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Scientists' performance and consolidation of research teams in Biology and Biomedicine at the Spanish Council for Scientific Research

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Empirical evidence is given on how membership in a consolidated, well-established research team provides researchers with some competitive advantage as compared to their colleagues in non-consolidated teams. Data were obtained from a survey of researchers ascribed to the 'Biology and Biomedicine' area of the Spanish Council for Scientific Research, as well as from their curricula vitae. One quarter of the scientists work as members of teams in the process of consolidation. Our findings illustrate the importance, for the development and consolidation of research teams, of the availability of a minimum number of researchers with a permanent position and of a minimum number of support staff and non-staff personnel (mainly post-doctoral fellows). Consolidation of research teams has a clear influence on the more academic-oriented quantitative indicators of the scientific activity of individuals. Researchers belonging to consolidated teams perform quantitatively better than their colleagues in terms of the number of articles published in journals covered in the *Journal Citation Reports*, but not in terms of the impact of these publications. Consolidation favours publication, but not patenting, and it also has a positive effect on the academic prestige of scientists and on their capacity to train new researchers. It does not significantly foster participation in funded R&D projects, nor does it influence the establishment of international collaborations. Impact is influenced to a remarkable degree by seniority and professional background, and is significantly greater for young scientists who have spent time abroad at prestigious research laboratories.

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Introduction

Contemporary science is characterized, among other things, by the importance of teamwork. Research teamwork gained increasing importance during the twentieth century (BUSH & HATTERY, 1956; ETZKOWITZ, 1992), a process that constitutes a substantial change in the evolution of modern science, as did, in past times, the professionalization of scientific research. To quote Robert K. Merton, 'the social organization of scientific inquiry has greatly changed, with collaboration and research teams the order of the day' (MERTON, 1968, p. 328). Over the last few years the trend has been for scientific research to be increasingly carried out by groups or teams of scientists rather than by individuals. Research and knowledge production in this new era thrive, in the words of VON TUNZELMANN et al. (2003, p. 15), 'on cross-communication, inter-linkages, networks and collaboration'. It can thus be claimed that teamwork, collaboration and interdisciplinarity are among the principal characteristics of modern science.

In this context of collaborative and multidisciplinary work, researchers' performance, and in general the whole of their research activity, have undoubtedly been influenced (both quantitatively and qualitatively) not only by individual characteristics but also by collective and contextual factors related to the structure and dynamics of research teams and units. Factors whose influence on the research habits, performance and productivity of scientists have been analysed in the wide-ranging literature available to date, which we will attempt to summarize below.

In previous studies (REY-ROCHA et al., 2002; MARTÍN-SEMPERE et al., 2002) we introduced the concept of the *level of research team consolidation* as a contextual factor that influences research activity and scientists' performance. We found evidence of how, within a given scientific community, membership in a consolidated, well-established research team can result in an enhanced capacity to establish contacts and collaborations with colleagues, foster participation in funded research projects, and enhance members' potential to publish in international mainstream journals. In these papers we presented the results of an evaluation of research performance of university researchers in a scientific field (Geology) where applied research and topics of local and national interest are important.

Here we extend our previous work to elucidate the factors that might explain how the team context influences research activity and performance, in an attempt to answer some of the questions these earlier analyses raised. In this paper we look at a different population of scientists who carry out their research in a very different context (a public research organization instead a university) and in a different scientific field (Biology and Biomedicine). Although the research this group is engaged in is eminently basic, there is a tendency to combine basic with more applied research. In addition to studying the productivity and impact of publications, collaboration, and the participation in R&D projects, we enrich the analysis offered here by examining other factors such as the prestige obtained by scientists and their contribution to the training of new scientists.

In this paper we provide empirical evidence on how, in the field of Biology and Biomedicine, consolidation of research teams in the Spanish National Research Council influences the volume and international impact of research output, as well as different aspects of the scientists' research activity such as collaboration and training of junior researchers. We also show how consolidation of research teams is related to scientists' prestige. The methods used here are based on a combination of a survey of scientists and content analysis of their curricula vitae.

Collective effects on individual research performance: a literature review

Here we attempt to summarize some of the main findings of previously published work on the effects of social and organizational attributes on the research habits, performance, and productivity of scientists, focusing upon studies that assess their collective effects on individual performance. In this regard individual performance must not be confused with team performance, and it should be remembered that the results at a collective level may be quite different from those for an individual researcher.

