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How do established firms improve radical innovation performance? The organizational capabilities view

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ABSTRACT

The paper examines organizational capabilities for improving performance, with respect to radical innovation (RI), in established firms. These organizational capabilities are (1) openness capability, (2) autonomy capability, (3) integration capability and (4) experimentation capability. The paper proposes four research hypotheses, to examine the relationship between four types of organizational capabilities and radical innovation performance. A dataset of 112 corporate RI-specific capabilities and innovation performance data, from the top 500 Taiwanese manufacturing firms, is collected via a postal questionnaire survey. The multiple regression results reveal a positive relationship between organizational capabilities and radical innovation performance. Finally, some managerial recommendations, to develop radical innovation capabilities, are provided.

1. Introduction

It is well documented that managing radical (or discontinuous/breakthrough) innovation is quite different from managing incremental (continuous) innovation (Watts, 2001; Phene et al., 2006; Junarsin, 2009; Koen et al., 2010). While dealing with radical innovation, established firms fall behind start-ups, in the introduction of radical innovations, because established firms may have inappropriate structures and systems, such as myopic and limited searching (Watts, 2001; Junarsin, 2009), insufficient planning framework and evaluating methods (Stringer, 2000; Watts, 2001; McDermott and O'Connor, 2002; Birkinshaw et al., 2007), rigid organizational routines and culture (Stringer, 2000; Watts, 2001; Philips et al., 2006; Birkinshaw et al., 2007; McLaughlin et al., 2008; Junarsin, 2009), incorrect staffing, compensation and rewarding systems (Stringer, 2000; Watts, 2001; Birkinshaw et al., 2007) and a reluctance to experiment in unknown territory (Lynn et al., 1996; O'Connor and McDermott, 2004; Junarsin, 2009; Eisenberg, 2010). Moreover, this paper does not study competition at radical innovation between new entrants and incumbent firms. Instead, this paper examines radical innovation capabilities and performance between incumbent firms.

To improve radical innovation in established firms, many studies have concentrated on the various mechanisms for introducing radical innovation in established firms, via projects and programs (O'Connor and Ayers, 2005; Kelly, 2009), lead-user research (Heiskanen et al., 2007; Eisenberg, 2010), artistic involvement (Stuer et al., 2010), new forms of networks (Birkinshaw et al., 2007) and internal and corporate ventures (Stringer, 2000; Maine, 2008; Junarsin, 2009). It was suggested that established firms could adopt probing and adaptive learning (Lynn et al., 1996; Stringer, 2000; Kelly, 2009), adapt their strategic planning (Stringer, 2000; McDermott and O'Connor, 2002; Junarsin, 2009), become ambidextrous organizations (Stringer, 2000; Philips et al., 2006; McLaughlin et al., 2008), use appropriate scanning and evaluation processes (Stringer, 2000; Gassmann and Zeschky, 2008; Junarsin, 2009) and establish corporate venture funds (Stringer, 2000), in order to cultivate and support radical innovations. Despite the fact that there are many organizational mechanisms and developmental procedures for the improvement of performance in radical innovation, in established firms, *the relationship between organizational capabilities and radical innovation performance* is largely neglected. What are the organization's

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capabilities in searching for, planning, organizing, cultivating and experimenting in radical innovation? How do these types of organizational capabilities influence the corporate radical innovation performance? This paper aims to answer these questions.

Based on organizational capability theory and the innovation capability view, the paper develops the organizational capabilities necessary for radical innovation that is a firm's ability to search, plan, organize and experiment in radical innovation. The radical innovation capabilities, including the ability to search (openness capability), plan (strategic integration capability), tolerate (autonomy capability) and commercialize (experimentation capability) radical innovation are elaborated upon. From a questionnaire survey, a dataset of 112 corporate organizational capabilities and innovation performance data, from the top 500 Taiwan manufacturing firms was collated. The paper not only theoretically develops the organizational capabilities for radical innovation but also empirically examines the relationships between four types of organizational capabilities and radical innovation performance.

The paper has the following structure. Section 2.1 defines radical innovation. Section 2.2 identifies five major organizational inertia-prohibiting established firms that have introduced radical innovation. Section 2.3 develops the notion of organizational capabilities for developing and facilitating radical innovation. Section 2.4 proposes four research hypotheses, to examine the relationship between organizational capabilities and radical innovation performance. The questionnaire design, response rate, measures and validity and reliability are described in Section 3. The research results are presented in Section 4. The results are discussed in Section 5. Finally, some managerial implications are made.

2. Organizational inhibitors and capabilities for radical innovation

2.1. *Definition of radical innovation*

The definition of radical innovation has long been debated. Linton (2009) identified a potential source of confusion, in that the language of innovation appears to be dependent on the perspective from which an innovation is considered. It is crucial to clearly state the perspective from which you are considering innovation (technological innovation or social innovation) and to clearly identify the level and unit of analysis (e.g., a process innovation, a product innovation, an individual, a firm, an industry or a supply chain) under consideration (Linton, 2009, 730–731).

Many definitions of radical innovation have been proposed. These definitions apply to different dimensions of innovation: (1) the degree of change in technology and the market, (2) the process of radical innovation and (3) the impacts on existing products and business. Based on a series study of the Radical Innovation Research Program, conducted in the US, Leifer et al. (2000) defined radical innovation as ‘‘involving commercialization of products based on significant *leaps* in technological development, with the potential for *entirely* new features and improvement in performance or cost, compared with the existing substitutes’’. This definition is in agreement with that of Linton (2009), that the radical innovation should involve two dimensions: a significant leap in technological development (technical dimension) and a potential for entirely new features and improvement (social dimension). A radical innovation should not be a ‘‘new-to-the-firm’’ innovation, but rather a ‘‘new-to-the-world’’ innovation.

Henderson and Clark (1990) proposed two dimensions, to define types of technological innovation: an innovation's impact on components and its impact on the linkages between components. Radical innovation creates a new dominant design and, hence, a *new* set of core design concepts embodied in components that are linked together in a *new* architecture. In other words, both the components and the linkages between components are significantly changed by a radical innovation. Verganti (2008) also pointed that radical innovations change technological and socio-cultural meanings of products. One of the radical innovations in integrated circuit technology is the emerging system-on-a-chip technology, which not only changes the interconnection between components, but also changes the functionality and capacity of each component.

