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Degree of Openness and Performance in the Search for Innovation

Regular Paper

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Abstract External knowledge has been the object of increasing attention in the past few years, corresponding to the rise in company innovation models that are based on a higher degree of openness towards external actors. This study investigates the practices that firms adopt in searching for external knowledge to innovate their products, exploring the relationships between performance of innovation processes and the breadth and depth of search practices. In so doing, we explore the role of openness through the lens of search practices, rather than examining the variety of external actors from which firms draw relevant knowledge for product innovation.

Keywords openness, innovation performance, search practices, survey

1. Introduction

Recent literature has pointed out the importance of openness [1] and refers to external knowledge identification as a search strategy[2,3]. Openness to external knowledge has been conceptualized according to the *breadth* and *depth* of the search for innovation. The breadth is measured by the diversity of external inputs and represents how widely a firm explores external knowledge; the depth is defined differently by differentauthors: in[4] it is the degree to which existing knowledge is reused (or exploited); in [2] it represents how deeply a firm draws on external sources. Along the same lines, in [3] it was argued that firms need to re-order their search strategies *"as a balancing act between fruitful diversity in potential knowledge impulses and the efficiency of how to access it"* (p. 4). They found that firms need to expand the search scope, since on average they only draw deeply from one source.

The domain of knowledge, it has been argued,also plays a role in defining a search strategy. In [3] the authors refer to the external knowledge impulses – market-driven or technology-driven – while in [5] the authors refer to the generated knowledge.

In addition, the effects of search strategies on innovation performance are under debate. While in [2] the relation is represented by an inverted U-shape (i.e., searching widely and deeply is curvilinearly related to innovation performance), in [6] the author's findings are different. The lack of conclusive evidence on this topic comes down to two research gaps: (1) the operationalization of search

strategies, which are more complicated than academics previously expected; and (2) the search strategies-performance link, which is not completely understood.

Over the last decades the gap between what people do in theory and what people actually do has led management scholars to adopt a practice-based approach [7] that emphasizes how actors interact with the socio-physical features of context in everyday activities (see also [8] for a case study). In this context, our work addresses the research gaps, examining the degree of openness in innovation searches through the lens of search practices – an area not yet explored– and providing empirical evidence for its impact on innovation performance.

2. Theory and hypotheses

The context of this paper is the search for innovation, and the analysis focuses on the practices firms are developing to search for ideas and knowledge in their innovation activities. Practice is taken to mean "*how things get done in organizations*" [9], including behaviours and accompanying structures or processes. Understanding searching in practice may also bring us closer to an understanding of organizational life.

In particular, our focus is on those search practices which highlight the relations a firm develops with external actors – i.e., the practices which define the degree of openness.

Previous contributions on search strategies have successfully tackled the operationalization question (research gap no.1), adopting a *where-to-search* perspective.). By contrast, we adopt a *how-to-search* perspective and investigate the organizational practices used for searching, thus focusing on the degree of openness.

2.1 Search practices in the literature

We reviewed literature on search topics according to two main perspectives: where to search and how to search. Contributions on the first perspective (where) refer to the choice of:(a) knowledge boundary (internal and external), (b) knowledge domain (market and technology), (c) knowledge proximity (local and distant) and (d) search intensity and scope (depth and breadth). Empirical articles focus on some of the above dimensions and sometimes the definitions adopted are different for the same concept. Table A in the Appendix synthesises the search dimensions, their definitions and the operationalization adopted in the literature.

Literature on the second perspective (how) investigates the search practices. According to the early front-end innovation literature, activities can be broken up into two broad categories [10]: the first group's activities deals with the process of idea generation while the second includes those related to idea management. Idea generation refers to opportunity identification and analysis carried out by environmental scanning [11,12], seeding ideas [13,14], and application exploration [15]. It can occur inside or outside a business.

Idea management is the process of capturing, storing, and organizing ideas adopted in the late front-end process. It can be used also for preliminary idea evaluation and screening, as well as idea diffusion across the company [16,17]. It integrates activities such as idea generation, screening, collaboration and idea development fromearly through to late innovation FE.

It is possible to identify a number of recurrent themes in the literature within these interlinked categories [18].

Learning about markets is related to lead users, experimentation, scouting for new ideas, and deep diving. The role of scouts or "idea hunters" is to search actively for new ideas to trigger the innovation process, often in unexpected places (technological triggers, emerging markets or trends, competitor behaviour, etc.). With the advent of powerful new tools there is huge scope for engaging users in active co-creation of products and services. For example, the Internet has enabled the open source movement to develop high quality software as a co-operative process, whilst tools like rapid prototyping, simulation and computer-aided design help create the spaces where active users can interact with professional designers [19,20]. Since it is often difficult to imagine a radically different future and to predict how things will actually develop, companies have started to use an approach we have called "probe and learn": products, prototypes and concepts are put out into the market and consumer reactions are carefully observed and monitored. Through this process emergent trends and potential designs can be explored and refined in a continuing learning process. An effective way of creating and exploring alternative futures is through scenario-based approaches. It was Shell that pioneered scenario planning [21]. Companies have realized that while predicting possible futures is useful, they must also take action to help shape and influence emergent alternatives. These activities may involve building links with different sets of stakeholders and being a part of a future which co-evolves out of those interactions. Another related approach is to build concept models and prototypes to explore reactions and provide a focus for various different kinds of input which might shape and co-create future products and services. More recently companies have started to develop these scenarios jointly with other organizations, discovering exciting opportunities for cross-industry collaboration.

