecy or speed to market—to be more important than patents for appropriating value from innovation, but that this depends on their collaboration strategies. Thomä and Bizer [19] investigated the appropriation strategies of small innovative firms in Germany (<50 employees), finding that they clustered into four different groups based on the nature of the appropriability strategy employed. One of these groups consisted of small firms that did not use any type of protection mechanism, leading the authors to conclude that “for many innovative small firms the main issue is not whether to use IPRs or not, but whether to protect their innovations from imitation at all” (p. 4). For the three remaining groups, informal protection mechanisms played an important role. Moreover, the authors found that the firms using any type of appropriability mechanism were more prone to create new-to-the-market innovations, especially the firms employing a patent-oriented strategy.

Veugelers and Schneider [7] examined the use of formal and informal protection mechanisms in young, small innovative firms relative to other innovating firms in Germany. Their findings indicated that young, small and highly R&D-intensive firms were associated with higher probabilities of using appropriation mechanisms. More specifically, they were more prone than other innovators to combine formal and informal protection mechanisms, predominantly when creating new-to-the-market innovations. We expect that for KIE firms, as compared to larger established firms, it will be more important to protect their intellectual assets, while at the same time harder to appropriate value from innovations.

3. Research Design and Method

3.1. Data and Sampling

To empirically study the relationship between collaboration, appropriability strategies and innovation performance in young, small KIE firms, we used microdata from a survey of approximately 2450 young knowledge-intensive firms in ten European countries across diverse sectors; to be included in the survey, firms had to be less than ten years old at the time of the survey, independent and operating in a knowledge-intensive sector (for more details regarding the survey, see, e.g., [3,23,28]). Knowledge-intensive firms were defined as “new learning organizations that use and transform existing knowledge and generate new knowledge in order to innovate within innovation systems” [2]; while KIE firms face similar challenges as other young, small ventures [10,16], these challenges are more extreme for KIE firms since these firms use knowledge and innovation to compete [2]. This made the dataset particularly relevant for studying the relationship between collaboration, appropriability strategies and innovation.

The survey of KIE firms consisted of a mix of novel survey questions with validated items from established surveys (including the Yale and Community Innovation Surveys). Specific questions that were relevant to our focus on the relationship between openness, appropriability mechanisms and innovation performance were posed in the survey. Since the relevant part of our particular focus in this paper was on the appropriability mechanisms needed for innovation, we only analyzed the subset of firms that reported that they had created at least one innovation during the previous three years at the time of the survey. Moreover, we included only those firms that had 50 employees or less. This reduced the sample size from 4004 to 2452 firms.

3.2. Variables

We analyzed two types of dependent variables, namely appropriability strategies and innovation performance. We examined two broad appropriability strategies, namely formal and informal protection mechanisms. We recognize that these strategies may not be mutually exclusive [19]. We used a survey item that asked the respondents whether the firm had used a set of common protection mechanisms in the last three years. Based on this, we constructed two binary variables to indicate whether the KIE firm used one or several of the formal protection mechanisms (patents, trademarks, copyright, confidentiality agreements) or, respectively, informal protection mechanisms (secrecy, lead time advantages, complexity of design). Measuring the use of protection mechanisms has been argued in previous literature to be associated with subjectivity bias to a substantially lower extent than measuring the perceived importance of these mechanisms [7]. These two variables were also used as independent variables when estimating innovation performance.

For innovation performance, we focused on the degree of innovativeness at the firm level. Since we analyzed only those firms that had generated at least one innovation during the previous three years, we operationalized this by classifying innovations as either *new to the market* or *new to the world*; to do so, we drew on a survey item asking whether the innovations introduced by the firm were new to the firm, market or world. We constructed two binary variables to indicate whether the firm had created innovations that were new to the world/market during the previous three years.

For openness, we were interested in the extent to which firms drew on knowledge from and collaborated with external actors and we focused on three types of external collaborators—i.e., suppliers, competitors and universities. For each type, we constructed a variable based upon the associated survey item, indicating the perceived importance of the focal external actor as a knowledge source for exploring business opportunities on a range between 1 (Not important) and 5 (Extremely important).