A series of articles published by UNESCO (ANDREWS, 1979) reviewed the different social and organizational factors that might influence or relate to the performance of research units and of their members. These factors were grouped in the following broad categories: R&D activities, research methods, scientific exchanges and contacts with other units, evaluation methods, planning of the work and choice of research topics, availability of resources, amounts and patterns of influence, supervision, remuneration and career advancement, working climate, and numerous demographic variables such as age, experience, staff size, staff turnover, institutional setting, and scientific discipline (DE HEMPTINNE & ANDREWS, 1979).

FOX (1983) scrutinized the literature on correlates and determinants of publication productivity among scientists, focusing upon productivity through publication among individual scientists, rather than research units or aggregates. Besides individual-level and demographic variables, she reviewed the literature available on structural aspects of the scientist's environment such as graduate school background, department or institution prestige, and organizational freedom.

More recently, VON TUNZELMANN et al. (2003) summarized the main findings on the effects of size on research performance, from the micro level of individuals in teams up to the macro level. CARAYOL & MATT (2004) reviewed selected publications related to the influence of research organization on academic production at the laboratory level.

Organizational context is a factor that may be related to scientific performance in a variety of ways (for a review, see LONG & MCGINNIS, 1981, and FOX, 1983). Besides the macro context delimited by the characteristics of the country and the scientific community considered, one contextual variable that significantly affects research activities and publication performance of scientists is the scientific discipline or field (see, for instance: PRPIĆ, 1994; HEMLIN & GUSTAFSSON, 1996; DUNDAR & LEWIS, 1998).

Beyond the scientific field, related contextual factors that decisively influence the research activity of scientists are the organizational context of employment (academic vs. non-academic) and institutional control (private versus public). The effect of these factors determines the research setting and facilities, as well as the degree of intellectual autonomy and of freedom to publish. They also affect the research performance and productivity of scientists, especially when the latter is measured in terms of scientific publications (see for instance JORDAN et al., 1988, 1989; FOX, 1992; GOLDEN & CARSTENSEN, 1992a, 1992b; DUNDAR & LEWIS, 1998; CARAYOL & MATT, 2004).

Studies of the role of the organizational setting on research performance tend to demonstrate that, in general, performance is positively influenced by factors such as good management and organization (PELZ & ANDREWS, 1966) and freedom (FOX, 1983). Nevertheless, HEMLYN & GUSTAFFSON (1996) found that the organizational factor was negatively related to paper production in the arts and humanities, and concluded that 'organizational factors apparently played a minor role in comparison to individual characteristics in the humanities than in the sciences'. At the micro level of research teams, numerous studies suggest that group norms may have a greater influence on individual performance than the knowledge, skills, and abilities the individual brings to the work setting, and that group identity can have a greater influence on productivity than working conditions (for a review, see HACKMAN, 1983).

The prestige of the unit to which the scientist belongs is another contextual factor that can influence research work and output. Empirical studies have found a positive effect ('departmental effect') of the reputation of the institution on different aspects of researchers' activity and productivity (COLE, 1970; COLE & COLE, 1973; HANSEN et al., 1978; LONG, 1978). Although different hypotheses have been proposed to explain the causality between productivity and department prestige, most studies tend to emphasize the preponderance of this departmental effect over the 'selection effect' (i.e., the influence of productivity on the prestige of the position obtained) (FOX, 1983; ALLISON & LONG, 1990; CARAYOL & MATT, 2004).

The current organizational context is indeed determinant. In fact, it seems that despite its previous history, scientists' productivity tends to conform to the characteristics of their current context. In this connection, studies by LONG (1978) and LONG & MCGINNIS (1981) of natural scientists in both academic and non-academic organizational contexts showed that when scientists moved to a new institution, their production patterns soon reflected the publication norms of the new institution.

Nevertheless, the importance of past organizational context can not be disregarded (HILL, 1974). Past reference groups may influence scientists' behaviour and expectations in future situations. In this regard, factors such as graduate school background, the context where pre-doctoral and post-doctoral training took place, and the organizational context of a scientist's first job may have important effects on later scientific achievement.