An interesting source of demand-side innovation triggers comes from taking a much deeper look at how people actually behave as opposed to how they say they behave. "Deep dive" is just one of the terms used to describe the approach [22].

2.1.1 Openness to external sources

This component is related to practices that ensure insights from outside, and includes sources such as universities [23], licensing [24], other companies, alliances [25] and also web 2.0 [26]. Increasingly, professional organizations are offering focused search capabilities– for example, in trying to pick up on emerging trends in particular market segments. Some firms have sophisticated IT systems giving them early warning of emergent fashion trends which can be used to drive a high-speed flexible response on a global basis. The web can also be used as a multi-directional information marketplace. Many websites act as a brokering service, linking needs and resources, creating a global market-place for ideasand providing a rich source of early warning signals. For example, the innocentive.com website is used as a match-making tool, connecting those with scientific problems with those able to offer solutions. Websites can also be employed as online laboratories for conducting experiments or prototype testing. Second Life (www.secondlife.com), for example, is an online role-playing game with over five million users. People assume alternate identities represented by avatars and interact in an alternative online world – in the process creating a powerful laboratory for testing out ideas. The potential of adver-gaming is being explored, for example, by US clothing retailer American Apparel, which has opened a virtual store; IBM has also set up offices at several locations.

2.2 Hypotheses

The research objective is to shed light on the relations between the degree of openness – expressed in terms of search practices' depth and breadth – and the innovation performance (see Figure 1). More specifically, this study draws on the concept of external search breadth and depth [2,3] and analyses these two constructs by looking at the usage patterns of different practices of external search that involve science/technology partners and value chain partners [27]. Specifically, *search breadth* is defined as the number of search practices that firms activate in their innovative activities, while *search depth* refers to the extent to which firms dig deep for new knowledge in their search practices.

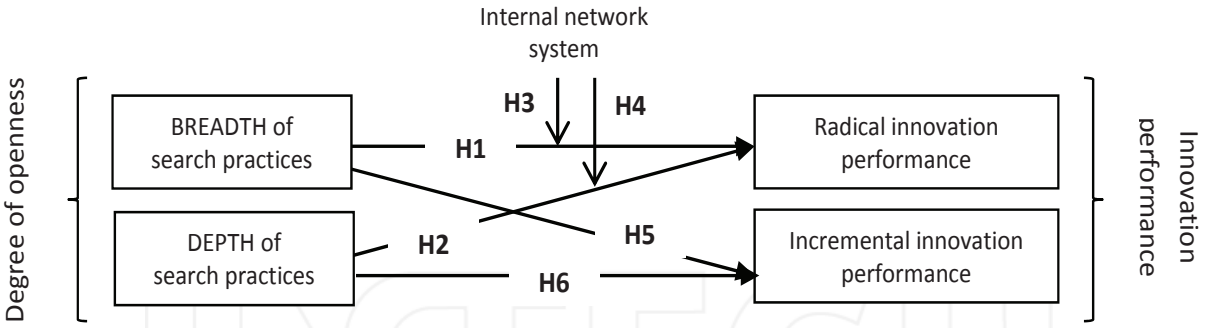

Figure 1. Research framework and hypotheses

Based on the theoretical arguments discussed above, we propose that both breadth and depth of search practices can be beneficial for radical innovation performance. There is indeed broad agreement that success in radical product innovation requires managers to combine aspects of technological and customer knowledge and competence in new ways [28]. Wide exposure to external knowledge and ideas can increase managers' chances of finding technological solutions that meet the needs of new customers [29,30]. Thus:

H1. Breadth of search practices positively affects radical innovation performance

H2. Depth of search practices positively affects radical innovation performance

The way firms enact search practices to draw on external knowledge can, however, be insufficient to determine the outcome of radical innovation endeavours. Their contribution to innovation performance is conditional to how firms can combine knowledge absorbed from outside with pre-existing knowledge available in the firm's resource base. This is an established idea that essentially draws on the concept of combinative capabilities introduced in [31] and on the traditional distinction between knowledge creation and knowledge application. Thus:

H3. The degree of use of internal network systems for knowledge integration positively moderates the effect of depth of search practices on radical innovation performance

H4. The degree of use of internal network systems for knowledge integration positively moderates the effect of breadth of search practices on radical innovation performance

