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"Measuring collective competencies of organisations - a systematic review of literature"

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Abstract

The present Systematic Review explores the existing academic literature on the instruments to measure collective competences of organisations. The purpose is to identify those that could be further used in a PhD work on the competences of organisations involved in co-operative R&D projects. This area of research is at the intersection of Strategic Management, Human Resources Management, Evolutionary Economics and Business Performance Measurement.

The methodology starts with a set of keyword strings for search in bibliographic databases. The extracted articles were then filtered for relevance and quality according to pre-defined criteria. An expansion of the resulting list was performed using cross-referencing and citation analysis. The final core list contains 33 articles.

Descriptive statistics illustrate an emergent and highly fragmented field: the number of articles in the list rises sharply over the last 25 years, but no agreement is reached on either the nature of the variables to measure nor on the means to do so.

The understandings of the concept of competence either aim at classifying firms (in a minority of articles), or at ranking them. In the latter case, the concept is assimilated to the proximity to best practices, to an efficiency or to an effectiveness in reaching functionally defined goals.

Four families of methods are used in the existing literature to measure collective competences of organisations: questionnaires, exploitation of secondary data, case studies and interviews, in descending order of frequency in the core list.

The selected articles provide a set of relevant concepts, of methods, of constructs, of third-party quantitative metrics and of individual questionnaire items useful for the further research.

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1 Scoping study - introduction

1.1 Justification for the research

Orthodox, neo-classical economics may be characterised by the following assumptions (Nelson and Winter, 1982):

- the economic system is a static equilibrium, based upon an intellectual model of Newtonian physics of perfect absence of friction and reversibility of time
- organisations experience diminishing returns as their size grows
- the behaviour of the firm and of the individual consumer is that of choice optimisation, between a set of options that are "given" at zero cost by the existing state of knowledge and technology.

Under these assumptions, orthodox economics demonstrates that the equilibrium attained possesses some (weak) properties of optimality: Pareto optimality, under which the situation of a given actor may not be changed without deteriorating even more the situation of another actor.

Even without considering the relevance of the optimality criterion of neo-classical economics, numerous critiques, specifically the school of evolutionary economics, have focused on the realism of its assumptions.

Historically, T. Veblen (1998) was the first, in 1898, to criticise the static nature of neo-classical economic theory. He specifically argued against the underlying "*hedonistic*" anthropology of an isolated and static individual only moved by "*given*" and immutable desires:

> *"The hedonistic conception of man is that of a lightning calculator of pleasures and pains, who oscillates like a homogenous globule of desire of happiness under the stimuli that shift him about the area, but leave him intact. He has no antecedent nor consequent. He is an isolated, definitive human datum, in stable equilibrium except for the buffets of impinging forces that displace him in one direction or another.[…] When the forces of the impact is spent, he comes to rest, a self-contained globule of desire as before "* (p.411)

On the contrary, according to Veblen, the human being and society as a whole, are embedded in historical development and evolution:

> *"The circumstances of temperament [...] are products of his hereditary traits and his past experience, cumulatively wrought out under a given body of traditions, conventionalities, and material circumstances; and they afford the point of departure for the next step in the process. The economic life history of the individual is a cumulative process of adaptation of means to ends that cumulatively change as the process goes on, both the agent and his environment being at any point the outcome of the past process"* (p.411)

He therefore called for an "*evolutionary*" economics, defined as a "*the theory of a process of cultural growth as determined by economic interest, a theory of cumulative sequence of economic institutions*" (p.413).

Following this early path, R. Nelson and S. Winter (1982), in their groundbreaking book, contended that the 3 main assumptions of neo-classical economics described above could be questioned.

The vision of the economic system as being static is in contradiction with the observation of economic change. Technical improvements to manufacturing methods, improving productivity in fabrication of a known and existing product, can be included in neo-classical models as exogenous inputs. However, further dimensions of change, such as the creation of new products and product differentiation, are not taken into account. In addition, changes in the environment are considered by neo-classical economics as mere external 'shocks' causing only temporary and reversible perturbation, after which the economic system is assumed to revert to its pre-existing 'equilibrium' sate. Observation shows that the economic system undergoes irreversible changes, under an historical process, with no return to the *status quo ante*.

The assumption of diminishing returns is essential for neo-classical economics to ensure the very existence of non-monopolistic equilibria in each market. However, fixed costs industries, typically those with high R&D or manufacturing investments, or network industries display large economies of scale and scope. This phenomenon was empirically identified by A. D. Chandler (1990) in the growth of large American and German concerns. It was conceptualised by W. B. Arthur (1988) as leading to self-reinforcing monopolies, and potentially to lock-in into technically sub-optimal solutions.

Finally, the 'perfect rationality' assumption of zero cost in the collection of information to define the set of solutions among which to choose, and in computing to find out the optimal one was criticised by March et al. (1958). They argued for a process of "*bounded rationality*", according to which the actors sequentially explore the possible solutions and stop at the first one that satisfies their minimum requirements, in a "*satisficing*" process.

As an alternative to neo-classical economics, R. Nelson and S. Winter (1982), alongside with G. Dosi et al. (2000) proposed the concept of **evolutionary economics**. Its main ambition is to account for historical developments and change, in a situation of permanent disequilibrium, thereby contrasting with the static equilibrium paradigm of neo-classical economics.

The evolutionary theory strongly relies upon the existence of stable capabilities of organisation or "*routines*", that evolve -slowly- over time. These stable, but yet not immobile, capabilities of the organisation are deemed to be the repository of "*organisational memory*" (Nelson and Winter, 1982, p.99) and the very subject of evolution in the organisation. The behaviours caused by these 'routines' are subsequently selected by an outside "*selective pressure*" (Cohen et al., 1996, p.683).

In this theory, the 'routines' used by organisations in their daily activities are in no way optimal. They would rather be some temporarily stabilised modes of operation or of solving a technical problem, considered as "*satisficing*"(March et al., 1958), and kept alive, "*often well beyond the circumstances which spurred their introduction*" (Cohen et al., 1996, p.660), for cognitive or political reasons., because they embody a "*truce*" between conflicting interests (Nelson and Winter, 1982).

Standard models of evolutionary dynamics introduce a mono-dimensional variability of firms, along one single dimension, that of productivity in the manufacture of a single, well-defined good (Nelson and Winter, 1982; Winter et al., 2003). However, in order to fully exploit the potential of the underlying cognitive and evolutionary micro-foundations of the theory, a greater level of diversity must be generated. In the same sense, a capacity to learn, and for each organisation to actually evolve in the space defined by its internal features and supporting routines, should be added to the theory. Specifically, **complexity theory** developed by P. M. Allen in the field of economic systems upon initial ideas of I. Prigogine and I. Stengers (1979) introduced micro-diversity in behaviours and search strategies (Allen, 2000).

In this sense, the theory of economics as an evolutionary complex system, if taken to its logical conclusions, could answer many of the critiques addressed to neo-classical theory.

However, in order for evolutionary economics to gain acceptance, its foundation stone, the existence of the stable, replicable and yet changing routines and capabilities of the organisation, must be empirically supported. Specifically, tools must be found to operationalize the observation and measurement of such collective routines and capabilities. This task is challenging, as recognised by M.Cohen et al. (1996), since the tools being considered by the scholars at that time are either historical, longitudinal investigation of organisations' archives, or ethnographical field studies. Both sets of tools are extremely costly in time and resources. The purpose of the present Systematic Review is to investigate the literature to consider how far existing research has gone in the direction of (potentially lower-cost) operationalisation and measurement instruments.

1.2 Discussion – Perspectives, key themes and concepts

The notion of organisations' capabilities or competencies is rather inter-disciplinary, being at the intersection of:

- evolutionary economics, as described above
- Human Resources management
- strategic management.

These disciplines consider the concept from very diverse perspectives: for evolutionary economics, the competencies of organisations are a theoretical foundation stone as seen above; for Human Resources management, they are an extension of the core concept of individual competencies, and this extension may contribute to better justify the existence of the discipline, for if the source of an

organisation's performance lie in its competencies, this justifies a greater role for those managing them; for strategic management, it is one hypothesis among others in the quest for sustainable competitive advantage, but the focus clearly is the latter.

On the other hand, the issue of measuring entities at the collective level of an organisation is the very purpose of the Business Performance Measurement discipline. This discipline focuses however on the measurement of 'performance', which is a distinct concept from that of 'competence' that I study.

1.2.1 The Strategic Management perspective

In strategic management, the aim of research is to identify the sources of **sustainable competitive advantage**. Two main approaches have been used in the literature: the consideration of the environment of the firm, and that of its internal status.

The first approach is rooted in the 'Structure-Conduct-Performance' paradigm familiar to Industrial Economics (Porter, 1985). In his book, M. Porter describes the list of features that an industry should have in order for the firm to thrive in it. For the author, the "*attractiveness*" of an industry is determined by his well-known "*5 competitive forces*": "*the entry of new competitors, the threat of substitutes, the bargaining power of buyers, the bargaining power of suppliers, and the rivalry among the existing competitors*" (chap.1) The author claims that a firm may change this competitive landscape by using appropriate strategies among the "*three generic strategies for achieving above-average performance in an industry: cost leadership, differentiation, and focus*". However, this vision considers that the firm has little limitation on the range of its available choices, and that the firm is able at any time, and at zero cost, to choose the industry it operates in or the 'generic strategy' that it considers as 'optimal' within the chosen industry. This assumption, based upon neo-classical vision of the firm as a free-floating optimising agent, appears little grounded empirically: firms do remain in a given industry for long periods, and have limited strategic mobility. The additional flaw in this vision is that for a firm to sustain any advantage obtained from the clever usage of Michael Porter's analysis framework, it would need to be able to prevent imitation by competitors, and no phenomenon in this framework prevents this.

In reaction to this belief that the sources of a firm's competitive advantage are external to it, E. T. Penrose (1995) coined the notion that "*the firm is more than an administrative unit; it is a* collection of productive resources*, the disposal of which between different uses and over time is determined by administrative decision*" (p.24, emphasis added). These resources can be physical and tangible: "*plant, equipment, land and natural resources, raw materials, semi-finished goods, waste products and by-products and even unsold stocks of finished goods*" (p.24). They can also be human resources, with different forms of (skilled or unskilled) labour and professions.

More importantly, according to E.T. Penrose "*it is never the* resources *themselves that are the 'inputs' in the production process, but only the* services *that the resources can render*" (p.25, emphasis in original). What she calls "*the services*

yielded by resources" are "*a function of the* way in which [the resources] are used" (p.25, emphasis added). In other words, the differences in the way a similar set of resources is actually mobilised are rooted in the competences present in the firm, and forms "*the uniqueness of each individual firm*" (p.25). It is the dense interaction and the co-evolution between highly heterogeneous human and material resources that build together the competitive position of the firm. This competitive position never is generic: it is specific to a given product-markets couple, and is based on a highly evolutionary and history-dependent path.

> *"No firm does produce just anything that happens to be in strong demand at any time in the economy [...] Each firm [...] focuses its attention on particular product-markets selected from the total market. The selection of the relevant product-markets is necessarily determined by the 'inherited' resources of the firm - the productive services it already has"* (p.82)

These early insights by E. T. Penrose were not fully formalised until the early 1990s (Barney, 1991; Prahalad and Hamel, 1990).

The main contribution of J. Barney (1991) is a formalisation of the features that a set of resources need to have in order for the firm to gain a sustained competitive advantage. His reasoning is that, in order for a set of resources to yield sustainable competitive advantage, they should not be mobile between firms, nor easy to acquire on an open market for production factors. Indeed, if the resources were mobile or easily accessible, any firm having initiated a winning strategy using this mobile or easily accessible resource would be imitated by its competitors and lose any advantage it may temporarily have had.

J. Barney posited that in order for resources to yield sustainable competitive advantage, they must simultaneously be "*valuable, rare, imperfectly imitable and non-substitutable*" (p.100). This list of features has become known under its acronym of VRIN resources. The resource must be developed internally, over time, since (by definition) they are not available in open factors markets.

C.K. Prahalad and G. Hamel (1990), in a more practitioner-oriented article of great influence, expose analogue theses, based on examples more than theoretical considerations. The "*core competencies*" are the technological and organisational bundles of "*diverse production skills and […] multiple streams of technologies […]in new and interesting ways*" (p.82). They provide the source of families of innovative and difficult-to-imitate products, following common technological principles declined into products suiting the needs of diverse markets. These product families, bringing high value to numerous customers, can be sold in large quantities at a premium. They should therefore generate high profit margins. In addition, if they are the result of an unique bundle of technologies and manufacturing skills, they should remain unchallenged in the market for long periods of time, and generate these above-average profits sustainably.

The vision of a firm's resources being static, in a sort of immobile repository, was

first criticised by D. J. Teece et al. (1997). In their view, the firm is embedded in a highly mobile and changing environment, to which it must adapt to survive and be profitable. They therefore define "*dynamic capabilities*" as "*the firm's ability to integrate, build and reconfigure internal and external competences to address rapidly changing environments*" (p.516). The competitive capacity of the firm isn't rooted in its position, as contended previously (Barney, 1991; Prahalad and Hamel, 1990), but in its mobility and internal processes: "*Competitive advantage of firms lies with its managerial and organisational processes, shaped by its (specific) asset position, and the paths available to it*" (p.518). The key capabilities become that of learning and reconfiguration, essentially by trial and error. This learning is a slow, path-dependent process, because changing many elements of a firm's activity simultaneously would jeopardise it: "*Learning is a process of trial, feedback and evaluation. If too many parameters change simultaneously, the ability to conduct [...] experiments [and] to ascertain cause-effect relationships is confounded*" (p.523). It is also slow because of the coherent nature of existing productive models and organisations, with organisational processes and incentives reinforcing one another (Boyer and Freyssenet, 2000). As a result, "*capabilities cannot be bought, they must be built. This sometimes takes years - possibly decades*" (p.528).

Although this inclusion of dynamics in strategic management was welcomed, it was also criticised on 2 grounds. On the first hand, the dynamic capabilities as "*internal processes*" were felt as vague and difficult to connect to empirical evidence. On the other hand, they were also considered as "*second-order*" capabilities, as "*capabilities to acquire capabilities*", in a potentially endlessly recursive fashion.

K. M. Eisenhardt and J. A. Martin (2000) reconsider this concept of 'dynamic capabilities', and contribute an answer to these critiques. For them, 'dynamic capabilities' correspond to specific, identifiable corporate processes, well-described in empirical research. They provide examples for each broad category of 'dynamic capabilities':

- integrating resources: product development, strategic decision making
- reconfiguration of resources: knowledge transfer processes, corporate re-organisation of business units
- gain and release of resources: knowledge creation, alliances & acquisitions, exit from obsolete positions.

Therefore, they conclude that the notion is indeed valid as a descriptive concept. However, they criticise the belief that they may explain competitive advantage. Following the (unsupported) assumption that organisational behaviours necessarily converge towards an industry "*best practice*", whatever the initial position, a phenomenon that they designate as "*equifinality*", they posit that the 'dynamic capabilities' are imitable and transposable. Therefore, competitive advantage doesn't lie in the dynamic capabilities themselves, but rather in the instantaneous set of resources existing. This explains why, according to the authors, the validity of the Resource-Based View of the firm is limited to "*moderately dynamic*" markets. On the other hand, in "*high-velocity*" markets, the relevance of any resource may be challenged by the evolutions of the market environment.

A very convincing clarification of the relationship between static and dynamic capabilities was given by S. G. Winter (2003), followed by C. E. Helfat et al. (2007). According to S. G. Winter (2003), "*ordinary or 'zero-level' capabilities [are] those that permit a firm to 'make a living' in the short term*" (p.991). The 'zero-level' capabilities defined here are also called "*operational capabilities*" by C. E. Helfat et al. (2007), while "*a dynamic capability is the capacity of an organisation to purposefully create, extend or modify its resource base*" (p.4).

This recent set of definitions also removes a conceptual ambiguity that tended to relate the concepts of 'competence' or 'capability' with superior performance, in the wake of the earlier works (Prahalad and Hamel, 1990). In these more recent definitions, "*capacity refers to the ability to perform a task in at least a minimally acceptable manner*" (Helfat et al., 2007, p.5). The word 'capacity' only implies adequate performance, sufficient for some effect to be obtained. The qualification of the capacity as being 'mediocre' or 'outstanding', its level of "*evolutionary fitness*" or "*external fit*" (p.7) is a different, subsequent problem to be solved, and isn't any more implied in the word 'capacity' alone.

