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Evaluating innovative processes in french firms: Methodological proposition for firm innovation capacity evaluation

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ABSTRACT

Measuring innovation processes is a major concern for academics and firm managers. This study proposes an innovation capacity (IC) measure framework based on a set of 15 innovation management practices. Every practice is subdivided into multiple criteria which are directly observable phenomena or facts. The statistical method of value test and a multi-criteria approach are adopted to propose a typology of four groups of innovative firms (proactive, preactive, reactive, passive). The features observed on these groups of firms allow the determination of the firms' innovation capacity and are useful for providing recommendations and practical actions for them, with a view to reinforcing it. Data from a sample group of 39 small and medium sized enterprises (SMEs) in the manufacturing industry in Lorraine, France were collected via a field survey and were fed into the model to determine the innovation capacity of the companies.

1. Introduction

Innovation processes appear in industrial systems in the form of technological innovation management actions, knowledge management practices and organizational change operations (Linton, 2009). These complex and uncertain processes require specific management, continuous improvements and investments. Thus, firms must continuously monitor the appropriateness of their innovation management actions and the resources dedicated to these actions. Consequently, evaluation tools and methods are required (Conn et al., 2009). This study is a contribution to international research in this field, aimed at developing the fundamental principles of an innovation metrology. Attention is directed toward the nature and the relevance of innovation management activities rather than estimating action productivity (input versus output).

Aiming at the identification and evaluation of the main actions that decision-makers have to deploy in order to improve their innovation process, a description of the innovation management in the form of operational levels is adopted. Thus, five innovation process management operational levels were proposed by Boly (2009). He defines: the global dimension (the external environment of the firm), the company, the project, the product, and the individuals (see Fig. 1). These innovation management levels represent different action levels for decision-makers in order to improve their innovation process. Every intervention level requires specific decision-making, methodologies and organizations. Thus, moving from one innovation level to another requires changes in practices and activities. This model constitutes a representation of the complexity of the dynamic of innovation, taking into account internal and external phenomena. Note that it is not a hierarchical model, as data and other resources produced at one particular level feed the other levels, and as their temporal horizons are different.

This study focuses on the "Firm" level, since it represents a major level to evaluate innovation management efficiency. The remainder of this paper is organized as follows. Section 2 clarifies the background of the innovation process evaluation at the firm level and discusses relevant literature. Section 3 presents the proposed innovation evaluation framework for evaluating the IC of SMEs. Section 4 then presents empirical results related to evaluating the IC of 39 innovative SMEs in the manufacturing industry in the Lorraine region (France). This is followed by a discussion and managerial implications in Section 5.

2. Innovation capacity evaluation background

Innovation evaluation has become a significant and critical concern for both practitioners and researchers, as well as for public authorities (Cañibano et al., 2000; Furman et al., 2002). Literature attests to propositions for measuring the innovation management of companies and identifying the conditions of a

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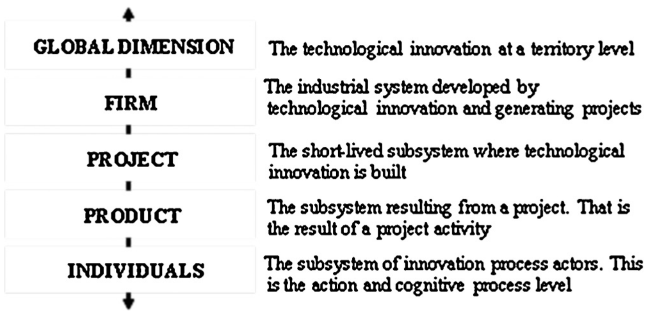

Fig. 1. The five intervention levels of innovation management.
Source: Boly (2009).

successful innovation process (Griffin and Page, 1996; Chiesa et al., 2008; Guan et al., 2006; Wang et al., 2008; Tseng et al., 2009). In order to present a structured state of the art, a systemic analysis of approaches proposed in the literature is adopted: (1) The resources used in the innovation process (input), (2) The practices or activities actually implemented (activities) and (3) The results of the innovation process (output).

2.1. *Input evaluation*

The R&D intensity, defined as R&D expenditure and workforce, is often used as an evaluation criterion for innovation process input (Hagedoorn and Cloodt, 2003). These R&D efforts represent not only the company's current input but offer information about strategic activities that are a complete part of the innovation capabilities of a company (Simonen and McCann, 2008). However, R&D efforts remain difficult to correlate with R&D results. Another means to evaluate the innovation process input is the evaluation of the human resources of companies (Kleinschmidt et al., 2007). Arundel (2001) states that the size of companies, in terms of number of employees, affects value creation and thus the performance of companies. Furthermore, the input of human capital cannot be measured clearly and the consequences of human capital are often masked by other factors (Pantzalis and Park, 2009). However, all these approaches are difficult to use because preconditions are necessary before application (accounting algorithms among others) and because of the influence of qualitative variables such as the organization mode (Laugen and Boer, 2008).

2.2. *Output evaluation*

Literature attests of research in the field of innovation performance. Performance is associated with the nature description and the assessment of the outcomes of the innovation process. Patents are intermediary results of the new product development process and are consequently indicative of the invention's activity and of research efforts (Jolly and Phillpot, 2004). However, this innovation criterion gives a reduced evaluation of innovation because only the technological results are patented (Artz et al., 2010). Researchers, particularly in the economic field, are increasingly using patent citations as an indicator of the inventive performance of companies and also journal-based innovation counts (Hagedoorn and Cloodt, 2003; Jensen and Webster, 2004). Some financial indicators are also developed, including the total percentage of sale volume represented by new products.

2.3. *Activity evaluation*

2.3.1. *Innovation capacity*

A review of the literature reveals many suggestions for measuring the Innovation Capacity (IC) of firms. IC can be defined as the continuous improvement of the overall capabilities and resources that the firm possesses for exploring and exploiting opportunities to develop new products to meet market needs (Szeto, 2000). The IC of a firm is based on a complex capacity hierarchy, and thus a simple conventional single performance criterion is insufficient to determine the level of an enterprise (Guan et al., 2006). According to Wang et al. (2008), measuring ICs requires simultaneous consideration of multiple quantitative and qualitative criteria. Authors adopt many statements before evaluation, particularly the number of ICs: three innovation capabilities (Koc and Ceylan, 2007), four innovation capabilities (Adler and Shenbar, 1990), five innovation capabilities (Burgelman et al., 2004; Lu et al., 2007; Wang et al., 2008), six innovation capabilities (Romijn and Albaladejo, 2002; Jonker at al., 2006), or seven innovation capabilities (Yam et al., 2004; Guan et al., 2006). The following sums up the related capabilities: resource allocation capability, capability to identify competitors' strategy and satisfy market requirements by developing new products, to foresee technological changes and manufacture new products using appropriate technological processes, to effectively respond to unanticipated technological activities created by competitors and unforeseen market forces, and to organize an inner learning process.

Literature review on the innovation capacity metrics (Table 1) shows that most of the proposed approaches are based on the evaluation of multiple factors. These factors are identified as leverage to manage innovation processes. A number of these factors being in common, the main difference resides in the aggregation technique used. MCDA (Multi-criteria Decision Aid) techniques have been widely applied to do these analyses, i.e. ELECTRA, Weighted Averages, and AHP (Analytic hierarchical Process), fuzzy integrals, parametric identification, or Data Envelopment Analysis (DEA).

However, these evaluation methods are not generic and therefore neither practitioners nor researchers have a real reference framework. Furthermore, these data collection methods are causing a problem because information is generally based on opinions expressed during interviews. Consequently, contributions are still possible through approaches based on in-situ observations within companies.

2.3.2. *Dynamic capabilities*

The aim of the research is the evaluation of innovation processes. A process may be considered as a sequence of tasks that are coherent in regard to the final artefact. Here the finality stands for a new product, a new service or a new technology. Thus, IC may refer to dynamic capabilities. Dynamic capabilities appear as routinized activities directed towards the development and adaptation of operating routines (Zollo and Winter, 2002). More precisely, it emphasizes two aspects (Teece and Pisano, 1994). First, it refers to the shifting character of the environment; second, it emphasizes the key role of strategic management in appropriately adapting, integrating and re-configuring internal and external organizational skills, resources, and functional competences toward changing environment. Innovative enterprises try to remain competitive on highly evolving markets or to revolutionize offers on more conservative markets. Innovation is based on newness (Garcia and Calantone, 2002) and, as a consequence, innovation management may be considered as a dynamic capability. Eisenhardt and Martin (2000) state that best practices definition is an adapted way to describe dynamic capabilities. Consequently, best practices observed in innovation companies have been selected as referential for the proposed model.

