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Fit and complementarity: cognitive distance and combined competence as predictors of co-operative R&D projects' outcomes in Europe

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Fit and Complementarity –

Cognitive Distance and Combined Competence as Predictors of Co-operative R&D Projects' Outcomes in Europe

Laurent Zibell and Peter M. Allen

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Wirtschaftsforschung GmbH

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Non-technical Summary

This article considers cognitive distance and combined competence as predictors of success in co-operative Research and Development (R&D) projects of firms. The concepts of cognitive distance and combined competence are operationalised based upon a dedicated survey, answered by matched pairs of projects managers in partnering organisations. The survey addresses technical and scientific competence, innovation-related management competence and cultural features. Empirical validation was performed on 92 R&D projects based in France, Germany and the United Kingdom in the industry of electronics and telecommunications equipment. Each R&D project was performed by an industrial partner jointly with another partner from industry or a partner from a public research organisation.

Our research questions are the following: (1) How to describe and operationalise cultural features and organisational competences? (2) What is the effect of cognitive distance and of combined competence, along the variables described above, on the success of co-operative R&D projects?

Organisational culture is operationalised using the parsimonious model of organisational "character" which is inherited from Jungian psychology and from the broadly-used Myers-Briggs Type Indicator (MBTI) personality model. Organisational competences are operationalised as the ability to perform specific tasks, using a scale in which the first issue is whether it lies within the "core" competences and, within the "core" competences, how they relate to competitors. Triangulation is performed by averaging the self-appreciation and the partner evaluation of each competence level.

Contrary to expectations from earlier literature, neither geographic distance, nor the difference between private firms and non-profit R&D organisations nor the difference in size has any significant influence on project outcomes (measured through nine complementary success indicators). In addition, neither the level of public support to the project nor the level of technical risk plays any statistically significant role in the project success.

Distance along the "behaviour in the outside world" dimension of organisational "character" has a significant, positive influence on project outcomes: this may be interpreted as a synergy between "explorative" and "exploitative" behaviours. Differences in nationality have a significant, negative influence on project outcomes, probably due to communication and

linguistic issues. Distance in technical & scientific competencies has a significant, negative effect on project outcomes: this may be interpreted as a cognitive difference in ontology, where partner organisations live in different intellectual "worlds".

Combined competence in management of R&D operations has a significant, positive influence on project outcomes, which means that project management procedures valid for in-house operations retain validity in co-operative projects.

Das Wichtigste in Kürze

In diesem Aufsatz wird die Rolle von kognitiver Distanz und gemeinsamen Kompetenzen für den Erfolg von kooperativen Forschungs- und Entwicklungs- (FuE-) Projekten von Unternehmen untersucht. Die Konzepte der kognitiven Distanz und der gemeinsamen Kompetenzen werden mit Hilfe eines eigens dafür entwickelten Befragungsinstruments operationalisiert, wobei von jedem kooperativen FuE-Projekt die Projektleiter beider beteiligter Partnerorganisationen befragt werden. Die Erhebung erfasst die technischen und wissenschaftlichen Kompetenzen, die Kompetenzen im Bereich Innovationsmanagement sowie kulturelle Merkmale der Organisationen. Die empirische Arbeit beruht auf Daten zu 92 kooperativen FuE-Projekten von Unternehmen aus Frankreich, Deutschland und Großbritannien aus dem Bereich der Elektronik- und Telekommunikationsindustrie. Bei den betrachteten FuE-Projekten handelt es sich um Gemeinschaftsforschungsvorhaben eines Unternehmens mit einem anderen Unternehmen oder einer öffentlichen Forschungseinrichtung.

Zwei Forschungsfragen stehen im Zentrum: (1) Wie können kulturelle Merkmale und Kompetenzen in Organisationen beschrieben und gemessen werden? (2) Welcher Einfluss üben kognitive Distanz und gemeinsame Kompetenzen auf den Erfolg von kooperativen FuE-Projekten aus?

Organisationskultur wird in Anlehnung an Modelle aus der Psychologie gemessen, die in der Tradition von Jung und dem Myers-Briggs-Typindikator (MBTI) stehen. Die Kompetenzen einer Organisation werden über die Fähigkeit zur Ausübung bestimmter Tätigkeiten gemessen, wobei zwischen Kernkompetenzen und anderen unterschieden und eine Relation zu den Kompetenzen von Wettbewerbern hergestellt wird. Durch eine Gegenüberstellung des Kompetenzprofils der beiden an einem kooperativen FuE-Projekt beteiligten Organisationen wird das Ausmaß der gemeinsamen Kompetenzen ermittelt.

Die empirischen Ergebnisse zweigen, dass weder die räumliche Distanz noch die institutionelle Distanz (d.h. ob es sich bei den Partnern um Unternehmen oder öffentliche Forschungseinrichtungen handelt) noch Unterschiede in der Größer der Organisationen einen signifikanten Einfluss auf den Erfolg der kooperativen FuE-Projekte (gemessen über neun komplementäre Indikatoren zum Projekterfolg) haben. Ebenfalls kein Einfluss geht von einer öffentlichen Förderung des Projekts oder von der Höhe des technischen Risikos aus.