Following the idea that firms enact different knowledge creation processes when they deal with incremental innovation compared to when they undertake more radical technical or market changes, we propose that incremental innovation requires different external knowledge search strategies. Following the theory on dominant design [32], we expect that when firms are engaged in fine-tuning a product by means of incremental innovations, exposure to a broad variety of knowledge sources may be beneficial. The variety of search practices a firm uses can, indeed, allow a broad scanning of the relevant environment. As the product matures and the market expands, the number of actors that can bring relevant market or technological ideas to the firm increases. However, as for incremental innovations the architecture has already been defined;improvements in the product require modular changes that do not require a deep coordination with external actors or within the firm's internal product development teams. In other words, incremental innovations are likely to require firms to draw more broadly on external knowledge by means of a greater variety of search practices, but less intensively than non-innovators. In much the same way, incremental innovations do not require a particularlygreat use of combinative capabilities. Thus:

H5. Breadth of search practices positively affects incremental innovation performance

H6. Depth of search practices negatively affects incremental innovation performance

H7. The degree of use of internal network systems for knowledge integration does not have any effect in the relationship between search practices and incremental innovation

3. Empirical study

3.1 Data

An online cross-sectional survey was utilized for data collection. A structured questionnaire was developed to measure the theoretical constructs, and 5-point Likert scales were used to measure the items. A test of the resulting questionnaire was conducted on two groups of subjects: colleagues and target respondents. The target sample frame consisted of Italian medium and high-tech companies selected according to the OECD science classification. Accordingly, 500 medium and high-tech firms were randomly selected from the AIDA dataset by considering only companies with more than 50 employees. The data collection process was supported by the use of Survey Monkey® web utilities. Respondents were typically the vice presidents or directors of R&D departments, or the CEOs of participating firms. Target firms were firstly contacted by phone in order to introduce the initiative. Those who agreed to participate were sent an email, including a cover letter of the survey and the Survey Monkey® account for survey access. This was followed by a reminder by phone and email two weeks after the initial contact. Of the 500 surveys emailed in Italy, 112 responses were received, a response rate of 22.4%. In order to test the non-response bias we compared the early and late respondents by a t-test (no statistically significant differences at 99% confidence interval).

3.2 Variables

Degree of openness of search practices.This is measured by two dimensions: breadth and depth. The breadth is measured by the diversity of external inputs (i.e., search practices – Table B1 in the Appendix) and represents how widely a firm explores external knowledge. The depth represents how deeply a firm draws knowledge from external sources (i.e., the search practice usage level). Search practices derived from evidence from the 80 cases developed by the DI-Lab researchers and discussed with industry experts in focus groups [18] have been integrated with the literature.

Radical and incremental innovation performance. In [33] the authors posited that the concept of performance of innovations should include a number of different aspects of performance, such as: "the number of new product innovations introduced by the firm, the percentage of sales of new product innovations, and the relative frequency of introducing innovations compared with competitors" (p. 65). Following this concept, we adapted the scales developed in [33] to evaluate both radical and innovation performance by taking into consideration the number of product innovations and the sales revenue from these types of technical and market changes. Since this paper represents a preliminary analysis, we decided to take into consideration the measures of innovation performance (number of innovations, sales from innovative products, and frequency of innovation) as separate, in order to consider whether search practices have different effects on the individual dimensions of innovation performance.

The degree of use of internal network systems for knowledge integration.
This comprises sub-factors related to bringing together people with different knowledge sets and network ambassadors to help teams connect with other people company-wide (Table B2 in the Appendix).

Control variables. Control variables included both environmental and structural conditions of firms. Specifically, among the structural conditions were included size and age. Compared to smaller enterprises, the greater resources available to larger organizations

allow them to enact a greater variety of search practices and to give continuity to their use through a greater formalization. With regard to the confounding effect of age, young firms can be involved in deeper relationships with some external partners, but they may be less capable of initiating a great variety of communication channels with external sources. The degree of dynamism (as perceived by respondents on a multi-item 5-level Likert scale) was included as a control, as more discontinuous environments may require a greater effort in environmental scanning. In the set of control variables, we also included firm spending in R&D, considered as the logarithm of the mean for the annual expenditures in R&D between 2006 and 2008. Indeed, R&D expenses reflect a firm's involvement in radical innovation performance and also their level of absorptive capacities, and they may thus facilitate the assimilation and application of the knowledge captured through external practices.

3.3 Method

Tobit regression models were considered to estimate the determinants of sales of innovative products. As the other performance indicators were measured on a Likert scale, we estimated the effects of their antecedents using ordinal Probit regression models. All the models were estimated using Stata 9.0. Table 3 (a and b) shows the estimates of regression models. In accordance with previous literature, we tested curvilinear effects of breadth and depth of search practices on sales revenue from product innovation by adding quadratic effects to the regression models, if they were significant. As multicollinearity can be a concern due to the high correlation between the breadth and depth of search practices, we estimated their effect on innovation performance by also considering distinct regression model specifications including these variables separately. The results of these models do not differ from the ones reported in this article, where regression models simultaneously consider the effect of breath and depth.