Moreover, drawing on the literature on dynamic capabilities, Bender and Laestasius (2005) introduce the concept of innovation enabling capabilities. This is composed of two dimensions, transformative and configurational capabilities. Transformative capabilities focus on the enduring ability of an organization to

Table 1
Innovation capacity metrics and aggregation methods.

Authors	Evaluated Factors	Aggregation method	Application
Chiesa et al. (1996)	Concept generation Process innovation Product development Technological acquisition Leadership Resources Systems and tools	Descriptive profile of the factors	British Industry
Yam et al. (2004)	Learning capacity R&D capacity Resource allocation Manufacturing capacity Marketing Organizational capacity Strategic planning	Parametric identification (multilinear regression)	Identification of innovation factors in China
Guan et al. (2006)	Learning R&D Manufacturing Marketing Organization Resources	DEA (Data Envelopment Analysis) (input-output model)	Innovative companies in China
Nemery et al. (2012)	Six meta-practices	Choquet Intégral	French companies receiving innovation awards
Fernandez de Canete et al. (2012)	Exploratory factors of innovative companies	Descriptive statistics	Spanish Biotech sector
Wang et al. (2008)	R&D capacity Decision aid tools Marketing Manufacturing capacity Capital	Fuzzy integral	Chinese high-tech sector
Tsai et al. (2008), Wang and Chang (2011)	Technical innovation technique Product Process Managerial innovation Creativity Marketing Organisation Strategy	AHP (Analytic Hierarchy Process)	Chinese high-tech sector
Cheng and Lin (2012)	Strategic planning Marketing Innovation infrastructure Knowledge and skills TICs capabilities External environment Manufacturing capabilities	Hybrid Fuzzy-MCDA	Main board electronic sector in China

transform globally available general knowledge into locally specific knowledge and competence, the latter on the enduring ability to synthesise novelty by creating new configurations of knowledge, artefacts and actors. Note that these authors use ability and capability as synonyms. Literature attests no generic approach to evaluate dynamic capabilities, and, as the environment is changing and innovation practices are improving, there is no evolutive evaluation system of these capabilities. Even routines to innovate are changing; consequently, an adaptive approach of IC evaluation is still required.

2.3.3. *Absorptive capacity*

Considering the scientific background, the concept of absorptive capacity is linked with the special interest of this research: innovation capacity. Absorptive capacity has been defined as a firm's ability to recognize the value of new information, assimilate it and apply it to commercial ends (Cohen and Levinthal, 1990). It is a set of organizational routines and processes by which firms acquire, assimilate, transform and exploit knowledge to produce a dynamic organizational capability (Zahra and George, 2002). Many studies address the enrichment of the concept, but the fundamental argument remains the same: by investing in certain (research or other capability-building) activities, firms can improve their ability to identify, value, assimilate and apply (or exploit) knowledge that is developed outside of the firm (Fabrizio, 2009). As a consequence, absorptive capacity gives priority, first, to the study of activities (capability-building), and second, to knowledge as a resource. Thus, this research makes a contribution to the literature, by considering both the process of knowledge exploitation and also the specific process of idea emergence (Brattström et al., 2012). The objective is then to contribute to a better understanding of, and the evaluation of, routines and systematic approach in the field of knowledge building and creative stimulation tasks.

3. Innovation capacity evaluation model development

Attention is directed in this research towards evaluation, assuming that each industrial context is unique, each acting environment of an innovative company is unique and the necessity to elaborate generic approaches to help decision makers (Lorino, 1995). Evaluation differs from measurement as it ultimately aims at the comparison between a certain value and an initial objective: evaluation is contingent upon the objectives. Here the data collection and treatment approaches represent part of the initial steps before decision and action targeting an IC improvement. The fundamental principles of the proposed model are:

- to evaluate innovation practices in the companies: the model is activity-oriented,
- to describe each practice thanks to observable phenomena (attributes) attested by tangible proofs: the model is independent of the observer,

- to allow an evolution of the model following the worldwide evolution of companies' innovation management practices: the model is adaptive in terms of referential innovation practices,
- to base the innovation capacity scores on iterative calculation: the comparative classification of companies changes if new companies enter the observation panel and if a company improves its innovation management practices.

These characteristics are detailed in the following sections.

3.1. Identifying innovation capacity dimensions through best practices

In order to develop the framework of a firm's IC evaluation, the proposed model is based on 15 fundamental innovation management best practices (Boly, 2009). The model has been elaborated during previous studies: observation of successful companies and confrontation with literature. The main criteria to determine the affectation of an innovation management activity to the firm level are:

- It involves top management,
- It is a permanent and structured activity within innovative companies observed upstream of this research programme about evaluation.

More precisely, in situ phenomena are listed during observation campaigns, then the importance of each particular management practice is hypothesized, and finally, a practice is integrated into the model if articles attest to its role in innovation management. These best practices are defined as follows:

- **P1 – Design:** tasks relating to the study achieved by people involved in innovation processes when collecting data, proposing new solutions and testing them.
- **P2 – Project management:** tasks concerning the follow-up of each innovative project,
- **P3 – Integrated strategy**: tasks assumed by top management allowing the global supervision of new innovative projects (budget, deadline, main technical decisions ...) integrating the strategic dimension,
- **P4 – Project portfolio management:** top management tasks ensuring consistent achievement among different initiatives within the project's portfolio,
- **P5 – Suitable organization definition:** tasks concerning the definition, the application and the evolution of context and working conditions stimulating innovation,
- **P6 – Innovation process improvement:** tasks allowing an ongoing evaluation and improvement of the new product development process (methodologies, tools among others),
- **P7 – Competence management:** tasks to allocate competences for the success of the innovation process,
- **P8 – Moral support:** top management and project managers' tasks aiming at moral support of innovation process participants,
- **P9 – Knowledge management:** tasks relating to the capitalization of know-how, knowledge and experience acquired during earlier projects, and tasks relating to the re-use of these elements to sustain forthcoming projects,
- **P10 – Competitive technology intelligence activities:** survey tasks (technological, competitive, economic, etc.) organized in order to open up the company to its external environment,
- **P11 – Network management:** top management tasks concerning the management of networks in which the company operates,
- **P12 – Collective learning:** tasks relating to the management of a suitable collective learning environment during the project,
- **P13 – Ideas research/Creativity:** continuous tasks concerning the emergence of new ideas from research, marketing or employee suggestions in order to sustain future projects.
- **P14 – R&D activities:** tasks relating to fundamental knowledge acquisition and creation,
- **P15 – Customer relationship management (CRM):** tasks stimulating the integration of customer knowledge and its sensitivity to the company's products.

According to this model, evaluating a firm's innovation process consists in evaluating innovation practices that are the model's attributes. Innovative companies develop all or any innovation practices with more or less relevance and in a formal or informal manner. The degree of development of these practices makes it possible to determine the IC of a company and its mastery level of the innovation process.

Emphasis is placed on the evolutionary nature of this 15-innovation-best practices model through time. Indeed, since new innovation management methods and techniques will appear, the nature and number of the innovation best practices may change without the evaluation method changing; the calculation approach and the treatment (comparison between companies) is not affected if the number and nature of practices evolve. On the contrary, one objective is to be able to adapt the data collection step to always be in line with the latest practices of innovative companies. Moreover, the number of practices is not a matter in itself, since the interest of the method lies in the exhaustiveness of the proposed classification in relation to reality.

3.2. Identifying innovation capacity indicators

Based on the definition of 15 best practices, the next stage consists in determining criteria relating to each practice. Innovation practices can be considered as meta-criteria that are impossible to evaluate directly. Thus, it is necessary to subdivide them into measurable criteria. To reduce the risk of subjectivity related to the criteria and to avoid problems related to data understanding and interpretation, the criteria are described in the form of *irrefutable and directly observable attributes (phenomena or facts)* (Furman et al., 2002). This consists of defining criteria characterized by a statement of presence or absence within the considered company. Therefore, during the data collection step in the companies, tangible proof of the achievement of each criterion is requested. Documents or material artefacts (intermediary design objects) are observed in order to validate the managers' assumption. Hence, if a manager suggests that its company innovates in partnership with a university department, researchers will verify that a contract has been signed between the company and the academic institution concerned. Another example could be the use of methodological tools such as "functional analysis": in this case the verification consists in reading a product specifications document. Consequently, the sensibility to the observer's judgment is rejected.