Ein positiver Einfluss konnte dagegen für die Distanz zwischen zwei Organisationen in Bezug auf ihr Verhalten gegenüber Dritten festgestellt werden. Wenn zwei Organisationen kooperieren, von denen eine als eher offen und die andere als eher geschlossen charakterisiert werden können, ist der Projekterfolg höher als bei Kooperationen zwischen zwei eher offenen oder zwischen zwei eher geschlossenen Organisationen. Von zwei anderen Maßen zur Distanz zwischen zwei Organisationen geht jeweils ein negativer Effekt auf den Projekterfolg aus, nämlich wenn sich die Nationalität der beteiligten Forscher in den beiden Organisationen unterscheidet (d.h. z.B. bei grenzüberschreitenden Kooperationen) und wenn sich die technisch-wissenschaftlichen Kompetenzen deutlich unterscheiden, d.h. die FuE der beiden Partner in anderen Denkzusammenhängen und Routinen stattfindet.

Ähneln sich dagegen die Kompetenzen im Bereich des Innovationsmanagements und verfügen beide Partner über ein gewisses Mindestmaß an solchen Kompetenzen, so erhöht sich der Projekterfolg signifikant.

Fit and Complementarity

Cognitive distance and combined competence as predictors of co-operative R&D projects' outcomes in Europe

Laurent ZIBELL[a,b] and Peter M. ALLEN[a]

October 2009

Abstract

This article considers cognitive distance and combined competence as predictors of concrete outcomes in co-operative Research and Development projects. The operationalisation is based upon a dedicated survey, answered by matched pairs of projects managers in partnering organisations, addressing technical and scientific competence, R&D management competence and cultural features. Empirical validation was performed on 92 projects based in France, Germany and the United Kingdom in the industry of electronics and telecommunications equipment. Selected dimensions of the cognitive distance and of combined competence being developed appear to be better predictors of concrete project outcomes than geographic distance, differences in organisation size or in legal status.

Keywords: Cognitive distance, Competence, Capability, Cooperation, R&D

JEL-Classification: M14, L24, L25, O31, O32

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1 Introduction

Since the late 1970s, firms have massively engaged in co-operative R&D activities with either suppliers, customers, competitors or academia. As an illustration, the number of inter-firm R&D partnerships recorded in the highly comprehensive, longitudinal, Merit-Cati database of Maastricht University has grown steadily from a few units per year in the 1960s and 1970s to ca. 160 in 1980 and to figures persistently above 300 since 1985, with a peak at almost 700 in 1996 (Hagedoorn, 2002, p. 480). These figures are independent of any public policy support. Simultaneously, the Framework Programmes of the European Commission, that specifically foster inter-organisational R&D co-operation, have increased their annual budget from an average of 817 m€ in the First Programme (1984-1987) to 7,800 m€ in the Seventh (2007-2013), an almost ten-fold increase in 25 years.

The motivations for these co-operative activities may be distinguished as (1) economic, such as sharing risks and costs, (2) strategic, such as the access to rare resources (and denying this access to competitors) or pre-empting a market with strong positive feedback effects, or (3) marketing, such as providing an early or combined offering (Dodgson, 1993; Doz and Hamel, 1998; Belderbos et al., 2004; Depret and Hamdouch, 2004). They rely upon the pooling of financial, material or intellectual resources of the partnering firms.

However, despite their growing popularity, inter-firm co-operations are reported to encounter high failure rates. Das and Teng (2000) report that their literature survey, comprised of 16 empirical studies (table 1, pp. 79-80), leads to the conclusion that "less than half of the alliances studied can be said to have performed satisfactorily" (p. 78). Similarly, failure rates of 50 to 70% are cited (Brouthers et al., 1995, p.18; Sivadas and Dwyer, 2000, p. 32).

Inter-firm co-operation has mainly been considered from a transaction economics and game theoretic point of view as an intermediate governance form between integrated hierarchies and markets. The investigation has therefore focused on minimising transaction costs and opportunistic behaviour. Researchers recommend to deter opportunism, using "both ex ante contracts and ex post monitoring" (Das and Teng, 2000, p. 98), by relying on the fact that alliances "are likely to resemble infinitely repeated games" (p. 80), in which a tit-for-tat strategy ensures co-operation (Axelrod, 1984), or by using equity participations as a "hostage" to deter the stealing of valuable resources. In addition, scholars (Bamford and Gomes-Casseres, 2002) recommend that firms should develop "tools, systems, staff and organisational structures that institutionalise alliance excellence" (p. 321), and that "include a streamlined corporate alliance unit, an alliance mapping system, a deep and extensive database" (p. 323).