Despite this recent clarification that conceptually disconnects 'capabilities' from 'performance', several studies have attempted to validate this connection empirically. These studies were systematically reviewed by S. L. Newbert (2007). His conclusions are that the level of empirical confirmation of the Resource-Based View of the firm's performance is relatively low, with only 53% of all studies confirming it. However, an even more interesting conclusion for our research is the extreme heterogeneity and apparent lack of consensus on the means to measure and operationalise the 'competencies' or 'capabilities':

> *"It is important to acknowledge the myriad ways in which the various independent [potentially explanatory] variables have been operationalised. Of the 417 (76%) tests in which a specific resource, capability or core competence serves as an independent variable, 26 different resources, 32 different capabilities and 6 different core competencies are studied[...]. However, relatively few resources, capabilities and core competencies have received attention in multiple studies"* (p.138)

To complete the last sentence, of the 26 'resources' listed, only 10 were investigated in 3 articles or more, with the maximum number of articles exploring a given 'resource' being 7; of the 32 'capabilities', only 3 were investigated in 3 articles or more, the maximum number of articles being 4 and of the 6 'core competencies' listed, all were studied in 2 articles or less (Newbert, 2007, Table 4).

1.2.2 The Human Resources Management perspective

In Human Resources Management, the concept of **individual competence** is the cornerstone for recruitment, assessment and promotion. As illustrated for example in a successful practitioner-oriented textbook, at each step, decisions are taken by comparison between what is expected from the individual in terms of these

competences and what is actually measured from him/her (Tyson, 2006).

In this environment, individual competencies are measured according to 4 broad, potentially overlapping dimensions: "*knowledge, skills, attitudes, personal attributes*" (p.129). The process of "*job analysis*" defines the competences necessary for each position. The methods used for this analysis are direct observation, interviews, diaries and questionnaires of people that are actually engaged in the job being analysed. The general principle is that of functional breakdown, a global task or capacity being decomposed into smaller, hopefully measurable components. For each component of the competence, a scale is defined, with each mark being associated to a short text defining the achievement level. The global competence requirements of a given position are typically displayed according to a "*spider diagram*".

Considering the strategic importance of competence, great care is taken to measure it on each individual, be it a recruitment candidate or a member of staff under periodic evaluation, according to reliable and valid instruments (p.163). The methods used are numerous (pp. 165-168), but their very number indicates how difficult the goals of reliability and validity are to reach:

- ability tests of achievement, on the technical aspects of the work that the person has learnt previously
- ability tests of aptitude, to evaluate what the person may develop after training
- personality tests
- group situational tests
- interviews
- "*behaviourally anchored rating scales -BARS*" (p.200)
- 360° feedback from colleagues, customers, managers and subordinates (p.201).

The evaluation tools for the individual performance and competence of employees are very often proprietary. The first reason is that the very job analysis is specific to each company and to the way it performs its division of labour, and as such may be considered as confidential information. Another is that the function of evaluating people is in itself a (lucrative) business, and the firms operating in this field keep their tools as internal trade secrets or under copyright protection.

Despite its paradigmatic dominance in the field of Human Resource Management, the notion of competence remains elusive in its nature. An interesting effort to conceptualise it was performed by G. Le Boterf (1994).

According to this author, competence is the ability to do something in a situation of action. He uses an analogy with linguistic competence (p.27):

- the ability to speak is the capacity to integrate vocabulary and grammar rules into individual linguistic performances (the sentences)
- the ability to act (in a professional environment), or professional competence, is the capacity to integrate knowledge, cognitive capabilities and skills (p. 25) into individual professional performances (actions and results).

He develops a "*systemic model of competence*" (pp.44-46, table 8), in which:

- the inputs are the professional situations and tasks
- the functions are:
  - the cognitive elaboration of an operative representations of the situation
  - the consideration of self-image - "*image de soi*" - that determine the extent to which resources will be mobilised, according to whether the task is considered reachable, compatible with one's dignity or within one's area of responsibility
  - the activation of memorised knowledge and of cognitive skills ("*inference operations of induction, deduction, transduction, comparison, operationalisation*" - p. 45),
  - the decision of choosing a given professional action
- the outputs are professional actions
- the feedback learning loops are activated according to the post-hoc results of the decisions taken.

Human Resources Management has thus developed a very large theoretical and practical expertise and toolkit to handle, evaluate, manage, plan, reward **individual** competences. In this sense, it mimics the methodological individualism prevalent in economics, and very present in Anglo-Saxon culture. However, organisations do exist as collective bodies, and the literature on strategic management has underscored the importance of collective competences.

Building upon the existing expertise in Human Resources Management in competences in general, some authors have endeavoured to explore the first steps of collective competences, in a bottom-up movement.

The first scale of collective action being considered is that of the team or small group of people. S. Tyson (2006) identifies 2 important tasks in a group: to ensure that the collective task is indeed performed; and to build up cohesiveness by to socio-emotional labour. He also lists 20 components of team competence (p.29), following this broad framework, that were the result of earlier work.

G. Le Boterf (1994) associates team competence with a "*common operative image*" of the situation and of the problem to be solved, a "*common language and code*", and a "*co-operative ability*" (or "*savoir coopérer*") (p. 129). He lists 3 types of teams (p.135):

- base-ball or cricket teams, in which people "*play within a team, but not as a team*"
- football, in which "*each player occupies a specific position, but co-ordinates its action with the others*"
- double tennis, in which each player "*permanently adapts himself to the other [player's] action*".

Although the reflection of Human Resources Managers on the definition and assessment of individual competence has proven to be very thorough, it seems from

these rather recent references that the reflection on collective competences in this field remains in its infancy.

1.2.3 The Evolutionary Economics perspective

As described earlier in the introduction, the micro-foundation of evolutionary economics theory is the fact that individual people's behaviours and organisations contain some **stable elements** subject to the **evolutionary processes** of random variation, environmental selection and retention (Paulré, 2004; Nelson and Winter, 1982). These stable elements are an individual's "*skills*" and "*routines*" at organisational level.

R. R. Nelson and S.G. Winter (1982) define an individual's "*skill*" as "*a capability for a smooth sequence of coordinated behaviour that is ordinarily effective relative to its objectives, given the context in which it normally occurs*" (p.73) It may be body movements coordinated with decisions (e.g. driving), or imprinted in mental process (e.g. calculus).

The authors define the "*routine*" at organisation level. The concept mainly is valid for organisations that provide roughly the same good or service over a given period, with "*criteria for doing well or poorly*" (p. 96), in the "*circular flow*" (Schumpeter, 1934) or static situation of absence of change. Routines act as the repository of "*organisational memory*" (p.99) and of memorising by doing. They are defined by the usual set of actions prescribed for a person's job, by the reactions to orders and other forms of "*coordinating messages*", so that every person behaves in a way that is expected by the other members of the organisation (should this behaviour be nominal or not). Routines are also the result of an "*intraorganisational truce*" (p.107) on the rules defining each person's role, on the sharing of workload and benefits, and on the allowances within the unspecified range of accepted action. A strong adherence to routines is often observed in order to prevent the (costly and uncertain) breach of this truce.

Since the routines are the stable elements in the organisation that undergo the evolutionary process, the authors introduced an analogy of "*routines as genes*" (p.134) that has exercised great influence on later works.

A more comprehensive definition of routines was later given by M.D. Cohen et al. (1996): "*A routine is an executable capability for repeated performance in some context that [has] been learned by an organisation in response to selective pressures*" (p.683). Routines are based upon deeply memorised individual skills of individuals, are semi-automatic, and rely upon "*tacit*" knowledge (Polanyi, 1967). The authors claim that their concept of 'routines' is embedded in scientific knowledge on "*short-tem memory limits, reasoning powers and differentiated forms of long-term memory and learning*". The underlying cognitive theory is the following. People act in an effective way when they are being required to repeat the same behaviour in identical or analogue situations. This set of analogue situation is progressively imprinted "*by doing*" in the actors' memories. When faced again with it, the actors recognise the common pattern and respond semi-automatically, fast and efficiently to

it. M.D. Cohen et al. (1996) thus consider that their theory of routines relies upon a form of "*cognitive realism*" (p.654).

The semi-automatic behaviour mode of routines was however considered not satisfactory when the issue is to consider actions of greater reflection level and intentionality. G. Dosi et al. (2000) thus introduced the concept of "*organisational capabilities*". For them:

> *"To be* capable *of some thing is to have a generally reliable capacity to bring that thing about as a result of intended action. Capabilities fill the gap between intentions and outcome, [...] in such a way that the outcome bears a definite resemblance to what was intended."* (p.2, emphasis in original)

They later gave empirical examples of such *'organisational capabilities'*: in semiconductor and automotive manufacturing (Appleyard et al., 2000; Flaherty, 2000; Florida and Kenney, 2000), in drug discovery (Henderson and Cockburn, 2000; Pisano, 2000), in bank process replication (Szulanski, 2000), in electronic equipment maintenance (Narduzzo et al., 2000) and even in pizza baking (Argote and Darr, 2000).

This empirical evidence does display the existence of 'organisational capabilities', although the distinction between these and 'routines' (supposedly in the intentionality level) does not appear as being very clear-cut. However, the investigation methods being used to evidence these 'organisational capabilities' generally are ethnographic. They are extremely costly to replicate, unless one may use "*an army of ethnographers*" (Cohen et al., 1996, p.681). The 'organisational capabilities' evidenced in these studies also are extremely idiosyncratic. They do not appear to relate to a common structure or pattern that would make them re-usable in another context than the one in which they were observed. It thus appears very difficult to use them in a cross-sectional investigation of several firms or organisations.

1.2.4 Perspectives on measurement

Business Performance Measurement as a discipline follows suit on the developments of accounting as a tool for managers to have a representation of the current situation of their business. The purpose is for business managers to have the relevant information at the right time, in order to take the right decisions.

Historically, the first methods were to re-use the data produced by the accounting procedures, and to adapt them to operations control and decision-making. From a cost of measurement perspective, it leveraged the mandatory costs incurred for an accurate accounting system and attempted to re-use the data in a broader scope. These first developments, initiated in the second half of the 19th century by DuPont, resulted in analytical cost accounting, in which costs were attributed to individual products according mainly to the direct labour effort attributable to them (Kaplan, 1984). The main perceived advantage of financial, accounting-based data is the high accuracy, reliability and repeatability of the figures provided.

However, these methods solely based upon financial data have proved to become increasingly limited in their usage and their relevance to business control and action needs. A very popular concept incorporating a much broader view of the information needed to make decisions, called the "*balanced scorecard*", was developed by R.S. Kaplan and D. P. Norton (1992). This set of measures attempted to group into a single view the elements considered as key for the future success of the firm (p.72):

1. "*How do customers view the company? [customer perspective]*" generally "*time, quality, performance and service, and cost*" (p.73)
2. "*What must the company excel at? [internal perspective]*", for example "*cycle time, quality, employee skills, and productivity*" (p.75)
3. "*Can the company continue to improve and create value? [innovation and learning perspective]*", mainly in a continuous improvement framework
4. "*How does the company look to shareholders? [financial perspective]*", typically "*profitability, growth, and shareholder value*" (p.77).

These developments have led to the progressive creation of the discipline of Business Performance Measurement; whose work programme was defined by A. Neely et al. (1995). For these authors, "*performance measurement*" is "*the process of quantifying action, where measurement is the process of quantification and action leads to performance*" (p.80). The purpose is indeed to design systems that set quantified, objective goals to people or sub-divisions within the organisation, in line with the organisation's overall strategy, and to assess in what extent these goals have been met, in order to trigger either rewards or corrective action. The key evaluation criteria for the appropriateness of a Performance Measurement System is then "*how much does [the measurement process itself] cost?*" and "*what benefit does [it] provide?*" (p.81). The individual performance measures typically focus on quality, time, cost and flexibility (Table 2, p.83). The overall vision is that of a form of company-wide cybernetics, with the Performance Measurement system providing the information necessary to close the feedback loop. As described by a 'white paper' of the leading supplier of Business Performance Measurement software, Business Objects, the issue is "*to set goals, measure success, and take the action needed to improve performance*" (Business Objects, 2007).

The main interest of this perspective is that measurement is at the very centre of the issues being investigated: what metrics should be used, how do they relate to the phenomena of interest, how reliable, accurate and noise-free are they? On the other hand, the difficulties in using this approach in a research on the competencies of organisations seem to be the following:

- first, what is measured is performance levels, and not specifically competence, a difference which will be discussed further in the "Findings" section of his study
- second, apart from the financial reporting that is specified in great detail and mandated with universal applicability within a given jurisdiction by law or by Generally Accepted Accounting Practices, the performance measurement system of a given organisation is highly specific to that firm. Since the objectives being set are deduced from the organisation's strategy, the very entities being measured are a consequence of this strategy. There is little

reason why the metrics used should be comparable from one organisation to the next. The transposability of measurements may thus be questioned

- third and finally, the data retrieved from those performance measurement systems is (probably righteously) considered as both strategic and confidential. Access to the data may be highly problematic in a study performed by an external researcher.

1.3 Proposal for a Systematic Review question

It may be concluded from the discussion above that each of the 4 approaches considered contributes to the investigation of measuring collective competences and abilities of organisations, but are all incomplete.

The Strategic Management approach, being mainly concerned with firm performance, has, until recently with C.E. Helfat et al. (2007), concentrated its investigation on the *relation* between collective competences and abilities, on the one hand, and this performance, on the other hand. It has therefore dedicated little energy to the actual measurement of either. This results in poor conceptual stability of the constructs and great heterogeneity in the operationalisation, as evidenced by S.L. Newbert (2007).

The Human Resources Management approach has considerable experience in competence measurement and in high-quality instrument design and validation, with the explicit aims of validity and reliability. However, this approach remains somewhat prisoner of its individualistic paradigm and of its intellectual sourcing in individual psychology. It thus applies these tools mainly to individuals, and experiences difficulties in adapting them to collectives, be they teams, groups and even more so to full organisations.

The Evolutionary Economics approach also starts its bottom-up description and observation with the very low-level micro-foundations of individual, tacit and semi-automatic skills. These elementary tasks have been progressively co-ordinated into larger scale 'routines' of increased degree of consciousness and intention, and of higher dynamic learning capacity. However, the epistemology of direct, ethnographic or archival empirical observation has produced an extremely costly methodology that is difficult to duplicate at large scale.

Finally, the techniques of Performance Measurement are highly relevant to measuring collective phenomena at firm or sub-division level, but they tend to measure performance rather than competence, to be idiosyncratic and highly confidential. They may then be difficult to leverage in a study performed by an external researcher.

The purpose of the present Systematic Review is thus to find what authors may have written on the issue of "**the measurement tools and instruments of collective competences and abilities of an organisation**": what tools were proposed, what their theoretical background is, what their empirical validation has been. This review will explore the literature at the intersection of these 4 fields of Strategic

Management, Human Resources Management, Evolutionary Economics and Business Performance Measurement, in order to draw from the contributions of each, and to overcome the limitations of either approach with the insights drawn from the others.

2 Systematic Review Protocol - Methodology

2.1 Consultation Group / Panel

The people that were consulted during the Systematic Review were the following.

Person	Title	Organisation
Prof. Cliff Bowman	Professor	Cranfield University, SoM, Strategic management
Dr. Véronique Ambrosini	Senior Lecturer	Cranfield University, SoM, Strategic management
Heather Woodfield	Information Specialist for Social Sciences	Cranfield Library
Dr. David Denyer	Senior Research Fellow	Cranfield University, SoM, Organization Studies

I consulted Cliff Bowman and Véronique Ambrosini at 2 stages of the Systematic Review:

- initially, to identify the works considered as essential / seminal in this field
- after I had set up my core list of papers, to hierarchise their importance and potentially add some more.

I consulted Heather Woodfield to use citation databases to find references that shared commonalities with the articles I already had identified, at the stage when I need to expand the "core list" of articles following the first round of investigation.

I consulted David Denyer on several occasions, initially on the very appropriateness of the research question for a Systematic Review, on the adequacy of my method for selecting, appraising and extracting data, and on the results of the process after the first and second rounds of investigation.

2.2 Personal statement

2.2.1 Intentions in making the Systematic Review

One of my ambitions in the full PhD work is to contribute to the evolutionary economics theory. This theory strongly relies on the existence of stable capabilities of organisations or 'routines'. However, these capabilities prove difficult to observe or to operationalise, which reduces the apparent empirical validity of this theory.