We also included a set of control variables, commonly employed as controls in studies of appropriability and innovation. We controlled for firm size, as measured by the number of full-time employees of the firm, and for the age of the firm at the time of the survey. Moreover, we included a control for the R&D intensity of the firm, measured as R&D expenditures over sales. A firm's size, age and R&D intensity have been shown to be associated with both the choice of appropriability strategy and innovativeness [7,11,16,28]. Finally, we controlled for unobserved heterogeneity by including dummies for the firm's sector, as well as country of origin.

Descriptive statistics for all variables are shown in Table 1 and the correlation matrix is presented in Table A1 in Appendix A.

Table 1. Descriptive statistics.

	Mean	S.D.	Min.	Max.
New-to-the-world innovation	0.219	0.414	0	1
New-to-the-market innovation	0.545	0.498	0	1
Formal protection mechanisms	0.747	0.435	0	1
Informal protection mechanisms	0.749	0.434	0	1
Suppliers (importance as knowledge source)	3.408	1.316	1	5
Competitors (importance as knowledge source)	3.329	1.162	1	5
Universities (importance as knowledge source)	2.222	1.283	1	5
No. of full-time employees	8.113	9.252	0	50
R&D intensity	15.64	21.24	0	100
Firm age	7.146	2.158	4	10

4. Results

Since our dependent variables (*Formal/Informal protection mechanism*, *New-to-the-market/world innovation*) were binary, we employed probit regressions for our estimations. Following common practice, we report the average marginal effects (AMEs) instead of the coefficients of the probit models in order to ease the interpretation of the results [42]. Table 2 presents the results from bivariate probit models concerning the relationship between the importance of suppliers, competitors and universities as external knowledge sources and the use of formal/informal protection mechanisms, while taking the correlation between formal and informal mechanisms into account.

Table 2. Bivariate probit models for formal and informal protection mechanisms (average marginal effects).

	Formal Protection Mechanisms	Informal Protection Mechanisms
Suppliers (importance as knowledge source)	−0.0087 (0.0070)	0.0160 * (0.0067)
Competitors (importance as knowledge source)	0.0173 * (0.0076)	0.0009 (0.0074)
Universities (importance as knowledge source)	0.0276 *** (0.0074)	0.0144 * (0.0070)
Control variables	Included	Included
Observations	2452	2452
Rho	0.4318 ***	

Robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Suppliers was only significantly, and positively, associated with *Informal protection mechanisms*, suggesting that the increased importance of this type of external collaborator did not influence the choice of formal protection mechanisms, such as patents. In contrast, the variable *Competitors* was only significantly, and positively, associated with *Formal protection mechanism*.

Universities, on the other hand, had a positive and significant effect on both dependent variables, indicating that the more important collaboration with universities was for these firms, the higher the likelihood that they used both formal and informal protection mechanisms. Universities were the only partner type that was positively and significantly associated with the combination of both formal and informal protection mechanisms. This regression was excluded from the paper, since our focus here was on comparing the choice of formal and informal protection mechanisms, but the results are available upon request. The AME was substantially larger for *Formal protection mechanisms* than for *Informal mechanisms* (and both these dependent variables had a similar base probability, cf. Table 1), suggesting that increased importance of university collaboration was to a larger extent associated with a higher likelihood of using formal protection.

Table 3 presents the results from probit models on the degree of innovativeness and its association with the different types of appropriability strategies and collaborations partners. The variable *Informal protection mechanisms* had a positive and strongly significant effect on the probability of *New-to-the-market innovation*, while *Formal protection mechanisms* did not have a significant association with this variable.

Table 3. Probit models for new-to-the-market/world innovation (average marginal effects).

	New-to-the-Market Innovation	New-to-the-World Innovation	New-to-the-Market Innovation	New-to-the-World Innovation
Formal protection mechanisms	0.1204 (0.0630)	0.3067 *** (0.0778)		
Informal protection mechanisms	0.2499 *** (0.0652)	0.1839 * (0.0799)		
Suppliers (importance as knowledge source)			0.0190 * (0.0082)	−0.0157 * (0.0067)
Competitors (importance as knowledge source)			−0.0115 (0.0090)	0.0052 (0.0073)
Universities (importance as knowledge source)			0.0148 (0.0085)	0.0194 ** (0.0067)
Control variables	Included	Included	Included	Included
Observations	2452	2452	2452	2452

Robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

In contrast, *Formal protection mechanisms* had a positive and strongly significant effect on *New-to-the-world innovation*, while *Informal protection mechanisms* had a smaller and weaker effect on the same. This suggests that the choice of using formal or informal protection mechanisms was strongly related to the degree of innovativeness of the generated product or service of the sampled young small firms; when generating innovations that were new to the market, it sufficed to use informal protection mechanisms, such as secrecy, but for generating innovations that were new to the world, these firms were more prone to use formal mechanisms, such as patents.