Simultaneously, research on high-tech clusters has focused on geographic proximity as a predictor of co-operative success, considering that the co-location of R&D activities was a sufficient condition for co-operation to take place. The local transmission of information between co-located organisations has been assumed to be somewhat automatic, following Marshall's (1890) often-cited observation that "industrial secrets" in clusters are "in the air". This automatic (and generally unplanned) transfer of knowledge from one organisation to the next over a short distance is being referred to in the literature as 'local knowledge spill-overs' (Feldman, 1994; Feldman, 2000; Audretsch and Feldman, 2004). This automatic understanding of local co-operation was severely criticised as ignoring the effective transmission processes of high-value, proprietary knowledge between organisations, that generally involve elaborate partnership contracts and Intellectual Property clauses (Breschi and Lissoni, 2001).

As a reaction to the limitations of pure geographic distance as an explanatory variable to co-operation success, the notions of "cognitive distance" (Nooteboom, 2000) and of "organised proximity" (Torre and Rallet, 2005; Pecqueur and Zimmermann, 2004) were developed. They are based upon the intuition that

"People perceive, interpret and evaluate the world according to mental categories […] In order to achieve a specific joint goal the categories of thought of the people involved must be co-ordinated to some extent. Different people have a greater or lesser ‘cognitive distance’ between them. […] A trade-off needs to be made between cognitive distance, for the sake of novelty, and cognitive proximity, for the sake of efficient absorption. Information is useless if it is not new, but it is also useless if it is so new that it cannot be understood." (Nooteboom, 2000, pp. 71-72)

Concepts of these enriched forms of 'distance' (or, reciprocally, of 'proximity') are highly diverse (Knoben and Oerlemans, 2006). Many descriptions of these result from in-depth qualitative case studies (Filippi and Torre, 2003; Gill and Butler, 2003; Lam, 1997; Wilkof et al., 1995). In quantitative studies, operationalisation is generally limited to two methods: (1) cultural differences are represented by a variable for the nationality (Coenen et al., 2004; Gertler, 1995), and (2) competences are restricted to technological competences, themselves represented by a technical specialisation index obtained from patent data (Colombo, 2003; Greunz, 2003; Nooteboom et al., 2007; Nooteboom et al. 2005; Wuyts et al., 2005; Cantner and Meder, 2007). These methods suffer from various limitations. First, regarding nationality as a proxy for cultural differences between organisations overlooks the fact that organisations themselves develop cultural features that may contradict, enhance or supplement national characteristics. Second, patent data, although easily available, is classified by application, not by underlying technology (World Intellectual Property Organization (WIPO), 2009): two patents belong to the same class if they solve the same problem, even by using different technical means. Therefore, the fact that organisations share the same patent classes means that they are involved with the same applications – inferring that they use the same technological knowledge to do so goes beyond the actual information present in the patent class data. In addition, the pairwise nature of co-operation is lost in patent data, as noted by Nooteboom himself (2005, p. 4): "patent data are only available by firm per year, and cannot be attributed to individual alliance partners of the firm, so that the model has to be tested on the basis of average distance to the firm’s alliance partners".

Finally, a stream of research has developed a concept of "alliance management capability" or "cooperative competency" that specifically describes the appearance of a new corporate function dedicated to its legal and procedural aspects, in the wake of transaction costs theory (Sivadas and Dwyer, 2000; Zajac, 1998; Gulati, 1998; Kale et al., 2002; Sampson, 2005; Rothaermel and Deeds, 2006). However, the contention that 'alliance management capability' be generic, i.e. that the knowledge and practice learnt during the interactions with one partner organisation are re-usable with any other one, has been hotly debated (Sampson, 2005; Zollo et al., 2002).

2 Purpose

The purpose of this article is to contribute to the better prediction of co-operative R&D projects outcome, using novel concepts and operationalisation of organisational competences and cultural features. We rely for the validation of these concepts and methods upon an empirical study performed on 92 co-operative R&D projects, based in France, Germany and the United Kingdom, in the industry of electronics and telecommunications equipment.

As compared to the previous studies on 'cognitive distance' described above, we introduce the following innovations and improvements:

(1) Our unit of analysis is the individual project performed by a dyad of partner organisations: we measure the relevant variables for each organisation, and relate them to the outcomes of the project that they have jointly performed. We are not forced by our data to average outcomes at firm level;

(2) we consider a richer set of cultural features of organisations, beyond nationality;

(3) we consider innovation-related management competences, in addition to scientific & technical knowledge;

(4) in addition to cognitive distance, that we understand as the difference in cultural features present in the partnering organisations and in their competence levels, we also consider the "combined competence" of partners, that describes the sum of the competence levels present in both partners.

Our research questions may be stated as follows:

(1) How to describe and operationalise cultural features and organisational competences?

(2) What is the effect of cognitive distance and of combined competence, along the variables described above, on the outcome of co-operative R&D projects?

3 Material and methods

3.1. Operationalisation of cultural features and organisational competences - Justification

We use a quantitative methodology, based upon an on-line survey with a closed set of pre-defined answers. Our unit of analysis is the "co-operative R&D project" that was jointly undertaken by the partnering organisations.

