Search practices for discontinuous innovation

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Search practices for discontinuous innovation: scale development and construct validation

Managing innovation and particularly searching for new ideas in a steady state environment is really different than in discontinuous conditions where traditional practices and routines may prove ineffective. This paper reviews and empirically explores the field of search strategies and practices for discontinuous innovation and, for the first time, tests the validity of a "Discontinuous Innovation (DI) Search Capacity" construct. Based on a comprehensive literature review on the innovation search stage and on the evidence of more than 80 case studies reported by the Discontinuous Innovation Lab a questionnaire was developed and submitted to a 500 high tech firm sample. Four DI Search dimensions were identified, each consisting of a bundle of interrelated yet distinct practices. We empirically tested the DI Search Capacity and measured it as second-order construct by using the Structural Equation Modelling.

Keywords: search for innovation; scale development; survey; search practices

Introduction

Management literature has highlighted that incumbents encounter serious obstacles in identifying, developing and commercializing innovations as traditional and validated 'good' approaches are not adequate, or even counterproductive under discontinuous conditions (Christensen, 1997; Benner and Tushman, 2003). The phenomenon has only found researcher's attention in the last decade (McDermott and O'Connor, 2002).

Under such discontinuous conditions, firms need to develop the capacity to 'see' weak early warning signals, extending their natural steady state search space (Day and Schoemaker, 2006). But – as Christensen and others observe – it is often firms that excel at managing innovation in a steady state environment that suffer most when

discontinuous shifts occur (Christensen, 1997). These firms typically deploy 'best practice' or steady state routines (Kahn et al., 2005) i.e. they work closely with customers/suppliers (Herstatt and von Hippel, 1992; Lamming, 1993), make use of sophisticated resource allocation mechanisms to select a strategically relevant portfolio of projects, and use advanced project and risk management approaches in developing new products, services and processes. Such practices are the product of well-developed adaptive learning processes (Senge, 1990; Argyris and Schon, 1970) that give the firm a strong position in managing innovation under steady-state conditions. However, they may also act as a barrier to detecting and responding to innovation threats and opportunities associated with discontinuous shifts. For this reason it is often new entrant firms who are best able to exploit the 'fluid phase' (Abernathy and Utterback, 1975) and develop innovations to take advantage of the conditions (Christensen, 1997).

The challenge for incumbent firms is thus to develop 'parallel' innovation capabilities to deal with both steady-state and discontinuous contexts which partially reflects the long-standing discussion about the challenge of ambidexterity. (March, 1991; Tushman and O'Reilly, 1996). Definitely, most of innovation literature is about steady state conditions, while discontinuous conditions is less researched so that firms are still vulnerable when the scope of changes in environmental elements give rise to discontinuities (Christensen, 1997; Benner and Tushman, 2003).

The research described in this article explores the components of DI Search Capacity (here following DI Search) and creates measures for it through scale development and modelling. In order to explore the organizational, technological and managerial practices which firms are experimenting with to develop Discontinuous Innovation (DI) Search capabilities an international learning network – the DILab (www.innovation-lab.org) - has been developed (Bessant and Tsekouras, 2001).

Covering around 200 firms in 12 countries, DILab acts as a community of practice, a co-laboratory for articulating key research issues around discontinuous innovation, sharing experiences and developing and implementing experiments to develop new routines for dealing with it. Within the research, this work particularly aims to develop a measurement scale for the DI search construct. On the basis of a comprehensive literature review on search practices, as well as 80 case studies carried out by the DILab, we modelled the DI search construct as a second-order construct, represented by four first-order factors each consisting of a bundle of interrelated yet distinct practices (globally 28 practices were identified). Then, we developed a questionnaire and submitted it to a 500 high tech Italian firm sample. Finally, DI Search construct has been empirically tested using the Structural Equation Modelling.

Theoretical background and research objective

Innovation can be described as a problem of Search, Selection, Implementation and Capture (Tidd and Bessant, 2009). Search focuses on how to find opportunities for innovation, while Selection refers to what to do and why; finally, Implementation and Capture conceive how to make it happens and how to get the benefits from it, respectively. Success is often rooted in the very early phase of the process (Brown and Eisenhardt, 1995; Verganti, 2007; Kim and Wilemon, 2002) where firms look both inside and outside for new ideas with which to renew themselves. In this context, the emphasis is mainly on the approaches firms use to select their search environments and if they explore them systematically.