4. Findings

4.1 Descriptive statistics

Table 1 shows descriptive statistics, and Table C in the Appendix reports the Spearman Correlation coefficients. The overall evidence of descriptive statistics shows some key facts. First, on average firms in the sample exhibit a strong orientation towards both radical and incremental innovation. Consistent with this, the level of environmental dynamism experienced by firms in the sample is high (median value: 3.667) and the firms' attitudes towards external searchesare also high. The difference between breadth and depth of search practices is particularly high (0.727, p-value <0.01%). Multicollinearity may thus come into play when estimating the impact of search practices on innovation performance.

	Variable	N	mean	std. dev.	median
Control	R&D expenses (log)	88	2.187	1.119	2.433
	size (log)	88	2.409	1.004	2.190
	age (log)	88	2.829	0.969	3.090
	dynamism	88	3.694	0.728	3.667
Search practices and idea management	degree of use of internal network systems for knowledge integration	88	3.097	0.928	3.125
	depth of search practices	88	3.563	0.657	3.600
	breadth of search practices	88	0.868	0.148	0.933
Radical innovation performance	radical process innovation	87	3.690	0.980	4.000
	sales revenue from new radical products	69	22.768	19.857	20.000
	number of new radical products introduced	82	3.390	0.716	3.000
Incremental innovation performance	sales revenue from incremental products	69	34.174	19.478	30.000
	number of incremental products introduced	81	3.617	0.644	4.000

Table 1. Descriptive statistics

In hypotheses H1 and H2 we posited that breadth and depth of search practices have a positive effect on radical innovation performance. The results show mixed evidence (Table 3a). Model 1 indicates that breadth of search practices has a negative effect on the number of radical product innovations introduced, whereas depth of search practices has a positive effect. Model 2 indicates that breadth of search practices does not have any effect on the sales revenue from radical products, whereas depth of search practices shows a U-shaped curvilinear relationship to this type of performance indicator. This overall evidence thus provides very partial support to hypotheses H1 and H2.

In hypotheses H3 and H4 we posited that the degree of use of internal networks for knowledge integration positively moderates the relationship between search practices and radical innovation performance. We tested these hypotheses applying a hierarchical approach to Tobit regression models on sales revenue from radical products (model 5, 6 and 7). As high correlation among interaction terms make it difficult to precisely estimate multiple interaction coefficients simultaneously, we tested the interaction effect of internal boundary spanning and breadth and depth of search practices separately. Models 3 and 4 show that the coefficients of the interaction effects are positive and significant, thereby supporting the argument that breadth and depth of search practices have a positive effect on the success of radical products in the presence of internal boundary spanning.

In hypotheses H5 and H6 we posited that breadth of search practices has a positive effect on incremental product innovation performance, whereas depth of search practices exerts a negative effect. The results do not support these hypotheses (Table 3b). Specifically, model 5 shows that depth of knowledge search is positively related to the number of incremental product innovations, whereas it does not exert any significant effect upon sales from incremental product innovations. In a similar way, models 5 and 6 indicate no effect caused by breadth of search practices on the outcome of incremental innovation endeavours.

Lastly, in hypothesis H7 we argued that the use of internal network systems for knowledge integration is not related to incremental innovation performance. Models 6, 7 and 8 confirmed this result, showing that internal boundary spanning had no effect on incremental innovation, either direct or as moderator.

Table 2 provides a summary of the validation of the hypotheses in relation to the regression models estimated.

Hypothesis	Expected sign	Test result
H1. Breadth of search practices → radical innovation performance	+	**Not supported.** Negative effect on the number of radical innovations introduced (model 1). No direct effect on sales revenue from new products incorporating radical changes (model 2)
H2. Depth of search practices → radical innovation performance	+	**Partially supported.** Positive effect on number of radical innovations introduced. U-shaped relationship with sales revenue from radical innovations
H3. Degree of use of internal network systems for knowledge integration ↓ effect of depth of search practices on radical innovation performance	+	**Supported.** The coefficient of the interaction effect between depth of search practices and internal networking is significant and positive (model 3)
H4. Degree of use of internal network systems for knowledge integration ↓ effect of breadth of search practices on radical innovation performance.	+	**Supported.** The coefficient of the interaction effect between breadth of search practices and internal networking is significant and positive (model 4)
H5. Breadth of usage of search practices → incremental innovation performance	+	**Not supported.**
H6. Depth of usage of search practices → incremental innovation performance	-	**Not supported.** Positive significant effect of depth on the number of incremental product innovations
H7. Degree of use of internal network systems for knowledge integration ↓ relationship between search practices and incremental innovation	-	**Supported.** No direct or interactional effect of internal networking on any incremental innovation performance indicators

Table 2. Hypotheses validation

5. Discussions and Conclusions

External knowledge has been the object of increasing attention in the past few years, corresponding to the rise in company innovation models that are based on a higher degree of openness towards external actors. In accordance with this focus, this study has investigated the knowledge search practices that firms enact to innovate their products, exploring the relationships between the performance of innovation processes and the breadth and depth of innovation processes. In so doing, we have explored the role of openness in explaining innovation performance through the lens of search practices rather than by looking at the variety of external actors from which firms draw relevant knowledge for their innovation activities [2]. Essentially, this analysis has highlighted three key findings. First, it shows that the depth of search practices is more beneficial to radical innovation performance than the breadth (i.e., the degree of external knowledge that firms gain through these

mechanisms is more beneficial than the variety of mechanisms used). This result is consistent with theoretical models [32] and empirical evidence [2] positing that, when firms are dealing with radical product innovation, deep coordination with a few partners is more beneficial than a broad external search.