In order to compute 'cognitive distance' and 'combined competence' between the partner organisations in the co-operative R&D project, we locate each of the organisations in a cognitive space of cultural features and organisational competences defined as follows:

1. the organisation's competences in the management of R&D operations, subdivided in 14 sub-fields expressed in functional terms, as the ability to perform the described tasks. The list of the subfields is further described in Appendix A.

2. the organisation's technical and scientific competences, in the three areas (subdivided in a total of 18 sub-fields) that we consider as relevant for the design of electronic & telecommunications equipment, based upon 16 years of direct and indirect professional involvement of one of us in R&D in this industry: (1) Fundamental & applied Physics, (2) Hardware design technologies and (3) Software design technologies. The list of the subfields is further described in Appendix B.

3. the organisation's organisational culture, expressed as a sub-part of its organisational "character" (Bridges, 2000) in the two dimensions that we believe are meaningful for innovation activities: "Mode of perception of information" – using 9 questions – and "Behaviour in the outside world" – using 9 questions. Both sets of questions are directly reproduced from Bridges' (2000) work. The former dimension may be described by its two poles: Sensing (identified by the letter S) – when "the organisation [is] primarily focused on the present, the details and the actuality of the situation" – and Intuition (identified by the letter N) - when it focuses on "the future, the big picture and the possibilities inherent in situations". The latter dimension may also be described by its two opposite poles, described hereafter by the letters "J" and "P" (since the full name, rather technical in origin, hinders understanding more than it helps it): "Organisations in which J[...] predominates prefer to reach firm decisions, define things clearly, and get closure on issues. Organisations in which P[...] predominates are always seeking more input, preferring to leave things loose, or opting to keep their choices open".

In addition, we consider more classical demographic variables on each of the partner organisations:

1. whether the organisation is a non-profit R&D body or a private firm (its legal status);

2. its number of employees, expressed as belonging to one of five pre-defined classes: (1) from 1 to 10 employees; (2) from 11 to 49 employees; (3) from 50 to 249 employees; (4) from 250 to 1 999 employees and (5) more than 2 000 employees;

3. its geographic location, which can then be translated into a nationality and on the project itself;

4. the risk level of the project, along a four-stage scale: (1) Low-risk project, straightforward development from existing knowledge; (2) Medium-risk project, minor uncertainties that only challenge development cost or duration; (3) High-risk project, major uncertainties that challenge its very feasibility and (4) Highly exploratory research, with very limited visibility on potential outcomes;

5. the fraction of the budget paid for by public bodies, along a four-steps scale: (1) less than 10 % of budget covered by public financing; (2) from 10 to 25 %; (3) from 25 to 75 % and (4) more than 75%.

The capability levels reached for each of the above-mentioned competences are estimated along a semi-quantitative scale, in which a capability is first described as belonging or not to the 'core' competence (Prahalad and Hamel, 1990) of the organisation, and if so, how the organisation positions itself in comparison with its competitors, on a four-step scale from "weak" to "world-leading" core competence. It is also validated by a cross-interrogation of the partner firm, in order to reduce self-approbation bias, in a form of "triangulation" (Deshpande et al., 1993).

We chose to describe organisational culture along the lines of the organisational "character", related to Jungian personality typology (Jung, 1923) and to the broadly-used MBTI personality model (Briggs-Myers et al., 2000). This mode of description was chosen for its simplicity and parsimony, and because it has been demonstrated to have a very significant impact on innovation performance (Stevens et al., 1999; Stevens and Burley 2003). However, only two dimensions of the organisational "character" were retained to describe the organisation (out of a total of four). We only kept those dimensions that define which of the "psychic functions" (Jung, 1923) are best mastered by the organisation, among the following that we consider as relevant for innovative activities: (1) Extravert Intuition, that explores all possibilities and investigate the unknown – the NP combination, (2) Introvert Intuition, that focuses efforts towards the achievement of a well-defined, but yet fully conceptual, goal – NJ combination, (3) Extravert Sensing, that achieves first concrete implementations, through all practical difficulties that may arise – SP combination, and finally (4) Introvert Sensing, that stabilises and streamlines the industrial procedures that will make the initial success repeatable – SJ combination. Indeed, we believe that an innovation, in order to proceed from the initial idea to a full-fledged industrial product, must be nurtured by these four psychic functions.

The outcomes of a co-operative R&D project are also measured along a multi-dimensional metric that incorporates (1) concrete achievements, such as publications, patents, prototypes, commercial launch… and (2) project management goals, such as reaching budget and schedule targets.

Full text of the survey may be obtained from the corresponding author.

3.2. Empirical setting and data collection methodology

The present article is based upon data collected via an on-line survey of co-operative R&D projects based in France, Germany and the United Kingdom, from September 2008 to August 2009 inclusive. The projects were selected in a single industry, electronics & telecommunications equipment, in order to limit the scope of the technical & scientific knowledge fields to investigate, to moderate inter-industry variation, and because one of us has a previous professional experience in this domain (and therefore knows the technical and scientific sub-fields in this area).