Moreover, Table 3 shows that the effect of *Suppliers* was positive and significant on *New-to-the-market innovation*, but negative and significant on *New-to-the-world innovation*. Thus, young small firms that collaborated more with suppliers were more likely to generate innovations that were new to the market, but the increased importance of these external sources at the same time decreased the likelihood of generating innovations new to the world.

The variable *Competitors*, on the other hand, had a negative, but nonsignificant, effect on both dependent variables. In contrast, *Universities* had a positive and significant effect on *New-to-the-world innovation* but was not significantly associated with *New-to-the-market innovation*; in other words, the higher the importance of universities as knowledge sources, the higher the likelihood of generating innovations that were new to the world.

Marginal effects of interaction terms in probit estimations were nonlinear in nature and therefore difficult to interpret. Following common practice, we therefore do not report the interactions between *Formal/Informal protection mechanisms* and the different partner types in Table 3, but instead provide graphical representations [42]. Due to limited space, we chose only to report the interactions for *Informal protection mechanisms* with *New-to-the-market innovation* and for *Formal protection mechanisms* with *New-to-the-world innovation*, since these were the strongest associations according to the estimations in Table 3.

Figure 1 plots the predictive margins of the use and non-use of *Informal protection mechanisms* with regard to *New-to-the-market innovation* against the importance of the three partner types. The figure shows that the use of *Informal protection mechanisms* was generally associated with a higher probability of *New-to-the-market innovation*. However, an increase in the perceived importance of all three types of external knowledge sources was associated with increasing margins for firms not using informal mechanisms. Thus, the positive effect of *Informal protection mechanisms* decreased with the higher importance of collaboration partner and became insignificant at higher values. This suggests that the more that KIE firms drew on these knowledge sources, the less important the choice of informal protection mechanisms, such as secrecy, was in generating innovations that were new to the market. This further suggests that KIE firms creating new-to-the-market innovations could to some extent substitute the use of informal protection mechanisms with closer (more important) collaboration with suppliers, competitors and universities. When instead estimating the effect of *Formal protection*

mechanisms on *New-to-the-market innovation*, we found similar but less pronounced patterns for the interactions with both *Suppliers* and *Universities*.