The size of the lab or research team is another crucial variable to take into account. The relationship between the size of research teams and their productivity is a topic that has attracted considerable interest, generating sometimes contradictory results. Some studies have reported a positive correlation between team size and productivity per scientist. These studies have found evidence of a size effect in the form of a 'critical mass' threshold, such that research productivity is closely associated with size, but at a diminishing rate (JORDAN et al., 1988, 1989; JOHNSTON, 1994; DUNDAR & LEWIS, 1998). The central point here is whether large research units receiving more resources (human, economic or equipment) can benefit from economies of scale (DUNDAR & LEWIS, 1998; VON TUNZELMANN et al., 2003).

On the contrary, a number of studies have found a negative correlation between team size and productivity (KNORR et al., 1979; MAIRESSE & TURNER, 2002; BONACCORSI & DARAIO, 2002; CARAYOL & MATT, 2004). Finally, other authors reported a weak relationship – if any – between both factors (BLACKBURN et al., 1978; STANKIEWICZ, 1979, 1980; COHEN, 1980, 1981, 1991; KRETSCHMER, 1985; GOLDEN & CARSTENSEN, 1992a; KYVIK, 1995; SEGLEN & AKSNES, 2000).

An issue related to size is that of selectivity and concentration of resources. The effects of resource concentration on research performance have been explored by, among others, ZIMAN (1987, 1989), JOHNSTON (1994) and VON TUNZELMANN et al. (2003). In ZIMAN's view (1989), 'the opinion is usually expressed through the notion that there is a minimum "critical mass" for internationally competitive research, and hence that entities below that size are non-viable and should be deliberately eliminated from the system'.

The individual characteristics of colleagues may also have collective effects on scientists' research performance. One of these individual characteristics is professional status. Structure of the team, in terms of the different professional status of team components, has been identified as a factor affecting individual research productivity (DUNDAR & LEWIS, 1998; CARAYOL & MATT, 2004).

Performance of colleagues may also influence individual productivity, in most cases positively (see, for instance, MAIRESSE & TURNER, 2002). A related factor is the effect of 'star' scientists on research productivity, the subject of a number of studies. The results indicate that the research productivity of a department or team, and of its members, can be influenced considerably by the presence and productivity of star scientists (JOHNES, 1988; COLE & COLE, 1972; NEDERHOF & VAN RAAN, 1993; DUNDAR & LEWIS, 1998; ZUCKER et al., 1998).

Researcher's age is another variable that may induce collective effects, although in principle should be considered an individual determinant of scientific productivity. At the research unit or team level, an important issue is the extent to which assembling researchers of different ages can increase team and individual performance. As pointed by CARAYOL & MATT (2004), 'senior or experienced researchers may increase the productivity of juniors thanks to collective work or simply due to informal contacts. Conversely, junior researchers may stimulate the productivity of older ones, known to have fewer incentives in their late careers'. Nevertheless, they did not find evidence to support the hypothesis of a potential effect of age mix on productivity in labs at the Louis Pasteur University. The induction of collective effects by the presence of different generations of scientists has also been explored by BONACCORSI & DARAIO (2003). In their analysis of labs of the Italian National Research Council, they found a systematic negative association between the average age of researchers and the number of international publications per capita.

In addition to the age of individuals, another contextual factor to be taken into account is the age of research teams, i.e., team longevity. Studies of the relationships between the age of research teams and their performance are limited, and once again yield mixed results. STANKIEWICZ (1979) reviewed the literature available up to 1979 and analysed a sample of Swedish academic research groups. This author found a relationship between group age and output per scientist. In contrast, a review of empirical studies on size, age and productivity (COHEN, 1991) concluded that group age did not correlate with output per capita, and that there was no evidence for an optimal age or range of ages for a research group. Other studies have reported a negative effect of group age per se on productivity (DAVYS & ROYLE, 1996; BONACORSI & DARAIO, 2003).

The kind and degree of social integration in research teams is another factor that can determine scientists' research activity and performance. In this connection, factors such as team stability, cohesiveness and synergy may affect group as well as individual performance. In his analysis of Swedish research teams, STANKIEWICZ (1979) reported that the relationship between the size and age of the team and output per scientist was conditioned, among other factors, by the level of team cohesiveness.