Contact was made with a total of 494 project managers that were identified through openly available databases of publicly-funded co-operative R&D projects (e.g. from the Technology Strategy Board in the United Kingdom, the Bundesministerium für Bildung und Forschung in Germany, the Agence Nationale de la Recherche in France or the European Commission, DG Research, at European scale), from the websites of organisations dedicated to co-operative R&D (such as the Fraunhofer Institute in Germany and the Instituts Carnot in France). Specifically, all projects under the "Electronics, Photonics and Electrical systems" and "Information and Communication Technology" Key Technology areas of the British Technology Strategy Board (139 projects) and all projects referenced under the relevant entries of the Systematic Plan of Activities – Leistungsplansystematik - in the German Federal Government's database of publicly-funded projects - Forderkatalog des Bundes- (104 projects) were investigated.

The data was collected using the "LimeSurvey" Open Source survey software tool (LimeSurvey Project Team 2009). The interviewee could choose his/her linguistic version of the survey between French, English and German, in order to have an immediate and unbiased understanding of the questions being asked.

Data collection methodology was the following:

1. sending of a postal letter to the project manager, requesting the participation in the research, and containing the access details to the on-line survey;

2. one follow-up telephone call to check the willingness of the project manager to take part in the research and the compatibility of the suggested project with the research requirements, followed by an e-mail summarising the main information and containing the links to the on-line survey;

3. two reminder e-mails, one reminder postal letter and one reminder telephone call.

According to the confidentiality level of the project, the contact with the partner was managed either by the project manager or directly by one of us. The data collection from the partner was identical to that with the project manager. In order to preserve the confidentiality of the project, neither the identity of the project, nor that of the partner organisation were transmitted to us during the survey: the only information that we collected (and that was sufficient for our investigation) was that the set of two answers matched the same project.

We received 92 complete answers, that is, matching pairs of answers from both partners in the same project. The overall yield of the data collection is thus 18.6%. Considering that two organisations needed to be convinced in parallel for every complete answer (instead of only one for conventional data collection methodologies), the yield may be considered as reasonable. The distribution of answers among the three target countries was the following:

- France: 31
- Germany: 41
- United Kingdom: 20.

In addition, we received 92 additional incomplete answers, that is, unmatched answers from one organisation only. Therefore, the total number of independent, unmatched answers was 276.

The data was exploited using the R Open Source statistical computing software tool (R Development Core Team 2009).

4 Results - Validation of Aggregated Scales

Some of our variables are the result of the aggregation of answers received on several items of the survey: (1) the position of the organisation on the scales for organisational culture and (2) the project outcomes. We therefore validated the unidimensionality of the obtained scales, using the classical Cronbach alpha coefficient (Cronbach, 1951). For each scale, only the fraction of the items that maximised the value of the Cronbach alpha coefficient was retained. These coefficients are computed over the whole number of independent answers received (i.e. 276).

Table 1: Cronbach’s Alpha coefficient for aggregated variables

Underlying variable	**# of items retained / total items**	**Nmin - Nmax**	**Cronbach’s Alpha for retained items**
Organisational “character”: mode of perception of information	9 / 9	206 - 236	0.67
Organisational “character”: behaviour in the outside world	9 / 9	180 - 241	0.56
Project success: concrete outputs + project management goals	11 / 12	228 - 276	0.43

As may be seen in Table 1, the unidimensionality of the constructs is correct for the variables considered. Additional qualitative validations were performed using Factor Analysis and showed that the retained items in each scale, projected on the principal dimensions, are all concentrated within a small geometric angle.

5 Empirical Results

We performed Ordinary Least Squares regressions, in order to identify the variables influencing the outcome of the co-operative R&D projects of our sample.

5.1. Independent variables

The independent variables in our models may be divided into four categories: (1) control variables, (2) cognitive distance between the organisational cultures of project partners, (3) cognitive distance between the technical & scientific competences of project partners and (4) combined competence of the project partners in R&D management.

The control variables are the following:

- the geographic distance between the locations of project partners (DistGeo), expressed as the sum of the differences in latitude and longitude in degrees
- the difference in nationality (DistNation) between the project partners, taking the value 0 for partners established in the same country, and the value 1 otherwise
- the distance in legal status (DistLegalStatus), taking the value 0 if both organisations are private firms or if both are non-profit R&D organisations, and the value 1 otherwise
- the distance in the size of the partner organisations (DistSize), expressed in the five pre-defined classes of number of employees defined above
- the level of public support received for the project (PublicSupport), on the four-step scale described above, averaged over the answers received from both partners. Since we have no other information on the project than the one being provided by the respondents (because even the identity of the project was unknown to us for confidentiality reasons described above), taking the mean level between both answers received appears as being the best estimate considering the information available.
- the level of technical risk estimated ex ante for the project (TechRisk), on the four-step scale described above, averaged over the answers received from both partners, for the same reason as above.

The distance between the organisational cultures of project partners is the absolute value of the difference between the scores obtained by each partner along the following dimensions of the organisational "character":

- Mode of perception of information (DistSN)

- Behaviour in the outside world (DistJP).