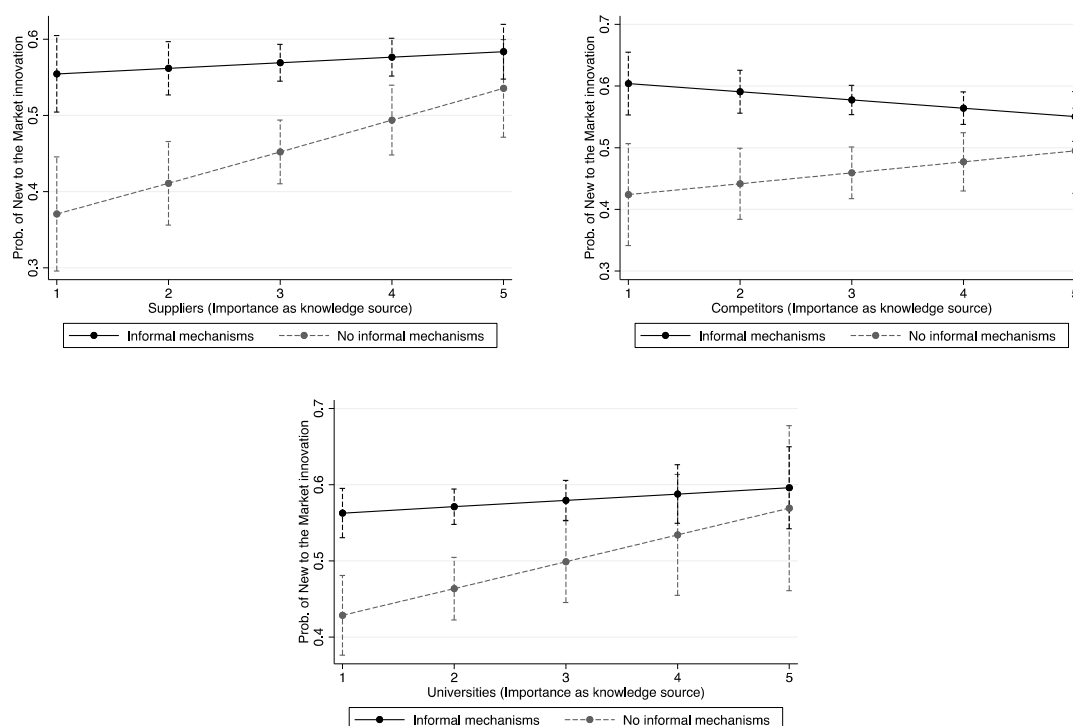


Figure 1. Predictive margins of the use of informal mechanisms with regard to new-to-the-market innovation against importance of collaboration.

Figure 2 plots the predictive margins of the use and non-use of *Formal protection mechanisms* with regard to *New-to-the-world innovation* against the importance of the three partner types. The figure shows that the use of *Formal protection mechanisms* was associated with a higher probability of *New-to-the-world innovation* for all three partner types. The use of formal protection mechanisms continued to be associated with a higher probability of *New-to-the-world innovation* at higher values of *Suppliers* and *Competitors*, and for these partner types there was no apparent interaction effect between importance of collaboration and *Formal protection mechanisms*. In other words, while the choice of using formal protection mechanisms was strongly linked to a higher likelihood of generating new-to-the-world innovations (see Table 3), this higher likelihood was more or less the same no matter how much the firm drew on suppliers or competitors as external knowledge sources.

In contrast, an increase in the perceived importance of *Universities* seems to be related to an increase of the effect of *Formal protection mechanisms*. That is, the use of formal protection mechanisms and a higher importance of universities as an external knowledge source, and especially a combination of the two, were related to a higher likelihood of generating innovations new to the world. When instead estimating the effect of *Informal protection mechanisms* on *New-to-the-world innovation*, we found a somewhat decreasing effect when interacted with *Suppliers* but no pronounced interaction effect together with *Universities*.

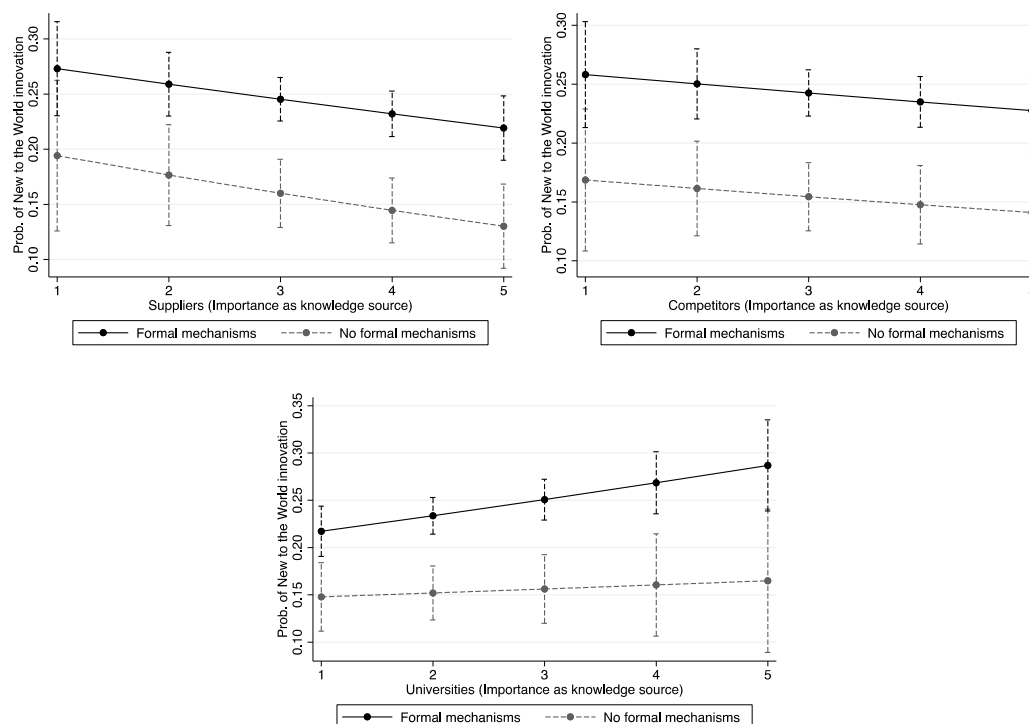


Figure 2. Predictive margins of the use of formal mechanisms with regard to new-to-the-world innovation against importance of collaboration.