The second key result is that – contrary to our expectations – depth of search practices has a positive influence on incremental innovation performance, intended as the number of products incorporating incremental changes introduced by firms in the last three years. This result is consistent with previous results found in[6], but is still surprising since it is at odds with implications from the theory of product life cycle [32] and empirical results that invoke this theory [2]. Thus, our result may be seen as a further argument in support of the possibility that the consequences of open search strategies are more complicated than researchers have believed[6]. For example, a plausible explanation in this regard could be that when firms use search practices for gaining deep external knowledge through their interaction with external actors, their deliberate focus is on radical innovation endeavours. However, following an emergent approach to search strategy, during this exploration firms may arrive at knowledge elements that are also useful in their efforts to refine existing products. In a similar way, knowledge elements that have been absorbed through rich interaction with external parties can also become useful in incremental products after they have been assimilated and applied in radical product changes. In future studies, the availability of longitudinal studies could allow researchers to test this type of relationship in more depth.

The third key result is that when firms foster internal networking and boundary spanning in order to reconfigure knowledge architecture and combine knowledge elements in new ways, search and breadth of search practices are more beneficial in terms of the market success of radical product innovation. Internal networking systems are unimportant in more incremental innovation processes, as this type of change does not require any particular reconfiguration of networks and knowledge architecture within organizations. We believe that this type of result is coherent with previous studies positing the importance of combinative capabilities [31] and internal boundary spanning.

	Hyp.	Model 1	Model 2	Model 3	Model 4
		Number of new radical products	Sales revenue from new radical products	Sales revenue from new radical products	Sales revenue from new radical products
Size		-0.204* (0.092)	-2.306 (2.317)	-2.688 (2.266)	2.143 (2.298)
Age		-.007 (0.148)	-1.312 (2.543)	-0.881 (2.508)	-0.986 (2.549)
R&D expenses		-0.045 (0.100)	-0.439 (2.143)	-0.106 (2.139)	0.045 (2.198)
Dynamism		0.867*** (0.231)	11.539*** (3.464)	11.552*** (3.301)	11.992*** (3.408)
Breadth of search practices	H1	-1.929† (1.1163)	36.702 (23.412)	5.553 (3.309)	3.964 (3.211)
Depth of search practices	H2	0.776* (0.314)	-73.109* (32.998)	-4.282 (4.251)	-2.010 (4.222)
Depth of search practices Squared		….	9.410* (4.348)	….	….
Network systems for internal integration		-0.032 (0.208)	2.301 (3.915)	2.740 (3.570)	2.289 (3.645)
Breadth *x* Internal Boundary Spanning	H3	….	….	….	4.281† (2.412)
Depth *x* Internal Boundary Spanning	H4	….	….	5.658* (2.338)	….
Fit Indexes					
Pseudo R square		16.47%	5.12%	5.31	4.86%
chi square (df)		Wald: 26.37*** (82)	LR: 17.65* (9)	LR: 18.76 (69)	16.19 (69)

**** p-value < 0.1%; ** p-value <1%, * p-value< 5%; † p-value < 10%; (…) standard error*

Table 3a. Antecedents of radical innovation performance

	Hyp.	Model 5	Model 6	Model 7	Model 8
		Number of incremental innovations	Sales revenue from incremental innovations	Sales revenue from incremental innovations	Sales revenue from incremental innovations
Size		0.171 (0.143)	0.750 (2.332)	0.808 (2.294)	0.314 (2.253)
Age		-0.265* (0.115)	-1.903 (2.532)	1.841 (2.501)	-1.724 (2.448)
R&D expenses		0.151 0.112	-1.942 (2.168)	-1.491 (2.167)	-1.590 (2.103)
Dynamism		0.339† (0.201)	1.558 (3.313)	2.394 (3.333)	2.195 (3.218)
Breadth of search practices	H5	-0.1633 (1.847)	-0.041 (3.091)	1.005 (3.152)	2.686 (3.222)
Depth of search practices	H6	0.512† (0.315)	2.414 (4.190)	2.583 (4.142)	0.497 (4.143)
Internal Boundary Spanning	H7	-0.009 (0.235)	-1.921 (3.659)	-1.409 (3.634)	-0.894 (3.567)
Breadth *x* Internal Boundary Spanning		…	….	3.238 (2.386)	….
Depth *x* Internal Boundary Spanning		….	….	….	5.265 (2.810)
Fit Indexes					
Pseudo R square		11.16** (81)	1.59 (7)	3.41 (8)	6.63 (8)
		12.90%	0.27%	0.58%	1.12%