Chandy and Tellis (1998) categorized innovation using *technology* and *market* dimensions and defined radical innovation as involving substantially different technologies while at the same time offering a substantial increase in customer benefits. Linton (2009) argued that each innovation involves two dimensions of innovation: technical innovation and social innovation. Technical innovation might involve changes to technical processes and products. Social innovation might involve in the introduction of new social systems, such as stock market, patent systems. In summary, this paper could easily consider radical innovation, discontinuous innovation and breakthrough innovation as interchangeable concepts. With regard to the impact of radical innovation on current mainstream businesses, Kanter et al. (1991) suggested that successful radical innovations should not only create new business ventures, but also contribute to the revitalization of current mainstream businesses.

2.2. *Organizational inhibitors/inertia for radical innovation in established firms*

McLaughlin et al. (2008, 300) argued that ‘‘established companies often lose the propensity to be innovative, as some of the cultural enablers of previous incremental changes become the current cultural inhibitors of radical innovation’’. Stringer (2000, 72) also argued that ‘‘most large firms are poorly equipped to implement a growth strategy based on radical innovation, because most large firms are ‘*genetically*’ programmed to preserve the status-quo’’. In other words, these large firms don't have the right organization, culture, leadership practices, or personnel, to implement radical innovation. It is well documented that many organizational inhibitors impede established firms to recognize, plan, evaluate, organize and experiment in radical innovation. These organizational inhibitors can be categorized into five types: (1) limited organizational searching (Watts, 2001; Junarsin, 2009); (2) insufficient organizational planning framework and evaluation tools (Stringer, 2000; Watts, 2001; McDermott and O'Connor, 2002; Birkinshaw et al., 2007); (3) rigid organizational routines and culture (Stringer, 2000; Watts, 2001; Philips et al., 2006; Birkinshaw et al., 2007; McLaughlin et al., 2008; Junarsin, 2009), (4) incorrect staffing, compensation and reward systems (Stringer, 2000; Watts, 2001; Birkinshaw et al., 2007) and (5) a reluctance to experiment in unknown territory (Lynn et al., 1996; O'Connor and McDermott, 2004; Junarsin, 2009; Eisenberg, 2010) and networks (Birkinshaw et al., 2007).

First, *limited organizational searching* is one of the inhibitors of radical innovation (Watts, 2001; Junarsin, 2009). The fruits of discontinuous innovation are uncertain, hard to understand and typically slow to emerge. The new offering typically comes together in a fragmented and apparently ad hoc manner, so that many firms give up along the way and fall back on their investments in more incremental, but predictable projects (Birkinshaw et al., 2007). Established firms tend to devote too much resources to internal R&D and existing networks, rather than external sources and emerging networks (Stringer, 2000;

Birkinshaw et al., 2007). This inward and *myopic searching* (March, 1991) prevents established firms from recognizing the new ideas and products necessary for radical innovation. Established business leaders cannot ‘‘see’’ the long-term potential of the new technology, because the very basis of competition changes (Stringer, 2000). Relying on ever-larger internal R&D budgets to keep abreast all of the potential breakthrough ideas have not worked in the past (Stringer, 2000).

The second inhibitor is *insufficient organizational capabilities to plan and evaluate* radical innovation (Stringer, 2000; Watts, 2001; McDermott and O’Connor, 2002; Birkinshaw et al., 2007). Traditional short-term biased methods for the evaluation of a portfolio of internal R&D projects (e.g., discount cash flow analysis, predictable and stable financial objectives and the stage-gated models for project control) also serve to inhibit the commercialization of radical innovation (Stringer, 2000; Watts, 2001). Radical innovation is often high-risk and offers a potentially high return, so it does not respond well to the management practices more suited to incremental innovation activities (McDermott and O’Connor, 2002).

The third inhibitor is *rigid organizational routines and culture.* Established firms find it difficult to break out of established and hitherto successful routines. Their existing structures and processes are organized around a historically determined set of customers and products and their reward and incentive systems are geared towards maintaining and improving the established system (Birkinshaw et al., 2007). Bureaucratic structures discourage the introduction of breakthrough, or radical innovations to market (Stringer, 2000). Mature companies often lose this propensity to be innovative, as some of the cultural enablers of previous incremental changes become the current cultural inhibitors of radical innovation (McLaughlin et al., 2008).

Junarsin (2009) argued that the incumbents tend to have organizational inertia and a fear of change, since current systems and procedures have helped shape the competitive advantage, making them complacent and resistant to changes. The incumbents benefit from the current *structured routines,* in terms of cost efficiency and quick information acquisition. However, as an era of turbulence arrives, the routines hinder their abilities to select and acquire new information and knowledge. In other words, the core competencies in incremental innovation become ‘‘core rigidities’’ in radical innovation (Leonard-Barton, 1992).

The fourth inhibitor is an *incorrect staffing, compensation and rewarding system*. A lack of motivational capabilities, such as social skills, prevents established firms from attracting, nurturing and motivating creative employees (Stringer, 2000). Watts (2001) emphasized that salary-based and fairness-emphasized compensation and internal staff re-use are the major barriers to the development of radical innovation, in established firms.

The fifth inhibitor is a *reluctance to experiment in unknown territory*. The process of understanding markets, from the point of view of radical innovation, is fundamentally unique; it is far more experimental and far less analytical than a conventional process (Lynn et al., 1996, 33). The development of a radical innovation becomes a process of successive approximation, probing and repeated learning, each time striving to become one step closer to a winning combination of product and market (Lynn et al., 1996, 19). Consequently organizations that seek to develop radical innovation capabilities move into unknown territory and experiment with new processes that largely elude systemization (O’Connor and McDermott, 2004; Taylor and Greve, 2006).

2.3. Organizational capabilities for radical innovation

Adler and Shenhar (1990) defined innovation capability as the ability to *develop, respond and identify* new processes, products and services. Damanpour (1991, 555) defined organizational innovation as the adoption of innovation in organizations that *generates, develops and implements* new ideas and behaviour. Burgelman et al. (2004, 11) defined innovative capabilities as *the comprehensive set of characteristics* of an organization that *facilitate and support* innovations. Burgelman et al. (2004) further defined innovative capacities in terms of *formulating* (e.g., *forecasting, planning and allocating*) capacities and *implementing* (e.g., *organizing and commercializing*) capabilities. Yam et al. (2004) defined technological innovation capacity in terms of learning, R&D, resource allocation, manufacturing and marketing and strategic management capacities.