The cognitive distance between the technical & scientific competences of project partners (DistPhysHardSoft) is computed as follows:

1. First, the “best estimate” value of the competence in each of the 18 technical & scientific sub-fields is computed by combining the self-estimation given by the target organisation and the estimation provided by the partner. We have chosen to use as the "best estimate" of the competence level the mean value between both provided, as being the one incorporating as much as possible of the available information, and in the absence of any external, third-party source that could justify valuating one estimation more than the other.

2. Once this “best estimate” value is established for the organisation’s competence in each of the sub-fields, the cognitive distance between the technical & scientific competences of the project partners is defined as the sum of the absolute values of differences in competence levels in each sub-field. In mathematical terms, this is a L1 distance between the vectors (of dimension 18) representing the technical & scientific competences of both project partners.

The combined competence of the project partners in R&D Management (CombRDMgmt) is computed as follows:

1. the "best estimate" competence level of each partner in each of the 14 sub-fields of R&D Management competence is computed as described above;

2. we compute the mean level of competence between both partners in each sub-field of competence;

3. we add these values over the 14 sub-fields to obtain the combined competence level of both partners in R&D Management.

5.2. Dependent variable

The dependent variable (ConcreteOutput_ProjMgmt) is the outcome of the co-operative R&D project undertaken by the two partners involved, measured in concrete terms and in terms of achievement of project management goals.

For each of the 9 following concrete achievements – (1) Scientific publications, (2) Patents, (3) Technical proof of concept (lab demo), (4) Functional prototype (meets functional specifications), (5) Industrial prototype (meets environment, production & cost requirements), (6) Pilot production, (7) Commercial launch & full-scale production, (8) Commercial success, (9) Spin-out creation – one point is attributed if this achievement has been obtained by the project. Once the total of points for each project has been computed, this score is divided by the mean value for all projects, in order to normalise this score to having a mean equal to 1.

For both questions referring to the compliance with planned schedule and resource budget, a score is attributed as follows:

- Effective operation under initial budget: 5 points
- Effective operation on initial budget (±10%): 4 points
- Effective operation slightly above initial budget (10-30%): 3 points
- Effective operation significantly above initial budget (30-100%): 2 points
- Effective operation well over initial budget (>100%): 1 point.

This score is divided by the mean value over all projects, in order to have a mean value equal to 1. The overall value of project outcome is then the sum of the normalised scores for concrete achievements and of the mean of normalised scores for schedule and for budget compliance. The relations between the variables of interest are described in Table 2.

Table 2: Descriptive statistics of variables intervening in the models: mean value, standard deviation and correlation

Name of variable	DistSN	DistJP	DistGeo	DistNation	DistSize	DistLegalStatus	PublicSupport	TechRisk	DistPhysHardSoft	CombRDMgmt
DistSN	**0.512** (0.368)									
DistJP	*0.109*	**0.396** (0.315)								
DistGeo	*-0.158*	*-0.034*	**2.288** (2.580)							
DistNation	*-0.024*	*0.048*	*0.628*	**0.188** (0.390)						
DistSize	*-0.207*	*0.061*	*0.052*	*0.145*	**1.25** (0.921)					
DistLegalStatus	*0.085*	*0.135*	*-0.042*	*-0.088*	*-0.006*	**0.620** (0.488)				
PublicSupport	*-0.213*	*0.073*	*-0.076*	*0.019*	*0.163*	*-0.089*	**2.908** (0.818)			
TechRisk	*-0.150*	*0.011*	*-0.018*	*-0.062*	*-0.095*	*0.054*	*0.174*	**2.701** (0.638)		
DistPhysHardSoft	*0.241*	*0.048*	*-0.058*	*-0.166*	*0.000*	*0.106*	*-0.279*	*-0.036*	**0.959** (0.489)	
CombRDMgmt	*0.191*	*-0.011*	*-0.056*	*-0.020*	*-0.047*	*0.139*	*-0.189*	*0.094*	*0.145*	**2.333** (0.732)

Note. Mean value is printed bold, standard deviation in parentheses, correlation coefficients in italics.

5.4. Regression model results

We have built three models, in order to estimate the effect of the independent variables that we introduced. Model 1 only consists of control variable, model 2 includes all variables, and model 3 is the final model and contains only those variables that proved to be significant. Table 3 shows the coefficients estimated for all three models.