One of my intended contribution in the PhD is to empirically validate the usage of some tools and instruments to measure and assess the competencies of organisations. This empirical validation should be in the field of innovative R&D projects in high-tech clusters.

Prior to this work, I need to know precisely what the existing state of the art is of such tools aiming at measuring the competencies of organisations: what tools were

proposed, what their theoretical background is, what their empirical validation has been.

I therefore ambition to obtain from this Systematic Review a list of tools that I will be able to use in my later PhD work to measure the competencies of the organisations I plan to survey in European high-tech clusters.

2.2.2 Personal and intellectual biases

My personal background is that of natural sciences, and specifically physics. I thus have a epistemological point of view that may be related to 'positivism', although with some significant reservations that are too long to expose in this format, and were the purpose of an external assignment on "Research Strategy".

For the sake of this Systematic Review, I understand a 'tool' or an 'instrument' as having the (typically 'positivist' and quantitative) properties of appropriateness or consistency (it actually measures what it intends to), of fidelity, repeatability or reliability (2 successive measures of the same phenomenon should lead to the same measurement result), universality / transposability (it may be used in a broad range of contexts), monotony (an increase in the entity being measured leads to a consistent increase of the measurement result) and clarity (the signal to noise ratio is high). In order to be able to actually use these tools and instruments in the concrete environment of a PhD, and considering that I intend to apply them to a significant number of organisations (several tens of organisations over the duration of my PhD), I will pay attention to the cost in terms of time and of other resources necessary to implement these tools and instruments.

I have no sponsor influencing my work, or other sources of financial conflict of interest.

I may however be biased by the fact that I already have identified a set of tools and instruments that I believe at this stage are of potential usage for my future research, and this may be a form of vested (intellectual) interest.

2.2.3 Key learning outcomes and limitations

The main learning I have received from this Systematic Review is the usefulness of writing the methodology Protocol beforehand. The permanent availability of is document has proved to be invaluable during the period of assessment of the retrieved articles on relevance and quality, as it allowed me to have the assessment criteria physically and mentally present upon the reading of each article. It thus assured the consistency of the evaluation, and contributed to its efficiency.

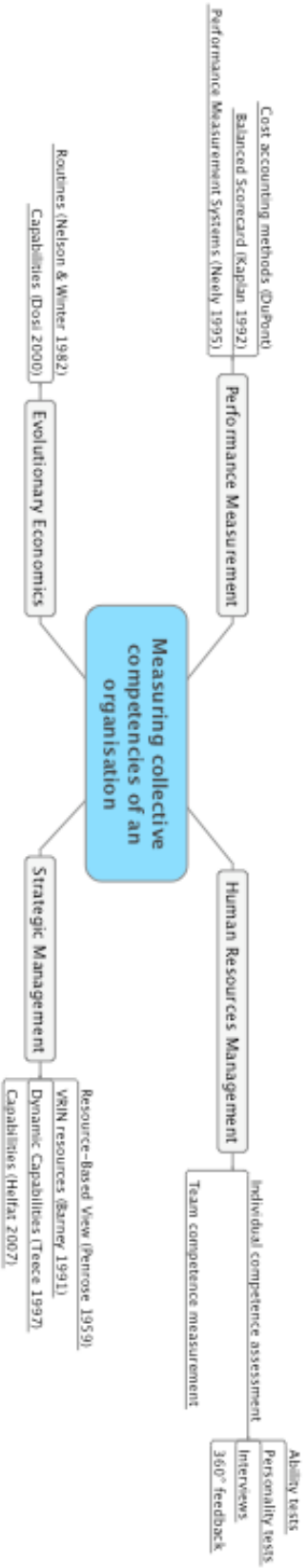
I will definitely import the results of this Systematic Review into my PhD. They may be facially considered as disappointing, in the sense that the literature on the subject is both fragmented and with little coherence. However, knowing this outcome, and being able to support it with rigour will help justify further methodological choices during the PhD proper.

The main limitations of this Systematic Review may reside in the following:

- I performed 2 iterations of search and selection, expanding from a first core set of articles using citation database search and cross-referencing. This operation yielded diminishing returns, and I stopped there. Although I argue that I have reached a point of saturation, it would have been possible to pursue the iterations one step further
- considering the emergent character of the subject, a further source of information could reside in unpublished works, such as conference papers or internal working papers by the authors identified in the core list. However, both time constraints and quality concerns from the published, and therefore peer-reviewed and filtered material made me consider that the potential from this source probably would not be worth the fraction of remaining time necessary to treat it
- finally, the Systematic Review methodology, being mainly based upon the material reachable through journal databases, did not give me access to books. Although the emergent character of the field may mean that little has yet been summarised into reference books, this latter form of publication often contains interesting and forward-looking ideas and theories that deserve attention.

If I had had the opportunity to re-do this Systematic Review, I probably would have liked to consider methods to investigate books in greater detail.

2.3 Map of the investigation field



2.4 Aim of the review

The aim of the Systematic Review is to obtain a list of validated tools and instruments used to measure and assess the collective competencies / (cap)abilities of an high-tech organisation. The focus is on 'high-tech' organisations, i.e. organisations involved in industries with a high intensity in R&D and innovation.

2.5 Search Strategy

The search strategy that I have adopted is summarised by the Figure 2.1 below.

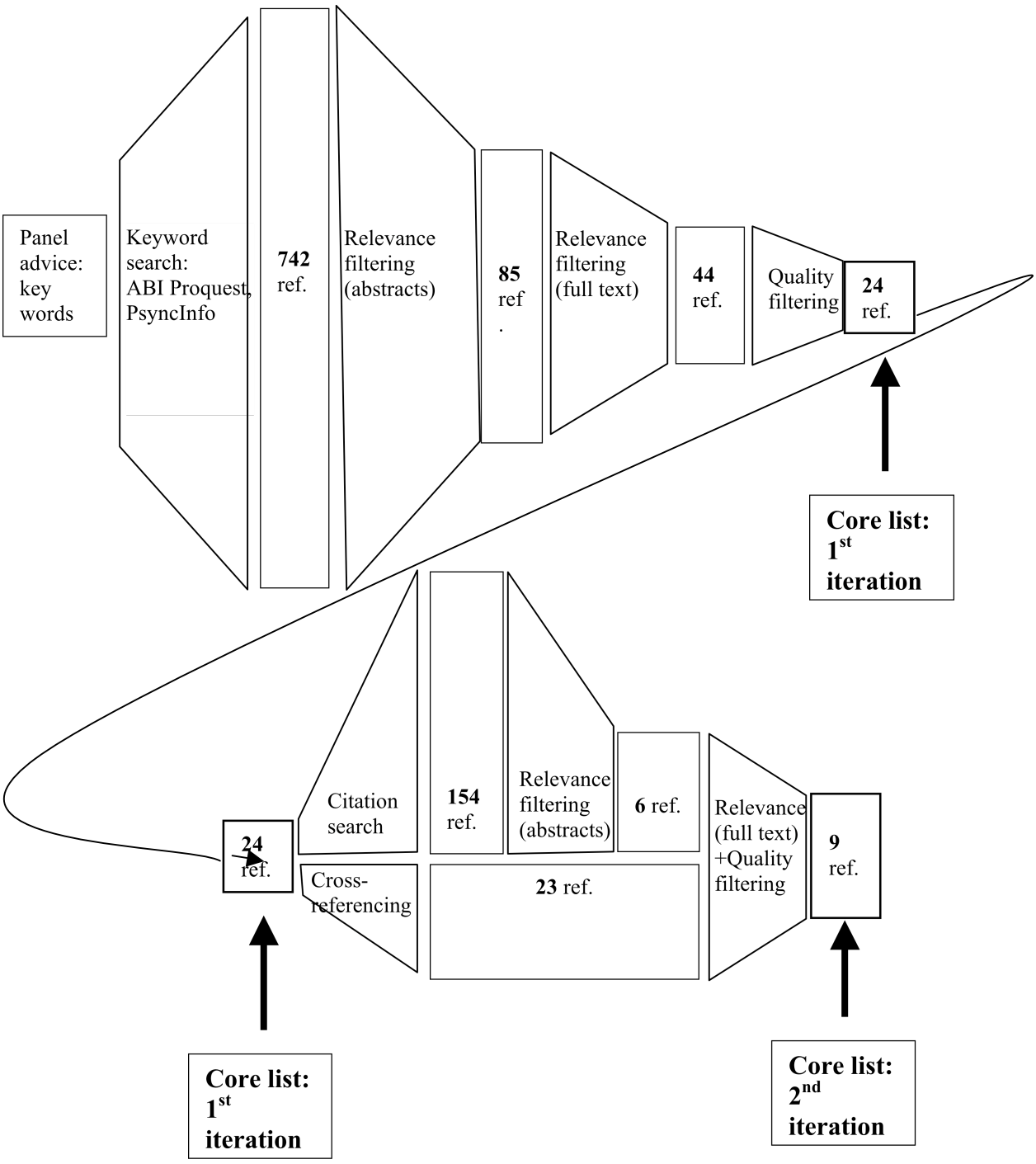


Figure 2.1: Search & selection methodology: Overview

I have first interrogated the members of my advisory panel to access the initial, seminal articles and review books that theoretically give definitions of collective,

organisation-level 'competencies', '(cap)abilities' etc, beyond those that I already knew. These initial references led to additional words to be used in the search strings: this proved to be specifically relevant in an evolving, unstabilised field such as that of collective competencies, in which there is disagreement among scholars on the very words, definitions and concepts.

2.5.1 Search strings that were used in the review.

Concept	Keywords	Rationale
Capabilities	(competenc* OR capacit* OR capabilit* OR skill? OR abilit*)	These are the very object I am investigating, my "main concepts'.
Collective / organisation level	(organi?ation* OR collective OR corporat* OR business* OR firm* OR compan*)	
Measurement	(measure* OR evaluat* OR estimat* OR quantif* OR operationaliz* OR tool* OR instrument*)	
Focus on innovation and R&D	(innovati* OR R&D OR research OR "New Product Development" OR NPD OR "New Business Development" OR NBD)	This is the context in which I will apply the measurement instruments.
Focus on business environment	medic* OR therap* OR health* OR government* OR educat*	Papers involving these concepts should be excluded

Table 2.1: Search strings used in the Systematic Review

2.5.2 Search strategies on keywords

The first 2 or 3 keyword strings were searched as being "*NEAR*" one another (to be more accurate, "*within 3 words*" of one another), when this search feature is being proposed, which is the case of ABI Inform (Proquest) and of PsycInfo.

I will use the measurement tools in an innovation and R&D context for the later PhD. Therefore, I preferentially investigated those tools and instruments that have been developed or validated in this field. It will improve the validity of re-using them, because the context of their development will be maintained.

I therefore used 2 search strategies, that I will describe hereafter using the "Concept" heading referring to each search set of keywords strings of Table 2.1 above:

- Search strategy A: Capabilities NEAR Collective / organisation level AND Measurement AND Focus on innovation and R&D. In this strategy, the constraint on having the 3 main concepts NEAR one another is relaxed, in

order to account for the context.

- Search strategy B: Capabilities NEAR Collective / organisation level NEAR Measurement. In this strategy, the 3 main concepts are investigated NEAR one another, but with no restriction on the context.

Since PsycInfo also handles publications in the medical, educational and government fields that I am not interested in, I used the last string connected with the "*NOT*" operator, in order to exclude the results in these fields.

The pilot searches performed with the target databases gave the following results.

Database	**Existence of search feature of 2 strings being "NEAR" one another**	**Search strategy A Number of results** (peer-reviewed journal articles only)	**Search strategy B Number of results** (peer-reviewed journal articles only)
ABI – Proquest	YES	508	165
Business Source Premier – Ebsco	*no*	*1 921*	*6 732*
PsycInfo (with focus on business environment)	YES	60	9

Table 2.2: Results of the pilot searches

Considering these pilot searches, I did not use Business Source Premier (Ebsco), and restricted myself to the following journal databases:

- ABI Inform (Proquest) for strategic management and economics journals
- PsyncInfo for Human Resources management journals.

2.5.3 Potential sources of information under the categories provided

The categories of information sources were investigated along the guidelines described in the Table 2.3 below.

Journals not cited in the databases	Were not investigated, because the management and psychology databases provide the information required
Conference papers Working papers or unpublished papers Documents on the internet	Were not be investigated, for most of the quality work is published in journals
Books	Were tentatively investigated, using reference databases and cross-referencing, but with limited results
Personal requests to knowledgeable researchers and/or practitioners	I consulted the Cranfield faculty in the fields of Strategic Management (from my panel) and Human Resources Management
Reports from relevant institutions: companies, public bodies etc	Not relevant for my research

Table 2.3: Guidelines for the sources of information

2.5.4 Relevance selection criteria:

The articles retrieved from the databases using the keyword strings described above in §2.5.2 were selected for relevance, along a 2-steps procedure:

1. by reading the titles and abstracts
2. by reading the full text, with selection criteria varying according to whether the article is empirical, methodological or theoretical.

The titles and abstracts of the articles must contain reference to:

- Collective capabilities, capabilities of organisations / firms
- Concern with measurement / operationalisation / empirical validation or observation.

The full text of the articles must contain the information described in the Table 2.4 below.

Nature of the article	Information required in the full text for the article to be selected for relevance
Conceptual / theoretical	• Concern with measurement / operationalisation / empirical validation or observation • E xamples of potential metrics
Methodological	• Precise mode of data collection, (e.g. exact questions used in surveys) • Discussion of appropriateness of metrics (do they measure what they intend to?) • Discussion of one at least among the following issues: repeatability / reliability, transposability, noise
Empirical	• Details of metrics used • Discussion or measure of coherence and consistency of metrics used • Assessment of validity of the metrics used • Report of measurement results

Table 2.4: Relevance criteria for full text articles

Of the 114 articles retained as potentially relevant after reading of their title and abstract (over the 2 iterations of the full procedure), 56 were discarded following the further reading of their full text. The relevance selection criteria that were not met by these articles, and thus justified their rejection from further consideration in the Systematic Review, are fully detailed in Appendix 1.

2.5.5 Quality Appraisal

I used the quality appraisal method described hereafter, inspired by a framework by J. Marcos (2000), to further select the articles retained as relevant. This Quality Appraisal method has been widely used in earlier Systematic Reviews. I selected it for its simplicity. Considering the large number of articles to evaluate in a short time frame, I believe that a simple tool is better suited than complete evaluation frameworks (Critical Appraisal Skills Programme (CASP), 2002). These complete tools are intended to be used for the evaluation of articles for inclusion in a journal or for the post-hoc evaluation of a full research programme. The time budget for the evaluation of a single paper is of several days, much larger than in the case of a Systematic Review, when I need to assess several tens of articles in about one week.

Criteria	0 - Absence	1 - Medium	2 - High
Contribution to knowledge in the field of measuring collective competences	This article does not provide enough information to assess this criterion / This criterion is absent from the article	Contribution to knowledge exists but is limited in importance and/or significance	Significant addition to current knowledge.
Discussion of the underlying theory		There is a connection between the paper's theoretical basis and extant theoretical knowledge in the field; Empirical / methodological papers built on existing theory	Excellent discussion of the adequacy of measurement tool to existing theory; Good review of prior literature
Discussion of Methodology		The connection between theoretical constructs and empirical proxies exists but is not fully developed	Excellent discussion of operationalisation of constructs and of the validity and appropriateness of proxies
Learning from Data Analysis		Appropriate sample, results are a relevant (but not sufficient) contribution for assessing the validity of measurement tool	Well-designed data sample; results are sufficient alone to draw final conclusions on the validity of measurement tool
Limitation of the Study		Paper mentions its limitations but does not explain their relevance to understand the results	Paper states clearly its limitations; implications are acknowledged

For each criterion, a "Not applicable" rating is available.
Source: adapted from (Marcos, 2000)
Table 2.5: Quality Appraisal method

Articles were further included in the Systematic Review if:

1. they do not score two 0s in the five categories under evaluation;
   AND
2. they score 2 at least once in any of the first four categories under evaluation.

This evaluation gives a premium to articles that have at least one feature of great interest, even if they display weaknesses in other areas.

The results of the Quality Assessment for both iterations of the search (see below §2.5.7) are given in the Appendix 4. They result in a list of **33** relevant and high-quality articles.