Absorptive capacity is an element of innovative capability. Cohen and Levinthal (1990) defined absorptive capacity as a firm’s ability to *recognize* the value of new external information, *assimilate* it and *apply* it to commercialized ends. Innovation capabilities are one type of dynamic capability. Teece (2007) defined dynamic capabilities as a firm’s ability to *sense, seize and reconfigure* internal and external competence, to address a rapidly changing environment. It is important to regard innovation capabilities as a comprehensive set of organizational capabilities that facilitate firms to recognize, seek out, learn, organize, apply and commercialize innovative new ideas, processes, products and services (Adler and Shenhar, 1990; Burgelman et al., 2004; Yam et al., 2004; Tasi and Tasi, 2010).

In additional to organizational innovation capacities, a firm’s innovative capabilities are different, when they are engaged in the different types of innovation- incremental innovation and radical innovation. Both types of innovation are different from organizational learning (exploration vs. exploitation), strategic management (adaptation vs. alignment) and organizational design (organic or mechanic). Firms engaged in incremental innovation tend to focus on exploitative, efficient, and aligning activities; whereas firms engaged in radical innovation tend to focus on exploration, flexibility-enhancing, and adaptive activities (Burns and Stalker, 1961; Burgelman, 1991; March, 1991; Roussel et al., 1991). By applying the concept of innovation capabilities, detailed above, the organizational capabilities necessary for radical innovation are a firm’s ability to seek out, integrate, tolerate and experiment with new products, processes and services, for non-mainstream businesses.

Recently, many studies have examined various ways of introducing radical innovation, in firms, via projects and programs (O’Connor and Ayers, 2005; Kelly, 2009), users (Heiskanen et al., 2007) and artists (Stuer et al., 2010) and internal ventures (Maine, 2008). Some studies have examined how firms can strategically manage radical innovation (Stringer, 2000; McDermott and O’Connor, 2002). O’Connor and Ayers (2005) proposed the three-stage model of radical innovation capabilities: from *discovery* capability, through *incubation* capability, to *acceleration* capabilities. Miron-Spektor et al. (2011) found that creative and conformist members in a team enhanced team radical innovation. The discovery capability is the ability to create, recognize, elaborate and articulate opportunities. These discovery activities can be internally focused, but may also be sourced *outside* the company. *Incubator* capability turns opportunity into investigable business propositions. The primary skill for incubation is experimentation. Acceleration capability allows *exploiting* and *commercializing.*

Consequently, radical innovation capability can be regarded as a firm’s ability to explore, adapt, tolerate and experiment with new products, processes and services for non-mainstream businesses. By combining the findings of existing organizational innovation capability studies, we can divide radical innovation capabilities into four types of capabilities: searching openness capability, strategic integration capability, tolerating and cultivating (e.g., autonomy) capability and experimentation capability. With reference to the discovery capability, incubation capability and acceleration capability, proposed by O'Connor and Ayers (2005), the openness capability is equivalent to the discovery capability; integration capability and autonomy capability are similar to incubation capability, and experimentation capability is the same as acceleration capability. Section 2.4 further discusses the relationships between the four radical innovation capabilities and their influences on innovation performance.

2.4. Organizational capabilities and radical innovation performance

2.4.1. Openness capability

Successful innovation requires the ability to harvest ideas and competencies from a wide array of sources. These diversified sources of innovative ideas are even more important to radical innovation (McLaughlin et al., 2008). Phene et al. (2006) suggested that this type of externally sourced knowledge determines the likelihood of the creation of a breakthrough innovation. Technologically distant knowledge, of national origin, has a curvilinear effect and technologically proximate knowledge, of international origin, has a positive effect on breakthrough innovation (Phene et al., 2006).

A firm's competitive advantage is not only dependent on in-house R&D, but also increasingly dependent on external technology sources. Due to the increasing complexity of technology and its shorter life cycle, not every firm can have all state-all-the-art technologies developed in-house. Firms that want to remain competitive in the market need to rapidly integrate internal technologies with external available technologies and launch the product on time (Iansiti, 1997).

Managing innovation as an opening in a firm's boundary is the key (Chesbrough, 2003a). Gradually, more and more firms have adopted the open innovation strategy. Procter and Gamble (P&G) pursued a "connect and develop" strategy that facilitates "illogical", "unpredictable" and "unobvious" connections. P&G implement an outside-in approach, in managing R&D organizations. The type of innovation partners should also be introduced into the analysis since firms rely for different kinds of innovations on specific knowledge sources and links. It seeks all of the possible connections of creative ideas and technologies available inside and outside of the firm and develops them into new products, to provide high customer value. Sakkab (2002) argued that a "connect and develop" strategy fosters breakthrough innovation in P&G products, packages and processes and significantly reduces products costs, improves quality and speeds product delivery.

Client involvement in the development process, at an early stage, is one of key success factors in managing the corporate new product development centre, in Raytheon (Kanter et al., 1991) and reducing customer's resistance to radical products (Heiskanen et al., 2007). Powell et al. (1996) studied the US biotechnology sector and concluded that firms with active collaborative networks, including involvement with new ventures and dedicated biotechnology firms, for the commercializing of radical innovation, are more innovative. By co-operating with artists, as a means to learn trans-disciplinary knowledge, firms increase the identification capability of radical innovation (Stuer et al. 2010).

By studying the types of firms in the US manufacturing sector that used universities as a source of innovation, Laursen and Salter (2004) found that firms that adopt an "open" search strategy and invest in R&D are more likely to draw innovation sources from universities. Based on data from the food processing industry, Ettlie et al. (1984) found that the adoption of radical packaging technology was significantly promoted by an aggressive technology strategy and a high degree of technical specialization, in firms.