One other factor that can help to understand the dynamics of research teams is the organizational setting. Some studies have compared settings other than those usually associated with scientific research activity, and have reported intriguing differences (see, for instance, COHEN & BAILEY (1997), CANNON-BOWERS & SALAS (1998), and LYNN & REILLY (2000)).

Methods

Key definitions

A key issue in the study of teamwork is how teams are defined. Different approaches to the definition of 'team' from different fields of knowledge refer to this concept in different ways, taking into consideration factors such as the number of individuals, their degree of interaction, degree of 'groupness', administrative arrangements, organizational structures, social identity, shared objectives, shared responsibility over results, and the dynamics of groups themselves (see, for instance, BLACKWELL, 1954/55; JOHNSTON, 1994; COHEN & BAILEY, 1997; CANNON-BOWERS & SALAS, 1998). COHEN (1991) identified two methodological patterns in studies dealing with groups: 'output-based' and 'input-based'. In output-based studies, 'definitions of group membership depend on output', and groups within a population of scientists 'are defined in terms of co-authorship or cross citation'. This is the case of studies of research productivity carried out with bibliometric techniques, where teams are usually considered in terms of co-authorship, and teams or networks of authors are identified on the basis of co-authorship frequencies. In output-based studies 'the groups do not necessarily have an administrative or institutional reality'. One of the drawbacks of this approach is that 'non-publishing scientists…are omitted'. In input-based studies, 'groups are defined by existing administrative arrangements', and 'all the scientists, whether or not they publish, in the selected set of social units constitute the population under study'.

We do not usually consider research teams in terms of co-authorship. Instead, we think of research teams in the sense of Cohen's input-based studies, although in our opinion they should not be considered only in terms of merely administrative arrangements. In the survey reported here *research team* is defined as a collection or cluster of two or more people belonging to a single research unit (department, laboratory, etc.), with common scientific interests and objectives, working on one or more common lines of research, sharing tasks and resources in order to achieve their objectives, usually publishing together, and having a certain degree of economic and decision-making autonomy.

In a previous paper (REY-ROCHA et al., 2002) we introduced the concept of *consolidation of research teams*. Consolidation should not be interpreted as the process of unification, combination or coalescence into a single unit. Instead, it should be understood to mean becoming firm and secure, and strengthening one's position or power.* In the study reported here, a research team is considered to be consolidated and

* Consolidate: To make firm or secure, strengthen (*The Merrian-Webster OnLine Dictionary*; *The American Heritage Dictionary of the English Language*); to strengthen one's position or power (*The Oxford English Dictionary*).

well-established when it has reached a certain size, composition, duration, level of member involvement, cohesiveness, external acknowledgement, competitiveness, autonomy and capacity to obtain funding in a continuous, stable manner. The relative importance of these characteristics can vary depending on the team context (scientific field, institutional sector, country, etc.).

Research instruments and data collection

The method used for this study is based on the combination of a survey and the analysis of scientists' curricula vitae (CV). The *modus operandi* consisted of obtaining the opinions of researchers and asking them to describe the consolidation level of their teams as they themselves perceived this. Accordingly, the team (or group) is conceived here as it is viewed in psychosocial studies, i.e., as a 'cognitive schema that exits in the mind of subjects', with team membership being 'a matter of individual choice rather than assignment' (WORCHEL et al., 1992). An example of this kind of approach can be found in the study by STANKIEWICZ (1979), who asked scientists to rate the degree to which they considered themselves as team members rather than individual workers. In our survey, researchers were asked to assign themselves to one of the following categories: a) a consolidated, well-established team (C researchers), b) a non-consolidated team that was not well established (NC), or c) not a member of any research team either because they work with different teams on different projects or because they usually work alone.

Respondents were asked to attach their CV when they returned the questionnaire. Despite its limitations, the CV is a research tool with enormous potential, providing a comprehensive source of information about academic researchers' careers (DIETZ et al., 2000; GAUGHAN & BOZEMAN, 2002; BOZEMAN & CORLEY, 2004). Nevertheless, it is rarely used as a tool in science and technology studies.

Population and sample

The universe that was to be studied consisted of all researchers who were tenured staff members of the Spanish Council for Scientific Research (CSIC). The CSIC is the largest public research organization in Spain, and unlike research councils in many other countries, it does not act as a funding agency but is basically an organization whose fundamental function is to perform scientific and technical research. The CSIC carries out research in all scientific fields, its activities ranging from basic research to technological development. It is organized in eight scientific and technological areas: Biology and Biomedicine; Natural Resources; Agricultural Sciences; Materials Science and Technology; Physics Science and Technology; Chemistry Science and Technology; Food Science and Technology; and Humanities and Social Sciences.