**** p-value < 0.1%; ** p-value <1%, * p-value< 5%; † p-value < 10%; (…) standard error*

Table 3b. Antecedents of radical innovation performance

Since some of these results contradict recent previous works on external search strategies, this study raises some important issues that should be the object of further discussion. In this regard, whereas some previous studies found an inverted U-shaped relationship between search strategies and innovation performance [4,27,2], we furnished evidence that apparently contradicts the perils of over-searching; we show that the depth of knowledge drawn from external search practices has an influence on radical innovation performance, in a U-shaped relationship. This discordance could be due to our method of focusing on search strategies, unlike previous studies we take into consideration how firms organize their search strategies. Another plausible explanation could be related to the possibility that we are considering an aspect of the relationship between search practices and radical innovation performance that is different to those investigated in other analyses. The strong propensity of our sample to open search and radical innovation could be seen as preliminary confirmation of this explanation. In this regard our data are from a survey carried out on a sample that may exhibit some self-selection bias in respect to survey initiatives such as the Community Innovation Surveys launched at each country level, which are typically addressed to a more broad and heterogeneous sample.

In collecting these results, this study does have some limitations beyond those discussed above. We believe that three limitations in particularcould identify important directions for future research. First, the sample size is small and this may limit the validation of the moderation effect exerted by network systems. Furthermore, we have investigated a sample with aptitude for exploratory innovation, and thus selection bias could hamper the generalizability of our results. Accordingly, a replication of the study on a broader and multi-country level in the high-tech industry could allow generalizability of our results to be tested.

The second limitation regards the type of innovation performance under analysis. Innovation performance is a multidimensional construct [33] and this study has only taken into consideration the number of product innovation and sales revenue from innovations. These dimensions do not, for example, consider possible continuity in firms releasing innovative products on the market over. Future studies on the effectiveness of knowledge search practices should therefore include a more comprehensive measure of a firm's innovation performance. Another open issue (our third limitation) is whether the relationship between search practices and innovation performance is mediated and moderated by variables not present in our theoretical framework.In accordance with the conceptual distinction between potential and realized absorptive capacities [34], we can plausibly expect that search practices may have a positive effect on knowledge absorption and accumulation, but

that some firms may fail to apply the knowledge absorbed from external sources in new products that prove successful on the market. The positive moderation role exerted by the degree of use of internal networking in the relationship between the usage of search practices and innovation performance points in this direction. However, a more comprehensive test of the effectiveness of the main attributes of search practices should take into consideration some "intermediate" level of innovation performance. Following this line of reasoning, we may for example expect that search practices may have more salient effects on exploratory learning about new market or technological opportunities, rather than on exploitative learning. Future studies on the topic should try to tackle these limitations.

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7. Appendix

AUTHOR	SEARCH DIMENSION	DEFINITION	OPERATIONALIZATION	FINDINGS
Katila and Ahuja (2000) Focus: internal search for new product	Depth	*The degree to which search revisits a firm's prior knowledge* (p. 1184).Or *the degree to which existing knowledge is reused or exploited* (p. 1184)	Average number of times a firm repeatedly used citations in the patents it applied for	H1. Search depth is curvilinearly related to the number of new products introduced by a firm H2. Search scope is curvilinearly related to the number of new products introduced by a firm H3. The interaction of search depth and scope is positively related to the number of new products introduced by a firm
	Scope - Local search - Distant search	*The degree of new knowledge that is explored* (p. 1184) *Organizations that search locally address problems by using knowledge that is closely related to their pre-existing knowledge bases (Helfat, 1994; Martin and Mitchell, 1998; Stuart and Podolny, 1996)* (p. 1184). *At the other end of the spectrum, exploratory searchbehaviours involve a conscious effort to move away from current organizational routines and knowledge bases (March, 1991; Miner, Bassoff and Moorman, 2001)* (p. 1184)	The proportion of previously unused citations in a firm's focal year's list of citations	
Laursen and Salter (2006) Focus: external search	(external) Depth	*The extent to which firms draw intensively from different search channels or sources of innovative ideas* (p. 140)	16 sources. Coded with: - 1 if firm reports to use the source to a high degree, medium or low - 0 no use The 16 sources are subsequently added up so that each firm gets a score of 0 when no kw sources are used to a high degree, and 16 when all kw sources are used to a high degree	H1. External search breadth is curvilinearly related to innovative performance H2. External search depth is curvilinearly related to innovative performance H3. The more radical the innovation, the less effective external search breadth will be in influencing innovative performance H4. The more radical the innovation, the more effective external search depth will be in influencing innovative performance
	(external) Breadth	*Number of external sources*	16 sources. Coded with: - 1 if firm reports to use the source - 0 no use The 16 sources are subsequently added up so that each firm gets a score of 0 when no kw sources are used, and 16 when all kw sources are used	
Sofka and Grimpe (2010) Focus: direction (market-driven and tech-driven) of (external) search strategies	(external) Search strategies	*Number and importance of the main external sources for innovation*	Seven sources. The respondents are required to evaluate the importance of the main sources for their innovation activities on a 4-point Likert scale ranging from "not used" to "high". Then → factor loadings and identification of three search strategies: market-driven, science-driven and supply driven	Three types of specialization in firm's search strategies, which reflect market knowledge (customers, competitors), scientific knowledge (universities, research institutions) and supplier knowledge (suppliers, conferences, trade fairs, journal articles)