Searching openness capability refers a firm's ability to search sources of radical innovation with external, distant and wider orientation rather than internal, local and narrow sources. With a higher degree of openness capability, firms tend to search for more information and knowledge from external and international sources (Srivastava and Gnyawali, 2011). Moreover, the openness capability indicates that the searching scope of radical innovation could be wider across industries, disciplines and stakeholders (e.g., artists, lead users). Consequently, this paper hypothesizes:

H1. *Organizational openness capability is positively correlated to radical innovation performance in established firms.*

2.4.2. Integration capability

Cabrales et al. (2008) suggested that the combined use of long-term and short-term incentives, based on results, is positively associated with more radical innovation. Kanter et al. (1991) found that clear R&D alignment and integration between corporate R&D centers and mainstream businesses may foster a firm's radical innovation performance. Radical innovation activities should be tightly coupled and perceived as co-produce (Kanter et al., 1991), or an integrated system (O'Connor and Ayers, 2005; Kelly, 2009) between corporate R&D and lines of businesses; otherwise the radical innovation performance will be sub-optimal.

The fine integration and alignment of corporate R&D units and existing lines of business is crucial to the commercialization of radical innovation. It is a crucial to transfer radical innovation from the R&D stage, generally in corporate research labs, to the manufacturing and marketing stages, in existing and new businesses. It is quite usual to find that the receiving business units are reluctant to divert resources to completing technical and market development of a radical innovation, given the uncertainty regarding the timing and magnitude of the eventual revenue stream. Consequently, in moving radical innovation from the R&D stage to manufacturing and marketing, in a received mainstream business, champions are needed to make the transition or "hand-over" smooth (Kanter et al., 1991; O'Connor and Ayers, 2005).

To remain successful over a long period, firms should create "ambidextrous organizations", as integration mechanisms that allow incremental innovation and radical innovation to coexist in the same firm (Tushman and O'Reilly, 1996). The first is dedicated to maximizing the value of the traditional technology and the other to commercializing radical innovation by corporate R&D centers/labs, or other independent entrepreneurial units (Stringer, 2000). Ambidextrous organizations create two different organizations, under one roof, to manage these different innovations. However, these two different innovation-supported organizations, in the same firm, do not work independently, but interdependently.

In a study to determine how Samsung successfully transformed its corporate R&D centres from development-based to research-based, Park and Gil (2006) identified close alignment between R&D units and business units, at the strategic planning stage, as one of the key success factors. By studying the corporate radical innovation programs in many multinational corporations, Kelly (2009) suggested that *strategic integration* allows radical innovation programs to create broader organizational connectedness with existing businesses (Kelly, 2009). Integration capability is regarded as a subset of the ability to integrate and align the organizational connectedness and ambidexterity of radical innovation with the mainstream business. Consequently, this paper hypothesizes:

H2. *Organizational integration capability is positively correlated to radical innovation performance, in established firms.*

2.4.3. Autonomy capability

A lack of clarity, or an ambiguity, in the project specification is likely to facilitate radical innovation (McLaughlin et al., 2008; Philips et al., 2006). An organizational culture equipped to support risk-taking, freedom and self-management encourages radical innovation to take place (McLaughlin et al., 2008). It is well documented that an autonomous culture, which fosters individuality, as well as creativity and tolerance of failure, supports the pursuit of radical innovation (Amabile, 1998; Sutton, 2001; O'Connor and McDermott, 2004). Consequently, Stringer (2000) suggested that firms could hire more creative and innovative people, to improve their innovativeness. Ekvall (2000) found that a creative climate, with autonomy and resources, could lead to higher organization innovativeness.

Cabrales et al. (2008) indicated that *team diversity* and the development of *risk-taking attitudes,* within a team, is positively associated with radical innovation. In his study of entrepreneurship climate, Hornsby et al. (2002) found that work discretion allows employees to take risks, make decisions in the work process and show a tolerance of failure, which are behaviours that lead to radical innovation (Hornsby et al., 2002; McDermott and O'Connor, 2002). Employees' perception of the availability of resources for entrepreneurial activities facilitates radical innovation. The availability of easily obtained resources usually encourages experimentation and risk-taking behaviors (Burgelman and Sayles, 1986). The organizational autonomy capability is a firm's ability to encourage and tolerate risky, ambiguous, unsuccessful radical ideas. Consequently, this paper hypothesizes:

H3. *Organizational autonomy capability is positively correlated to radical innovation performance, in established firms.*

2.4.4. Experimentation capability

It is well documented that a firm's ability to learn (Lynn et al., 1996; Philips et al., 2006; Kelly, 2009), to probe (Lynn et al., 1996; Philips et al., 2006) and to experiment with (Lynn et al., 1996; O'Connor and McDermott, 2004; McLaughlin et al., 2008; Junarsin, 2009) new ideas, new R&D, manufacturing/marketing tools, new disciplines and territories facilitates the introduction of radical innovation, in established firms. From the organizational culture view, McLaughlin et al. (2008) argued that supporting experimentation is one of the key cultural elements necessary for the support of radical innovation, in established firms. Based on studies of famous radical innovations, such as optical fibers in Corning, CT scanners in GE, cellular phones in Motorola, Lynn et al. (1996) found that probing and learning are two crucial ingredients to the introduction of radical innovation.

Probing is a firm's ability to experiment- to introduce an early version of radically innovative products to a plausible initial market. *Learning* is a firm's ability to learn about technology and determine whether and how it can be scaled up for the market, any potential applications, or segments, and exogenous factors. Development of a radical innovation becomes a process of successive approximation, probing and repeated learning, each time striving to become one step closer to a winning combination of product and market (Lynn et al., 1996, 19).

The process of understanding the markets for radical innovation is fundamentally different; it is far more experimental and far less analytical than conventional market testing (Lynn et al., 1996, 33). Lead-user research may be the best market research tool, for radical innovation (Junarsin, 2009). Eisenberg (2010) argued that the lead-user research method goes a step further, looking not only at the typical customer, but also at those users whose needs and preferences lead the breakthrough innovation. The lead-user research method provides a unique way to uncover rich information about emerging and future customer needs.

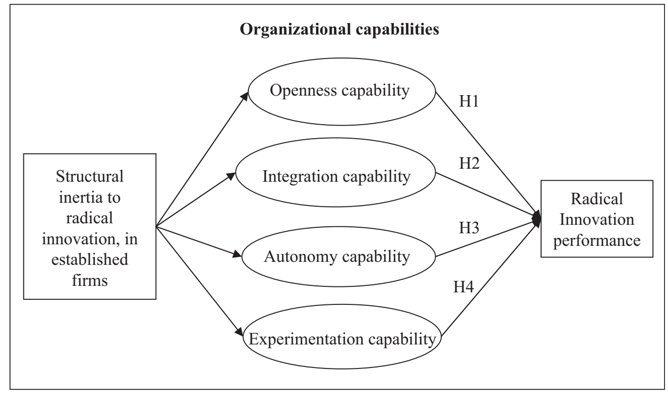

Fig. 1. Structural inertia and radical innovation performance in established firms: the organizational capabilities as mediators.