Under steady state conditions, the convergence of successful experiences around innovation management has allowed models and best practices for effective innovation

management to emerge (Ettlie 1999; Dodgson 2000; Shavinina 2003). Although they still require extensive configuration to suit particular circumstances, emergent models are considered a starting point to be used as a structured framework for internal audit and assessment activities (Johne and Snelson 1988; Chiesa and Coughlan, 1996).

Differently, in discontinuous surroundings traditional routines may prove ineffective. The context is in fact much dynamic and closer to the 'fluid' phase of the Abernathy and Utterback's innovation life-cycle model (Abernathy and Utterback 1975; Utterback 1994) which is characterised by co-existence of old and new technologies/markets and by rapid improvements of both (Foster 1986; Tushman and Anderson 1987). Under these conditions existing incumbents and new entrants know equally nothing about the nature of the technological or market trajectory. The former have the ability to handle high levels of ambiguity but lack the resource base to sustain much in the way of blind alleys or other short-term failures. By contrast, existing incumbents have a resource-based resilience which can carry them through the exploration but may lack the motivation, especially when their internal systems militate against changing the rules of the game as a result of sunk costs, reluctance to cannibalise, cognitive and perceptual barriers, etc. (Tripsas and Gavetti 2000).

As is clearly stated in literature, a key advantage for effectively managing Discontinuous Innovation is associated with the capability to pick up early and weak signals about the emergence of discontinuity. Firms need to extend and enhance their peripheral vision (Day and Schoemaker 2004) and extend their (re)search activities into new and unexpected areas. This is often very challenging because of the difficulty of deciding both *how* and *where* to focus such alterative search activity. While 'steady state' innovation involves the problem of systematic search within known or 'knowable' selection environments, discontinuous innovation requires a much more open ended and

agile approach to managing innovation and emergent fields where search strategies are difficult to predict in advance (McKelvey, 2004). Currently, there is not a well-codified 'best practice' model – nor even well-established practices of any kind – for this. Rather firms find themselves in the 'pre-routine' stage of capability development, using trial and error experimentation to approach practices which work and may become routinized in the future.

In the following discussion the focus is placed on the question of search: *how do firms explore their environments and pick up weak and early signals about potential discontinuities?*. While recent research has in fact focused on developing a theoretical model of the process and structure for the fuzzy front-end of new product development for discontinuous innovation (DI), no research to date has focused on DI Search practices to propose a validated scale. A deeper understanding of this phenomena is indeed needed for both research and practice, as it is seen as a first step for understanding innovation performance.

The aim of this paper is to systematize search strategies and practices for discontinuous innovation into an integrated conceptual construct and to measure its validity. The objective is to provide an integrative contribution consolidating the preliminary existing research and empirical findings in order to built a first measurement scale for DI Search Capacity. Such a reliable and valid measure can be useful, for example, for studying the relevance and utilization of the various search strategies and their effectiveness from a practitioner's point of view.

Research design and data collection

The research design is composed of two stages: scale development (Section 4) and construct validation (Section 5).

As for scale development, two main sources have been used: literature review and empirical background from DILab research network. Subsequently, a questionnaire has been developed and submitted to a sample of 500 high and medium-tech Italian companies. Instead, in the construct validation process content, construct and nomological validity were performed. The overall design of the research is reported in Fig. 1.

Please insert Figure 1.

Data collection

Various perspectives have been used to build the conceptual framework for developing an understanding of what DI Search capacity is comprised of.

Literature review was focused on articles published in different academic journals for the period 2000-2012. We queried different online databases of peer-reviewed journals in the social sciences: the Business Source Premier database, the Wiley Inter-Science database, the Science Direct database and the ISI Web of Science database. We employed keywords such as “search for innovation”, “radical innovation”, "discontinuous innovation", "open innovation" in full text, abstracts, titles or topic. Furthermore, we decided to limit our sources to empirical works published in IF journals because these can be considered validated knowledge and are likely to have the highest impact in the field.

In the scale development we were also supported by the strong contribution of DILAB cases. The companies had to be established in their industry and engaged in some form of product/service innovation. Focus groups were used to gain a better understanding of (1) how firms use the search strategies; (2) the usefulness of the search strategies; (3) how the strategies have been implemented; and (4) the related barriers. Each team held separate discussions followed by a group discussion aiming to identify practices of radical idea search.