2.5.6 Data Extraction

All articles being retained as relevant for the Systematic Review (following the procedure described in §2.5.4) were stored in the RefWorks database for further citation. The import procedure into this database automatically stores all relevant bibliographical data, such as author, publication, date, journal name, etc…

In addition to this I created a spreadsheet-based database containing additional data on these articles retained as relevant. This database was used for the sake of statistical exploitation and of Quality Assessment filtering. It contains:

- a shorthand identification string of the author name, e.g. Prahalad
- the journal name
- the publication date
- whether the article is theoretical, methodological or empirical
- the mark given on each of the 5 Quality Assessment criteria described above
- the inclusion decision
- the industry involved
- the geographical setting
- the sample size (if relevant)
- the type of method proposed for measurement of collective competencies; e.g. questionnaire, external database analysis, ethnographic study
- the nature of the competence or ability being measured
- the underlying theory or main concepts being investigated; e.g. core competencies, routines, dynamic capabilities

The articles being selected after the Quality Appraisal procedure (described in §2.5.5), the "core list", were then re-read thoroughly in order to add the following fields to the database for each of them:

- physical location of the paper (local storage, Cranfield library, British Library on loan, etc…), for later retrieval
- my comments and critique on the article
- my summary of the article
- anticipated further usage of the article in the Systematic Review or the full PhD.

2.5.7 Expansion of the initial "core list" using cross-referencing and citation analysis

The "core list" resulting from this first keyword search and selection amounted to a "core list" of **24** articles. This "core list" was deemed to be too restricted by my panel members and methodology advisor. I consulted my information specialist, and she advised me to expand this "core list" through the following methods:

- cross-referencing: for each article of the "core list", I have extracted the cited articles relevant to my study, i.e. those that describe measurement methods for collective competencies. This relevance was made apparent from the circumstances in which the article was cited in the article of the "core list"
- citation analysis: for each article of the "core list", I have used the Social Sciences Citation database in order to find the "related articles". I have operationalised this concept of "related articles" as those articles that share more than N/4 citations or more with the article of the "core list", N being the number of articles being cited by the article of the "core list". I found these related articles by using the "*related records*" function available from the Social Sciences Citation database

The results of the expansion using the cross-referencing method are described in Appendix 2: for each article of the initial "core list", the table provides the number of articles appearing as relevant references. This relevance was assessed according to both the article title and the way it was referenced in the article of the initial "core list".

The results of the expansion using the citation analysis method are described in Appendix 3: for each article of the initial "core list", the table provides the number N of article being cited, the number of articles that share at least N/4 references in common with this focal article, and the number of articles appearing both as relevant references and absent from the initial "core list".

These articles were then filtered according to the same relevance and quality criteria as above, and yielded **9** additional articles. The articles of the resulting "2nd order core list" were then again summarised and commented. Considering the time constraints of the study and the diminishing returns of the process, I have considered that I had approached by then a form of saturation point and did not reiterate the process further.

2.5.8 Synthesis

I have organised my synthesis along the types of methods used to measure collective competencies, ranked in the order of cost (in time and other resources) to use them operationally.

My conclusion consists of a set of measurement tools that appear as fulfilling as much as possible of the validity programme described initially:

- appropriateness / consistency
- fidelity / repeatability
- universality / transposability
- monotony
- clarity
- cost in time and other resources to use operationally.

I will thus be able to select those tools that could be used further in my PhD work, keeping in mind the focus on technology-intensive industries.

3 Findings

3.1 Final core list

The final "core list" of relevant and high-quality articles, following the 2 iterations described in the §2.5 above, contains **33** articles. They are briefly summarised below in chronological order and in Appendix 5, in which the following fields are added:

- Search iteration number
- Publication date
- Type of article (Theoretical/ Methodological/ Empirical)
- Method of measurement being used
- Competence being measured.

N°	Reference	Journal name
1	(Lenz, 1980)	Academy of Management Review
2	(Hitt and Ireland, 1985)	Strategic Management Journal
3	(Durand, 1988)	R&D Management
4	(Cohen and Levinthal, 1990)	Administrative Science Quarterly
5	(Conant et al., 1990)	Strategic Management Journal
6	(Leonard-Barton, 1992)	Strategic Management Journal
7	(Deshpande et al., 1993)	Journal Marketing
8	(Henderson and Cockburn, 1994)	Strategic Management Journal
9	(McGrath et al., 1995)	Strategic Management Journal
10	(Murthi et al., 1996)	Journal Marketing Research
11	(Lane and Lubatkin, 1998)	Strategic Management Journal
12	(Dutta et al., 1999)	Marketing Science
13	(Makadok and Walker, 2000)	Strategic Management Journal
14	(Ritter et al., 2002)	Journal of Business & Industrial Marketing
15	(Schoenecker and Swanson, 2002)	IEEE Transactions Engineering Management
16	(Stratman and Roth, 2002)	Decision Sciences
17	(De Carolis, 2003)	Journal of Management
18	(Camison, 2004)	Management Research
19	(Denrell et al., 2004)	Management Science
20	(Moehrle and Lessing, 2004)	Creativity & Innovation Management
21	(Wang and Ahmed, 2004)	European Journal of Innovation Management
22	(Dutta et al., 2005)	Strategic Management Journal
23	(Escrig-Tena and Bou-Llusar, 2005)	Decision Sciences
24	(Ethiraj et al., 2005)	Strategic Management Journal
25	(Jantunen, 2005)	European Journal of Innovation Management
26	(Jerez-Gomez et al., 2005)	Journal of Business Research

27	(Narasimhan et al., 2006)	Marketing Science
28	(Prieto and Revilla, 2006)	The learning organisation
29	(Tu et al., 2006)	Journal of Operations Management.
30	(Vinding, 2006)	Economics of Innovation & New Technology
31	(Garcia-Muiña and Navas-Lopez, 2007)	Technovation
32	(Grimes et al., 2007)	Journal of Small Business & Enterprise development
33	(Wang and Ahmed, 2007)	International Journal of Management Reviews

Table 3.1: Core list of relevant and high-quality articles

3.2 Descriptive statistics of the 58 relevant articles

The following section provides information on the 58 relevant articles, broken down between the 33 articles that were "included" in the Systematic Review following the Quality Assessment (and therefore part of the "core list" described above in §3.1) and the 25 articles that were "excluded" for quality reasons.

As may be evidenced from these descriptive statistics below, the measurement of collective competencies of organisations appears as both an emergent and highly fragmented field.

3.2.1 Publication dates

The statistics on the publication dates display the characteristics of an emergent subject. The number of relevant and high-quality articles remains low, but grows significantly over each of the 5-years periods being considered, with a very significant proportion of articles having been published in the 5 years to date of the present Systematic Review.

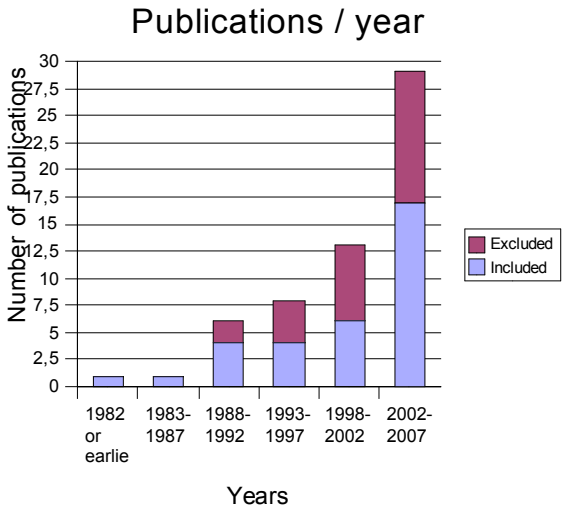


Figure 3.1: Relevant articles / year

Quantitatively, the number of articles being published in each 5-years period is the following.

Period	Included articles	Excluded articles	Total
1982 or earlier	1	0	1
1983-1987	1	0	1
1988-1992	4	2	6
1993-1997	4	4	8
1998-2002	6	7	13
2002-2007	17	12	29
Total	**33**	**25**	**58**

Table 3.2: Number of relevant articles / year

3.2.2 Journals

The journals in which the relevant articles were published are very numerous, most journals only publishing one article on out topic of interest: measuring collective competencies of organisations. This characterises a highly fragmented area of literature.

However, some journals have published 2 articles, and the Strategic Management Journal, as an exception, published 11 relevant articles.

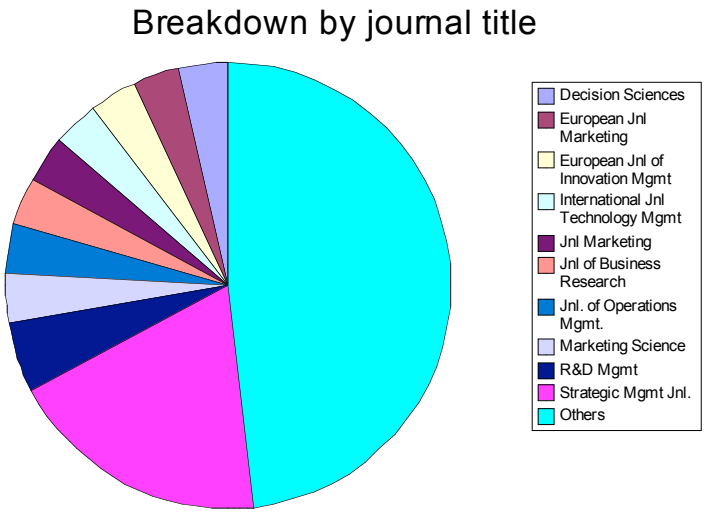


Figure 3.2: Breakdown of relevant articles by journal title

Journal name	Number of relevant articles published
Decision Sciences	2
European Journal Marketing	2
European Journal of Innovation Management	2
International Journal Technology Management	2
Journal Marketing	2
Journal of Business Research	2
Journal of Operations Management.	2
Marketing Science	2
R&D Management	3
Strategic Management Journal	11
Others (1 article each)	28

Table 3.3: Number of relevant articles published per journal title

3.2.3 Type of article (Theoretical, Methodological, Empirical)

The articles belong to 3 broad types: Theoretical, Methodological and Empirical. The highly predominant type of articles is that of empirical studies (58.6% of total), with reflection on measurement methodology and even more so on theory remaining a minority concern. This may be considered as surprising, since our investigation focus clearly has been on methodological issues.

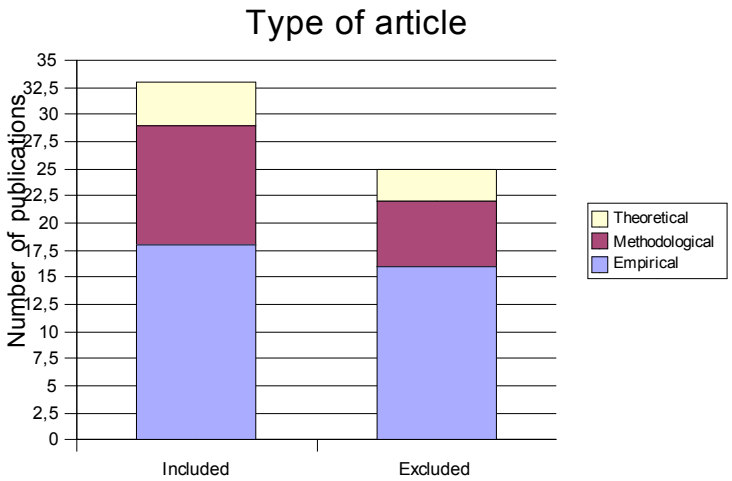


Figure 3.3: Breakdown of articles by type (Theoretical, Methodological, Empirical)

Quantitatively, the numbers are given in Table 3.4 below.

Type of article	Included articles	Excluded articles	Total	Proportions
Empirical	18	16	34	58,6%
Methodological	11	6	17	29,3%
Theoretical	4	3	7	12,1%
			58	100,0%

Table 3.4: Number of articles by type (Theoretical, Methodological, Empirical)

3.2.4 Competence being measured

The fragmentation of my investigation field is most strikingly evidenced by that of the actual competencies being measured in the relevant articles. As may be seen in Table A5.1 of Appendix 5 for the 33 high-quality, "included", articles, and from the consideration of the additional 25 "excluded" articles, the description of the competence being measured varies almost with every single relevant article. The only concept being measured in more than one article is that of 'absorptive capacity', that is considered in 4 articles only. All 54 other articles each study a different competence or a different set of competencies.

3.2.5 Measurement methods

My investigation focuses on methods to measure collective competencies. The Systematic Review yielded a breakdown of articles along investigation methods that are well-known in social sciences. The highly predominant methods are questionnaires (55.2% of relevant articles) and the usage of secondary data. (25.9% of relevant articles). However, interviews and detailed case studies also are present, albeit in smaller numbers.

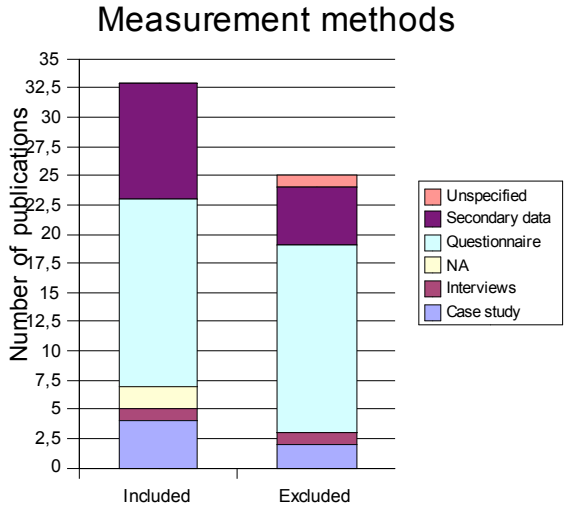


Figure 3.4: Breakdown of articles by measurement method

Method type	Included articles	Excluded articles	Total	Proportions
Questionnaire	16	16	32	55,2%
Secondary data	10	5	15	25,9%
Case study	4	2	6	10,3%
Interviews	1	1	2	3,4%
NA	2	0	2	3,4%
Unspecified	0	1	1	1,7%
		Total	58	100,0%

Table 3.5: Number of relevant articles per measurement method

The most obvious reason for the predominance of questionnaires and secondary data analysis appears to be their lower cost and their ability to handle larger number of cases. The order ranking of cost efficiency among the measurement methods may indirectly be evidenced by the Table 3.6 below of descriptive statistics on the size of the samples being treated by the relevant articles. The ability to handle large number of cases is privileged in an intellectual environment where quantitative validation is the norm, as can be expected for people considering measurement from a strictly positivistic point of view.

Method type	Sample size				
	Minimum	Maximum	Median	Mean	Std deviation
Case study	1	138	3,0	33,0	59,2
Interviews	18	50	-	34,0	-
Questionnaire	1	9648	172,5	639,3	1 799,9
Secondary data	64	7240	615,0	1 534,1	2 079,7

Table 3.6: Descriptive statistics on the size of the samples being treated by the relevant articles

As may be deduced from Table 3.6, interviews and case studies approximately have the same low cost efficiency, while questionnaires are significantly more efficient, and the analysis of secondary data has the highest level.

3.3 Definitions of competences and (cap)abilities

A repeated statement among the articles that were selected for this Systematic Review is that of a lack of agreement among scholars on the very definition of collective competences, abilities or capabilities. This lack of agreement obviously adversely impacts the chances of an efficient and agreed-upon operationalisation and measurement.

The definitions and implicit understanding of the concept of collective competencies,

abilities or capabilities partially depend upon the very purpose of the measurement being performed.

The evaluation of a firm's competencies may be used to evaluate it along a single dimension, with the ambition to predict the firm's overall economic or financial 'performance'. The intention is that of **ranking** the firm, either against its own set objectives, or against its nearest competitors. The general framework is that of competition among essentially identical organisations. This position is the very dominant view among the articles selected for this Systematic Review.

However, a minority understanding of the purpose of evaluating collective competencies also exists. For these authors, the purpose is that of **classifying** firms among a set of equivalent categories. The issue is to know what category the firm belongs to, what is the nature of the competence or ability the firm masters, what it is able to do or achieve. The purpose is not to know how it behaves within its category compared to the other firms of the same category, or how well it masters its competence. In this framework, the firms are considered as essentially heterogeneous in the nature of their abilities, more than in their level of competence. They are therefore susceptible to co-operate. This understanding is very important in the perspective of my future PhD on the co-operation of heterogeneous firms around R&D projects.

3.3.1 The understanding of a collective competence as the belonging to a class

This minority understanding of collective competence as the belonging to a type within a set of categories is illustrated by an article that considers means to classify firms along the 4 archetypal strategic types of the strategic typology proposed by R.E. Miles et al. (1978): 'prospectors', 'analysts', 'defenders' and 'reactors' (Conant et al., 1990).