Heiskanen et al. (2007) suggested that companies introducing radical product innovations might need to take consumers' resistance more seriously. They might need to reconsider the acceptability of new product innovations and integrate these considerations at earlier stages of the innovation cycle.

A more *open-ended approach* to concept testing is suggested, encouraging users to evaluate concepts more critically. Concept testing should not be used as a pass/fail screen, but as an experimental approach (Junarsin, 2009), or as an opportunity to learn more about the potential impact of the innovation on everyday life and society. Experimentation capability is a subset of a firm's ability to probe, experiment with, test, and commercialize radical ideas and concepts, across R&D, manufacturing and marketing disciplines. Consequently, this paper hypothesizes:

H4. *Organizational experimentation capability is positively correlated to radical innovation performance, in established firms.*

Having identified five major organizational inhibitors, or inertia, to radical innovation, in established firms, in Section 2.2, established firms might develop the appropriate organizational capabilities (Section 2.3) to allow them to avoid, or to escape from these organizational traps, when dealing with radical innovation. Amara et al. (2008) summarized different novelty measures, including single scale items, and multi-dimensional scales, and a tool for measuring the implementation difficulty and emissions benefits of innovations. Thus, this paper proposes a research framework in which these four types of organizational capabilities can play a mediating role, to avoid the organizational inertia to radical innovation performance, in established firms (Fig. 1). In other words, the research framework allows established firms to develop their core capabilities for radical innovation and prevents them from falling into the vicious cycle of organizational core rigidities (Leonard-Barton, 1992).

3. Methods

3.1. Questionnaire development

The questionnaire was an adaptation of the Canada MINE Innovation Management Survey. The questionnaire consisted of five parts: (1) openness capability, (2) integration capability, (3) autonomy capability, (4) experimentation capability and (5) company information. As suggested by Brislin (1980), semantic differences between original and back-translated items showed no significant statistical difference. In order to develop new measures for these constructs, we first, reviewed relevant literature and generated a pool of questions, pertinent to the domain of each construct. From this pool of items, we conducted a pre-test, involving 35 top managers at different firms. We asked these managers to complete the questionnaire and indicate any ambiguity in the phrasing of questions. During follow-up interviews, we invited managers to provide suggestions for the improvement of the questionnaire. The phrasing of questions was further refined by the authors and peers, until the final version of the questionnaire was generated. The wording, phraseology and structure were improved. Exploratory factorial analyses of the data from the pilot study indicated that the meaning of the survey questions were clear. Fifteen items of the original survey were removed, since they were found to be cross-loaded (Conway and Huffcutt, 2003).

3.2. *Response rate*

The paper focuses on radical innovation in established firms. Consequently, the paper mainly investigates large firms, such as top 500 manufacturing firms in Taiwan, rather than SMEs. The survey investigated top 500 Taiwanese manufacturing firms, according to a 2006 survey by China Trust. The questionnaires were mainly sent by post to the senior managers in charge of corporate R&D, such as Chief Technology Officers, Vice Presidents of R&D, or senior R&D managers. A covering letter, attached to the questionnaire, explained the purpose of the research and provided assurance of anonymity and confidentiality. After a three-wave postal survey, 117 firms had responded to the questionnaires. Once the postal questionnaires were sent, detailed follow-up was conducted, by phone, email, or fax, one week later. Each wave of the survey was separated by two weeks. Finally, the first, second and third waves yielded 42, 38 and 37 completed questionnaires, respectively. There were five invalid questionnaires. Ultimately, 112 effective responses were collected, with an overall response rate, 22.4%.

Of 112 effective respondents, the major respondent firms were located in the north of Taiwan (62 firms (55%). 32 firms (28%) were from the south of Taiwan, and 18 firms (16.1%) from central Taiwan) (Table 1); in terms of the size of these firms (e.g., number of total employees), 35 small firms (size < 500 persons) represented the lion's share (31%). There were 25 medium-sized firms (size of 501–1000 persons, representing 22%, 30 medium-large firms (size of 1001–3000 persons), representing 27%, 14 large firms (size 3001–5000 persons) and 8 super-large firms (size > 5000 persons), representing 7%.

In terms of corporate R&D size, more than 40% of corporate R&D centres (47 firms) were micro-sized (size < 20 persons), 21% of corporate R&D centres (23 firms) were small (size of 21–50 persons), 27% of corporate R&D centers (30 firms) were medium-sized (size of 51–200 persons) and 11% of corporate R&D centers (12 firms) were large (size > 200). In terms of the types of firms, 47% of the firms were information and technology manufacturing firms (53 firms). Finally, in terms of their corporate business model, 58 firms were OBM's, which equates to 52% of all respondents. The demographics of the respondents are shown in Table 1.

Table 1
Demographics of respondents.

Demographics		Respondents	Percentage (%)
Location	North	62	55
	Middle	18	16
	South	32	28
	Total	112	100
Firm size (No. of employees)	25–500	35	31
	501–1000	25	22
	1001–3000	30	27
	3001–5000	14	13
	5001–16,000	8	7
	Total	112	100
R&D size (Number of R&D personnel)	< =20	47	42
	21–50	23	21
	51–200	30	27
	> 201+	12	11
	Total	112	100
Type of firms	ICT	53	47
	Non-ICT	59	53
	Total	112	100
OBM	Non-OBM	54	48
	OBM	58	52
	Total	112	100

3.3. *Measures*

It is crucial to clearly state from what perspective innovation is to be considered (technological innovation or social innovation) and to clearly identify the level and unit of analysis (e.g., a process innovation, a product innovation, an individual, a firm, an industry, or a supply chain) under consideration (Linton, 2009, 730–731). This paper mainly focuses on measurement of the magnitude of the output of radical innovation. From a technical perspective of radical innovation, technological innovation is the measure most used (product and process innovations) in the manufacturing sector. From a social perspective of radical innovation, a firm's radical innovation performance can be measured in profit-level. A radical innovation may revitalize current product lines, create new business ventures and generate new sources of profit. Based on previous studies, two measures of radical innovation performance were identified (Chu, 2009, Ernst and Kim, 2002): (1) the share of radical innovation sales, as a percentage of total sales, within five years, and (2) the profit ratio of radical innovation/total innovation. The respondents of this study were asked to indentify types of radical (new-to-the world, new platform, or new-to-the generation) innovation. Once, they indicated that they undertook radical innovations, they are asked to provide the performance of the profit ratio of radical innovation in the definition.