Finally, as concerning the quantitative empirical test (construct validation), an online cross-sectional survey was utilized for data collection. A structured questionnaire was developed to measure the theoretical constructs and five-point Likert scales with end points of "strongly disagree" and "strongly agree" were used to measure the items. A test of the resulting questionnaire was conducted on two groups of subjects: colleagues and target respondents. These two tests were conducted independently and led to improvement and update of the survey instrument. The target sample frame consisted of Italian Medium and High Tech companies selected according to the international OECD science classification. 500 firms were randomly selected from all the AIDA (2009) companies with more than 50 employees and covering the specific two-digit ATECO (2007) codes 20, 21, 25, 26, 27, 28, 29, 30, 32. Analysed sectors include the areas reported in Table 1a.

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. Of the 500 surveys mailed in Italy, 112 responses were received, resulting in a response rate of 22.4%. 16 responses were discarded due to incomplete information, resulting in an effective response rate of 19.2%. Statistics about the number of employees in surveyed companies are reported in

Table 1b.

Please insert Table 1a and Table 1b.

Scale development

DI Search Capacity: domain and related sub-dimensions

Literature on the "Search" topic can be interpreted and reviewed accordingly to two main previously cited perspectives: *where* to search vs *how* to search. Contributions on the first perspective (*where)* mostly refer to the choice of knowledge boundary (internal and external), knowledge domain (market and technology), knowledge proximity (local and distant) and search intensity and scope (depth and breadth). Literature about the second one (*how)* instead investigates the organizational practices used for searching. These practices are behaviours and accompanying structures or processes that deal with search for innovation.

The focus of this work is on the successful behaviours, structures and processes which firms are experimenting to deal with search for DI. Thus, our unit of analysis is the search practice. For this purpose, the *how* view of DI literature seems more useful to map and systematize the practices since and an useful lens to be used is to refer to the macro activities of the search phase, considering that it resides at the early front end (FE) of the innovation process.

In this line, O`Connor (2008) suggests taking an holistic view when studying a (radical innovation) capability as it develops from a complex system of interdependent elements. One aspect should not be analysed as isolated from the others. Therefore, we

reviewed early FE literature, adopting an holistic approach on search practices, in order to identify its domain and dimensions.

According to the early FE literature, activities can be broken up into two broad categories (Crawford and Di Benedetto, 2000): the first is about the process of Idea Generation while the second is related to the Idea Management. Idea Generation refers to identification and analysis of opportunities by environmental scanning (Flynn et al., 2003; Kim and Mauborgne, 2005), seeding ideas (Hargadon and Sutton, 2000; Gamlin et al., 2007), application exploration (Thongpapanl et al. 2008). It can occur inside or outside a business. Idea Management is the process of capturing, storing, and organizing ideas to be used in the late front end process. It can be used also for preliminary evaluations and screening of ideas and to diffuse them across the company (Gorski and Heinekamp, 2002; Van Dijk and Van den Ende, 2002). It integrates activities, such as generation of ideas, screening, collaboration and idea development, from the early and late FE of innovation.

Gassmann (2006) highlights some issues with the current literature on idea generation and management: among them, the need to integrate the two categories and the need to include knowledge management (KM), which is transversal to both the categories (Hargadon and Sutton, 2000; Flynn et al., 2003), in the fuzzy FE process. According to this last definition of the "*how-to-search"* dimension it is possible to identify in the literature a number of consistent themes within these interlinked categories. These dimensions are reported in Table 2 and further described in the following paragraphs together with preliminary evidence from case studies.

Please insert Table 2

Market learning

Market learning is related to lead users, experimentation, scouting for new ideas, 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 (Von Hippel, 2005; Von Hippel et al. 2011). 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 watched and monitored. Through this process emergent trends, potential designs can be explored and refined in a continuing learning process.

Another effective way of creating and exploring alternative futures is through scenario-based approaches (de Geus, 1996). Companies have also 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.

Finally, 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 (Kelley et al. 2001).

Openness to external sources

This component is related to the practices which ensures insights from outside. It includes sources such as universities (Tennenhouse, 2004), licensing (Chesbrough, 2004), other companies, alliances (Phillips et al. 2004) and also web 2.0. Increasingly there are professional organizations who offer focused search capabilities– for example, in trying to pick up on emerging cool trends among 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 ideas – and providing a rich source of early warning signals (www.innocentive.com). Websites can also be employed as online laboratories for conducting experiments or prototype testing (www.secondlife.com). The potential of adver-gaming is being explored, for example, by US clothing retailer American Apparel which opened a virtual store whilst IBM has set up offices at several locations.

Managing (radical) idea generation

Another component of search is related to the company-wide system to capture ideas,

corporate intrapreneurship, management support to come forward with ideas. Managing idea generation is interrelated with the other two categories and spans from both inside and outside the company`s boundaries. Idea hunters (Leifer et al., 2000) and dedicated teams (Van Dijk and Den Van, 2002).