The population covered by the survey was drawn from the list of 2252 scientists supplied by CSIC Human Resources Department (as of December 2002). After removing the addresses of individuals who had retired or moved to other institution, and of those scientists in CSIC administrative units, the on-line survey was sent to 2161 active scientists doing research work at CSIC research units. The response period for the electronic questionnaire was from March to June 2003. A reminder was sent to all non-respondents. The data in this paper correspond to the population of 357 researchers ascribed to the 'Biology and Biomedicine' area of the CSIC. A total of 123 respondents returned usable questionnaires (34.5% response rate), and 113 respondents also supplied their CV.

As of 2002 the Biology and Biomedicine area employed 36.5% of the human resources (researchers, technicians and administrative staff) at 20 different CSIC research centres and units, and 20.6% of all CSIC researchers in the organization (CSIC, 2003). Research performed by CSIC scientists in this area is characterized by its focus on basic processes of animal and plant life, with particular emphasis on molecular aspects. Research is eminently basic, although there is a tendency to combine basic with more applied research, particularly in the Biotechnology and Biomedicine fields. This is one of the most competitive areas within the CSIC, with numerous teams and researchers who have attained international prestige.

Variables

Differences between researchers were investigated for the five-year period from 1998 to 2002, with regard to a) size and composition of the team to which the scientist belongs (see Table 1); b) collaboration of individual researchers with other research teams (Table 2); c) participation of researchers in funded research and development (R&D) projects or contracts; d) prestige; e) contribution to the training of junior researchers through the supervision of doctoral dissertations; f) individual productivity of researchers; and g) impact (see Table 3 for data on factors c to g). Information for factors a and b was obtained from the survey; data for the rest of the factors analysed here were obtained from the participants' CV.

A further issue analysed in this study is the extent to which relations between the level of research team consolidation and the indicators of individual activity, performance and prestige noted above were conditioned by age and seniority. The latter was calculated as the time elapsed since individuals obtained their doctoral degree. The three 33.3 percentile groups of scientists considered in the present study were a) 'junior scientists', i.e., those who obtained their doctorate between 6 and 15 years previously (with 2002 as the reference year); b) individuals in the middle percentile (degree obtained from 16 to 21 years previously), and c) 'senior scientists' (doctorate obtained 22 to 41 years previously).

Table 1. Number of members in consolidated and non-consolidated teams

Professional category	Mean rank		Average number of members		
	C	*NC*	*C*	*NC*	*Total*
Permanent researchers (*)	*67.1*	*43.4*	2.0± 1.2 (1-8) 2	1.2± 0.5 (1-3) 1	1.8±1.1 (1-8) 1
Technicians (permanent staff)	*59.8*	*64.6*	0.2± 0.5 (0-2) 0	0.3± 0.6 (0-3) 0	0.2±0.5 (0-3) 0
Support staff (*)	*65.5*	*47.9*	0.7± 0.7 (0-3) 1	0.4± 0.8 (0-4) 0	0.6±0.7 (0-4) 0
Post-docs (*)	*65.3*	*48.5*	1.6± 1.7 (0-9) 1	0.8± 0.9 (0-3) 1	1.4±1.6 (0-9) 1
Pre-doctoral fellows	*64.4*	*51.1*	3.6± 3.0(0-21) 3	2.4± 1.1 (1-5) 2	3.3±2.7 (0-21) 3
Other	*63.1*	*54.8*	0.6± 1.0 (0-5) 0	0.4± 0.8 (0-3) 0	0.6±0.9 (0-5) 0
Support staff / Permanent researchers (*)	*64.5*	*50.8*	0.4±0.4 (0-2) 0.25	0.3±0.8 (0-4) 0	0.4±0.5 (0-4) 0
Post-docs / Permanent researchers	*63.9*	*52.4*	1.0±1.2 (0-6) 0.67	0.7±0.8 (0-3) 0.5	0.9±1.1 (0-6) 0.67
Pre-doctoral / Permanent researchers	*59.7*	*64.8*	2.2±1.9 (0-11) 2	2.2±1.2 (0.5-5) 2	2.2±1.7 (0-11) 2
Total team size (*)	*68.5*	*39.3*	8.6± 4.2 (3-26) 8	5.5± 2.1 (2-10) 5	7.8±4.1 (2-26) 7