This classification along somewhat equivalent types is also present in a work by R. Deshpande et al. (1993) that classifies 'organisational culture' by following R. E. Quinn and J. Rohrbaugh (1983), that define a "*competing values*" model of "*organisational effectiveness*". R. Deshpande et al. consider that organisational cultures are a blend of 4 types, that are related to the Jungian model of personality. These types are a combination of polarities along 2 axes:

- "*one axis describes the continuum from organic to mechanistic processes, that is, whether the organisational emphasis is more on flexibility, spontaneity and individuality, or on control, stability and order*" (p.26)
- "*the other axis describes the relative organisational emphasis on internal maintenance (i.e. smoothing activities, integration) or on external positioning (i.e. competition, environmental differentiation)*" (p.26).

"*The four resulting types are labelled clan [internal maintenance - organic processes], hierarchy [internal maintenance - mechanistic processes], adhocracy [external positioning - organic processes] and market [external positioning - mechanistic processes]*" (p.26).

The purpose of identifying the nature of the collective competence in a given R&D organisation (i.e. what are the scientific and technical competences present), and only secondarily of measuring them, also appears in one article (Durand, 1988). It may also be identified in a work that identifies the nature of the 'inventive processes' (as defined the TRIZ model) being mastered by third-party organisations, in order to select potential co-operation partners that would be complementary of the focal firm being studied (Moehrle and Lessing, 2004).

3.3.2 The 3 understandings of competence as a performance level

The mainstream understanding of a competence as a performance level often stems from the general ambition of the discipline of Strategic Management (described in §1.2.1 above) to identify the sources (or even the single source) of sustainable competitive advantage. When researchers investigate in the direction of immaterial sources of competitive advantage, to which 'competencies' (or 'abilities', 'capabilities', 'capacities') belong, they tend to consider that any such immaterial source or predictor of further performance may be indifferently labelled as a 'competence' (or an 'ability', 'capability' or 'capacity'). This leads to a significant amount of intellectual confusion (Grimes et al., 2007; Hitt and Ireland, 1985; Stratman and Roth, 2002).

As an example, the tool developed by A. Grimes (2007) to assess "*the capabilities of SMEs to compete internationally*", containing 18 'components' illustrates this mixture of heterogeneous concepts of competence:

- 2 'components' relate to overall firm achievements in the chosen area (export marketing)
- 4 'components' refer to intermediate-scale achievements
- 3 'components' refer to intentions and strategy
- 2 'components' relate to culture
- 7 'components' refer to practices (Appendix 2, p.79).

In order to introduce some clarity, I have further subdivided this understanding of 'competence' into 3 schools of thought. A collective competence may be understood either as (1) the proximity to a pre-defined set of 'best practices' or routines or (2) as the economic efficiency with which a goal is achieved, with the implicit understanding that the goal is in essence achievable by all, the only difference among organisations being the cost at which it is reached or finally (3) as the degree to which a collective goal is achieved.

The understanding of collective 'competence' as the proximity to a single set of practices deemed to be 'best' is illustrated by several articles (Grimes et al., 2007; Ritter et al., 2002; Stratman and Roth, 2002; Tu et al., 2006). This approach appears to me as essentially flawed by the assumption that there be a single, eternal 'best' practice, and by a confusion between the end and the means to reach this end. The very history of management practices and management science shows that an evolution takes place, with no reason to stop at any point of time. Therefore, assuming that 'competence' in a field is measured by the distance to what is, temporarily and provisionally, considered as the 'best' practice cannot be correct. In addition, considering that there only is one valid operational mode negates the very

possibility of innovation and improvement of the practice, and negates the fact that several paths may exist to reach the same end.

However, more subtle and interesting means to take into account contemporary 'best practices' may be found. In one article, the level of Human Resources Management skills is measured by the number of practices being implemented in the firm, from a list of 7 that were considered as 'advanced' in 1997 when the empirical investigation for the article was performed (Vinding, 2006). This measurement of the Human Resources Management skills may be criticised as above. However, and although such an interpretation is not suggested by the author, this raw number of contingent practices being implemented may be considered as a stable, organisation-wide feature of attempting to provide the employees with the "best available" environment to work in, and therefore as an authentic 'collective competence'.

The understanding of competence as an efficiency to reach one's goals at a low expenditure in resources is found in a string of related articles by a stable group of researchers: (Dutta et al., 1999; Dutta et al., 2005; Murthi et al., 1996; Narasimhan et al., 2006). These articles define competencies in their fields of interest - marketing, R&D, operations, 'absorptive capacity' (Cohen and Levinthal, 1990) - as the ratio of attained goals to the expenditures needed to reach these goals.

More specifically:

> *"capabilities as the efficiency with which a firm uses the inputs available to it (i.e., its resources, such as R&D expenditures) and converts them into whatever output(s) it desires (i.e., its objectives, such as developing innovative technologies)" (*(Dutta et al., 2005, p.278).

In this understanding of competence as an efficiency, the focus is on how well the organisation mobilises its resources towards its objective, how effective it is in doing so. This efficiency probably gives an indirect indication on how clever and how cohesive the people are in the organisation. However, it makes the key assumption that all firms are able to reach any technical objective, the only difference being the cost at which they reach it. In this world, the only differentiator in the market is the mere cost, which is typical of commodities markets.

This understanding of capabilities as **efficiency** contrasts with one of capability as an **effectiveness**. In the latter, the issue is to know what target the organisation can reach or aim at, or how far it goes in the way to that objective. In this vision, the assumption is that not all organisations are able to reach any target: some can achieve technical feats that others simply can't - and this is not an issue of pouring more money into it. In order to achieve the same performance, specific knowledge and competence needs to be developed, and this takes time and expertise - more than bare financial resources. In this world view, the differentiators between firms on the market lie in the non-cost dimensions of product performance and functionalities, which is more relevant for innovative, high-technology markets.

For my further PhD research in the field of innovation economics in high-tech clusters, although the indirect methods being used for these efficiency measurements

may be attractive, and albeit the notion of efficiency in R&D may be of interest as an indirect measure of coherence, of intellectual creativity and of problem-solving capacity, I believe that it relates to an industrial setting that is significantly distinct from the one I intend to investigate.

Ultimately, a collective competence may be understood as the degree by which an organisation is able to achieve certain goals, these goals being expressed in functional terms. The stress is not placed on the tools and practices used to achieve the specified goals, nor on the cost incurred to reach them, but on how far the organisation is able to go along this path. This definition is rather well expressed by A. B. Escrig-Tena (2005), for whom a competence

> *"will appear in the performance of certain activities and the achievement of certain results. Skills and knowledge cannot be observed [directly]: the only observable factors are the efficiency and effectiveness manifested in the activities carried out by a company and the consequences derived from this. [...] Competencies can be operationalised by identifying and evaluating the activities and the results arising from them" (pp.230-231).*

A linguistic analogy may be the wording of the Common European Framework for Languages developed by the Council of Europe (2001) to assess the competence level of individuals in a foreign language, for whom "*Competences are the sum of knowledge, skills and characteristics that allow a person to perform actions*" (p.9).

This understanding of a collective competence as the ability to achieve a goal described in functional terms is rarely explicitly present in the articles selected for the Systematic Review. In several of the questionnaires being used, items relevant to such a concept do appear, although they are intertwined with other items that relate more to the other understandings of 'collective competence' as a performance described above. Such implicit definitions of competence as an ability to achieve functional goals may be found in an article where, among the 55 items describing the firm's potential "*distinctive competence activities*", 16 describe practices, and 39 describe the capability to achieve goals expressed in functional terms (Hitt and Ireland, 1985, Appendix, pp.289-291).

This functional expression of competences may also appear in the definition of specific abstract and high-level competencies like:

- the "*absorptive capacity*" defined as "*the ability to exploit external knowledge", and "to recognise the value of new information, assimilate it and apply it to commercial ends*" (Cohen and Levinthal, 1990, p.128));
- "*comprehension*" (McGrath et al., 1995, p.254) defined as "*what do we know and how well do we know it?*" (p.267) and "*deftness*" as "*how well group processes are operating*" (p.267)
- the "*strategic capability*" defined as "*the capability of an enterprise to successfully undertake action that is intended to affect its long-term growth and development*" (Lenz, 1980, p.226)
- "*knowledge processing*" defined as the firm's "*ability to recognise emerging*

trends and identify latent market needs [...] in sensing weak signals and seizing opportunities" (Jantunen, 2005, p.337)

- "*organisational learning*" defined as "*the capability of an organisation to process knowledge - in other words, to create, acquire, transfer and integrate knowledge, and to modify its behaviour to reflect the new cognitive situation, with a view to improving its performance*" (Jerez-Gomez et al., 2005, p.716).

This functional concept of competence may also be very clear and apparent in the case of smaller-scale collective professional competences, when the competence being investigated is the forecasting ability in the context of short-term money market portfolio management (Makadok and Walker, 2000), or when forecasting ability is applied to the "*effort*" needed and the "*schedule*" of a software development (Ethiraj et al., 2005).

3.4 Measurement methods

As was described above in §3.2.7, the methods used in the articles selected for this Systematic Review belong to a set of well-known categories, ranked hereafter in descending order of frequency:

- Questionnaires
- Exploitation of secondary data
- Case studies
- Interviews.

I will therefore present them according to this classification, entering into greater detail in the classification for the most numerous category, that of questionnaires.

Three theoretical articles (Cohen and Levinthal, 1990; Lenz, 1980; Wang and Ahmed, 2007) do not belong to this classification, since they are not specific enough on the operationalisation modes being supported, and will not be further described.

3.4.1 Questionnaires

Questionnaires are the most widely-used category of tools to measure collective competences in the literature selected for this Systematic Review. The reasons for this popularity may be that they allow for large numbers of cases to be treated at low cost, permit quantitative validation using standard statistical tools, and yet provide flexibility to generate the exact data needed for the study.

A first observation, drawn from the selected literature, on using questionnaires to assess collective competences of organisations is that they should be used with care, due to the associated inaccuracy of the results, as evidenced by J. Denrell et al. (2004).

Keeping in mind this general remark, the main findings of this section are that the quality of the questionnaires in this Systematic Review is highly heterogeneous. Beyond a satisfying formal validation using statistical tools, the semantic validity

and the relevance to the concept being measured in the questionnaires appear to be often questionable (§3.4.1.2). However, a significant number of articles display a range of interesting items and concepts that may be useful in further research (§3.4.1.3).

3.4.1.1 General considerations on the inter-rater reliability of questionnaires

J. Denrell et al. (2004) study the reliability of the measurement of collective capabilities within multinational firms. They consider the subsidiaries of these large multinational corporations, and compares the assessments of the capabilities made by the subsidiary itself and by the central headquarters of the firm. The capabilities chosen for the investigation were marketing capabilities, in order to be sufficiently generic across industries, and in order for the evaluation not to rely on well-known and widely used objective metrics (as is the case in manufacturing). The study was performed with 6 Swedish-based multinational firms. For each multinational firm, a set of 3 to 6 marketing capabilities was identified as being of strategic importance to the firm, and as being the focus of existing evaluation and attention. In total, 29 capabilities were evaluated. The empirical setting was thus designed be optimal for a high inter-rater reliability.

Overall, responses were obtained for "*689 pairwise evaluations*" (p.1498). Agreement between both raters was obtained in 28% of the cases only, with a **systematic bias** towards better ratings from the subsidiary, the difference being of **0.4 points** (in a 7-points Likert scale), "*which is significantly different from zero (p-value<0.001)*" (p.1498). The difference between raters displays a bell-shaped curve (Figure 1, p.1498), that displays a **standard deviation of 1.62** on the same 7-points Likert scale, in addition to the systematic bias described above. These figures, obtained in a favourable environment, place boundaries on the reliability of the measure to be expected from a questionnaire: self-evaluation will probably be biased towards a more positive assessment than external opinion, and a significant level of noise must be expected. The fact that the curve displays a bell shape indicates that the measure, although it is corrupted by noise and a systematic bias, still is meaningful, in the sense that the measured value, corrected from its bias, is a good estimator of the 'true' value.

3.4.1.2 The low semantic quality of several questionnaires

A significant number of articles selected for this Systematic Review, although they facially display a high level of professionalism, and mobilise a fair number of quantitative statistical tools to assess the validity of the construct (such as Cronbach's alpha, Confirmatory Factor Analysis, Goodness of Fit,…) , apparently fail to take a critical view of their final result. As a consequence, many of the questionnaires, when considered in the detail of the items, display considerable weaknesses in terms of semantic coherence and relevance (Camison, 2004; Escrig-Tena and Bou-Llusar, 2005; Jantunen, 2005; Jerez-Gomez et al., 2005; Prieto and Revilla, 2006; Ritter et al., 2002; Stratman and Roth, 2002; Tu et al., 2006; Wang and Ahmed, 2004).

One very frequent critique that may be addressed to these articles is that the items

describe a set of socially desirable behaviours, a sort of 'wish list', that are therefore highly susceptible to cause very positive self-assessments, particularly in the absence of any external control check. This source of bias can sometimes almost be related to a form of naïveté, (Jerez-Gomez et al., 2005, Appendix A, p.724; Prieto and Revilla, 2006, Table 2, p.174).

Another frequent critique is the lack of semantic relation between the items of the questionnaire and the concept they claim to operationalise. This is to be found for example in an article that attempts to design and test a measurement tool for the competencies associated with Quality Management (Escrig-Tena and Bou-Llusar, 2005).

Although the article seems to rest on a clear vision of the components of the Quality Management processes - broken down into "*customer orientation, continuous improvement, focus on people, global vision of the organisation*" (p.226) -, it adopts a classification of competences that appears as highly inadequate (although it was drawn from previous literature), breaking them down in the categories of "*managerial, input-based, transformation-based, and output-based*" (p.225). Trying to force the concepts of Quality Management into this inadequate framework leads to a structure of 9 sub-competencies (Figure 3, p.227) that are difficult to understand in themselves, difficult to relate to the categories each sub-competence is supposedly related to and difficult to relate to the individual items of the questionnaire. The ensuing statistical validation may attempt to validate the resulting instrument, but the overall impression remains little convincing.

Another source of inconsistency resides in the confusion on the very definition of competence, as described in §3.3.2 above (Grimes et al., 2007; Stratman and Roth, 2002).

Despite these weaknesses, some individual items of the questionnaires described here deserve being remembered for further potential use, specifically some items from the rather ambitious work by C. Camison (2004), that builds a complete instrument to measure the "*interfunctional or coordination competences*" (p.29) of an organisation:

- 2 items in the "*Managerial experience*" factor
- the "*Managerial leadership*" and "*Incentive for change & innovation*" factors
- 3 items in the "*Commitment culture*" factor
- 5 items in the "*Stakeholder cooperation & satisfaction*" factor.

3.4.1.3 The relevance of well-designed questionnaires

When questionnaires keep a close attention to the semantic meaning of their items, and to their connection to the underlying constructs, while keeping the same rigour as above in their quantitative validation, they result in interesting suggestions for further work (Conant et al., 1990; Garcia-Muiña and Navas-Lopez, 2007; Grimes et al., 2007; Hitt and Ireland, 1985; Lane and Lubatkin, 1998; McGrath et al., 1995).

M. A. Hitt and R. D. Ireland (1985) provide an interesting break-down of the global corporate activity into 55 functional units (related to the primary corporate functions

such as Marketing, Manufacturing, Finance, etc.), each of which may be assessed as a capability. The notion of 'capability' is conceptually confused with that of practices, as in many other studies (see §3.3.2 above). In addition, the questionnaire is frequently (but not systematically) worded in terms of "*improvement*" needed. This does not allow to know what level of capability currently is achieved by the firm. Considering that a function requires 'improvement' may mean anything between an absolute lack of competence (and the recognition that this gap this must be fixed) to a great level of expertise (when people know what they ignore, and see the scope and nature of the improvement to be brought in).

Quantitatively, the 55 items describe the firm's "*distinctive competence activities*" (Appendix, pp.289-291). Among these, 29 items describe the 'competence' as an "*improvement*", and 26 items simply as the statement of the current situation. Provided the wording is readapted towards statements of the current situation, most of the 39 items describing goals in functional terms could be considered for further research.

J. Conant et al. (1990) operationalise the "strategic typology" proposed by R. E. Miles et al.(1978), and of its consequences on marketing competencies and overall economic performance.