Organisation are often already over-stressed, and lack resources for new and different search activities. In order to amplify search capacity is useful making a better or different use of existing resources: for example, refocusing the core tasks of groups like procurement, sales or finance staff to pick up peripheral information about trends in the wider world. Another element in mobilizing the mainstream is the use of multiple stakeholders –players who may not always share the same values or indeed who may be opposed to the core business model (their objections and concerns act as a stimulus for new directions).

Corporate entrepreneuring includes various ways of mobilising high involvement innovation across the organisation. Sometimes called 'intrapreneurship', it attempts to build on ideas generated within and across the organisation to move it into new areas. Creating the culture to enable this is not simple, it requires a commitment of resources but also a set of mechanisms to take bright ideas forward, including various internal development grants, venture funding processes, strong incentive schemes Entrepreneurs offer a powerful route to new ideas but they also provide an implementation pathway to make sure those ideas get taken forward. Many intrapreneurship programmes stress the importance of informal networking, bootlegging and other mechanisms to take ideas forward below the radar screen of formal corporate systems.

Network management system

The concept of a network management system for idea generation embraces sub-factors related to bringing together people with different knowledge sets and network ambassadors to help teams connect with other people company-wide.

Much innovation happens at the boundary between one knowledge set and another; not at the frontier of knowledge. The scope for transferring ideas from one sector to another is huge, and a powerful source of discontinuous innovation. Based on this assumption, much recent research work on networks and broking suggests that a powerful search strategy involves making or facilitating connections – 'bridging small worlds'.

Increasingly organizations are looking outside their normal knowledge zones, as they begin to pursue open innovation strategies. There is a clear message that networking, whether internally across different knowledge groups, or externally, is one of the big management challenges of the 21st Century. Some organizations use social networking analysis and other tools to map their networks and spot bridges – this is a source of a growing professional services (IDEO, for example, is specialized in making and facilitating connections).

Creating diversity of vision by hiring different skills and experience sets is a key strategy in this field, as well as creating heterogeneous groups and teams within the firm. A variation on this theme is to collaborate with 'strange' partners to learn new perspectives. One of the interesting observations about close working relationships between firms is that, in terms of innovation, sometimes 'the ties that bind become the ties that blind'.

Item generation, content and face validity

Once the DI Search space was defined and a priori dimensionality postulated, it was necessary to generate a pool of items – the search practices – that scaled each dimension. A total of 28 items (practices) were generated from both the literature that sampled the domains of the four postulated dimensions and the 80 case studies developed by the DILab scholars. These practices do not yet have the character of 'routines' but are rather indicators of emerging patterns and trajectories around which such routines may form. In fact, the process of developing and codifying routines for discontinuous conditions still require extensive experimentation – learning though trial and error, leading to a relatively structured set of approaches for dealing with innovation in complex environments. Table A in appendix provides details of the practices used to scale each dimension.

The initial pool of items was then subject to an expert panel review to enhance content validity. The content validity of an instrument aims to demonstrate that the empirical indicators are logically, as well as theoretically, connected to the construct (Nunnally, 1978; Pedhazur and Schmelkin, 1991). The content validity test is not numerical, but subjective and judgmental (Emory, 1980). It is usually assumed to be established grounding constructs and measurements in the existing literature and pre-testing the measurement instrument before the collection of data further validated it. In the article, we built on a literature review and DILab case studies to define the conceptual framework, the measurement focus and specific items. moreover researchers and experts were asked to review and validate the questionnaire for structure, readability, ambiguity, and completeness. The final survey instrument incorporated several changes due to the validation process.

Please insert Figure 2.

To summarize, Fig. 2 illustrates our conceptualization of DI search capacity, related dimensions and their relationships with underlying practices. *DI Search capacity* is a multidimensional (second order) construct that is formed by four main underlying dimensions: market learning, managing (radical) idea generation, network management system, openness to external sources. Search dimensions are modeled as a first-order latent construct (factor) consistent with their conceptualization as a "bundle of practices".

Construct validation

Construct validation is a multifaceted process that consists of three basic steps (Fig. 3): content validity, construct validity and nomological validity. In particular, the validation process presented in this article follows the general methodologies presented by O'Leary-Kelly and Vokurkar (1998) and Chen and Paulraj (2004).

Please insert Figure 3.