(*) Significant differences Mann-Whitney Test (α<0.05)

Table 2. Collaboration indicators for researchers belonging to consolidated and non-consolidated teams

	% Yes			Mean rank		Average		
	C	*NC*	*Total*	*C*	*NC*	*C*	*NC*	*Total*
Collaborations with other teams								
Domestic teams(*)	96.7	93.3	95.9	*66.7*	*44.4*	3.4±2.3 (0-10) 3	2.0±1.4 (0-6) 2	3.0±2.2 (0-10) 2
Foreign teams (total)	96.7	83.9	93.5	*63.9*	*52.6*	4.2±3.8 (0-19) 3	2.8±2.3 (0-9) 2	3.9±3.5 (0-19) 3
Bilateral (with EU teams)	80.0	74.2	78.9	*63.0*	*55.1*	2.1±2.1 (0-10) 1	1.6±1.5 (0-5) 1	2.0±2.0 (0-10) 1
Bilateral (with non-EU teams)	65.5	54.8	62.6	*63.7*	*53.2*	1.5±1.8 (0-9) 1	0.9±1.2 (0-4) 1	1.4±1.7 (0-9) 1
Multinational teams	33.3	29.0	33.3	*62.1*	*57.8*	0.6±1.2 (0-8) 0	0.4±0.7 (0-3) 0	0.5±1.1 (0-8) 0
Total (*)	98.9	100.0	99.2	*66.0*	*46.6*	7.6±5.2 (0-25) 6	4.8±2.9 (1-12) 4	6.9±4.9 (0-25) 6
Collaborations with private companies or institutions								
Domestic	36.7	38.7	37.4	*61.0*	*61.0*	0.6±0.9 (0-3) 0	0.6±0.8 (0-3) 0	0.6±0.9 (0-3) 0
Foreign	23.3	6.5	18.7	*63.7*	*53.3*	0.3±0.6 (0-3) 0	0.1±0.3 (0-1) 0	0.2±0.5 (0-3) 0
Total	47.8	41.9	46.3	*62.6*	*56.7*	0.9±1.2 (0-6) 0	0.6±0.9 (0-3) 0	0.8±1.2 (0-6) 0

(*) Significant differences Mann-Whitney Test (α<0.05)

EU: European Union

Table 3. Performance, productivity, impact and prestige indicators for researchers belonging to consolidated and non-consolidated teams