The reasons why we do not take the number of radical innovations into considerations for measuring performance are described as follows: (1) It is practically difficult for the respondents to recall the number of radical innovations introduced in the last five years; (2) More increasing examples show that a large profit ratio in high-tech industry may be from few radical innovations, e.g., iPhone or iPad developed by Apple company; (3) some studies proposed the radical innovation performance could be defined by the above two measurements (Chu, 2009; Ernst and Kim, 2002). According to these three reasons, the number of radical innovations was not designed in the questionnaire. This papers include four control variables; R&D intensity (annual R&D expenditure/sales), firm size (no. of employees), R&D department size (no. of R&D personnel) and whether firms are ICT firms, or Original brand manufacturers (OBM). It is expected that the higher R&D intensity, firm size and R&D size, the higher will be the radical innovation performance (Brown, 1991; Buderi, 2000). Most top 500 manufacturing firms are ICT firms. Consequently, it is initially expected that ICT firms tend to have a higher radical innovation performance than non-ICT firms. Finally, the business models of manufacturing firms matter, in introducing radical innovation. OBM's (original brand manufacturers) tend to demonstrate a higher innovative capability than OEMs (original equipment manufacturers) (Chu, 2009; Ernst and Kim, 2002). The "firm size" and "R&D size" are defined by the total number of total employees and total number of R&D personnel, respectively (Bettis, 1981; Katila and Ahuja, 2002; Montgomery, 1982). An "information and communications technology (ICT)" firm has a value of ICT firms=1. If otherwise, "ICT firms"=0. The other control variable is the business model operated by the firms. The "OBM" is defined by the orientation of original brand manufacturers (Berger and Diez, 2006). The value of "OBM" is the sum of three items: "branding component or software", "branding module" and "branding product". By obtaining an averaging of these three items, the mean value of the variable "OBM" is 13.0. For those firms whose mean "OBM" is larger than 13.0, OBM=1, otherwise OBM=0. However, the number of innovations should be a very important variable once considering the performance of incremental innovations. The number of innovations may be considered as a control variable to overcome omitted variable bias.

There are three separate measures of openness capability (OC); integration capability (IC), autonomy capability (AC) and experimentation capability (EC). For all items, we used a seven-point Likert scale (1: strongly disagree, 4: fair, 7: strongly agreed). Exploratory factorial analysis clearly replicated the intended two-factor structure, with each item loading clearly on its intended factor (all factor loadings were above 0.74, with cross-loading below 0.23) and all factors having eigenvalues greater than one. The details of factors and items are listed in Appendix.

3.4. Reliability and validity

To determine the reliability of the scales of organizational capabilities, in the model, we calculated Cronbach's alpha, for the scales. The Cronbach's alpha values were 0.77, 0.83, 0.78 and 0.79, for openness capability (OC), integration capability (IC), autonomy capability (AC) and experimentation capability (EC), respectively (Hair et al., 1998). These values suggest a moderate to high internal consistency between the items and their related constructs (Guilford, 1965). To test the construct validity of each scale, we conducted a confirmatory factor analysis (CFA) and analyzed the covariance matrix, using the maximum likelihood procedure of Lisrel. The statistical fit of the overall model (χ^2/df=1.28, goodness-of-fit index [GFI]=0.90; adjusted goodness-of-fit index [AGFI]=0.85, Normalized Fit Index [NFI]=0.885, Non-Normalized Fit Index [NNFI])=0.939, comparative fit Index [CFI]=0.98, Root Mean Square Error of Approximation [RMSEA]=0.037) corresponds reasonably well with those found in the literature. The CFA results show that indicators loaded significantly on their respective constructs.

Item loadings were as proposed and significant ($p<0.01$). We also performed eight additional confirmatory factor analyses (CFA's), in which we grouped items, to obtain better parameter to degree-of-freedom ratios. The first CFA model contained openness capability (OC) and integration capability (IC), autonomy capability (AC) and experimentation capability (EC). The third and fourth CFA model grouped openness capability (OC) and experimentation capability (EC), integration capability (IC) and autonomy capability (AC), openness capability (OC) and Autonomy capability (AC) and integration capability (IC) and experimentation capability (EC). Finally, the second and other CFA models singled the experimentation capability (EC), integration capability (IC), openness capability (OC) and Autonomy capability (AC). The fit indices were as Table 2. Model 8 is the best situation (χ^2/df=1.44, NFI=0.92, GFI=0.91, CFI=0.98, RMSEA=0.05). Furthermore, all factor loadings were significant ($p<0.05$). These additional results confirm the convergent and discriminate validity of our scales. Therefore, the scales of openness capability (OC) and integration capability (IC), autonomy capability (AC) and experimentation capability (EC) and radical innovation performance show convergent validity (Fornell and Larcker, 1981).

4. Results

Descriptive statistics (means, standard deviations, and correlations) for all the variables are presented in Table 3. On average, the company size, in terms of number of employees, was 1977 persons and the corporate R&D size, in terms of number of R&D personnel, was a little over 50 persons, for the sample. About 47% of firms were ICT manufacturers. Finally, the average R&D intensity of the sample firms was 3.73%, which is higher than the 2009 Taiwanese national R&D/GDP, of 2.68%, suggesting that the sampled firms have a higher R&D commitment than the national average. Overall 52% of the firms operate an OBM business model.

Openness capability (OC), integration capability (IC), autonomy capability (AC) and experimentation capability (EC) were significantly and positively correlated with the radical innovation performance. The strong correlations indicate the importance of the organizational capabilities. More importantly, the findings show evidence that organizational capabilities are related to radical innovation performance. Other diagnostic tests conducted suggest no problem of multicollinearity, we calculated variance inflation factors (VIFs) for each the regression equations. The maximum VIF within the model was 1.43, which is well below the rule-of-thumb cut-off of 10 (Neter et al., 1990). Moreover, the results of a modified Kolmogorov-Smirnov Goodness-of-Fit test supported the validity of the manufacturing industry normality assumption (Massey, 1951, 37).