After the content validity of the instrument was established, a three-stage CFA continuous improvement cycle was adopted for assessing the construct validity and unidimensionality of the instrument (Ahire et al., 1996; O'Leary-Kelly and Vokurka, 1998):

- firstly, a Cronbach's alpha value was generated for each construct. Constructs were selected according to a threshold of 0.7 (Flynn et al., 1994) while the other

constructs with an acceptable Cronbach alpha of at least 0.6 were further evaluated for the possibility of improvement. Items that contributed least to the overall internal consistency were considered for exclusion using the inter-correlation matrix (items that negatively correlated as also, items with a correlation value below 0.10 were discarded). Then constructs that failed to achieve the minimum alpha value of 0.60 have been discarded.

- the second stage involved an exploratory factor analysis (EFA) using principal component analysis and the commonly recommended method of varimax rotation with Kaiser normalization (Loehlin, 1998). The exact number of factors were fixed according to the theoretical framework. Indicator items were discarded after comparing their loading on the construct they were intended to measure, to their loading on other scales. In the same way, also indicators which did not load on the factor they intended to measure were excluded.
- in the final step, a confirmatory factor analysis (CFA by AMOS) was applied in evaluating construct validity and unidimensionality. Indicator items were eliminated from further consideration if their features do not belong to the selected threshold. More details about this phase are presented in the next sections.

The three-stage continuous improvement cycle was reiterated until the theoretical constructs exhibited acceptable levels of reliability, validity, and unidimensionality.

Construct validity

Reliability was tested using the internal consistency method that is estimated using Cronbach's alpha (Cronbach, 1951; Nunnally, 1978; Hull and Nie, 1981). Typically, reliability coefficients of 0.70 or higher are considered adequate (Cronbach, 1951;

Nunnally, 1978). Nunnally (1978) further states that permissible alpha values can be slightly lower (0.6 or less) for newer scales. The constructs reported in this analysis can be certainly considered as news in the field.

As can be seen from table 5, Cronbach's alpha values of three factors were well above the cut-off value and ranged from 0.7 to 0.85 while the other one is lower. We consider these results reflecting quite good psychometric properties for the constructs since they belong to a very new measurement scale.

Assessing unidimensionality means determining whether or not a set of indicators significantly reflect one, and only one construct (Gerbing and Anderson, 1988; Droge, 1997). There are two common methods for assessing the unidimensionality: exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) (Pedhazur and Schmelkin, 1991). In this study it was tested by the use of CFA as superior technique for assessing unidimensionality as stated by O'Leary-Kelly and Vokurkar (1998).

Unidimensionality was established by assessing the overall model fit of the general model by AMOS. Table 3 presents the details of the results. As recommended, multiple fit criteria were used (Bollen and Long, 1993; Tanaka, 1993). All the selected indexes respect the goodness threshold for a very good fit so that the test can be considered successful.

Please insert Table 3.

Testing of construct validity means also to assess both convergent validity and discriminant validity. Convergent validity measures the similarity or convergence between the individual items measuring the same construct. Discriminant validity measures the extent to which the individual items of a construct are unique and do not measure any other constructs. In this study, we chose CFA in order to test both convergent and discriminant validity since it is considered a more powerful tool and requires fewer assumptions than the traditional Campbell and Fiske MTMM matrix method (O'Leary-Kelly and Vokurkar, 1998).

Using CFA, the convergent validity is considered verified if individual item's path coefficient is greater than twice its standard error (Gerbing and Anderson, 1988), alternatively by examining the loadings and their statistical significance through t-values (Dunn et al., 1994). It is verified when the factor loadings of each construct are significantly high. Evidence of a successful test are show in table 5.

Discriminant validity is established (after convergent validity) verifying that correlations for all possible pairs of latent constructs is significant different from 1. These models were run on each selected pair, (1) allowing for correlation between the two constructs, and (2) fixing the correlation between the constructs at 1.0. A significantly lower $\chi 2$ value for the model in which the trait correlations are not constrained to unity would indicate that the traits are not perfectly correlated and that discriminant validity can be inferred (Anderson, 1987).

Six model tests were performed to assess discriminant validity among the 4 constructs. Table 4 reports the results and shows that all the differences, with exception of one significant at the 0.05 level, are significant over the 0.01 probability level so that the discriminant validity of constructs can be confirmed.

Please insert Table 4.

The refined model, resulting after the testing procedure, is reported in the AMOS scheme. Eleven of twenty-eight items were retained in the tested constructs, details about the AMOS-based CFA are reported in table 5.

Please insert Table 5.