Table 3: Linear regression models: coefficients (p-values) and significance levels

Explanatory Variable	**Model 1: Control variables**	**Model 2: All variables**	**Model 3: Most significant variables**
Intercept	1.676 ***	1.641 ***	1.590 ***
	(7.77e-09)	*(2.84e-06)*	*(4.43e-15)*
DistSN		-0.1422	
		(0.28464)	
DistJP		0.3084 *	0.2844 *
		(0.03262)	*(0.04185)*
DistPhysHardSoft		-0.2476 *	0.2448 **
		(0.01276)	*(0.00932)*
CombRDMgmt		0.1913 **	0.1994 **
		(0.00331)	*(0.00145)*
DistGeo	0.0055	0.0162	
	(0.812)	*(0.47971)*	
DistNation	-0.1865	-0.3131 *	-0.2547 *
	(0.232)	*(0.03952)*	*(0.02962)*
TechRisk	0.1165	0.0777	
	(0.122)	*(0.29569)*	
DistLegalStatus	0.0658	0.0430	
	(0.494)	*(0.63900)*	
DistSize	0.0226	0.0273	
	(0.663)	*(0.58474)*	
PublicSupport	-0.0284	-0.0743	
	(0.634)	*(0.21891)*	

Note: Significance levels codes: ***: better than 1‰; **: better than 1%; *: better than 5 %

The adjusted R-squared for the final Model 3 incorporating the significant variables from all categories is 0.176, which indicates that a significant proportion of the variance is explained by the model. The Shapiro-Wilk normality test applied to the residuals of the final Model 3 displays a p-value = 0. 3458, which indicates that the residuals may be considered as normal, and therefore that the model respects one of the key validity requirements of the Ordinary Least Squares regression.

The regression results demonstrate both significant and non-significant effects. The first non-significant effect is in contradiction with most of the literature on geographic proximity and local knowledge spill-overs (Feldman, 1994; Feldman, 2000; Audretsch and Feldman, 2004). Indeed, geographic distance (DistGeo) plays no apparent role in the outcome of the co-operative R&D projects being investigated in our survey. Direct encounters and face-to-face interactions that geographic proximity fosters seem to have a minimal effect on project outcome.

Also in contradiction with the most usual common sense, the fact that the co-operating organisations belong or not to the seemingly contrasting worlds of non-profit R&D organisations and of private firms (DistLegalStatus) plays no role either in the projects investigated in our survey. This may mean that the organisations that answered the survey have a good experience of the differences between these two institutional environments, and have learnt to cope with them.

Another contradiction with most expectations is that the differences in organisational size (DistSize) appear to play no role in the outcome of the co-operative R&D project, despite the much discussed differences between SMEs and large corporations.

Contrary to our expectations, the difference in organisational culture along the dimension of "Mode of perception of information" (DistSN) does not have any significant influence on the outcome of the co-operative R&D projects being investigated.

In what may appear as a satisfactory outcome for those public bodies funding co-operative R&D, the level of public financing (PublicSupport) has no effect either on the outcome of the co-operative R&D projects being investigated. Indeed, one could fear that organisations take benefit of the existence of a public subsidy to engage in more risky, or second-grade R&D, effectively having the taxpayer paying for the potential losses. It appears from our empirical study that public support for co-operative R&D causes no bias in the project outcome, and that the public funding plays its role of enabling a good-quality work that would otherwise not have taken place because of financial constraints.

Rather surprisingly, the anticipated risk level (TechRisk) plays no role either in the average project outcome, although one could have anticipated that riskier projects are, on average, less successful than straightforward developments. This result would probably need to be completed by an analysis of the variance in the project outcomes, according to the level of anticipated risk.

The significant effects that our research evidences are the following:

- The distance along the dimension of "Behaviour in the outside world" (DistJP) of organisational cultures has a strongly significant positive influence on the outcome of the co-operative R&D projects being investigated in our research.

- In a confirmation of previous studies (Coenen et al., 2004; Gertler, 1995), the cognitive distance expressed as the difference in the partners' nationalities (DistNation) has a strongly significant negative influence on the outcome.

- The distance in partners' technical & scientific competences (DistPhysHardSoft) has a strongly significant negative influence on the outcome of the common co-operative project.

- The combined competences of the partners in "Management of R&D operations" (CombRDMgmt) have a strongly significant positive influence on project outcome.

6 Discussion - Interpretation of Significant Effects

The significant effects evidenced by our research may be interpreted in the following way.

The positive influence on project outcome of distance along the cultural dimension of "Behaviour in the outside world" could be a surprise. Indeed, the "Behaviours" being described at the two opposing poles of this dimension of the organisational "character" are highly contrasted, and could very well lead to conflict. Organisations of the "P" type tend to believe that the world is essentially mobile, flexible, and in a constant process of change. They consider it as an endless repository of information, and would tend to delay any decision as much as possible, in order to maximise the chances that additional data could be gathered, under the motto "why should we decide today something that may become obsolete tomorrow?", at the risk of procrastination. They thus tend not to respect schedules and deadlines. Organisations of the "J" type on the other hand believe that the world is essentially stable and constant. They consider it as a locus of action and decision-making, and tend to take early decisions, under the motto "why should we delay to tomorrow a decision that could be taken today?", at the risk of precipitation. They set up accurate schedules, and respect them scrupulously. One could thus potentially anticipate that organisations contrasting along this dimension in the same project may engage in persistent conflict between those wanting to decide early and respect deadlines (of the "J" type), and those wanting to take more time to explore more options (of the "P" type).