Table 2 makes a census of the observable criteria identified during a previous in situ campaign. The criteria are related to:

- The use of a specific methodology: functional analysis in the case of P1 (Design),
- The presence of a stakeholder with a particular responsibility: a technological survey manager in the case of P10 (intelligence survey),
- A sub-activity: meetings to analyse New Product Development Processes of P6,
- A technology or equipment: Customer Relation Management internet software in the case of P15 (customer contacts).

Table 2
List of observable phenomena (for reasons of table size, only 91 of 196 criteria are given).

P1 Design activities	P2 Project management	P3 Integrated strategy
Company organization integrates a design department	Regular progress reports available for each project	Formalized strategic planning available (including roadmap)
In-house designer(s)	Notes written about Intellectual Property for each project	External strategy experts hired
Use of functional analysis methodology	Planning boards available for each project	Reports written after strategic meetings between top management and project managers
Use of design methodologies (including: formulation method, finite element mode)	An initial reference frame established (objectives, responsibilities, budgets, . . .) for each project	Decision aid approaches are used (SWOT, Porter forces among others)
Formalized testing protocol	Continuous resource monitoring (materials, financial, personnel, . . .) assigned to each project	Value management tools are used
Inter-service meeting reports written about intermediary and final decision making	An expenditure monitoring table established for each project	A clear strategic and financial policy in terms of study, investments and introduction to new technologies are made
A prototyping workshop	A formalized new product development process	Documents, films about plans and goals broadcast to each employee
A testing laboratory	Project management software is used	
Computer-aided design (CAD) tools are used		
P4 Project portfolio management	**P5 Suitable organisation definition**	**P6 Innovation process improvement**
Reports written after meetings between top management and project managers about inter-project coordination	Project manager identified for each project	Meetings to analyse NPDP activities
A project portfolio coordinator	Documents about project manager responsibilities	Top management regularly reviews tasks of all project teams and managers
A multi-criteria table established to supervise all ongoing projects	Project teams composed of members from different departments	Facilitator groups or “wise” groups are available in the company
Meetings reports about inter-project resource allocation (material, human, financial, . . .)	Official assignment of tasks and responsibilities for project team participants is done	Internal methodological experts
Decision aid tools are used to manage its project portfolio	A communication network (intranet) available	Methodological training
P7 Competences management	**P8 Moral support**	**P9 Knowledge management**
Technological training	Internal media (Intranet, Magazine, . . .) stimulating innovation	There is a dedicated system or tool for recording know-how and experience gained during past projects (database, for example)
Annual training programme integrates knowledge required for future product industrialisation	Annual individual interviews integrate innovation	There are knowledge recording procedures
Staff hired according to skills needed for future projects	Promotion to innovating actors	Information is pre-treated (codification, classification, . . .) before being saved
Identification of staff's individual expertise in innovation management	Financial rewards to innovators	There is individual know-how assessment and mapping
An internal mobility system at all company levels	Financial and material resources allocated to people who wish to innovate	Knowledge management methodologies are used
A human resource manager available in the company	Internal annual innovation exhibition	
P10 Competitive technology intelligence	**P11 Network management**	**P12 Collective learning**
Survey process formalized	Company officially member of industrial networks	Inter-service meetings organized
A technological survey team and/or manager	A manager allocated to network management	Meetings between people involved in innovation and production/sales services
Members of the company officially mandated to participate in the survey tasks	Contracts with engineering subcontractors	Assessment meetings held at the end of projects
Data collection methodologies and tools used	Contracts with private research centres	Managers in charge of collective learning tasks
Workshops organized for data analysis	Contracts with universities	
Meetings held to transform collected information into innovation projects	Cooperation agreements with partners	
Visits (exhibitions, symposia etc.) planned and prepared in advance		
P13 ideas creation and creativity	**P14 R&D**	**P15 Customer relationship management**
Ideas are gathered from staff, R&D and marketing services	An in-house research service	The company has a marketing department
Creativity groups	A R&D manager	There is a person or department responsible for CRM
Formalized procedure to collect ideas within the company	A formalized R&D programme	After-sales service
Meetings dedicated to idea emergence between staff, R&D and marketing services	Annual meetings for future research themes programming	A call centre to interact with the client
Databases capitalizing ideas,	Specific equipment devoted to research (testing laboratory, measuring devices.) available	Report of meetings about customer satisfaction and new project launches
There is a fast assessment process for new ideas	A special budget dedicated to R&D activities	Customers invited to creativity sessions
		A internet tool or a system devoted to measuring customer satisfaction

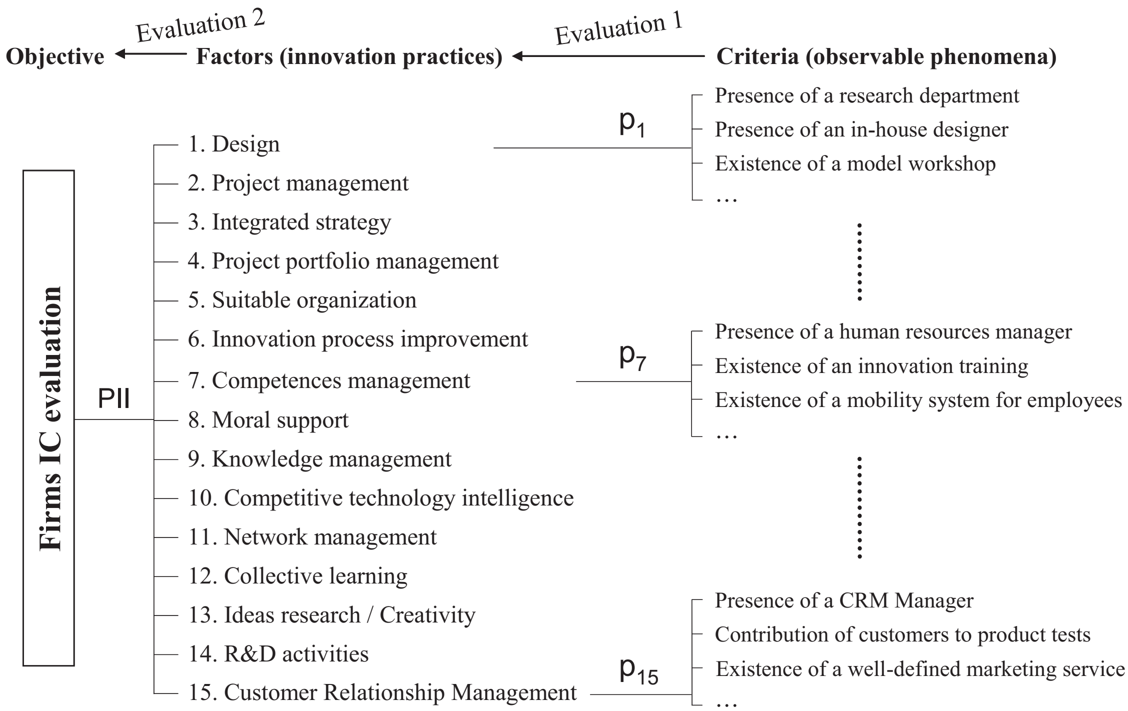

Fig. 2. Hierarchical structure of innovation practices and related observable criteria for evaluating company innovation capacity.

3.3. *Quantification of innovation capacity indicators*

The next stage consists in defining the possible states of every observable phenomenon. A criterion could be present or absent in a surveyed company, so the following scores were adopted: 1 if the criterion is observed and 0 otherwise. An observation grid was developed to carry out the IC evaluation study. It is made up of the 15 innovation best practices and the associated observable phenomena. This observation grid now constitutes an interesting information source for practitioners because it offers them a "benchmarking" of their current innovation activities. Consequently, the presence (or absence) of all observable phenomena relating to a practice is detected, and the performance level of the practice is represented by the percentage of presence – meaning the more innovation management sub-practices the company achieved, the higher the IC score will be at aggregation level one. The limits of this approach are discussed later; however, it focuses fundamentally on structural logic (versus performance assessment logic): the capacity is evaluated through the presence of an activity and consequently it does not strictly give information about "how efficiently" this activity is achieved. This evaluation gives information about the potential of the companies when innovating. Note that some observable phenomena indirectly illustrate an expertise level: if a particular methodology (functional analysis, QFD among others) is used, it attests to the designers' skills.

Finally, it is stated that IC evaluation is quantified as a score or potential innovation index (PII) that represents the global innovation performance of the company. The PII is obtained by using the hierarchical model of the IC evaluation shown in Figs. 2 and 3 below. Two levels of aggregation are necessary to calculate the PII. The first aggregation or *Evaluation 1* gives the development degree of each practice. It is performed on all the observable criteria related to a practice. The second aggregation or *Evaluation 2* takes place at the practice level and gives the PII of a company as well as its class of companies.