Nomological and predictive validity

Finally, nomological validity was investigated. It assesses to what extent does the developed measurement operates within a set of theoretical constructs and their measurements (Netemeyer, et al., 2003). In other words, we tested if the developed construct behaves as expected with respect to other constructs to which it is theoretically related.

Previous studies highlighted that one of the outcomes of DI Search Capacity is the exploration/creation of new knowledge/competence (Attuahene and Gima, 2005). Therefore, we included measures for knowledge-competence exploration (KW_EXP) in our analysis in order to test Nomological and Predictive Validity by checking the existence of significant correlation patterns. Table B in appendix reports the operationalization of the KW_EXP construct.

First evidence of Nomological validity is confirmed by strong and significant correlations between the four dimensions of DI Search Capacity construct and Knowledge-Competence Exploration (table 6).

Please insert Table 6.

Furthermore, we also tested a structural model that related DI Search to knowledge exploration. As predicted, we found that DI Search construct has a significant positive effect on knowledge-competence exploration (KW_EXP) (standardized structural estimates: Correlation .65, with $p < 0.001$). The model exhibits a very good fit to the data with $\chi 2 = 93{,}897$ (df = 85), $\chi 2/df = 1.1$, NNFI or TLI=. 973, NFI= .84, IFI=.98, CFI = .98, PNFI= .595, PCFI=.695 and RMSEA = .034. As a consequence, we can conclude that the construct has sufficient Nomological and Predictive Validity.

Test results

The testing procedure allowed refining the constructs (Fig. 4): 17 items were deleted in order to improve reliability of the underlying theoretical constructs. Many items were removed from the constructs "Market Learning" and from "Idea Generation Management". These constructs singly presented a good reliability but in the original configuration they failed to assess convergent and discriminant validity so that modifications were necessary. Many indicators seem to share variance with other construct and also EFA showed a not well defined factorial structure so that they were refined and simplified. Most likely these problems are influenced by the novelty of the research field which has not yet achieved a consolidated taxonomy.

Please insert Figure 4.

Conclusions and limitations

This article explores the components of DI Search and creates for the first time measures for it through scale development and modelling. The underlying items were identified based on a review of literature across diverse disciplines and more than 80 case studies reported by DILab researchers. A SEM-based CFA was chosen to perform the test, as it is considered a more powerful tool than factor analysis and traditional techniques to check unidimensionality, convergent validity, discriminant validity and construct reliability (Lu et al., 2007). The validity of the DI Search Capacity construct was analysed and tested through an iterative development and purification process as proposed by Chen (2004).

The result of the study is a preliminary set of reliable, valid, and unidimensional measurements of DI Search capacity that can be used in different contexts to refine or extend conceptualization and measurements or to test various theoretical models for theory building in innovation management. The construct in its actual configuration offers a good support of the measurement proprieties, so that we hope it will be adopted by other researchers both directly in their studies and as a basis for future refinement.

This study also provides managers a preliminary and potentially useful tool with which to assess their companies strengths and weaknesses in regard to DI Search Capacity. Further developments of the proposed measures could make it possible to compare a firm's capability to those of other firms, providing a basis for determining where improvements are needed or desirable. Thus managers can creatively leverage these capabilities by defining and exploring ways to integrate the four DI search dimensions.

As for research limitation, we should state that DI Search Capacity is as yet a new and not consolidated construct in innovation management field. As several

indicators were removed from the original construct the final measurement model should just be considered as a preliminary measurement instrument requiring further improvement. Future studies should extend this constructs by including other appropriate measures and dimensions, refine and strengthen the existent ones by adding items, specifically for the categories Openness for external sources and Idea Generation Management.

Another major limitation of the study concerns the population: sample consists of Italian firms from some specific (medium-high tech) sectors. So the extent to which results can be generalized is somewhat limited by the sample feature and the sampling process. An extension of the validation sample in other countries is also desirable, as well contextual analysis finalized to investigate cultural, geographical or other relevant differences.

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Appendix

Please insert Table A

Please insert Table B

Table 1a. Business sectors in the sample

HIGH-TECH	Aerospace	3%
	Computers, office machinery	10%
	Electronics-communications	3%
	Pharmaceuticals	10%
MEDIUM-HIGH TECH	Scientific instruments	3%
	Motor vehicles	9%
	Electrical machinery	22%
	Chemicals	15%
	Other transport equipment	3%
	Non-electrical machinery	22%

Table 1b. Number of employees of companies in the sample.