5. Discussion and Conclusions

This paper investigated the relationship between collaboration, appropriability strategies and innovation performance in KIE firms in light of the fact that sustainable transitions require collaboration between multiple, diverse actors in order to provide innovative solutions to grand challenges. This paper contributed to a transition to a more sustainable future by investigating the key issue of how to promote collaboration for innovation amongst multiple, diverse partners, from the perspective of KIE firms. We investigated this issue by studying how KIE firms can overcome the openness paradox [17] by choosing a combination of collaborative partners and appropriability strategies that support their ability to innovate. This paradox is an important barrier to sustainable transitions and overcoming it is crucial for supporting and creating new radical innovations, which are needed to achieve a more sustainable future [1].

We are particularly interested in how KIE firms solve the paradox of openness—how they are able to both collaborate and benefit financially from their innovations—because previous literature suggests that these firms may play a particularly important role in transforming the economy. With regard to entrepreneurial firms more generally, these young innovative firms on the one hand make important contributions to technological development and innovation [7] but on the other hand face particular difficulties appropriating the value from their innovations due to their resource constraints [7,15,16]. Moreover, understanding how they solve collaboration problems matters because entrepreneurial firms may especially suffer from the openness paradox [17], since their resource constraints lead to an inherent need for external collaboration [9,10,18], but also to a limited ability to employ suitable appropriability strategies [7,15].

In this paper, we built on the existing literature concerning the interplay between collaboration and appropriability and between appropriability and innovativeness [7,16,19]. We did so by investigating how the choice and importance of three types of collaboration partners influenced the choice of formal and informal protection mechanisms, as well as how the combination of these two choices in turn was associated with the degree of innovativeness in KIE firms. The findings in this paper demonstrate that KIE firms' choice of external collaborative partner (and their perceived importance)

was closely related to their choice of appropriability strategy (formal/informal protection mechanisms). Close collaboration with suppliers was found to be associated with a higher likelihood of using informal mechanisms but not with formal mechanisms. Suppliers commonly provide access to market or production knowledge [21,29,30] and such knowledge may often be of a more generic character. The preferred protection mechanism may have therefore been based more on a need to protect not the knowledge itself, but rather the market application of this knowledge. Informal protection mechanisms, such as secrecy and lead-time advantages, may in this way be the most suitable choice for collaboration with suppliers. This also resonates with the finding that both collaboration with suppliers and the use of formal mechanisms were positively related with the creation of new-to-the-market innovations.

In contrast, our findings also point out that close collaboration with competitors was instead only (positively) associated with the use of formal protection mechanisms. This was arguably due to the fact that collaboration between rival firms is uncertain and risky, commonly entailing the exchange of proprietary knowledge [21,32]; this increases the need for formal protection, e.g., through patents, to safeguard internal know-how from collaboration partners.

We moreover found that only close collaboration with universities was positively associated with the use of both informal and formal protection mechanisms. When universities are the source of the external knowledge that young small firms draw on for their innovations, the knowledge in itself is likely to be of a more exploratory and scientific character [21,34,35]. In these cases, formal protection of the knowledge may be the most appropriate choice, as the specific areas of market application may still be under consideration. This was also further supported by the finding that university collaboration was more strongly associated with formal mechanisms, and that the use of formal protection mechanisms was positively related to the creation of new-to-the-world innovations.

These findings regarding the association between collaboration and the choice of appropriability strategy are largely in line with results from the few existing studies on this topic for small firms. Leiponen and Byrma [16], for instance, showed that using horizontal (e.g., competitor) collaboration was associated with perceiving speed to market (i.e., lead-time advantage) as an important protection mechanism, while only those firms collaborating with universities considered patents as the most important mechanism. Their study, however, used broad categories of collaboration types (e.g., vertical collaboration, by collaborating with either clients or suppliers) and did not differentiate the degree to which this collaboration was important for the firm. In contrast, we have here shown that the choice of formal or informal mechanisms was related not only to the type of partner but also to how important the firm perceived the collaboration partner to be, or put differently, to how closely they collaborated.