3.4. *Proposing a model*

3.4.1. *Criteria evaluation: Evaluation 1*

Evaluation at hierarchical level 2 determines the development degree (or score) of each innovation practice, based on its related criteria that are observable phenomena. Considering a company *E*, the development degree *pi* is defined as follows:

$$\forall i, \quad p(i)(E) = \frac{1}{m_i}\sum_{j=1}^{mi} qij(E) \qquad (1)$$

where p_i is the development degree of the practice *i*, $p_i \in [0,1]$; q_{ij} is the value of the criterion *j* associated with the practice *i*, $q_{ij} \in \{0, 1\}$; m_i is the number of criteria associated with the practice *i*.

The development degree of a practice is obtained by calculating the percentage of observed phenomena with regard to all observable phenomena related to this practice. For its calculation, the weight of every criterion is equal to 1. Indeed, criteria have the same states, that is, 1 when they are present or 0 otherwise. Thus, they consequently have the same weights. Equi-weighting is chosen as, firstly, the relation between the practices and the observable phenomena is not causal, secondly, priority is given to the second level of aggregation (practices) to determine key factors (critical practices in a specific industrial sector).

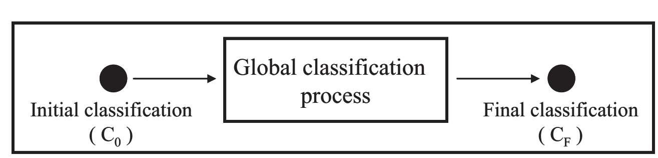

Fig. 3. Firm IC evaluation process.

3.4.2. *Innovation practice evaluation and company classification: Evaluation 2*

Evaluation at hierarchical level 1 has two major objectives. First, the calculation of the PII[1] values for all firms, which are scores included in the interval [0,1]. Secondly, according to PII values, an innovative company typology is defined and is confronted with the categorization of (Godet et al., 2000). He identified four classes of companies that correspond to strategies adopted by companies to face the future. These classes are defined as follows:

- **Proactive:** most dynamic firms. They stimulate long-term changes in their environment and adopt an aggressive strategy. In order to achieve these goals, they manage structured innovation processes and permanent innovation piloting organizations.
- **Preactive:** these firms are also dynamic. They anticipate changes by adopting a medium-term vision and using a performing survey system. Organization to innovate exists, but these companies do not direct their attention towards activities allowing technological ruptures such as fundamental research.
- **Reactive:** these firms react to environment changes. They adopt a flexible, adaptable and short-term strategy. At firm level, permanent activities to master innovation are not well defined and investment (financial funds, human resources involvement among other things) in the field of innovation processes is not regular.
- **Passive:** adopting a defensive strategy in regard to the changes in their environment, they are in a survival position. Permanent innovation management activities do not exist or are weak.

The PII value of a company is computed by using the following multi-criteria method:

$$\mathrm{PII}(E) = \sum_{i=1}^{e} w_i p_i(E_i) \quad \text{with} \quad \sum_{i=1}^{e} w_i = 1 \tag{2}$$

where PII is the potential indication index of a firm E, PII $(E) \in [0,1]$; e is the number of practices, $e = 15$ in this study; p_i is the development degree of practice i, $p_i \in [0,1]$; w_i is the weight of practice i, according to its importance $w_i \in [0,1]$.

Consequently, the hypothesis is to define the boundaries of company classes thanks to PII limits.

3.4.2.1. Methodology generalization. In this approach, the same preference profiles (in other words, the same weighting system is used for each class and no specific theoretical reference is defined) are used to compute the PII values of companies for each innovative class (proactive, preactive, reactive and passive), whereas these classes have different strategies, different constraints and various visions of the future. This implies using specific preference profiles for each class. The generalization method assumes that the 15 practices may not have the same importance for each group. Thus, the characteristics of the companies constituting the panel are used to define the preference profiles. This means that preference profiles could change in regard to the evolution of the panel composition. These characteristics are determined by using the statistical method called "value test".

Using a basic classification (C_0) on a first sample of companies, a classification called "final" (C_F), which takes into account the specificity of classes of companies, is established. The C_0 is obtained using the same weights for all practices in the four classes to compute the PII values (Eq. (2) with $w_i = 1/e$ and $e = 15$). The boundaries of PII values for each class are defined in Table 3. These boundaries emerge at the very beginning of the research, when observing twenty

[1] PII: Potential Innovation Index

Table 3
Basic classification (C0) of companies according to their PII values and based on expert definition of the 15 weighting practices.

PROACTIVE	PREACTIVE	REACTIVE	PASSIVE
1 — 0.6	0.6 — 0.41	0.41 — 0.29	0.29 — 0

+ ← Significance level of groups of firms −

companies constituting an initial innovative company panel. Discussion with experts about practices, observable phenomena and the Innovation Capacity Index show uncertainties when interpreting the outcomes concerning companies getting a score near 0.6, 0.4 and 0.3. As a consequence, limits are fixed following experts' opinion. However, as the calculation of these boundaries is an iterative process, they change each time supplementary companies are introduced into the panel. Thus, the initial categories' limit scores only represent starting references with no real impact on further classification.

Thus, the IC evaluation process of companies can be described as follows:

In the IC evaluation process, a global classification process receives as input the initial classification (C_0) and gives as a result the final classification (C_F) of companies involved in the evaluation. Fig. 4 represents the various operations of this process.

Defining the appropriate class of a company while taking into account the PII score appears as an iterative process. Thus, both the final classification (C_F) and final preference profiles for every class are obtained in p "value test computing" steps. Preference profiles (weights of practices) for each class in the classification C_k for iteration k are calculated using the previous classification C_{k-1} obtained in the step $k-1$. More precisely, the initial data of companies is ranked in the same class in the previous classification C_{k-1}. For example, the preference profile of the proactive class in the classification C_1 is calculated using the data of companies ranked in the proactive class of the C_0 classification. The classification process is close to the genetic algorithms logic; a new classification is better than the previous one.

Stability is reached in the successive classifications, when as from an iteration p, all the following classifications are equal to classification C_p. This means:

$$\exists p > 0, \quad \forall_r > p, \quad C_r = C_p \tag{3}$$

where p, r is the iterations of the global classification process, $0 < p < r$; C_p, C_r is the classifications in ranks p and r.

The classification generation process for an iteration k (C_k) is achieved following five stages. More precisely, finding the appropriate class for a company consists in calculating its PII and rank, the preference profile of the corresponding class and the relative key practices (see Fig. 5):

Stage 1: Finding preference profiles and key practices, using classification C_{k-1}

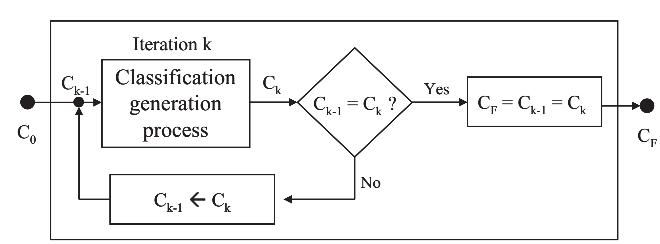

Fig. 4. Global classification process.

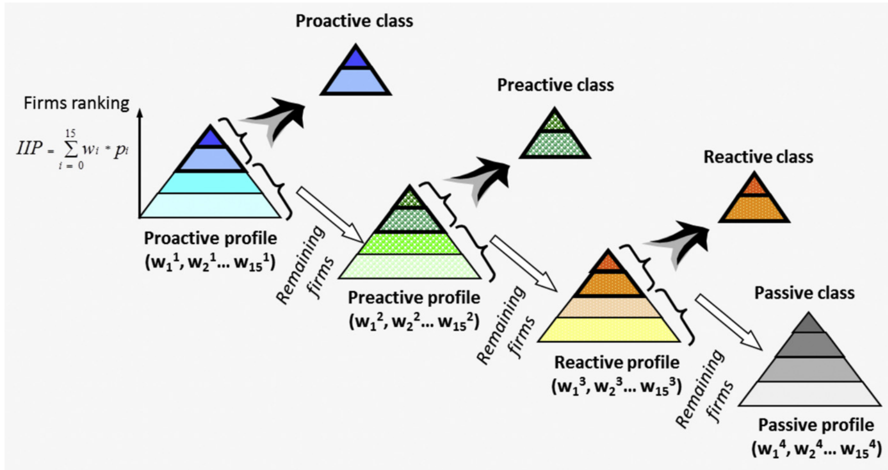

Fig. 5. Classification generation process.