HIGH-TECH	Aerospace	3%
	Computers, office machinery	10%
	Electronics-communications	3%
	Pharmaceuticals	10%
MEDIUM-HIGH TECH	Scientific instruments	3%
	Motor vehicles	9%
	Electrical machinery	22%
	Chemicals	15%
	Other transport equipment	3%
	Non-electrical machinery	22%

Table 2. Search domain

DIMENSION	MEASUREMENT FOCUS	MAIN REFERENCES
Idea generation		
Market learning	Emphasises on practices such as lead users, experimentation, unconventional tools	Lynn et al. (1996); O`Connor (1998); O`Connor and Veryzer (2001); Thomke (2001); Von Hippel and Katz (2002); Christensen et al. (2005); Tidd et al. (2005); Kim and Mauborgne (2005); Heinerth (2006);
Openness to external sources	Emphasis on practices that enable the search breadth	Chesbrough (2003a,b); Chesbrough (2004); Tennenhouse (2004); Phillips et al. (2005); Gassmann (2006); West and Gallagher (2006)
Idea management & knowledge management		
Managing idea generation	A system for capturing ideas should look both inside and outside the organization. Emphasis on idea hunters, dedicated teams	Hargadon and Sutton (2000); Leifer et al. (2000); Flynn et al. (2003); Andriopoulos and Gotsi (2005); Hamel (2006)
Network management system	Emphasis on practices related to internal organization	Hargadon and Sutton (2000); O`Connor and McDermott (2004); O`Connor et al. (2008); Kelley et al. (2010)

Table 3. Model fit indices

Index	Value	Recommended values for a good fit	Recommended values for very good fit	Sources
χ^2	58.5	-	-	-
RMSEA	0.07	< .08	< .05	Byrne (1998)
NFI	0.85	>.8	> .9	Byrne (1998); Zhang et al. (2002)
N-NFI or TLI	0.91	>.8	> .9	Byrne (1998); Zhang et al. (2002)
CFI	0.95	>.8	> .9	Byrne (1998); Zhang et al. (2002)
IFI	0.95	>.8	> .9	Byrne (1998); Zhang et al. (2002)
PNFI	0.52	-	> .5	Mulaik et al. (1989); Byrne (1998)
PCFI	0.57	-	> .5	Mulaik et al. (1989); Byrne (1998)
χ^2/df	1.46	>1 and <5	>1 and <3	Jöreskog, 1969; Carmines and McIver (1981); Bollen (1989); Hair et al. (1995)

Table 4. Assessment of discriminant validity: chi-square differences between fixed and free models

	Market learning	Idea generation management	Network management system	Openness to external sources
Market learning	-			
Idea generation management	9.55 **	-		
Network management system	11.49 ***	6.28 *	-	
Openness to external sources	17.93 ***	6.33 *	12.95 ***	-

* significant at the 0.05 level, ** at the 0.01, *** at the 0.001 level (for 1 d.f.).

Table 5. AMOS-based CFA

	Measurement model				
	Principal component factor loading	Standard coefficient	Un-standard coefficient	R^2	t-value[2]
MARKET LEARNING	(α = 0.77; eigen value = 1.08)				
MKT_6	0,60	0,61	0,78	0,37	4,98
MKT_7	0,77	0,72	0,99	0,51	5,96
MKT_9	0,73	0,73	1,00	0,53	
MKT_10	0,67	0,72	0,87	0,52	5,96
IDEA GENERATION MANAGEMENT	(α = 0.70; eigen value = 1.04)				
MNG_2	0,64	0,70	1,00	0,49	
MNG_3	0,71	0,75	0,99	0,56	5,74
NETWORK MANAGEMENT SYSTEM	(α = 0.82; eigen value = 4.86)				
NET_2	0,73	0,77	0,85	0,59	6,92
NET_3	0,76	0,81	0,92	0,66	7,26
NET_4	0,87	0,77	1,00	0,59	
OPENESS TO EXTERNAL SOURCES	(α = 0.54; eigen value = 0.83)				
OPEN_4	0,74	0,59	1,00	0,34	
OPEN_6	0,80	0,64	0,92	0,40	2,96

Table 6. Correlations among the four dimension of DI Search and KW_EXP

	Knowledge_exploration
Market learning	0.53***
Idea generation management	0.60***
Network management system	0.56***
Openness to external sources	0.40***