The positive influence of the distance along this dimension on project outcomes that we observe in our research can on the other hand be interpreted as a synergetic effect of the co-operation between two types of organisations, respectively oriented towards "exploration" (preference for "P") and "exploitation" (preference for "J"), following March (1991). The interpretation from our empirical data seems to mean that contrasting organisations along this dimension of "Behaviour in the outside world" learn to work with one another, and to benefit from each other's qualities: the organisation of a "J" type benefits from the propensity of the partner organisation (of a "P" type) to look for more information and data – which may be highly beneficial in R&D activities that generally involve some form of uncertainty – while the organisation of a "P" type benefits from the capacity of its partner (of a "J" type) to take decisions and actually proceed in the work plan.

The negative influence on project outcome of distance between the organisations' technical & scientific competences may be interpreted as the effect of a difference in ontology. The organisations that are involved in different technical & scientific areas of knowledge refer to different worlds of objects in their thinking and in their expression. When organisations operate in at different levels of competence in technical & scientific knowledge, the very reality to be described and that matters differs, the concepts and the language are distinct. In all these cases, communication and co-operation between these organisations may prove to be difficult.

Ultimately, the positive influence of combined competence in "Management of R&D operations" is good news for engineering and management schools. The techniques of R&D management appear to be indeed useful for co-operative R&D outcome (i.e. involving external organisations), as much as they are for purely internal projects.

7. Conclusions

In this article, we have both developed and validated a tool to measure organisational competences (in R&D management and in technical & scientific fields), as well as key features of organisational cultures. This tool overcomes many of the limitations of earlier methods aiming at measuring cognitive distance between organisations. We have used this tool to predict the outcome of co-operative R&D projects in the industry of electronics and telecommunications equipment, and have reached the results that cognitive distance in terms of ontology and nationality hinder co-operation, while complementarity between "explorative" and "exploitative" cultures and combined competence in R&D Management foster it. These results complement (and contradict partially) earlier studies on the effects of cognitive distance on co-operation, that had been obtained with different tools.

Like any research, the one presented here presents limitations. One first obvious limitation is that we restricted ourselves to the industry of electronics and telecommunications equipment. Despite its innovativeness and its relevance for overall industrial development, it is not the whole picture of industrial innovation.

Another limitation is related to the number of cases being investigated: our initial sample was of 494 projects, out of which 92 accepted to contribute to the research. Although the initial sample contained a significant proportion of the publicly-available population of co-operative projects that have been undertaken in the last years in the countries under study, the total number of cases being investigated remains limited.

Although 78 % of our respondents have stated that the presence of specific technical & scientific knowledge with their potential partner is a "major" reason for co-operation, we have not found any positive influence of cognitive distance in scientific & technical fields on project outcome. Our interpretation at this stage would be that the positive effects of cognitive distance (i.e. a complementarity of technical & scientific skills, that would have a positive effect on co-operation) operates at much smaller scales of knowledge granularity than the one we used in our investigation. In order to validate this hypothesis, we would need to investigate technical & scientific knowledge at a much greater level of detail, distinguishing between much finer sub-fields than those we used. This further investigation might however be restricted by strong (and legitimate) confidentiality issues. Another issue may be that the outcome of a co-operative R&D project may be measured not only in concrete terms, but also in terms of learning: it may then be that differences in competence levels between partnering organisations, although detrimental to concrete outcomes and to budget and schedule compliance, have a positive effect on learning. This would constitute the purpose of a further study.

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Appendix A: list of sub-fields describing competences in R&D Management

1. Anticipate technical and scientific evolutions
2. Identify, locate, and qualify relevant external sources of technical and scientific competencies
3. Specify and control exploratory research
4. Influence decisions in international co-operative technical standardisation work
5. Define technical specification of the final product from the functional specifications provided by Marketing
6. Design the technical solution meeting specified requirements
7. Incorporate user feedback on product failures
8. Anticipate research project / technical development budget (manpower and material resources) and schedule
9. Manage the specific human requirements of R&D scientists, engineers and technicians
10. Share and allocate tasks, set goals among members of the research / development team
11. Meet the research / development duration schedule
12. Meet the research / development costs budget
13. Meet the technical requirements of the product / of the research outcome = compliance with functional specification
14. Meet the cost objectives of the product = successful "design to cost"

Appendix B: list of sub-fields describing technical & scientific competences

Fundamental & applied Physics:

1. Quantum and statistical physics
2. Laser physics
3. Solid-state physics and materials science
4. Thin-film and surface physics

Hardware design technologies:

1. Placement and routing of microcircuits
2. Radio frequencies, electromagnetic compatibility
3. Lasers and diodes
4. Magnetism, electricity, electrostatics, fluidics
5. Mechanical, optical and thermal design
6. Chemical and biological design

Software design technologies:

1. Hardware description language programming (VHDL, Verilog)
2. Digital Signal Processing (audio, video, radio, xDSL, error detection & correction)
3. Cryptography
4. Compiling, synthesising
5. Real-time programming and scheduling, time-aware parallel programming
6. Sequential and object-oriented language programming (C, Java, C++…)
7. Communication protocols, telecommunications and networks
8. Built-In electrical and functional tests