The 'strategic typology' (Miles et al., 1978) presents 4 archetypal strategic types: 'prospectors', 'analysts', 'defenders' and 'reactors'. Each type is defined by a set of characteristics along 11 dimensions that define the coherent answers and solutions given to entrepreneurial, engineering and administrative problems (Conant et al., 1990, Table 1, p.367). The typology is inhomogeneous: the innovative and exploratory "*prospector*" and the conservative and exploiting "*defender*" types are considered as "*pure*", while the "*analyst*" is an hybrid between the 2 'pure' types, and the "*reactor*" is considered as a residual type, structurally performing worse than the other three.

The research tests a tool classifying organisations in either of the 4 types using: a self-evaluation using one-paragraph description of each type (that include only 2 or 3 of the 11 dimensions of the strategic typology), and a set of 11 questions, each related to a dimension of the typology and proposing a set of 4 possible answers, each connected to a strategic type.

The understanding that the 'reactor' type is inferior may cause a bias in the wording of the questionnaire, despite the claim made to the respondents that all 4 options are equivalent. The consideration of the 'analyst' type of being 'hybrid' also is a sign of an unfinished theoretical construction.

Despite these theoretical weaknesses, the tool could be adapted, specifically after I relate these strategic types to psychological functions of the MBTI model of organisational 'characters' (Bridges, 2000), along the following lines:

- prospector - Extravert Intuition
- analyst - Introvert Intuition
- defender - Introvert Sensation

- reactor - Extravert Sensation.

R. G. McGrath et al. (1995) develop a model of a firm's persistent performance based upon its competence to renew its product repertoire through 'new initiatives', and upon 2 precursors of competence, called 'comprehension' and 'deftness':

- "*comprehension*" is "*the process by which those pursuing an initiative come to understand precisely what combination of resources will allow it to achieve objectives*" (p.254) or "*what do we know and how well do we know it?*" (p.267);
- "*deftness*" is "*how well group processes are operating*" (p.267), or "*a quality in a group which permits [mutually] heedful interactions to be conducted at minimal cost*" (p.256).

'Comprehension' is necessary for the success of a 'new initiative' because at the outset of it, neither the exact goals are defined with accuracy, nor are the environmental conditions very clear, nor are effective tools and methods ready and validated. The group must thus operate in a given level of uncertainty, that should diminish over time, as the project evolves.

'Deftness' contributes to the attainment of a group's goals by reducing "*opportunity, transaction and agency costs*" (p.256).

This model was investigated, "*the level of analysis [being] the project level*" (p.258). "*The data for the study were collected from 160 projects underway in 40 different firms in 16 different countries*" (p.260).

In the conclusions, "*Deftness [...] appears to be a fundamental construct for the study of emerging competence*" (p.262). Study of the "*genesis of deftness*" (p.265) should be fruitful for the studies of "strategic alliances, joint ventures, mergers and acquisitions [...] networks" (p.265).

In my opinion, this article sheds very interesting light on the process of effective collective work. The concept of 'deftness' appears to describe with both accuracy and parsimony a collective body working efficiently and effectively, with efficient transmission of information and the shared feeling that people all contribute to the common effort. The description does not fall into the naïveté of believing that efficient collective work implies harmony or absence of conflict. The questionnaire provided in the appendix (pp.270-275) gives a highly relevant tool to measure the degree by which a group works efficiently and smoothly: this competence definitely is collective, it resides in no specific individual, and to me is a determinant of the efficiency in any collective work. The emergence and development of this 'deftness' in a group probably should be understandable and related to the history of the group, the characteristics of the task, the performance assessment system and the personalities of the members. The work programme of finding the sources and origin of this 'deftness' however apparently hasn't been undertaken, as may be inferred from the titles of the 66 papers citing this one in the Social Science Citation database: this highly specific word of 'deftness' appears in no title, and obviously would if an article had undertaken this task.

On the other hand, the concept of 'comprehension', does not appear to be as fruitful. Its origins are difficult to trace, and the complexity of the concept means that it not simply a 'given' of the group.

I would therefore consider including a measure of the 'deftness', at the level of each co-operative R&D programme, in my further research.

F. E. Garcia-Muiña and J. E. Navas-Lopez (2007) explore the effect of technological capabilities on firm results, and take an innovative approach to measuring both.

The authors focus their investigation on 3 broad types of technological capabilities: exploitation capability, itself subdivided into exclusive and non-exclusive exploitation, and exploration capability. These capabilities are related to a model of innovation made of punctuated equilibria, in which successive "*dominant designs*" (p.32) structure the market. During the life span of a 'dominant design', the firm that initiated it enjoys temporary monopoly rents, of 'exclusive exploitation', as long as its innovation is neither imitated nor substituted. Once imitation or substitution has taken place, a period of incremental, non-exclusive innovation and exploitation takes place. If however the life span of dominant designs reduces significantly, to an extent that exploitation periods effectively vanish, innovation enters in a regime of permanent upheaval and renewal, where the driving firms are those that permanently explore new grounds.

Exclusive exploitation capability refers to the capacity that a firm has to establish its product as a first-mover innovation, and to protect it from imitation and substitution. Non-exclusive exploitation capability refers to the capacity that a firm has to "*rapid[ly] and efficient[ly] incorporate [...] incremental innovations, which is only valuable over short periods of time*" (p.32). Exploration capabilities are "*the permanent development and incorporation of new knowledge with a short life-cycle and a constant re-defining of current technological paths*" (p.33).

These technological capabilities are operationalised using simple metrics drawn from the answers to a questionnaire (Fig. 4, p.37):

- exclusive exploitation capability is measured as "*the average time that innovators consider it takes to imitate [or to] substitute [the innovation, relative to] the average time in which the innovation was valuable to the industry*" (p.36)
- non-exclusive exploitation capability is measured as "*the average time over which incremental innovations were developed*" (p.36)
- exploration capability is measured as "*the number of high-potential products under development (in relation to firm size)*" (Fig.4, p.37).

For me, this article provides an interesting perspective on technological capabilities, with simple yet effective and innovative measurement techniques, that I may want to re-use or adapt.

3.4.2 Exploitation of secondary data

Secondary data from existing databases bears the advantage of being already present, at large scale. When the information available fits the needs of the researcher, which is a condition not easily met, it provides the means to reach large numbers of cases at relatively low cost, and therefore to quantitatively validate results. The data sources used by the articles being investigated in this Systematic Review were provided by the following organisations: United States of America Patent Office, Moody's, the Center for Research Planning, Lexis-Nexis, Dialog, the Danish government, Compustat, the Strategic Planning Institute.

The articles selected for this Systematic Review either exploit directly the data, without much elaboration (§3.4.2.1), or mobilise more sophisticated econometric techniques to extract information such as an organisation's efficiency (§3.4.2.2).

3.4.2.1 Direct exploitation of databases

One empirical study aims at interpreting the sources of the persistent differences existing between the R&D efficiency of pharmaceutical firms, after having accounted for differences in scale and scope of the firms (Henderson and Cockburn, 1994). The authors distinguish between "*component competence*" on specific scientific and technical areas and "*architectural competence*" on the ability to assemble these elements into coherent systems and to include new ones (p.65).

Component competence is the reunion of disciplinary expertise in a field of science and of competence in a disease area. The discounted stock of patents is used as a proxy of component competence in a given disease area. No proxy is given for the component competence in a scientific disciplinary field. The operationalisation of 'component' competence using patent data is rather straightforward, and is often used in the literature on innovation, but it is often criticised as being simplistic.

Architectural competence is operationalised through interview data, that will further be described in §3.4.4 below.

P. J. Lane and M. Lubatkin (1998) conceptualise and empirically test the notion of "*relative absorptive capacity*": a "*student*" firm will learn more from a "*teacher*" firm in a knowledge transfer alliance if the dyadic relation between both firms meets certain conditions for the efficient transfer of knowledge. This concept builds upon and enriches the earlier "*absolute*" absorptive capacity developed by W. M. Cohen and D. A. Levinthal (1989; 1990), that stated that a firm's capacity to learn is intrinsic and only dependent on the firm's R&D spending level (relative to its sales).

The article specifically measures the capacity the 'student' firm has to understand new knowledge from the 'teacher' firm, through a complex calculation. First, the "*participation rate*" of a firm to a given scientific discipline is computed as the ratio of the number of 'research communities' - as defined by the Center for Research Planning database - the firm is involved in to the number of 'research communities' dependent on that scientific discipline. In order not to give too big a weight to scientific disciplines that generate a small number of 'research communities', the

'participation rate' is "*weighted*" by multiplying it by the square root of the number of 'research communities' that the scientific discipline leads. This results in a "*weighted participation rate*" of each firm in the scientific disciplines present. The 'weighted participation rate' of the teacher (the biotechnology firm) is normalised to a common mean and standard deviation value, and the 'weighted participation rate' of the student (the pharmaceutical firm) in the same scientific discipline is multiplied by this normalised value, resulting in a "*knowledge relevance score*" (p.469) that translates the relative importance of each scientific discipline to both the teacher and the student.

The 'knowledge relevance score' is applied to biochemistry, which is considered as the common 'basic' set of knowledge, and to all the other scientific disciplines, that are considered as the 'specialised' knowledge fields in which the knowledge transfer is supposed to take place. The capacity to understand new knowledge is then a function of the common 'knowledge score' in biochemistry and of its difference in the other disciplines.

This article provides a very innovative insight into the dyadic nature of the competencies involved in interorganisational relations. The fact that an organisation's competences should also be considered in the light of the partner organisation(s) is very welcome. Although I may not re-use the full complexity of the quantitative tool provided, I will probably keep in mind its concepts for the analysis and understanding of co-operative R&D projects in my PhD work.

T. Schoenecker and L. Swanson (2002) investigate the global Firm Technological Competence, measured both by the means available (the input) and by the achieved goals (the output), and both in terms of scale and quality.

The measures of the **scale** of Firm Technological Competence are (table 1, p.37): the total amount spent on R&D per year, the total number of patents the firm was granted and the number of new product introductions.

The measures of the **quality** of Firm Technological Competence are (table 1, p.37): R&D intensity, i.e. the amounts spent on R&D divided by sales, the impact of the firm's patents (as the ratio comparing the frequency in which the firms' patents are cited to the average frequency), the science linkage (measured by the number of scientific articles cited in the firm's patents), the technology cycle time (measured by the median age of the patents cited by the firm's own patents).

Although simple, these metrics are classics in the field of innovation economics.

D. M. De Carolis (2003) investigates the relation between a firm's performance, its competence and the imitability of its knowledge.

'Technological competence' of the firm is measured as follows: "*Company A has issued N patents during a given year. Within 2 years of their issue date, M patents had cited these N patents. Of these M citations, X citations belonged to company A - self-citing. The ratio X/N is the measure used for technological competence*" (p.39).

'Imitability' of the firm's knowledge is measured symmetrically. "*Of these M citations, Y patents were by other companies. The ratio Y/N is the measure used for imitability*" (p.39).

This article is an interesting attempt to capture 2 major concepts of the core competency theory: internal build-up of competence and imitability. However, some important conceptual limitations appear in the operationalisation of the latter concept.

'Imitability of the firm's knowledge' is operationalised using citations from other firms than the one having issued the patent. The argument goes that if company B cites a patent from company A in its patent, it is imitating and appropriating knowledge from company A. This vision is highly debatable. From a legal point of view, citing an earlier patent is exactly the opposite of appropriating the content of that patent: it is the acknowledgement of the existence of this prior Intellectual Property Right, and marks the boundary between the existing state of the art (where no property may be claimed), and the innovation contained in the current patent (where property is indeed claimed).

This objection notwithstanding, the idea of using self-cites of patents to track the build-up of internal competence, as a trace left of past R&D activity, is most interesting, and deserves being kept for further study.

A. L. Vinding (2006) studies the relationships between innovativeness of a firm and the components of its 'absorptive capacity' (Cohen and Levinthal, 1990), i.e. of the firm's capacity to "*assimilate and utilise external knowledge*" (p.509).

The variables representative of the firm's 'absorptive capacity' are:

- the share of employees that have an academic degree
- the average work experience of the employees
- the level of Human Resources Management, being measured by the number of practices being implemented in the firm, from a list of 7 that were considered as advanced in 1997
- the level of connection to the outside world, measured on a 3-levels scale: the firms that have developed no closer relationships to external actors during the reference period 1993-1995, those that have developed them with "*either customers / suppliers [...] or with knowledge institutions*" (pp.509-510) and those "*that have developed closer relationships with both types of actors*" (p.510).

Despite the observations made in §3.3.2 on the reference to 'best practices' to assess competence, this article uses simple but rather straightforward tools to assess the components of 'absorptive capacity'.

3.4.2.2 Mobilisation of econometric techniques

A stable team of researchers, S. Dutta, O. Narasimhan and S. Rajiv (1999; 2005; 2006), has consistently used Stochastic Frontier Estimation to measure collective

competence as an efficiency of either the whole firm (its 'absorptive capacity') or of specific functions within the firm (R&D, marketing, operations).

The efficiency of the R&D, marketing or operations function may be measured by modelling a representative output as a function of a set of potentially contributing inputs (Dutta et al., 1999). The relative (in)efficiency of a given firm A is the difference between the efficiency reached by the firms at the frontier of efficiency and the one reached by firm A. The relationship between output and input takes the shape of a Cobb-Douglas production function, with the error term containing both a purely random, zero-mean, error, and a inefficiency term that only takes positive values (a truncated normal distribution function).

Each capability is measured by the efficiency a specific input-output relation:

- marketing efficiency is measured by the relation of sales to "*technological base, advertising stock, stock of marketing expenditures, investment in customer relationship and installed base*" (eq.2, p.552)
- R&D efficiency is measured by the relation of "*quality-adjusted [by innovativeness or width] technological output*" to "*technological base, cumulative R&D expenditures and marketing capability*" (eq.3, p.553) and to the product of market capacity and technological base (eq.6, p.558)
- operations efficiency is measured by the relation of "*cost of production*" to "*output, cost of capital, labour cost, technological base and marketing capability*" (eq.4, p.554).

Stocks are cumulated with a "*Koych lag function, with earlier years [...] receiving a lower weight than later years*" (p.555).

In a much simpler article, the authors only measure the efficiency of the R&D function of firms, by modelling an output, the "*firm's production of innovative technologies*", as a function of an input, "*R&D expenditures*", and of "*environmental conditions*" (Dutta et al., 2005, equation 1, p.279).

Another article is more ambitious, and explores the origins of 'absorptive capacity'(Cohen and Levinthal, 1990), as a combination of R&D, marketing and operations capabilities (Narasimhan et al., 2006). 'Absorptive Capacity' is defined as the "*ability to acquire and utilise external know-how*" (p.511), and conceptualised as the "*efficiency with which a firm absorbs, relative to what it could have absorbed given the resources it has deployed*" (p.512).

In addition to measures of functional efficiencies analogous to those described above, the absorbed knowledge by a firm is operationalised using patents and patents citations (p.518). Each year, the firm's "*Domain of Expertise*" is defined as the set of patent classes (as defined by the US Patent Office taxonomy) the patents of the firm belong to. The "*Know-How Drawn On*" by the firm is the set of patent classes that patents cited by the firm's patents belong to. The number of patent classes that are cited by patents of the firm without belonging to the firm's 'Domain of Expertise', "*normalised with the number of [patent] classes that are backward cited*" (p.518) represents the amount of knowledge that has been drawn by the firm from 'outside',

and therefore the knowledge 'absorbed'.

Beyond the general issue of considering competencies as an efficiency rather than an effectiveness, and that I have treated elsewhere (§3.3.2), these articles raise a host of technical questions, mainly on the relevance of the variables used as inputs and outputs to the Stochastic Frontier Estimation models. These issues may be illustrated by the fact that the authors incorporate macroeconomic market conditions into the model as 8 field-specific dummy variables (Narasimhan et al., 2006, p.518) within the "*semiconductors and computers*" (p.517) industry. This implies that economic conditions differ more between sub-fields of this industry than from one year to the next. However, this industry is highly cyclical: accounting for variability of macroeconomic conditions probably would have better been done using dummy variables for each year of the sample.

Despite these reservations, it may be that more appropriate specifications of Stochastic Frontier Estimation models could be useful to measure functional or global efficiency of a firm, using secondary data, if this measure of efficiency proved to be relevant to my further work.