1. Determining the preference profile for each class: proactive $(\mathbf{w_1^1, w_2^1 \ldots w_{15}^1})$, preactive $(\mathbf{w_1^2, w_2^2 \ldots w_{15}^2})$, reactive $(\mathbf{w_1^3, w_2^3 \ldots w_{15}^3})$ and passive $(\mathbf{w_1^4, w_2^4 \ldots w_{15}^4})$,
2. Determining the key practices for each class.

Stage 2: Constituting the new proactive class

3. Calculating PII values for all companies using the proactive preference profile $(\mathbf{w_1^1, w_2^1 \ldots w_{15}^1})$, and then ranking in descending order,
4. Selection of "well-ranked" companies (with the highest PII values). These companies form the new proactive class.

Stage 3: Constituting the new preactive class

5. Calculating PII values for remaining companies using the preactive preference profile $(\mathbf{w_1^2, w_2^2 \ldots w_{15}^2})$, and then ranking them in descending order
6. Selection of "well-ranked" companies. These companies form the new preactive class.

Stage 4: Constituting the new reactive class

7. Calculating PII values for remaining companies using the reactive preference profile $(\mathbf{w_1^3, w_2^3 \ldots w_{15}^3})$, and then ranking in descending order
8. Selection of "well-ranked" companies. These companies form the new reactive class.

Stage 5: Constituting the new passive class

9. Calculating PII values for remaining companies using the passive preference profile $(\mathbf{w_1^4, w_2^4 \ldots w_{15}^4})$, and then ranking them in descending order. These companies form the new passive class.

3.4.2.2. Key practices and preference profile for each group of companies. Key practices are the most distinctive practices of a given class. They are defined using the statistical concept of "value test". The value test is involved in the explorative and descriptive approach of large numerical tables (Morineau, 1984). Computing the occurrence probability of this statistical hypothesis simulates the importance of each variable and determines a set of variables that better characterizes a group of subjects. The value test allows us to estimate whether a deviation from the average is small (due to chance) or large (due to the factor). The law of probability of this hypothesis can be defined as follows:

$$\text{For a class } k, \quad t_k(X) = \frac{\bar{X}_k - \bar{X}}{S_k(X)} \quad \text{with} \quad s_k^2(X) = \frac{n - n_k}{n-1}\frac{S^2(X)}{n_k} \tag{4}$$

where $t_k(X)$ is the value test of practice X in class k; $\bar{X}_k$ is the average of practice X in class k; $\bar{X}$ is the average of practice X in the sample; $s_k(X)$ is the standard deviation of practice X in the class k; $s(X)$ is the standard deviation of practice X in the sample; n is the number of companies in the sample; n_k is the number of companies in class k.

For a class k, a practice X is considered as a key practice if $|(t_k(X)| > 2$; this corresponds to a probability of 0.05. Thanks to this condition, significant practices ($t_k(X) > 2$) and neglected practices ($t_k(X) < -2$) of each class are determined. A practice is all the more significant (respectively neglected) for a class if its value test is very high (respectively weak). Thus, value test calculation provides a hierarchy of innovation practices for each class. Consequently, key practices are used to identify the strengths and weaknesses of companies.

Since value tests represent the importance of practices for each class of companies, the preference profile (a set of 15 weights) of a class is calculated in proportion to value tests (positive values). The sum of all weights for one class must be equal to 100. However, a preliminary transformation is made for classes that contain negative value tests. A translation of all value tests is made according to the smallest negative value test. In that case, the absolute value of this value test is added to all value tests in order to obtain positive numbers (translated value tests). Then, the weight of the most neglected practice (with the smallest negative value test) would be equal to zero. This is not too problematic, since the contribution of such neglected practices to the improvement of the firm's innovation performance is limited. Furthermore, the calculation of value tests for a class requires the presence of at least one company in this class. Thus, if a class of companies does not contain any company in an intermediate classification C_{k-1}, then the "identity" preference profile, that is, adopting the same weights for all practices, is used to determine the corresponding class of companies in classification C_k.

3.4.2.3. Selection of companies for each class of companies. In order to extract firms that will be assigned to a class, an approach close to the ABC method is adopted. Analytical methods such as ABC allow evaluation of the cost of a product from a breakdown of the work required into elementary tasks, operations or activities with known (or easily calculated) costs (Ben Arieh and Quian, 2003). In this case, innovation capacity replaces the cost in order to rank experimental phenomena by order of importance. In this study, 50% (instead of the 80% generally used) of the PII value sum for "well-ranked" firms in the iteration step ranking is used as a selection criterion. This criterion is adopted following previous experiments: too many companies are ranked as "proactive" if this threshold is higher, and, as a consequence, the differences between the IC scores are not followed by a differentiation in terms of class repartition.

Table 4
Distribution of the participating firms by activity sector and firm size.

	Activity domain	Number of employees			
		1–10	11–50	51–250	
1	Machine and equipment manufacturing	1	8	3	12
2	Food industry	1	3	1	5
3	Pharmaceutical industry	2	2		4
4	Furniture industry	1	5	3	9
5	Chemical industry	1	1	2	4
6	Electrical equipment manufacturing		3	2	5
		6	22	11	39

3.5. Conclusion

The principle contribution of the model is the possibility to collect data through observation. These data are treated in order to calculate a score called Potential Innovation Index. This IC score is useful for comparing companies but also for objectively attesting an evolution in the IC of a certain company when the evaluation is repeated over time. The model is dynamic on two levels. Firstly, new observable phenomenon and new practices may be added at any moment. Secondly, the classification moves with the total number of companies within the panel and also with the evolution of the scores of the companies (present member of the panel and new entrants). Finally, simulation is possible: testing the consequences of a new activity (supplementary observable phenomenon) on class attribution.

4. Innovation capacity evaluation of Lorraine's SMEs: Applying the model

4.1. Firm sample and data collection

Innovative small and medium sized enterprises (SMEs) of the Lorraine region (France) in the manufacturing industry were selected as a research field. Their activities span the domains of machine and equipment manufacturing, the food industry, the pharmaceutical industry, furniture production, the chemical industry and electrical equipment manufacture. Firm selection was based on criteria developed by the Economic and Social Council of Lorraine in the first chapter of its annual report (C.E.S. Lorraine, 2004): the R&D budget, the relations between the company and the academic institutions and the number of employees involved in technological development. Furthermore, a restriction of less than 250 employees for the SMEs was decided in order to limit size effects on the experimental outcomes and to allow comparisons.

Sixty-seven firms were randomly selected and the observation technique was adopted as a data collection method. A complete diagnosis was carried out based on our observation grid with the top management including head of marketing and project managers. After examination, data from 39 firms proved to be sufficiently substantial and exploitable (Table 4). The average number of employees is 5 for the category 1–10, 31 for the category 11–50 and for the category 51–250.

The initial data of the 39 firms is shown in Table 5. Values in columns E1–E39 represent the number of observable criteria of every practice actually carried out by the company in question. The "Total" column represents the total number of possible observable criteria for all innovation practices. For example, firm E1 carries out 4 among 18 observable criteria describing practice P1 "Design" and 10 among 16 criteria of practice P3 "Integrated strategy". The last line of the table (Total) indicates the total of observable criteria carried out by each firm among 196.

4.2. Practice development degree of companies

Equation (1) with the values of Table 1 gives the development degrees for the practices of the 39 companies of the sample (see Section 3.4.1). This consists in dividing the values of columns E1–E39 by the values of the value total sum. This initial data, synthesized in Table 6, will be used afterward for the PII calculation and the company classification (Evaluation 2). For example, company E5 has a development degree equal to 100% for practices P5 "Suitable organization", P8 "Moral support", P9 "Knowledge management" and P15 "Customer relationship management" and equal to 78% for practices P1 "Design" and P4 "Project portfolio management".

Table 6 attests to the fact that company E5 remains the most competitive company in regard to a large number of practices: eight practices in all, and four with a development degree equal to 100%. However, E5 does not implement any observable criteria of practice P11 "Network management" (0%) and is among the companies which do not completely implement at least one practice. Only twelve companies, namely E1, E4, E7, E10, E18, E24, E27, E30, E34, E36, E38 and E39, partly implement all 15 innovation practices. Companies E15 and E17 are those that partly implement fewer practices, that is nine practices in all.

At this stage, comparison may be done but such tables cannot be interpreted if the number of companies increases.

4.3. Potential innovation index (PII) of companies and classification

Table 7 shows the final results (ranks, PII and classification) of companies after 2 iterations of the classification generation process (Evaluation 2 discussed in Section 3.4.2). In this classification, companies are ranked from the highest IC score company (E3) to the lowest (E9).