Our study provides important policy implications for how to support and promote future sustainable transitions and also establishes a foundation for future research directions regarding entrepreneurship and sustainable transition [1,12]. We show that the use of informal protection mechanisms, such as secrecy or lead-time advantages, can to a large extent be substituted by closer collaboration with suppliers, competitors and universities when creating innovations that are new to the market. Our results furthermore show that formal protection mechanisms, such as patents and confidentiality agreements, are always advantageous when creating new-to-the-world innovations and cannot be substituted by closer collaboration with suppliers and competitors. Moreover, our findings indicate that there are complementary effects between the use of formal protection mechanisms and closer collaboration with universities for new-to-the-world innovation. We have thus demonstrated how different partners and different appropriability strategies are more, or less, relevant to generating the breakthrough knowledge and radical innovations needed to transform society into one with a sustainable future.

One policy implication of our results when considered with regard to future sustainable transition is thereby that policymakers need to be aware of and take into account the need to carefully match collaborative partners and the proper appropriability strategy when designing initiatives to promote sustainable transitions through innovation in small entrepreneurial firms. Policy makers must facilitate adaptable support schemes for entrepreneurial firms, which aid appropriability depending

on the composition of collaboration and innovation. When pursuing new-to-the-market innovations, entrepreneurial firms need incentives to collaborate and support in navigating informal protection mechanisms and conditions for establishing close collaboration. Furthermore, when pursuing new-to-the-world innovation, entrepreneurial firms need support in establishing formal protection mechanisms, which are often highly demanding for small resource-constrained firms. Our findings suggest that university collaboration and the use of formal protection mechanisms may be especially important to support and promote, since these relate positively to new-to-the-world innovations. Thus, while collaboration in the generation of new market and technological knowledge is needed for grand challenges, caution in policy and innovation studies is needed with regard to which types of partners to involve in such collaboration and under which circumstances.

We further suggest that KIE firms may be especially necessary in making advances in knowledge to solve large societal problems but at the same time particularly disadvantaged in collaboration. In addition to the general problems of entrepreneurial firms, KIE firms are leading firms in their industries and will have to be content with more knowledge spillovers (i.e., less possibility of generating rents from innovations) as compared to follower firms [24]. Hence, “emerging and open-ended coordination in the process of working together towards transformative change” [13] (p. 1563) may not be possible.

There are several limitations to this study which open up future trajectories of research. Due to the nature of survey data, we only showed the association between collaboration, appropriability strategies and innovation performance; further research is needed in order to establish causal interpretations of these relationships. Future research could also address, in a more fine-grained manner, whether and how the relationship between openness, appropriability strategies and innovation performance of KIE firms remains the same across different types of industries and service sectors. Continuing to develop a more realistic and empirically validated view of the opportunities and limits of collaboration in relation to radical and incremental innovations is required in order to achieve societal-wide knowledge to accomplish transitions. Finally, while we have here focused on collaborating in general, future research should address these issues with regard to collaboration with new partners since this may be especially important for achieving radical innovations and future sustainable transitions.

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Appendix A

Table A1. Correlation matrix.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. New-to-the-world innovation									
2. New-to-the-market innovation	−0.042								
3. Formal protection mechanisms	0.118	0.087							
4. Informal protection mechanisms	0.118	0.109	0.257						
5. Competitors (importance as knowledge source)	−0.017	−0.01	0.05	0.02					
6. Suppliers (importance as knowledge source)	−0.032	0.015	−0.054	0.043	0.267				
7. Universities (importance as knowledge source)	0.112	0.048	0.111	0.114	0.205	0.184			
8. No full-time empl.	0.043	0.012	0.069	0.094	0.07	0.034	0.062		
9. R&D intensity	0.229	0.073	0.158	0.183	0.004	−0.048	0.199	0.011	
10. Firm age	−0.002	−0.017	−0.006	−0.036	−0.005	−0.018	0.008	0.074	−0.054

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