Table A: Construct operationalization for DI Search practices

CONSTRUCT	ITEM	DESCRIPTION
Market learning MKT	MKT1	It 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 analyses 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.
Managing radical idea generation MNG	MNG1	The company has teams dedicated to research and implementation of strategically relevant ideas for new business.
	MNG2	We encourage people to come forward with ideas, even if they have only a vague idea of the potential market applications for the idea
	MNG3	Our organization supports corporate entrepreneurship as part of our Discontinuous Innovation efforts.
	MNG4	There is a centralized system for managing ideas, available throughout the enterprise, which each employee can submit ideas and receive feedback on which.
	MNG5	There is a financing system designed to support radical innovation projects.
	MNG6	In R & D budgets are sufficient resources dedicated to exploring new technologies that could potentially lead the company beyond its existing products and markets.
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 that enable the 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
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, which 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 (eg. 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, along with long-term strategic alliances and consolidating, developing short-term technology partnerships with other companies

Table B. Operationalization for KW_EXP construct

KW_EXP Knowledge-Competence exploration (Zahra, Ireland, and Hitt 2000; Atuahene-Gima, 2005)	– Acquired manufacturing technologies and skills entirely new to the firm – Learned product development skills and processes (such as product design, prototyping new products, timing of new product introductions, and customizing products for local markets) entirely new to the industry – Acquired entirely new managerial and organizational skills that are important for innovation (such as forecasting technological and customer trends; identifying emerging markets and technologies; coordinating and integrating R&D; marketing, manufacturing, and other functions; managing the product development process – Strengthened innovation skills in areas where it had no prior experience

Figure 1. Research design

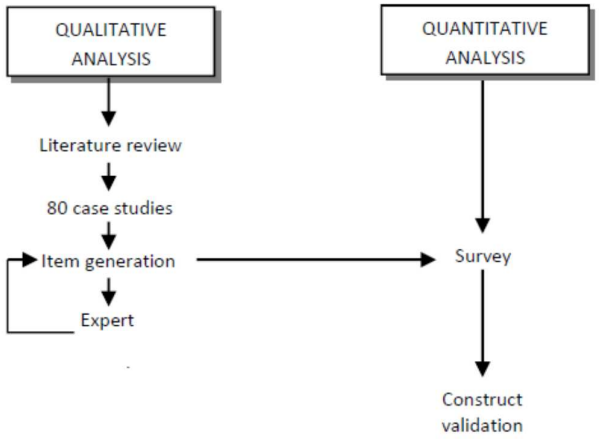

Figure 2. Second-order factor model for measuring search capacity

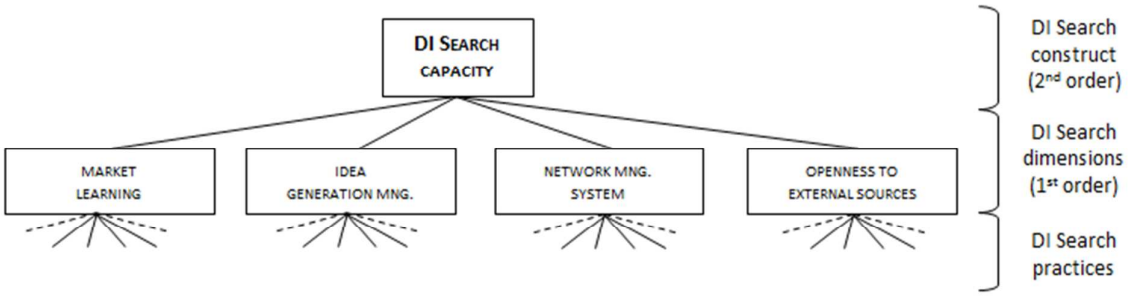

Figure 3. Construct validation process (source: O'Leary-Kelly and Vokurkar, 1998).

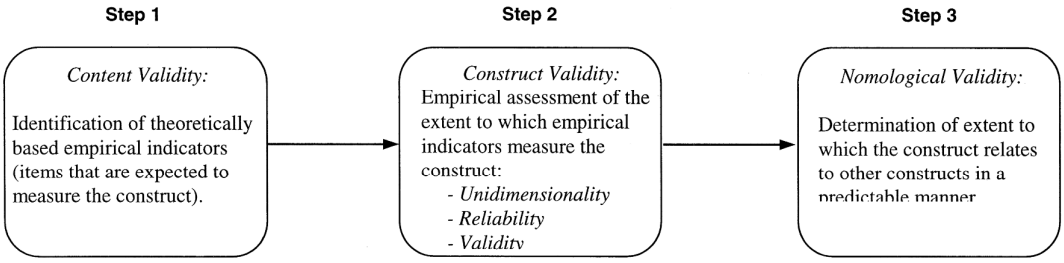

Figure 4. Structural model test