B.P.S. Murthi et al. (1996) assess the complex notion of "*managerial skills*" in the discussion of 'first-mover advantage'. To that end, they use as a proxy the measure of the firm's efficiency in 2 areas: marketing and manufacturing, using a different econometric method, Data Envelopment Analysis. The purpose of this method is to "*maximise the ratio of the weighted outputs to the weighted inputs of a firm, subject to the condition that all such ratios are less than or equal to one*" (p.331).

The authors use data from the PIMS database, that contains more than 500 data per firm per year (described in appendix A, p.335). "*Marketing efficiency*" as understood by the authors, "*describes the relation between 2 outputs, namely ROI and market share, and 5 managerial inputs, namely, product quality, price, marketing expenditures, image and direct costs*" (p.331). "*Production efficiency*" is computed using "*ROI as the output, and purchases and manufacturing expenses as inputs*" (p.331).

Provided access to this very rich database is possible, provided the database contains data relevant to R&D, and provided data is available for European firms, this method could prove to be an interesting alternative to Stochastic Frontier Estimation for the measurement of competence as an efficiency.

R. Makadok and G. Walker (2000) investigate forecasting ability, in the context of short-term money market portfolio management. The object whose evolution is to be forecast is extremely simple and one-dimensional: the short-term interest rates of US Treasury bonds. Forecasting ability has a much more general applicability in management situations, in "*any [...] decision requiring an irreversible investment*" (p.854).

Forecasting ability is measured using the coefficients of a regression model (Hatanaka, 1974) explaining the interest rates of a period t with those of the

preceding period (t-1) and the average maturity of the considered fund in period (t-1), using the concept of Granger causation (Granger, 1969): "*X is said to Granger-cause Y if Y can be forecast better using past Y and past X rather than just past Y*" (Makadok and Walker, 2000, p.859). Forecasting activity of the fund manager is evidenced by the fact that the maturity of his/her portfolio appears to 'Granger-cause' interest rates. Since a good forecaster would shorten this maturity in case of interest rates rises, the measure of "*forecasting ability*" is the opposite of the regression factor. The data for interest rates and average maturity of funds were collected using archival data of professional journals of the industry, thus avoiding survivor-selection effects and self-censorship.

This operationalisation using archival data both meets excellent validity and avoids the risks of survivor selection and filtering memories. In addition, forecasting capability is a essential competence of an innovative firm, and it would make sense to include a measure of it in a further research on innovation. Unfortunately, the tool being presented here is highly specific to the industry being investigated – money market management - , and its generalisability is very poor. It will therefore require significant adaptation to be re-used in a different context.

3.4.3 Case studies

In case studies, the authors dedicate more time to each of the organisations under investigation, in order to obtain deeper and better controlled information.

T. Durand (1988) presents a method in 3 steps to quantify the technical and scientific competencies of an R&D laboratory, with a target size of between 10 and 200 people. The method is well-suited for R&D laboratories that apply their knowledge to engineering and industrial problems, and therefore mobilise multidisciplinary skills.

The first step is to investigate the history of past R&D programmes. R&D programmes are "*the parts of [a laboratory's] activity that are organised to respond to certain well-defined objectives: developing a prototype, modifying a process, solving a technical problem*" (p.172). The objective of the programme often is defined in terms of functional and technical specifications to reach, and is associated with both a funding and a deadline in time, which relates it to industrial settings. The method is to interrogate either written archives or older members of staff to obtain first the chronological list of programmes and then the budget and workforce allocations of each programme over the years.

The second step is to establish a "*Programme-competencies*" matrix. To do so, a list of competencies relevant to the lab must first be established, by in-depth interviews of members of the staff. Once the list of relevant competencies is complete and stable, the matrix is constructed: each row is associated to a competence, and each column to a programme.

The third and final step is to establish the competence profile of the R&D lab, by adding up the person-years related to each competence in the 'Programme-

competencies' matrix, in each row. Thus, the cumulated person-years experience of the R&D lab on each competence may be quantitatively evaluated.

This in-depth study requires about one week of audit work to complete in a medium-sized R&D laboratory of 50 people.

The limitations of this simple approach are (1) the depreciation of competence over time and (2) the usage of a common, coarse unit of "*person-years*", whatever the individual competence of the person is. In addition, it requires a good access to the firm and to its confidential information, which may be problematic.

Despite these limitations, this method appears as sound and interesting to quantitatively investigate the competencies of an R&D organisation. It is well-suited for industrial and engineering environments, and clearly takes into account the cumulative, historical process of competence-building. If the time budget allows, some key organisations in my PhD work may be investigated using methods inspired by this one.

One theoretical article evidences and coins the phenomenon of "*core rigidities*" (Leonard-Barton, 1992). When the coherent set of knowledge described as 'core capacity' becomes inadequate to some new challenges, they become 'core rigidities' (p.118).

> *"Values, skills, managerial systems, and technical systems that served the company well in the past and may still be appropriate for some projects or parts of projects, are experienced by others as core rigidities - inappropriate sets of knowledge. Core rigidities are the flip side of core capabilities" (p.118).*

Misalignment between a project and the firm's 'core capacities', i.e. when these become 'core rigidities', is illustrated in the 4 dimensions of *"(1) employee knowledge and skills [...], (2) technical systems [...], (3) managerial systems [...] (4) values and norms"* (p.113). "*Less strength in non-dominant disciplines*" (p.118) ends up with some technical problems being not being solved, or in inadequate decisions taken. Incompatible technical systems between the requirements of the new product and the legacy may lead to delivery delays. The managerial reward system may prove to be a dis-incitation to engage in non-core capacity projects: "*highly-skilled people are understandibly reluctant to apply their abilities to project tasks that are undervalued, lest that negative assessment of the importance of the task contaminate perceptions of their personal abilities*" (p.119). Giving responsibilities to people in projects non-aligned with 'core capacities' is considered as very risky, with their "*corporate identification badges*" (p.120) at stake.

These phenomena were evidenced in an empirical study based upon a set of 20 case studies of new product and process development in 5 technology-intensive firms (4 cases/firm). Qualitative interviews, each lasting from 1 to 3 hours, were performed with the people who had been involved in the selected R&D projects, design, manufacturing and marketing. Interview notes and analyses were submitted to the

firms, so that they could validate how generalisable the findings were of the other projects within the firm. Reciprocally, the academics provided information about the generalisability across firms.

Considering the very real difficulties experienced by firms when venturing outside of their 'core competencies', the cost, delays and risk of failure attached to such projects, the article suggests to me an indirect mode of identifying competences (although this reflection is absent from the article proper). It is when organisations attempt to **diversify**, when they venture outside of their field of competence, that the nature of this competence is best evidenced – by default, and as in a form of negative image. The diversification attempts that are easy and successful belong to the organisation's competence, while those more difficult, that fail or that require external help or even incorporation of external knowledge, evidence the frontier of the organisation's capabilities.

M. G. Moehrle and H. Lessing (2004) expose a method to investigate the nature of the inventive capacity of a firm, by considering the 'inventive principles' that are mobilised in the firm's published inventions. The 'inventive principles' relate to the "*Theory of Inventive Problem Solving*" (or TRIZ according to its Russian acronym) that had been developed by the Russian researcher Altshuller (1984, 1996). The list of 40 'inventive principles' was determined empirically following the analysis of ca. 40,000 patents between 1946 and 1970: the main intuition being that all inventions mobilise a limited set of inventive principles. The list, being empirical, does not display any structure, nor is it based upon any theory of invention, creativity or cognition.

The assumptions of the research are:

> *"(1) each inventive principle represents a large group of inventions based on the same major idea. Therefore, the application of such a principle by a company shows a specific technical competence (2) the set of principles used by a company gives a profile of its technical problem-solving competencies" (p.233)*

Thus, determining the inventive principles mobilised by a firm's inventions should give an insight into a hidden dimension of that firm's innovative competence.

These assumptions were tested in a case study with a major German firm manufacturing chemical products and cleaning aids. The technical field chosen was that of "*floor-cleaning aids (mops)*" (p.234). Using patent database search, 300 patents were produced. Expert analysis was used to select the 65 patents describing major inventions.

Each of the 65 patents was associated with the one or several 'inventive principles' that it mobilises, ending with a list of 104 occasions to mobilise an 'inventive principle'. This stage was the most time-consuming, requiring 2 hours of expert work per patent. These were then associated with their (individual or collective) inventor, to create a profile. The focal firm for which the study was performed and its 2 major competitors were analysed and given a verbal profile, according to the 'inventive principles' each firm mobilises most (Figure 3, p. 237).

If the 'inventive principles' were indeed stable within a person or an organisation and difficult to transfer from one person or organisation to the next, then the proposed method would have some descriptive power of the nature (and not only of the intensity) of the inventive capability of the person or organisation. If evidence existed of the validity of such assumptions, using this method in the further PhD could provide very original information on a rarely considered aspect of an organisation's competence.

S. K. Ethiraj et al. (2005) operationalise and measure the influence of 2 key capabilities - 'firm-specific' capabilities and 'project management' capabilities - on the profitability of software-services projects, in a large Indian software firm:

- "*Client-specific capabilities are a function of repeated interaction with a given client across multiple projects over time. They largely reflect tacit knowledge of the client's business domain and operating routines*" (p.26).
- "*software development and project management capability*" that encompass (p.33) .
  (1) "software design and building capabilities [...] the capability to understand the requirements of the client and design an appropriate system or architecture to address them [...] to efficiently build the code in conformance to the design and co-ordinate the entire code development process that is usually distributed [...]"
  (2) "effort estimation and management capabilities"
  (3) "schedule estimation and management capabilities".

The study was performed in one of the 25 largest Indian software services firms, over 138 projects that were executed between 1996 and 2001 for 57 different clients.

The variable operationalising 'client specific capabilities' is a binary variable, "coded 0 if the [focal] firm has executed projects for the client in the past and coded 1 if it is the first project executed for the client" (p.36).

'Project management capabilities' are operationalised with "*3 metric variables*" (p.36):

- "*the number of in-process defects identified during the project execution phase*" (p.36) normalised by a metric of project size
- "*effort overruns, i.e. difference between actual [number of] person-months required to complete the project and [the number of] person-months that were initially estimated*" (p.36)
- "*the extent of schedule slippage, i.e. delay in project completion date*" (p.37).

The variable used to operationalise the variable of 'client-specific' capability is a coarse, binary variable, and this negatively impacts its empirical significance. The mean value of this variable is 0.15 (Table 1, p.39), which means that only 15% of the sample population is made of projects with new customers. The accumulation of experience that is expressed by the concept of 'client-specific' capability most probably develops over time and over several projects. This implies that the difference in 'client-specific' capabilities between 2 firms being both 'existing'

customers may be greater than the difference between one of them and a 'new' customer. Therefore, a more reliable operationalisation of this concept would have been the total number of projects executed for a given customer.

Providing access is to the data is available, the metrics used by this article (with the minor modification stated) for these 2 competences may prove to be highly relevant for my further study of co-operative R&D projects, that share many common features with software development projects.

3.4.4 Interviews

R. Henderson and I. Cockburn (1994) in their study of biopharmaceutical firms, evidence 'architectural' competencies in addition to the 'component' competences described above (§3.4.2.1). These 'architectural' competence variables are measured by exploitation of more than 110 qualitative interviews with chief scientists, R&D directors and field chemists, each interview being 1 to 3 hours long, and referring to the actual history of the R&D programme. Four organisational (or "*architectural*") variables are constructed from the interviews, and placed on a 5-points Likert scale (p.72):

- "*PROPUB: Publication plays a key role in promotion*". This variable is strongly correlated to the fact that the R&D lab is geographically close to a major university and to the fact that the firm is involved in co-operative research projects with universities
- *"CROSS: Firm sustains a rich flow of information across [internal] boundaries*"
- "*DICTATOR: a single individual makes key resource decisions*"
- "*GLOBAL: Worldwide research is managed as an integrated whole*"

The advantage of using qualitative data to inform the variables is that it avoids respondent bias to a direct question implying socially valued behaviours (e.g. "do you work in teams ?"). If the researcher is in the role of simply receiving the descriptive narrative, it gives a better chance to understand into the actual history, what actually happened, independently from any moral or social judgement. On the other hand, the effort to measure these 4 variables is considerable, so the issue of yield of such an effort may be raised. This is specifically true when considering that in the further empirical work by the authors, 2 of these 4 'architectural' variables prove not to have any significant effect on the phenomenon under study.

R. Deshpande et al. (1993) explore the relations between market orientation, innovativeness, business culture, on the one hand and performance on the other hand, in the Japanese context.

The definition of 'business culture' described above (§3.3.1) and inspired by earlier works (Quinn and Rohrbaugh, 1983), although it claims to be related to Jungian categories, grossly misinterprets it, and displays a striking ignorance of Jungian theory. The 4 'culture types' being displayed (p.26) appear along 2 existing dimensions of the MBTI model ('focus of energy' and 'attitude in the outer world'). However, the 'types' appearing at the crossover of the poles of these 2 dimensions are

related to some of the 8 'psychological functions' of the Jungian model, but with no consistency whatsoever in their relation to their position along the 2 dimensions described.

The interesting feature of this article is that it leads its investigation by interrogating "*matched sets of buyer-seller pairs [... or] matched dyads*" (p.28). They designate their sampling unit as a "***quadrad**, that is, the combination of 2 buyer-seller dyads*" (p.28, stress added). In each of the 50 Japanese firms under study, 2 "*marketing executives*" (p.28) were submitted a questionnaire on their culture, market orientation, innovativeness and performance. They were then asked to name a specific customer, to which the same set of questions on the seller's customer orientation were asked.

The fact of having pairs of respondents in each firm moderates the single-informant bias. In addition, interviewing the counterpart in the other (buyer) firm provides a more 'objective' view on the claimed qualities of the selling firm, which partially address the respondent bias issue described above (§3.4.1.1) and raised in another work (Denrell et al., 2004). These features of the interview configuration make it very interesting for my further research, specifically when investigating co-operative R&D relationships between organisations.

4 Conclusions. Instruments for further study

Following this Systematic Review of literature, I will consider using the following elements of method and of instruments in my further study on the collective competences of organisations engaged in co-operative R&D projects.

Measurement method	**Element to be further considered**	**Reference in the 'core list' of the Systematic Review**
Questionnaire	Questionnaire items on "Managerial experience", "Managerial leadership", "Incentive for change & innovation", "Commitment culture", "Stakeholder cooperation & satisfaction".	(Camison, 2004)
Questionnaire	Questionnaire items describing the ability to achieve goals in functional terms, re-worded towards describing the current situation	(Hitt and Ireland, 1985)
Questionnaire	Description of 'strategic types' following a description closer to the MBTI model of organisational 'characters'	(Conant et al., 1990)
Questionnaire	Questionnaire measuring 'deftness'	(McGrath et al., 1995)
Questionnaire	Metrics for 'exploitation' and 'exploration' capacity	(Garcia-Muiña and Navas-Lopez, 2007)
Exploitation of secondary data	Method to measure the capacity to understand new knowledge from the partner firm	(Lane and Lubatkin, 1998)
Exploitation of secondary data	Metric of patents self-cites to track the build-up of internal competence	(De Carolis, 2003)
Exploitation of secondary data	Idea that forecasting ability may be an interesting collective competence to measure in an innovative environment	(Makadok and Walker, 2000)

Table 4.1 (first part): Measurement instruments to be considered in further study

Measurement method	Element to be further considered	Reference in the 'core list' of the Systematic Review
Case study	Programme-competencies matrix method	(Durand, 1988)
Case study	Idea that the collective competencies of an organisation are well evidenced during diversification attempts	(Leonard-Barton, 1992)
Case study	External inventory of the 'inventive principles' of a firm along the TRIZ framework	(Moehrle and Lessing, 2004)
Case study	Metrics for 'project management' and 'client-specific' capabilities	(Ethiraj et al., 2005)
Interview	Procedure of cross-checking information through matched pairs of respondents in partner organisations	(Deshpande et al., 1993)
Interview	Procedure of interrogating 2 people in the same organisation to limit single-respondent bias	(Deshpande et al., 1993)

Table 4.1 (last part): Measurement instruments to be considered in further study

In addition, if the understanding of competence as an efficiency proved to be relevant, I would consider the econometric methods of Stochastic Frontier Estimation (Dutta et al., 1999; Dutta et al., 2005; Narasimhan et al., 2006) or of Data Envelopment Analysis (Murthi et al., 1996), in order to assess R&D efficiency.

Appendix 1: Irrelevant documents

The following articles were discarded as non relevant following the reading of the full text. The relevance criteria that were not fulfilled are specified in the following tables.