To test the proposed hypotheses, we performed separate regression analysis for each independent variable. Initially, only the control variables were entered into the equation. The Model 1 contains control variables on firm size, R&D size, ICT firm, and original brand manufacture (OBM) business model. In the second step, Model 2, 3, 4 and 5 were used to test the hypotheses, respectively. Then, we use a single multiple regression, say Model 6, to test the four hypotheses. The test results are described as follows.

Table 2
Discriminant validity analyses results.

Measurement model	χ^2	df	χ^2/df	$\triangle\chi^2$	CFI	NFI	RMSEA	GFI
1. OC and IC, AC and EC model	283.67	53	5.35	-	0.74	0.70	0.23	0.66
2. EC, OC, IC and AC model	233.99	53	4.41	27.68	0.80	0.75	0.19	0.72
3. OC and EC, IC and AC model	226.51	53	4.27	7.48	0.80	0.76	0.18	0.73
4.OC and AC, IC and EC model	217.7	53	4.11	8.81	0.81	0.77	0.18	0.72
5. IC, OC. AC and EC model	209.89	53	3.96	7.81	0.82	0.78	0.17	0.75
6. AC, OC, IC and EC model	208.25	53	3.93	1.64	0.82	0.78	0.17	0.75
7. OC, IC, AC and EC model	165.94	53	3.13	42.31	0.87	0.83	0.15	0.78
8. OC. IC. AC. EC model	69.25	48	1.44	96.69	0.98	0.92	0.05	0.91

Table 3
Descriptive statistics and correlations.

Variable	Mean	S.D	1	2	3	4	5	6	7	8	9
1. Firm size	1977.04	2694.4									
2. R&D size	2.06	1.06	0.329**								
3. ICT firm	.47	.50	0.266**	0.198*							
4. OBM	.52	.50	0.062	0.023	0.306**						
5. R&D intensity	3.73	3.79	−0.008	0.249**	0.304**	0.162					
6. Openness capability	13.25	3.37	0.098	0.074	0.142	0.343**	0.211*				
7. Integration capability	16.17	2.79	0.145	0.204*	0.058	0.098	0.238*	0.183			
8. Autonomy capability	15.03	3.05	0.020	0.081	0.082	0.089	0.121	0.214*	0.403**		
9. Experiment capability	15.63	2.89	0.194*	0.226*	0.043	0.179	0.169	0.290**	0.489**	0.470**	
10. Radical innovation performance	34.35	23.49	0.163	0.178	0.236*	0.113	0.188*	0.269**	0.284**	0.241*	0.304**

Note: $N=112$ (firms); two-tailed tests.
** $p<0.05$;
** $p<0.01$;

Table 4
Results of Hierarchical Regressions Analyses.

Variable	Radical innovation performance					
	M1	M2	M3	M4	M5	M6
Firm size	0.093	0.073	0.063	0.095	0.049	0.067
R&D size	0.089	0.089	0.060	0.078	0.048	0.049
ICT firm	0.146	0.153	0.167	0.140	0.180	0.163
OBM	0.042	−0.030	0.024	0.029	−0.006	−0.038
R&D intensity	0.115	0.077	0.063	0.097	0.078	0.080
Openness capability (OC)		0.227*				0.077
Integration capability(IC)			0.235*			−0.147
Autonomy capability(AC)				0.207*		0.159
Experimentation capability(EC)					0.263**	0.237*
ΔR^2	0.049+	0.044*	0.050*	0.042*	0.061**	0.034*
R^2	0.092	0.136	0.142	0.134	0.153	0.183
Adjusted R^2	0.092	0.087	0.093	0.084	0.105	0.111
F	2.15+	2.752*	2.895*	2.7*	3.163**	2.543*

Note: $N=112$ firms.
+ $p\le 0.1$;
* $p\le 0.05$;
** $p\le 0.01$.

Hypothesis 1 states that openness capability (OC) is positively related to radical innovation performance. As depicted in Table 4, the coefficient for openness capability, in Model 2, was positive and *statistically significant* ($\beta=0.227$, $p<0.05$). The coefficient for organizational integration capability (IC), in Model 3, was positive and *statistically significant* ($\beta=0.235$, $p<0.05$), which supports Hypothesis 2. Hypothesis 3 predicted that organizational autonomy capability (AC) is positively correlated to radical innovation performance. As shown in Model 4, this prediction was also supported ($\beta=0.207$, $p<0.05$). Hypothesis 4 predicted that organizational experimentation capability (EC) had a positive and statistically significant relationship with the radical innovation performance variables ($\beta=0.263$, $p<0.01$,) in Model 5. Overall, Model 6, including all the independent variables (OC, IC, AC and EC), shows only the experimentation capability (EC) has a significantly positive relationship with the radical innovation performance ($\beta=0.237$, $p<0.05$). This result shows that OC, IC and AC may have a nonlinear, dynamic or causal relationship with radical innovation performance.

5. Discussions

Most control variables are not statistically significant, in all models, suggesting firm size, R&D size, ICT-firm, or OBM business model do not significantly affect radical innovation performance. Overall, the results indicate that the four research hypotheses are supported, suggesting that these four types of organizational capabilities increase radical innovation performance in established firms. Of these organizational capabilities, followed by openness capability ($\beta=0.23$, Model 2), integration capability ($\beta=0.24$, Model 3), autonomy capability ($\beta=0.21$, Model 4) and experimentation capability has the highest positive coefficient ($\beta=0.26$, Model 5). Observing the test results of Model 6, only the experimentation capability (EC) has a significantly positive relationship with the radical innovation performance ($\beta=0.237$, $p<0.05$). In other words, experimental capability is more important than the other three capabilities. These values suggest their relative importance to radical innovation performance. The R^2 values, for Models 2–6, are all above 13.4%, suggesting an acceptable explanatory power for radical innovation performance, for each capability. Future research should explore additional innovation capabilities and context characteristics. However, it is worth noting that the main determinants of radical innovation still may be unidentified. Other factors such as leadership or resource commitment may need to be considered, in future studies. We may have the structural equation model (SEM) of organizational capability to understand the context of the innovation process.