Each company PII value is obtained by using Eq. (2) and the preference profile for its class. These preference profiles are shown in Table 8. The weights of practices in each preference profile are calculated in proportion to the importance of their value test (or translated value tests if there is at least one negative value test) for a class as indicated in Section 3.4.2.2.

The proactive class is composed of 14 companies (E5, E34, E22, E27, E39, E4, E10, E14, E36, E26, E37, E24, E35 and E33) and their PII values range from 0.81 to 0.57. Company E5 is the best company in this class and also in the sample. The least competitive companies (E35 and E33) of this class have almost the same PII value: 0.58 and 0.57 respectively), despite the disparities in the development degrees of practices. Company E14 implements fewer observable phenomena (114) than companies E36, E26 and E35, which respectively implement 123, 122 and 104 observable phenomena and yet E14 is better classified than the three previous ones. Indeed, company E14 has good management of its resources. The same analysis may be done within each class. At this level it is easy to get a comparison between companies. The comparison concerns the practice

Table 5
Initial data of firms E1–E39.

	Innovation practice	Total	Firms																			
			E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18	E19	E20
1	Design	18	4	9	0	15	14	3	3	7	7	14	7	3	6	15	0	9	4	8	3	4
2	Project management	19	9	16	9	16	18	7	3	18	16	12	10	4	7	11	0	12	0	12	14	7
3	Integrated strategy	16	10	10	9	6	9	11	6	7	7	8	7	8	6	6	6	6	2	4	4	6
4	Project portfolio management	9	4	5	7	6	7	4	4	1	5	8	4	5	7	5	0	4	0	4	4	4
5	Suitable organisation	13	8	8	9	11	13	0	6	10	7	13	5	8	4	8	0	11	5	8	7	6
6	Innovation process improvement	9	2	4	4	4	8	0	4	4	3	6	0	2	1	9	0	2	0	2	4	0
7	Competences management	12	8	5	9	12	10	8	2	10	8	8	8	3	3	7	3	5	3	5	7	5
8	Moral support	8	6	4	7	4	8	4	3	0	5	8	4	0	0	7	5	0	2	2	3	3
9	Knowledge management	9	4	0	6	6	9	0	3	3	6	6	4	0	1	6	2	3	0	3	2	3
10	Competitive technology intelligence	18	14	14	10	9	13	8	6	3	5	5	3	4	5	3	0	2	0	6	15	11
11	Network management	11	7	5	5	9	0	3	2	7	0	8	0	5	3	9	5	0	0	6	0	2
12	Collective learning	9	3	3	7	8	8	2	2	2	7	5	3	2	0	0	3	2	1	2	3	3
13	Ideas Research/Creativity	11	8	6	5	6	7	5	1	2	2	7	5	1	2	7	3	2	3	2	4	2
14	R&D activities	17	6	13	3	15	12	6	7	14	7	12	13	9	7	7	1	10	9	9	12	6
15	Customer Relationship Management	17	14	10	8	14	17	11	12	10	12	8	10	8	4	14	6	6	3	8	5	13
	Total	196	107	112	98	141	153	72	64	98	97	128	83	62	56	114	34	74	32	81	87	75

	Innovation practices	Total	Firms																		
			E21	E22	E23	E24	E25	E26	E27	E28	E29	E30	E31	E32	E33	E34	E35	E36	E37	E38	E39
1	Design	18	11	15	2	12	10	14	14	11	2	7	10	8	6	14	0	9	3	8	8
2	Project management	19	4	19	4	12	9	14	12	9	0	7	9	4	17	11	12	12	13	9	16
3	Integrated strategy	16	3	6	6	12	8	11	15	4	0	6	4	6	9	12	9	8	7	3	14
4	Project portfolio management	9	7	8	2	7	6	1	8	7	3	5	7	5	8	6	6	7	4	7	8
5	Suitable organisation	13	11	13	8	11	7	13	8	8	5	2	5	8	10	9	9	10	8	6	5
6	Innovation process improvement	9	3	6	2	8	5	6	6	4	3	3	1	0	6	7	8	4	5	2	8
7	Competences management	12	5	12	3	5	7	10	11	5	0	5	2	5	5	10	8	8	10	7	12
8	Moral support	8	6	8	1	2	1	6	8	0	1	3	1	0	3	7	7	6	6	6	6
9	Knowledge management	9	0	6	0	3	2	0	2	0	7	3	1	0	5	6	5	6	7	6	2
10	Competitive technology intelligence	18	7	0	0	10	0	10	15	6	12	8	0	3	8	14	13	10	0	10	8
11	Network management	11	5	9	2	8	9	7	3	9	7	6	5	3	0	10	4	8	4	6	8
12	Collective learning	9	0	6	1	3	1	0	5	0	0	5	0	3	7	6	5	5	7	3	6
13	Ideas Research/Creativity	11	5	3	2	4	5	6	9	3	4	3	3	3	4	8	6	5	5	5	6
14	R&D activities	17	11	14	5	15	15	10	15	11	8	9	10	8	16	15	0	12	15	11	14
15	Customer Relationship Management	17	13	14	10	9	8	14	14	13	5	9	2	2	8	16	12	13	14	9	14
	Total	196	91	139	48	121	93	122	145	90	57	81	60	58	112	151	104	123	108	98	135

Table 6
Practice development degree of firms E1–E39 (First level evaluation).

	Innovation practices	Firms																			
		E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18	E19	E20
1	Design	0.22	0.50	0.00	0.83	0.78	0.17	0.17	0.39	0.39	0.78	0.39	0.17	0.33	0.83	000	0.50	0.22	0.44	0.17	0.22
2	Project management	0.47	0.84	0.47	0.84	0.95	0.37	0.16	0.95	0.84	0.63	0.53	0.21	0.37	0.58	0.00	0.63	0.00	0.63	0.74	0.37
3	Integrated strategy	0.B3	0.63	0.56	0.38	0.56	0.69	0.38	0.44	0.44	0.50	0.44	0.50	0.38	0.38	0.38	0.38	0.13	0.25	0.25	0.38
4	Project portfolio management	0.44	0.56	0.78	0.67	0.78	0.44	0.44	0.11	0.56	0.89	0.44	0.56	0.78	0.56	0.00	0.44	0.00	0.44	0.44	0.44
5	Suitable organisation	0.62	0.62	0.69	0.85	1.00	0.00	0.46	0.77	0.54	1.00	0.38	0.62	0.31	0.62	0.00	0.85	0.38	0.62	0.54	0.46
6	Innovation process improvement	0.22	0.44	0.44	0.44	0.89	0.00	0.44	0.44	0.33	0.67	0.00	0.22	0.11	1.00	0.00	0.22	0.00	0.22	0.44	0.00
7	Competences management	0.67	0.42	0.75	1.00	0.83	0.67	0.17	0.83	0.67	0.67	0.67	0.25	0.25	0.58	0.25	0.42	0.25	0.42	0.58	0.42
8	Moral support	0.75	0.50	0.88	0.50	1.00	0.50	0.38	0.00	0.63	1.00	0.50	0.00	0.00	0.88	0.63	0.00	0.25	0.25	0.38	0.38
9	Knowledge management	0.44	0.00	0.67	0.67	1.00	0.00	0.33	0.33	0.67	067	0.44	0.00	0.11	0.67	0.22	033	0.00	0.33	0.22	0.33
10	Competitive technology intelligence	0.78	0.78	0.56	0.50	0.72	0.44	0.33	0.17	0.28	0.28	0.17	0.22	0.28	0.17	0.00	0.11	0.00	0.33	0.83	0.61
1 1	Network management	0.64	0.45	0.45	0.82	0.00	0.27	0.18	0.64	0.00	073	0.00	0.45	0.27	0.82	045	000	0.00	0.55	0.00	0.18
12	Collective learning	0.33	0.33	0.78	0.89	0.89	0.22	0.22	0.22	0.78	0.56	0.33	0.22	0.00	0.00	0.33	0.22	0.11	0.22	0.33	0.33
13	Ideas Research/Creativity	0.73	0.55	0.45	0.55	0.64	0.45	0.09	0.18	0.18	0.64	0.45	0.09	0.18	0.64	0.27	0.18	0.27	0.18	0.36	0.18
14	R&D activities	0.35	0.76	0.18	0.88	0.71	0.35	0.41	0.82	0.41	0.71	0.76	0.53	0.41	0.41	0.06	0.59	0.53	0.53	0.71	0.35
15	Customer Relationship Management	0.82	0.59	0.47	0.82	1.00	0.65	0.71	0.59	0.71	0.47	0.59	0.47	0.24	0.82	0.35	0.35	0.18	0.47	0.29	0.76