A1.1 Irrelevant theoretical articles

The articles resulting from the first investigation (i.e. using keywords) are displayed below. The articles resulting from the second investigation using cross-referencing and citation analysis are given in the following table.

Theoretical article	**Relevance criterion not met by the theoretical article from the first investigation (i.e. using**	
	Concern with measurement / operationalisation / empirical validation or observation	Examples of potential metrics
(Becker et al., 2005)		X
(Bitar and Hafsi, 2007)	X	X
(McElroy, 2002)	X	X
(McGuinness and Morgan, 2005)		X
(Muffatto, 1998)	X	X
(Nielsen, 2006)	X	X
(Quinn et al., 2005)	X	X
(Ritter et al., 2004)		X
(Tasmin and Woods, 2007)	X	X

Theoretical article	**Relevance criterion not met by the theoretical article from the second investigation (i.e. using cross-referencing and citation analysis)**	
	Concern with measurement / operationalisation / empirical validation or observation	Examples of potential metrics
(Cohen and Levinthal, 1989)	*(does not apply to collective competencies)*	
(Dierickx et al., 1989)	X	X
(Peteraf, 1993)	X	X
(Spender, 1996)	X	X
(Zahra and George, 2002)	X	X

A1.2 Irrelevant Methodological articles

The articles resulting from the first investigation (i.e. using keywords) are displayed below. No irrelevant methodological articles were found following the second investigation using cross-referencing and citation analysis.

Methodological article	**Relevance criterion not met by the methodological article from the first investigation (i.e. using keywords)**		
	Precise mode of data collection, (e.g. exact questions used in surveys)	Discussion of appropriateness of metrics (do they measure what they intend to?)	Discussion of one at least among the following issues: repeatability / reliability, transposability, noise
(Barclay and Porter, 2005)		X	X
(Bennebroek Gravenhorst et al., 2003)	X	X	X
(Chiesa et al., 1999)	X	X	X
(Gallon et al., 1995)	X	X	X
(Hafeez et al., 2007)	X	X	X
(Maleyeff, 2003)	X	X	X
(Lemon and Sahota, 2004)	X	X	X
(Loewe and Dominiquini, 2006)		X	X
(Marti, 2001)	X	X	X
(Muller et al., 2005)	X	X	X
(Ulrich and Smallwood, 2004)		X	X

A1.3 Irrelevant Empirical articles

The articles resulting from the first investigation (i.e. using keywords) are displayed below. The articles resulting from the second investigation using cross-referencing and citation analysis are given in the following table.

Empirical article	**Relevance criterion not met by the empirical article from the first investigation (i.e. using keywords)**			
	Details of metrics used	Discussion or measure of coherence and consistency of metrics used	Assessment of validity of the metrics used	Report of measurement results
(Ahmed et al., 2003)	*(does not apply to **collective** competencies)*			
(Alkaraan and Northcott, 2006)	*(does not apply to **collective** competencies)*			
(Bhatnagar, 2006)	X	X	X	
(Bouzdine-Chameeva, 2006)	X	X	X	
(Canto and Gonzalez, 1999)		X	X	
(Cooke et al., 2005)	X	X	X	
(Hänninen and Kauranen, 2006)	X	X	X	X
(Hyland and Beckett, 2005)	X	X	X	
(Lau et al., 2004)	X	X	X	
(Lindgren et al., 2004)	X	X	X	X
(Onyeiwu, 2003)	X	X	X	
(Prencipe, 2000)	X	X	X	X
(Ratnatunga et al., 2004)	X	X	X	X
(Santhanam and Hartono, 2003)	X			
(Smart and Conant, 1994)	*(does not apply to **collective** competencies)*			
(Stock et al., 2001)			X	
(Tsai, 2004)			X	
(Vickery, 1991)	X	X		

Empirical article	**Relevance criterion not met by the empirical article from the second investigation (i.e. using cross-referencing and citation analysis)**			
	Details of metrics used	Discussion or measure of coherence and consistency of metrics used	Assessment of validity of the metrics used	Report of measurement results
(Avlonitis et al., 1994)	X	X	X	
(Capon et al., 1992)	*(does not apply to **collective** competencies)*			
(Conant et al., 1993)		X	X	
(Lorenzoni and Lipparini, 1999)	X		X	
(Mangematin and Nesta, 1999)	X	X	X	
(Snow and Hrebiniak, 1980)	X	X	X	
(Subramanian and Nilakanta, 1996)		X	X	
(Garcia-Muiña et al., 2006)	X	X	X	

Appendix 2: Cross-referencing results

Articles from the "Core list"	**Number of articles cited as relevant to collective competence measurement**
(Camison, 2004)	1
(Conant et al., 1990)	1
(De Carolis, 2003)	1
(Denrell et al., 2004)	0
(Durand, 1988)	0
(Dutta et al., 2005)	1
(Garcia-Muiña and Navas-Lopez, 2007)	2
(Grimes et al., 2007)	0
(Henderson and Cockburn, 1994)	2
(Jantunen, 2005)	0
(Jerez-Gomez et al., 2005)	0
(Lane and Lubatkin, 1998)	3
(Lenz, 1980)	0
(Makadok and Walker, 2000)	0
(Moehrle and Lessing, 2004)	0
(Murthi et al., 1996)	0
(Narasimhan et al., 2006)	0
(Prieto and Revilla, 2006)	1
(Ritter et al., 2002)	1
(Schoenecker and Swanson, 2002)	0
(Stratman and Roth, 2002)	0
(Tu et al., 2006)	0
(Vinding, 2006)	2
(Wang and Ahmed, 2007)	8
Total	**23**

Appendix 3: Citations analysis results

Articles from the "Core list"	**Number N of citations in the article of the "core list"**	**Number of articles sharing N/4 citations or more with the article of the "Core list"**	**Number of articles that are both relevant following the reading of the title & abstract and absent from the first search**
(Camison, 2004)	*Not found in Social Sciences Citation database*	-	-
(Conant et al., 1990)	47	8	1
(De Carolis, 2003)	*Not found in Social Sciences Citation database*	-	-
(Denrell et al., 2004)	44	0	0
(Durand, 1988)	11	96	1
(Dutta et al., 2005)	21	20	4
(Garcia-Muiña and Navas-Lopez, 2007)	*Not found in Social Sciences Citation database*	-	-
(Grimes et al., 2007)	*Not found in Social Sciences Citation database*	-	-
(Henderson and Cockburn, 1994)	60	3	0
(Jantunen, 2005)	*Not found in Social Sciences Citation database*	-	-
(Jerez-Gomez et al., 2005)	*Not found in Social Sciences Citation database*	-	-
(Lane and Lubatkin, 1998)	78	0	0
(Lenz, 1980)	*"Related records" function not available in Social Sciences Citation database*	-	-
(Makadok and Walker, 2000)	42	14	0
(Moehrle and Lessing, 2004)	*Not found in Social Sciences Citation database*	-	-

(Murthi et al., 1996)	38	11	0
(Narasimhan et al., 2006)	*Not found in Social Sciences Citation database*	-	-
(Prieto and Revilla, 2006)	*Not found in Social Sciences Citation database*	-	-
(Ritter et al., 2002)	*"Related records" function not available in Social Sciences Citation database*	-	-
(Schoenecker and Swanson, 2002)	32	2	0
(Stratman and Roth, 2002)	77	0	0
(Tu et al., 2006)	*Not found in Social Sciences Citation database*	-	-
(Vinding, 2006)	*Not found in Social Sciences Citation database*	-	-
(Wang and Ahmed, 2007)	*Not found in Social Sciences Citation database*	-	-
Total		**154**	**6**

Appendix 4: Quality Assessment

Search iteration	Author	Publication date	Contribution to Knowledge	Theory discussion	Methodology discussion	Data analysis	Limitations	Inclusion decision
1	Bacot	1992	1	1	0	1	0	excluded
1	Barclay	2006	1	1	0	0	0	excluded
1	Camison	2004	2	2	1	2	1	INCLUDED
1	Capaldo	2003	1	1	1	1	1	excluded
2	Carmeli	2004	1	1	1	1	1	excluded
2	Cohen & Levinthal	1990	2	2	1	2	0	INCLUDED
1	Conant	1990	1	2	2	1	2	INCLUDED
1	Coombs	2006	0	1	0	0	0	excluded
1	De Carolis	2003	2	2	2	2	1	INCLUDED
1	Deeds	2001	1	1	1	1	2	excluded
1	Denrell	2004	1	1	2	1	0	INCLUDED
2	Deshpandé	1993	2	1	1	1	1	INCLUDED
1	Dillon	2005	2	1	1	0	1	excluded
1	Durand	1988	2	1	2	1	2	INCLUDED
1	Durand	2003	1	0	1	0	1	excluded
2	Dutta	1999	2	1	2	1	0	INCLUDED
1	Dutta	2005	1	1	1	2	2	INCLUDED
2	Escrig-Tena	2005	2	1	2	1	1	INCLUDED
2	Ethiraj	2005	2	2	1	1	2	INCLUDED
1	Garcia-Muiña	2007	2	2	1	1	1	INCLUDED
2	Gibson	2004	1	1	1	1	0	excluded
1	Grimes	2007	2	1	1	2	0	INCLUDED
1	Guimaraes	2001	1	0	0	1	0	excluded
1	Henderson	1994	2	1	2	2	2	INCLUDED
1	Henri	2006	0	1	0	1	1	excluded
2	Hitt	1985	2	1	1	0	0	INCLUDED
1	Hult	1997	1	1	1	1	0	excluded
2	Hurley	1998	1	1	0	1	1	excluded
1	Igel	2002	1	1	0	X	0	excluded
1	Jantunen	2005	2	1	1	1	1	INCLUDED
1	Jerez-Gomez	2005	2	2	2	1	1	INCLUDED
1	Kaplan	1992	2	0	0	X	0	excluded
1	Lane	1998	2	1	2	1	0	INCLUDED
1	Lee	2002	0	0	0	0	1	excluded

Search iteration	Author	Publication date	Contribution to Knowledge	Theory discussion	Methodology discussion	Data analysis	Limitations	Inclusion decision
1	Lenz	1980	2	1	1	X	1	INCLUDED
2	Leonard-Barton	1992	2	1	1	1	0	INCLUDED
1	Lin	1997	1	1	1	1	0	excluded
1	Ma Prieto	2006	2	1	1	1	1	INCLUDED
1	Makadok	2000	2	1	2	2	0	INCLUDED
2	McGrath	1995	2	2	2	2	2	INCLUDED
1	Moehrle	2004	2	1	1	1	0	INCLUDED
1	Murthi	1996	2	1	1	1	1	INCLUDED
1	Narasimham	2006	2	1	2	1	1	INCLUDED
2	Oktemgil	1996	1	1	0	1	1	excluded
2	Pitt	1996	1	1	1	1	2	excluded
1	Ritter	2002	2	1	1	1	0	INCLUDED
1	Rondeau	2000	1	1	1	1	1	excluded
1	Schoenecker	2002	1	1	2	1	2	INCLUDED
1	Shuiabi	2005	1	1	1	1	1	excluded
1	Stratman	2002	1	1	2	1	2	INCLUDED
1	Tracey	2005	1	1	1	1	0	excluded
1	Tu	2005	2	1	2	2	1	INCLUDED
1	Vinding	2006	2	1	1	1	1	INCLUDED
1	Vorhies	1999	1	1	1	1	1	excluded
1	Wang	2004	1	1	0	1	0	excluded
2	Wang C.	2004	1	2	1	1	2	INCLUDED
1	Wang C.	2007	2	2	1	X	1	INCLUDED
1	Yang	2006	1	1	0	0	1	excluded

Appendix 5: Details of the final "core list"

Search iteration	Reference	Journal name	Publication date	Theoretical/ Methodological/ Empirical	Method type	Competence being measured
1	(Lenz, 1980)	Academy of Mgmt Review	1980	T	NA	Knowledge-Technique, capacity to generate & acquire resources, general management
2	(Hitt and Ireland, 1985)	Strategic Mgmt Jnl.	1985	E	Questionnaire	Functional competences
1	(Durand, 1988)	R&D Mgmt	1988	M	Case studies	R&D scientific competencies
2	(Cohen and Levinthal, 1990)	Administrative Science Quarterly	1990	T	Secondary data	Absorptive capacity
1	(Conant et al., 1990)	Strategic Mgmt Jnl.	1990	M	Questionnaire	Strategic types, marketing competencies
2	(Leonard-Barton, 1992)	Strategic Mgmt Jnl.	1992	T	Case studies	Core capabilities
2	(Deshpande et al., 1993)	Jnl Marketing	1993	E	Interviews	Customer orientation, innovativeness

Search iteration	Reference	Journal name	Publication date	Theoretical/ Methodological/ Empirical	Method type	Competence being measured
1	(Henderson and Cockburn, 1994)	Strategic Mgmt Jnl.	1994	E	Secondary data; Qualitative interviews	Component technical competence, architectural competence
2	(McGrath et al., 1995)	Strategic Mgmt Jnl.	1995	M	Questionnaire	Competence, deftness, comprehension
1	(Murthi et al., 1996)	Jnl Marketing Research	1996	E	Secondary data; Data Envelopment Analysis	Marketing & Production efficiency
1	(Lane and Lubatkin, 1998)	Strategic Mgmt Jnl.	1998	E	Questionnaire; Secondary data	Knowledge base, problem-set, knowledge processing
2	(Dutta et al., 1999)	Marketing Science	1999	E	Secondary data, Stochastic Frontier Estimation	Marketing, R&D and operations capability
1	(Makadok and Walker, 2000)	Strategic Mgmt Jnl.	2000	E	Secondary data	Forecasting ability
1	(Ritter et al., 2002)	Jnl of Business & Industrial Mktng	2002	E	Questionnaire	Network competence
1	(Schoenecker and Swanson, 2002)	IEEE Transactions Engineering Mgmt	2002	E	Secondary data	Technological capability

Search iteration	Reference	Journal name	Publication date	Theoretical/ Methodological/ Empirical	Method type	Competence being measured
1	(Stratman and Roth, 2002)	Decision Sciences	2002	M	Questionnaire	ERP competence
1	(De Carolis, 2003)	Jnl of Mgmt	2003	E	Secondary data	Technological competence, imitiability
1	(Camison, 2004)	Mgmt Research	2004	M	Questionnaire	Managerial & organisational capabilities
1	(Denrell et al., 2004)	Mgmt Science	2004	E	Questionnaire	Marketing capabilities
1	(Moehrle and Lessing, 2004)	Creativity & Innovation Mgmt	2004	E	Case studies	Technical problem-solving competencies
2	(Wang and Ahmed, 2004)	European Jnl of Innovation Mgmt	2004	M	Questionnaire	Innovativeness
1	(Dutta et al., 2005)	Strategic Mgmt Jnl.	2005	M	Secondary data, Stochastic Frontier Estimation	R&D capabilities
2	(Escrig-Tena and Bou-Llusar, 2005)	Decision Sciences	2005	M	Questionnaire + interview	Quality management
2	(Ethiraj et al., 2005)	Strategic Mgmt Jnl.	2005	E	Case study	Client-specific + project management capabilities

Search iteration	Reference	Journal name	Publication date	Theoretical/ Methodological/ Empirical	Method type	Competence being measured
1	(Jantunen, 2005)	European Jnl of Innovation Mgmt	2005	E	Questionnaire	Knowledge processing capabilities
1	(Jerez-Gomez et al., 2005)	Jnl of Business Research	2005	M	Questionnaire	Organisational learning capability
1	(Narasimhan et al., 2006)	Marketing Science	2006	E	Secondary data, Stochastic Frontier Estimation	Absorptive capacity
1	(Prieto and Revilla, 2006)	The learning organisation	2006	E	Questionnaire	Learning capability
1	(Tu et al., 2006)	Jnl. of Operations Mgmt.	2006	M	Questionnaire	Absorptive capacity
1	(Vinding, 2006)	Economics of Innovation & New Technology	2006	E	Secondary data	Absorptive capacity
1	(Garcia-Muiña and Navas-Lopez, 2007)	Technovation	2007	E	Questionnaire	Technological capabilities
1	(Grimes et al., 2007)	Jnl of Small Business & Enterprise development	2007	M	Questionnaire	Export capabilities
1	(Wang and Ahmed, 2007)	International Jnl of Mgmt Reviews	2007	T	NA	Dynamic capabilities

Table A5.1: Core list of relevant and high-quality articles

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