Shilling and Green (2011) Focus: atypical connections between different domains	Depth	*Refers to the extensiveness of search within a given kw area* (p. 1323)	The concentric weighted count of Dewey decimal classification represented in the references of a specific article	Search scope, depth, and atypical connections between different research domains significantly increase a paper's impact
	Scope	*Refers to the number or breadth of kw domain searched, and is often invoked to refer specifically to kw domains in which the actor lacks prior experience or competence (Fleming, 2001; Katila, 2000)* (p. 1323) *The term local search is typically meant to convey when an actor searches deeply but with low scope. The inverse – low depth and high scope – is indicative of distant, or exploratory, search* (p. 1323)		
Chen, Chen and Vanhaverbeke (2011) Focus: external search	Depth	*Refers to the intensity of relations with external partners*	7-point Likert scale for each of the 10 sources, with (7) highly important Depth of openness is the average of the 10 scores	H1. For firms in STI industries, the scope of openness to external organizations has a curvilinear effect on innovative performance H2. For firms in STI industries, the depth of openness the external organizations has a curvilinear effect on innovative performance H3. For firms in DUI industries, the scope of openness to external organizations has a positive effect on innovative performance H4. For firms in DUI industries, the depth of openness the external organizations has a positive effect on innovative performance H5. The types of partners that have a positive effect on innovative performance are different for STI and DUI innovation modes
	Scope	*Refers to the diversity of relations with external partners*	10 sources, each with two codes: - (1) cooperation with partner type i - (0) never cooperated with i	
	Orientation	*Enables the innovating firms to source different types of external knowledge*	Partner types split into two main categories: - Value chain partners - Technology partners A factor analysis examined how different types of external sources are used in the STI (for codified knowledge) and DUI industries (for experience based know-how and informal learning)	
Lavie and Rosenkopf (2006) Focus: alliance formation	Structure domain - Local search - Distant search	*Exploration in the structure domain refers to a firm's tendency to seek opportunities by forming alliances with new partners that lack prior ties to the firm, wherein the firm expands its network boundaries beyond the immediate structure of its alliance portfolio* (p. 3). *(…) recurrent alliances with prior partners entail local search* (p. 3)	Two codes: - (1) whether the firm has no prior alliances with partner j - (0) whether such an alliance existed for the firm	
	Function domain - Value chain upstream activities (i.e., R&D) - Value chain downstream activities (i.e., marketing and commercialization)	*Firms that engage partners in R&D that may lead to innovative technologies and applications can be said to participate in exploration, whereas firms that rely on alliances for commercializing and using existing technologies or employing complementary partner capabilities undertake exploitation* (p. 799)	Three codes: - (1) whether the alliance involves a knowledge-generating R&D agreement - (0) whether the agreement is based on existing knowledge involving joint marketing and services, OEM/VAR, licensing, production or supply - (0.5) whether the alliance involves a combination of R&D and other agreements	

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Köhler, Sofka and Grimpe (2012) Focus: selective external search	Search breadth	*Number of different sources used*	Seven sources and 4-point Likert scale. Same as Laursen and Salter (2006)	H1. Market-driven search is stronger associated with imitation success than with new-to-market innovation success H2. Science-driven search is stronger associated with innovation success of new-to-market innovations than with imitation success H3. Supplier-driven knowledge search is equally associated with success of new-to-market innovations as well as imitations
	Search depth	*Number of highly important sources*		
	Search direction	*Firms apply targeted knowledge searches* (Sofka and Grimpe, 2010)	Applied a principal component factor analysis in order to identity underlying factors. 3 factors identified	
Berchicchi (2012) Focus: open R&D	External R&D	*Captures the extent to which firms engage in external R&D activities*	Managers are asked to indicate which % of R&D activities is outsourced and which % is performed in-house: - (0) in-house only - 100% fully outsourced	H1. An inverted U-shaped relationship exists between the share of external R&D activities and a firm`s innovative performance H2. The inverted U-shaped relationship exists between the share of external R&D activities and a firm`s innovative performance is moderated by R&D capacity in such a way that greater R&D capacity is associated with a higher point of maximum efficiency in the inverted U-shaped curve for a smaller share of external R&D
	R&D capacity	*Measures the effort of a firm to build a stock, of knowledge, which allows one to produce and acquire new knowledge across industries*	Number of employees working in the R&D dept. divided by the total number of the employees in the firm	
Chiang and Hung (2010) Focus: open search strategies	Depth	*Indicates from how many channels the focal firm intensively sources ideas for innovation* (p. 295)	Same as Laursen & Salter (2006)	H1. Open search breadth is positively related to the innovating company`s radical product innovation performance H2. Open search depth is positively related to the innovating company`s incremental product innovation performance These findings are different from Laursen & Salter (2006), who found that the more radical the innovation, the more effectively external search depth will influence innovative performance. Chiang and Hung (2010) use multiple measures for innovation performance, while Laursen & Salter (2006) measured innovation only as the proportion of turnover related to new products.
	Breadth	*Number of external sources*	Same as Laursen & Salter (2006)	