	Innovation practices	Firms																		
		E21	E22	E23	E24	E25	E26	E27	E28	E29	E30	E31	E32	E33	E34	E35	E36	E37	E38	E39
1	Design	0.61	0.83	0.11	0.67	0.56	0.78	0.78	061	0.11	0.39	0.56	044	0.33	0.78	0.00	0.50	0.17	0.44	0.44
2	Project management	0.21	1.00	0.21	0.63	0.47	0.74	0.63	0.47	0.00	0.37	0.47	0.21	0.89	0.58	0.63	0.63	0.68	0.47	0.84
3	Integrated strategy	0.19	0.38	0.38	0.75	0.50	0.69	0.94	0.25	0.00	0.38	0.25	0.38	0.56	0.75	0.56	0.50	0.44	0.19	0.88
4	Project portfolio management	0.78	0.89	0.22	0.78	0.67	0.11	0.89	0.78	0.33	0.56	0.78	0.56	0.89	0.67	0.67	0.78	0.44	0.78	0.89
5	Suitable organisation	0.85	1.00	0.62	0.85	0.54	1.00	0.62	0.62	0.38	0.15	0.38	0.62	0.77	0.69	0.69	0.77	0.62	0.46	0.38
6	Innovation process improvement	0.33	0.67	0.22	0.89	0.56	0.67	0.67	0.44	0.33	0.33	0.11	0.00	0.67	0.78	0.89	0.44	0.56	0.22	0.89
7	Competences management	0.42	1.00	0.25	0.42	0.58	0.83	0.92	0.42	0.00	0.42	0.17	0.42	0.42	0.83	0.67	0.67	0.83	0.58	1.00
8	Moral support	0.75	1.00	0.13	0.25	0.13	0.75	1.00	0.00	0.13	0.38	0.13	0.00	0.38	0.88	0.88	0.75	0.75	0.75	0.75
9	Knowledge management	0.00	0.67	0.00	0.33	0.22	0.00	0.22	0.00	0.78	0.33	0.11	0.00	0.56	0.67	0.56	0.67	0.78	0.67	0.22
10	Competitive technology intelligence	0.39	0.00	0.00	0.56	0.00	0.56	0.83	0.33	0.67	0.44	0.00	0.17	0.44	0.78	0.72	0.56	0.00	0.56	0.44
11	Network management	0.45	0.82	0.18	0.73	0.82	0.64	0.27	0.82	0.64	0.55	0.45	0.27	0.00	0.91	0.36	0.73	0.36	0.55	0.73
12	Collective learning	0.00	0.67	0.11	0.33	0.11	0.00	0.56	0.00	0.00	0.56	0.00	0.33	0.78	0.67	0.56	0.56	0.78	0.33	0.67
13	Ideas Research/Creativity	0.45	0.27	0.18	0.36	0.45	0.55	0.82	0.27	0.36	0.27	0.27	0.27	0.36	0.73	0.55	0.45	0.45	0.45	0.55
14	R&D activities	0.65	0.82	0.29	0.88	0.88	0.59	0.88	0.65	0.47	0.53	0.59	0.47	0.94	0.88	0.00	0.71	0.88	0.65	0.82
15	Customer Relationship Management	0.76	0.82	0.59	0.53	0.47	0.82	0.82	0.76	0.29	0.53	0.12	0.12	0.47	0.94	0.71	0.76	0.82	0.53	0.82

Table 7
Ranking, PII and final classification of firms E1–E39.

Proactive

Firms	E5	E34	E22	E27	E39	E4	E10	E14	E36	E26	E37	E24	E35	E33
PII	0.81	0.77	0.75	0.73	0.70	0.70	0.69	0.63	0.62	0.60	0.60	0.59	0.58	0.57
Ranks	1	2	3	4	5	6	7	8	9	10	11	12	13	14

Preactive

Firms	E1	E3	E2	E38	E19	E9	E8	E21	E25
PII	0.60	0.58	0.57	0.54	0.51	0.50	0.48	0.46	0.43
Ranks	15	16	17	18	19	20	21	22	23

Reactive

Firms	E28	E30	E18	E29	E20	E11
PII	0.48	0.45	0.42	0.41	0.39	0.38
Ranks	24	25	26	27	28	29

Passive

Firms	E12	E32	E16	E6	E31	E13	E7	E23	E15	E17
PII	0.38	0.37	0.37	0.37	0.37	0.33	0.33	0.25	0.21	0.17
Ranks	30	30	32	33	34	35	36	37	38	39

Table 8
Preference profiles and value tests (initial or translated) for each group of firms.

	Innovation practices	Preference profiles				Translated value-tests				Value-tests			
		Proactive	Preactive	Reactive	Passive	Proactive	Preactive	Reactive	Passive	Proactive	Preactive	Reactive	Passive
1	Design	6.9	0.0	8.3	11.6	3.3	0.0	1.6	1.4	3.3	-0.8	-0.7	-2.3
2	Project management	7.2	12.1	4.8	0.0	3.5	1.8	0.9	0.0	3.5	1.0	-1.3	-3.6
3	Integrated strategy	6.8	2.4	0.0	20.0	3.3	0.4	0.0	2.4	3.3	-0.5	-2.3	-1.3
4	Project portfolio management	5.4	5.4	7.9	12.2	2.6	0.8	1.5	1.4	2.6	0.0	-0.8	-2.2
5	Suitable organisation	7.0	8.1	2.7	8.7	3.4	1.2	0.5	1.0	3.4	0.4	-1.8	-2.6
6	Innovation process improvement	10.3	2.9	2.6	0.5	4.9	0.4	0.5	0.1	4.9	-0.4	-1.8	-3.6
7	Competences management	7.9	10.8	2.9	1.1	3.8	1.6	0.6	0.1	3.8	0.8	-1.7	-3.5
8	Moral support	8.0	8.1	2.8	4.1	3.8	1.2	0.5	0.5	3.8	0.4	-1.7	-3.1
9	Knowledge management	6.3	5.0	12.1	3.1	3.0	0.7	2.3	0.4	3.0	-0.1	0.1	-3.3
10	Competitive technology intelligence	3.0	13.9	14.0	4.4	1.4	2.0	2.7	0.5	1.4	1.2	0.4	-3.1
11	Network management	4.2	5.9	12.5	10.7	2.0	0.9	2.4	1.3	2.0	0.0	0.1	-2.4
12	Collective learning	6.9	4.8	5.5	9.6	3.3	0.7	1.1	1.1	3.3	-0.1	-1.2	-2.5
13	Ideas Research / Creativity	7.6	9.3	3.9	3.1	3.6	1.4	0.8	0.4	3.6	0.6	-1.5	-3.3
14	R&D activities	5.4	6.6	9.4	8.9	2.6	1.0	1.8	1.0	2.6	0.1	-0.5	-2.6
15	Customer Relation Management	7.2	4.6	10.5	1.8	3.4	0.7	2.0	0.2	3.4	-0.1	-0.3	-3.4
	Translation values					0.0	0.8	2.3	3.6				

and it also possible to go into greater detail by considering the related criteria (observable phenomenon).

However, it must be noted that PII value intervals for classes of companies are not separate. Indeed, company E33 of the proactive class has a PII value of 0.57 and company E1 of the preactive class has a PII value equal to 0.60. This case occurs when companies are on the border between two successive classes, that is, for the least competitive companies of a class and the best ones of the class directly above (passive and reactive classes, reactive and preactive classes, preactive and proactive classes). Indeed, PII values are calculated for each class, with its specific preference profile. If company E1 were a member of the proactive class, its PII value calculated with the preference profile of the aforementioned class would be equal to 0.53. It would be considered less innovative in the proactive class than company E33. On the other hand, if company E33 were classified in the preactive class, its PII value calculated with the preference profile of the aforementioned class would be equal to 0.57. Company E33 would be less innovative in this preactive class than company E1 (see Table 9). Thus, there are fuzzy domains of PII values with companies meeting the requirements of two successive classes. In such a case, company E33 could be considered a proactive company with a preactive tendency and company E1 to be a preactive company with a proactive tendency.

Thus, in this IC evaluation framework, belonging to a class of companies is the discriminatory element in comparing companies. A company is regarded as more competitive than all the companies of lower classes. Company classes are ranked according to their importance as follows: proactive > preactive > reactive > passive. If this condition is not observed, this means that companies belong to the same class and consequently the PII is used to compare them. Thus, the PII constitutes the discriminatory element within a class of companies. Thus, the approach introduces a notion of reference framework for every class. Two companies belonging to the same class or reference framework are directly comparable using the PII. For companies belonging to different reference frameworks, the importance order of the two reference frameworks is used.