The paper finds that the openness capability, which is a firm's ability to search for diversified sources of creative ideas from external, distant and wider orientations, rather than from internal, local and narrow ones, increases radical innovation performance. The result is in line with the study of Phene et al. (2006), which found that that open and multi-dimensional searching capability, for ‘‘technological distant knowledge in national origins’’ and in ‘‘technological proximate knowledge of international origins’’, increases radical innovation. Laursen and Salter (2006) also found that a greater external search depth, not breadth, influences innovative performance. Consequently, to facilitate radical innovation, the openness capability should allow firms to access diversified sources of innovation, such as universities, research institutes and other firms (Chang, 2003; Chesbrough, 2003a, 2003b; Laursen and Salter, 2004; McLaughlin et al., 2008).

This paper reveals that organizational integration capability, which a subset of the ability to integrate and align organizational connectedness and ambidexterity of radical innovation into mainstream businesses, can increase radical innovation performance. The result agrees with the findings of Park and Gil (2006), who studied the transformation of Samsung’s corporate R&D Center from a development-oriented to a research-oriented center, by enhancing the R&D capabilities, aligned with business strategies and integrated R&D processes, using Design for Six Sigma. The result is consistent with the studies of Gibson and Birkinshaw (2004) and He and Wong (2004). Based on the survey to measure alignment and adaptability in 41 business units, Gibson and Birkinshaw (2004) found a positive correlation between organizational ambidexterity and business unit performance (Gibson and Birkinshaw, 2004). In the same line of argument, He and Wong (2004) also found that a good balance between exploiting and exploring innovation strategies is positively related to sales growth. It is crucial that established firms become ambidextrous, to integrate and differentiate radical innovation and incremental innovation, within the same organization, in turn facilitating radical innovation performance (Lawrence and Lorsch, 1967; Ettlie et al., 1984; Tushman and O’Reilly, 1996).

This paper confirms that the organizational autonomy capability, which is a firm’s ability to encourage and tolerate risky, ambiguous, or unsuccessful radical ideas, increases radical innovation performance, in established firms. This result is consistent with an organizational culture that encourages risk-taking (Cabrales et al., 2008; McLaughlin et al., 2008), tolerance of ambiguity (McLaughlin et al., 2008), slack resources (Ekvall, 2000) and tolerance of failure (Hornsby et al., 2002; McDermott and O’Connor, 2002), which facilitates crazy ideas and more radical innovation.

Finally, the experimentation capability, which is a subset of firms’ ability to probe, experiment, test, and commercialize radical ideas and concepts across R&D, manufacturing and marketing activities, which increase radical innovation performance in established firms, is mostly neglected in existing references, but it is one of the most important capabilities for radical innovation. This result strongly supports the notion that the development of radical innovation is a series of experimental processes (Lynn et al., 1996; O’Connor and McDermott, 2004; McLaughlin et al., 2008; Junarsin, 2009). As radical innovation deals with the transfer of resources and the acceleration of innovation capabilities, it is argued that the dynamic capability view can help to explain how such transfer of resources and change in capabilities can be achieved.

6. Conclusions

Although it is well recognized that there are many organizational inhibitors and inertia, which prevent established firms from planning, developing and organizing and commercializing radical innovation, there is little research focusing on how to develop organizational capabilities to turn organizational inertia to radical innovation into core capabilities. The thematic, qualitative, RPI (Rensselarer Polytechnic Institute) approach illustrates how established firms can outsmart new, entrepreneurial firms in radical innovation, from the strategic, structural and capability perspective (Leifer et al., 2000; McDermott and O’Connor, 2002; O’Connor and Ayers, 2005). However, the organizational capabilities that are thought necessary for radical innovation are quite fragmented and far from comprehensive.

Based on organizational capability theory and innovation capability studies, this paper develops a comprehensive set of organizational capabilities to search, integrate, tolerate and experiment in radical innovation. Along with RI-organizational capabilities, the paper elaborates four types of organizational capabilities, namely openness capability, integration capability, autonomy capability and experimentation capability. The major findings of the paper are that established firms that develop organizational openness capability, integration capability, autonomy capability and experimentation capability will increase their radical innovation performance. In other words, established companies need different sets of organizational capabilities, to search, plan, organize and prove radical ideas. These results strongly agree with those of previous studies (see Discussions). The paper suggests that established companies should broaden their organization’s search of ideas to external sources and, explore widely. Established firms can foster ambidexterity in innovation, to integrate and align radical innovation and incremental innovation. Needless to say, an autonomous organizational climate and a culture that supports and tolerates radical innovation is a necessary condition for the cultivation of radical innovation. Finally, firms with high radical innovation performance must enthusiastically probe and experiment with all sorts of value chain activities, such as new tools/concepts for R&D/manufacturing productivity enhancement, markets and users (Amara et al., 2008; Bocken et al., 2012).

The paper considers the four RI capabilities independently. Further research might shed some lights on the structural, interdependent and staged (O’Connor and Ayers, 2005) relationships between the four types of RI-organizational capabilities. It is noteworthy that the radical innovation process is not *linear,* but

Table A1

Factor	Items
Openness capability (OC)	– We participate in industrial networks such as industrial associations, standard organizations and industrial forums. – We invite scientists and gurus to predict the future. – We co-operate with universities/research institutes, to develop brand new ideas.
Integration capability (IC)	– We apply the knowledge gained in previous projects to new projects. – We encourage cross-functional learning and fertilization. – We upgrade and integrate our technology capabilities, new product development and marketing.
Autonomy capability (AC)	– BU managers are able to frequently renew product portfolios. – BU managers are able to update necessary technological and market information. – We empower BU managers to implement their own innovation strategy.
Experimentation capability (EC)	– We usually adopt new ideas and develop them as reliable products. – We commercialize proven concepts into market. – We develop methods and tools, to improve R&D.

one which involves networks and systemic integration (Rothwell, 1992). The structural equation model (SEM) method may be used to test how these organizational capabilities influence one another and radical innovation performance. This paper's measurement of radical innovation performance is far from perfect. The time from incubation to the launch of radical innovation could be years or decades. It might be very fruitful to include the wider and long-term measurement of radical innovation in future research.

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Appendix: Questionnaire items

See Table A1.

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