Table A. Search dimensions, definitions and operationalization in the literature

CONSTRUCT	ITEM	DESCRIPTION
Market learning MKT	MKT1	Makes use of conventional market research methods such as: focus groups, interviews or telephone surveys, online surveys, brainstorming.
	MKT2	We shake relations with lead-users (users of a particular product / service and suggest changes or improvements to existing products that are able to anticipate the needs of the market still untapped).
	MKT3	We establish relationships with end customers (customers of customers in the B2B case) and you get regular feedback on their needs.
	MKT4	We analyse the use of products and services in various real-life situations.
	MKT5	Often prototypes and pilot tests are used as tools for learning and refining, to test new ideas.
	MKT6	We explore the future, using tools and techniques such as scenario analysis, exploration of trends and other forecasting techniques.
	MKT7	We use scenarios to help understand and influence our organization's future.
	MKT8	We currently have someone (full or part-time) officially charged with scouting for new ideas outside the organization and looking for trends and developments that might have implications for our organization's future
	MKT9	We have a dedicated group of people (e.g., from marketing, sales, R&D) that explores new ways to apply our existing technology to new industries and new customers
	MKT10	When we have a very new and different technology, we search for multiple applications and conduct several market experiments to discover promising markets. We appeal to organizations / companies engaged in the third scanning and the search for innovative ideas.
Openness to external sources OPEN	OPEN1	We have a website where outsiders can submit their suggestions and ideas for new markets, products and/or services
	OPEN2	There are brokers to establish relationships outside the enterprise to transfer knowledge.
	OPEN3	The different functions in the organization are encouraged to systematically collect ideas and opinions from outside sources.
	OPEN4	There is a website (e.g., blog, wiki, corporate social networks) where the different actors can submit suggestions and ideas about markets, products and / or services.
	OPEN5	We encourage people to attend events / conferences / workshops that help to increase knowledge and experience.
	OPEN6	We use an open innovation system in which technology-related challenges are posted online by our R&D staff so that a community of registered scientists anywhere in the world can propose their solutions.
	OPEN7	The research environment is open to collaborations with universities, research centres and specialized agencies.
	OPEN8	The company works with long-term strategic alliances and aims to consolidate and develop short-term technology partnerships with other companies.

Table B1 Construct operationalization for search practice openness

Network management system for idea generation NET	NET1	We consciously hire people who are different to encourage diversity within our organization.
	NET2	In the firm there are organizational practices to enable integration skills, background or other features to support innovation.
	NET3	In our organization, we encourage radical innovation teams to expand their resource network by tapping into the knowledge of any employee in our firm.
	NET4	In our organization, we have "network ambassadors" who can help radical innovation teams connect with other people company-wide when new knowledge or insight is needed

Table B2 Construct operationalization for knowledge integration

	Variable	1	2	3	4	5	6	7	8	9	10	11	12
1	R&D expenses (log)	1.000											
2	Size (log)	-.044	1.000										
3	Age (log)	-.111	.125	1.000									
4	Dynamism	.143	.049	-.129	1.000								
5	Internal boundary spanning	.106	-.003	-.074	.225*	1.000							
6	Depth	.097	.037	.030	.052	.727**	1.000						
7	Breadth	.062	.090	.077	.033	.380**	.585**	1.000					
8	Radical innovation process (frequencies)	.140	-.081	.037	.253*	.281**	.155	-.094	1.000				
9	Frequencies of new radical products	-.036	-.046	.097	.058	.272*	.101	-.025	.119	1.000			
10	Sales revenue from new radical products	.094	-.184	-.110	.458**	.267*	.263*	.039	.449**	.237*	1.000		
11	Number of new radical products introduced	.093	-.128	.021	.403**	.038	.000	.130	.258*	-.005	.396**	1.000	
12	Sales revenue from incremental products	-.104	.046	-.163	.005	-.036	-.029	.043	-.138	-.031	-.052	-.043	1.000
13	Number of incremental products introduced	.145	-.047	-.217	.199	.234*	.219*	.121	.114	.122	.464**	.074	.060

*** *p-value < 0.1%; ** p-value <1%, * p-value< 5%; † p-value < 10%*

Table C. Spearman correlation coefficients