5. Managerial implications: From evaluation to innovation development

The innovation capability (IC) evaluation framework is used to assess the impact of company innovation practices on their IC. The

Table 9
Computing firms PII for proactive and preactive classes, using each class preference profile (Second level evaluation).

Preference profiles	Proactive class													
	E5	E34	E22	E27	E39	E4	E10	E14	E36	E26	E37	E24	E35	E33
Proactive profile	0.81	0.77	0.75	0.73	0.70	0.70	0.69	0.63	0.62	0.60	0.60	0.59	0.58	0.57
Preactive profile	0.79	0.76	0.70	0.74	0.69	0.72	0.66	0.55	0.64	0.61	0.57	0.57	0.61	0.57

	Preactive class								
	E1	E3	E2	E38	E19	E9	E8	E21	E25
Proactive profile	0.53	0.55	0.52	0.49	0.41	0.51	0.47	0.45	0.47
Preactive profile	0.60	0.58	0.57	0.54	0.51	0.50	0.48	0.46	0.43

value test table is used to identify the characteristics of the four classes of companies (see Table 8). Note that a practice is considered significant for a class of companies if its value test $t_k(X) > 2$ and is considered to be neglected if its value test $t_k(X) < -2$[2] (see Section 3.3.2.2.). Thanks to value test analysis (Table 8), it is possible to point out typical practices in each class:

- **Proactive class:** Except for practice P10 "Competitive technology intelligence", where the level remains a bit low, the companies of this class widely develop other practices, specifically practices P5 "Suitable organization", P7 "Competence management", P8 "Moral support", P13 "Ideas research/Creativity", P6 "Innovation process management" and P15 "Customer relationship management". No practice is neglected in this class. Innovation is clearly a permanent and structured process in these companies.
- **Preactive class:** These companies rely on practices P10 "Competitive technology intelligence", P7 "Competence management" and P2 "Project management" attesting few observable phenomena. The practice P1 "Design" is the least implemented in this class. Most practices have an implementation level generally above average. Six practices in fifteen have value tests lower than 0. Within this category, innovation process is in place but organizations remain weak.
- **Reactive class:** In this class, firms focus their efforts on providing their employees with moral support (P8) in order to innovate and adapt to the changes in their environment. These companies are at a disadvantage due to a weak level in strategic visibility (P3), Innovation process improvement (P6), Suitable organization (P5), Competence management (P7), Moral support (P8), Collective learning (P12) or Idea research/creativity (P13) notably. Globally, the practice implementation levels for this class are limited and low, with a rather negative tendency. These companies may be considered as more "entrepreneurial" than "innovative".
- **Passive class:** As opposed to the proactive class, the companies of this class have very weak levels in all the practices, slightly less for practice P3 "Integrated strategy". This allows them to maintain their position in the environment, as well as the competitiveness of their current products. The most developed practices in the proactive class are systematically neglected in this class. It must be noted that the value tests of practices all have a negative sign, that is, the global practice development level of companies in this class is much lower than the average of all companies.

Value tests are useful when giving advice to companies, helping them in the improvement of their innovation process. A practice becomes especially significant (respectively neglected) when its value test tends towards 2 (respectively −2). A practice whose value test tends towards zero can be considered as a basic practice for companies of the class in question. Its development may be important, but offers no IC score improvement. Thus, this approach is useful when directing managers' attention towards decisions for efficient improvement of innovation management. The hypothesis is: a company aims at a better IC score and at being ranked in a superior class. Firstly: it is possible to simulate the impact of a decision on the IC score. In fact, changing the number of achieved observable phenomena changes the related practice score and consequently the global IC score of the company. After several tests, it is possible to determine the decisions that have the biggest impact. Secondly, IC evaluation may be performed periodically, and its evolution within the panel may then be formalized (change in the ranking and change in the class). Hence, and as an example, innovation process improvement activities (P6) characterize the proactive class. That means that, within the panel, high IC score companies continuously adopt new innovation management methodologies and make a return on experience at the end of each project. A preactive class company hoping to enter the proactive class may develop the priority given to these criteria.

Moreover, the weights being proportional to the value tests, to increase its IC a company would have to develop, as a priority, the practices that have the strongest weights. Thus, detailed information about practices (preference profiles, value test tables and tied observable phenomena) is important for managing the innovation process through a better resource allocation and also the identification of interlinked or complementary practices. Thanks to the preference profile table, the strengths and weaknesses of a company in its class are easy to point out and appropriate recommendations emerge in the domain of innovation process management. The improvement suggestions are based on the observable phenomena that may be taken into account in order to progress within a particular practice. Focusing on high preference profiles, development degrees and target values to identify the practices to be improved is not the only strategy: a company may decide either to strengthen its position and IC performance in its current class, or to change its management in order to move towards a more competitive class.

Hence, recommendations can be made to the panel companies using the practice development degree tables for each class, filled in descending order of practice weight (appendix two).

6. Conclusion

This study is in line with the research carried out in the field of company innovation activities or IC evaluation, which seeks success conditions within innovation process management (Chiesa et al., 2008; Yam et al., 2004; Guan et al., 2006; Koc and Ceylan, 2007; Wang et al., 2008). A quantitative evaluation of company IC is developed, based on a set of 15 innovation practices, which are subdivided into several quantitative criteria. These criteria are directly observable phenomena in companies. This approach contributes to the clarifying and characterization of not well-defined

[2] Value tests of significant practices in Table 6 are highlighted in pink and those of neglected practices are in grey.

innovation criteria and key factors. Indeed, a finer analysis of the TIC concept is suggested (Technological Innovation Capability) by describing it in the form of innovation management practices. Most studies (Yam et al., 2004; Guan et al., 2006; Wang et al., 2008) propose evaluation frameworks based on five or seven TICs models, almost all of which have an equivalent in our model made up of 15 innovation practices. The following correlation may be observed: resource allocation capability (P4 “Project portfolio management”, P7 “Competences management”), learning capability (P12 “Collective learning”), R&D capability (P14 “R&D activities”), manufacturing capability (here we focused more on the innovative objects improvement: P1 “Design”), marketing capability (P15 “Customer relationship management”), organizational capability (P5 “Suitable organization”) and strategic capability (P3 “Integrated strategy”, P6 “Innovation process improvement”). Furthermore, literature attests to data collection methods based on questionnaires, and innovation performance is measured by means of seven-point scales ranging from (1) much unfulfilled to (7) much fulfilled. These measures are sensitive (sometimes even too much so) in the opinions of the people interviewed. The observation technique, supported by observable phenomena, is independent of any appreciation by the evaluators.

Using the *innovation practices/observable phenomena* model seems to be relevant insofar as it can be updated by adding new practices and consequently new observable phenomena. The progressive characteristic of the model is fundamental because the innovation management changes over time. The proposed model is then based on iterative calculation and class boundaries evolve with the number of companies entering the panel and also with the eventual emergence of new practices.

Our evaluation framework uses a multi-criteria method to calculate the potential innovation index (PII) of a set of companies. It enables the classification of companies into four classes of companies (proactive, preactive, reactive and passive) according to their IC.

To summarize, these research outcomes are:

- A finer innovation process analysis for companies,
- A method of classification into four classes of companies (proactive, preactive, reactive and passive) according to their IC,
- A company strength and weakness determination approach,
- An advising approach to companies, in order to facilitate and improve their innovation process.

Considering this last aspect, the model is mainly an IC evaluation model. However, recommendations are possible as long as:

- It is possible to simulate the impact on IC score of an improvement to a particular practice, and the impact in terms of classification. Thus, it is possible to indicate the criteria and practices that allow a particular company to enter a higher class in consideration of the whole present panel.
- Some practices are widely achieved in each class: some practices are typical of a class at a certain moment and within the status of the present panel. These practices may be considered as goals for a company targeting that particular class.

Finally, an extension of this framework to industrial networks may be important (Sala et al., 2011); the question is then to define a collective or consortium innovation capacity. Furthermore, the influence of firm size (human capital) and industry sector on our results should be taken into account and analysed in future research.

The improvement of the activity performance assessment approach may be one research perspective. Using a binary evaluation (presence or absence) of an observable phenomenon may be replaced by maturity models describing the degree of mastery of the people involved in the innovation process. The principle of proof collected in the company may be maintained: it requires the definition of four or five reference statements for each subpractice allowing a performance evaluation: this could be based on the percentage of projects or people affected by the criteria.

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