	Mean rank		Average		
	C	*NC*	*C* (*n=82*)	*NC* (*n=30*)	*Total*
Participations in funded R&D projects or contracts					
– Domestic projects	*58.7*	*50.3*	5.5±2.3 (2-13) 5	4.8±2.2 (1-9) 4	5.3±2.2 (1-13) 5
– International projects	*58.5*	*51.0*	1.9±2.4 (0-14) 1	1.3±1.5 (0-5) 1	1.7±2.2 (0-14) 1
– Total	*59.5*	*48.3*	7.4±3.7 (2-21) 7	6.1±2.4 (3-12) 6	7.0±3.4 (2-21) 6
Scientific productivity					
– Journal articles (total) (*)	*60.4*	*45.9*	15.9±10.8 (1-46) 13	11.4±7.3 (2-38) 10	14.9±10.4 (1-46) 12
– Articles in JCR journals (*)	*60.1*	*46.6*	14.8±10.3 (1-44) 13	10.7±7.2 (2-38) 10	14.0±10.0 (1-44) 11
– Articles in non-JCR journals	*57.5*	*53.8*	1.1±1.9 (0-9) 0	0.7±1.0 (0-4) 0	1.0±1.7 (0-9) 0
– Books and book chapters	*57.0*	*55.1*	1.3±1.7 (0-8) 1	2.0±4.4 (0-22) 0	1.5±2.7 (0-22) 1
– Patents	*57.9*	*52.8*	0.4±1.0 (0-6) 0	0.2±0.6 (0-2) 0	0.4±0.9 (0-6) 0
– Other documents	*56.3*	*57.1*	0.1±0.6 (0-3) 0	0.1±0.3 (0-1) 0	0.1±0.5 (0-3) 0
– Contributions to conferences and congresses	*56.0*	*44.6*	13.0±11.6 (0-79) 11	9.6±9.1 (0-38) 7	12.0±11.0 (0-79) 10
Impact					
– Average expected Impact Factor authors (*)	*52.0*	*68.7*	5.2±2.5 (1.0-13.9) 4.7	7.0±3.6 (1.3-15.8) 5.8	5.6±2.9 (1.0-15.8) 5.1
– Maximum expected Impact Factor authors (*)	*52.2*	*68.1*	12.0±8.2 (1.5-36.2) 9.8	14.3±7.5 (1.5-30.7) 14.0	12.6±8.0 (1.5-36.2) 10.7
– Expected Impact Factor articles (*) (n=1537 articles)	*752.8*	*830.3*	5.2±4.3 (0.15-36.2) 3.9	6.2±5.3 (0.16-30.7) 4.9	5.3±4.6 (0.15-36.2) 4.0
Training of new researchers					
Dissertations supervised (*)	*62.7*	*39.5*	1.9±1.5 (0-6) 2	0.9±1.2 (0-4) 0	1.6±1.5 (0-6) 1
Prestige indicators					
– Reviewer or editorial board member of international journals (number of journals) (*)	*60.8*	*44.7*	3.8±5.0 (0-19) 2	1.6±3.1 (0-12) 0	3.2±4.7 (0-19) 1
– Serving as evaluator or member of peer review panels for international R&D projects (*)	*59.9*	*47.2*	1.0±2.0 (0-9) 0	0.2±0.5 (0-2) 0	0.8±1.8 (0-9) 1
– Scientific awards received (*)	*60.8*	*44.6*	1.3±2.0 (0-10) 0	0.4±1.0 (0-4) 0	1.0±1.9 (0-10) 0

(*) Significant differences Mann-Whitney Test ($\alpha<0.05$)

Table 4. Indicators that yielded significant differences based on researcher's age, seniority and background

	AEIF authors		MaxEIF authors		EIF articles		Dissertations	
	Mean Rank	*Average*	*Mean Rank*	*Average*	*Mean Rank*	*Average*	*Mean Rank*	*Average*
Age								
A: 32-40 (n=21)	*75.2*	7.1±2.9 (2.5-11.7) 7.0	*73.9*	16.4±8.5 (3.6-30.7) 14.1	*952.1*	7.2±6.0 (0.36-30.7) 5.8	*26.3*	0.4±0.7 (0-2) 0
B: 41-50 (n=57)	*61.7*	6.0±2.9 (2.0-15.8) 5.6	*61.2*	13.3±7.8 (3.2-36.2) 10.8	*821.3*	5.4±4.3 (0.17-36.2) 4.2	*62.5*	1.9±1.6 (0-6) 1
C: >50 (n=34)	*38.4*	4.1±2.3 (1.0-13.9) 4.3	*40.0*	9.03±6.8 (1.5-29.5) 7.7	*635.5*	4.1±3.5 (0.15-29.5) 3.3	*66.4*	2.1±1.3 (0-5) 2
Significant differences	***(A = B) > C***		***(A = B) > C***		***A > B > C***		***(C = B) > A***	
Seniority								
Junior (n=39)	*70.3*	6.8±3.0 (2.2-12.5) 6.1	*68.3*	15.3±8.8 (3.2-36.2) 14.0	*928.4*	6.8±5.7 (0.31-36.2) 5.6	*39.4*	0.9±1-3 (0-5) 0
Medium (n=38)	*57.7*	5.6±2.9 (1.4-15.8) 5.1	*59.3*	12.8±7.8 (1.8-30.1) 11.6	*815.9*	5.4±4.2 (0.17-30.1) 4.1	*65.7*	2.1±1.5 (0-6) 2
Senior (n=35)	*41.9*	4.4±2.3 (1.0-13.9) 4.4	*42.3*	9.4±6.3 (1.5-29.5) 8.3	*650.7*	4.1±3.3 (0.15-29.5) 3.4	*66.9*	2.1±1.4 (0-5) 2
Significant differences	***(J=M)>S***		***(J=M)>S***		***J > M > S***		***(S=M)>J***	
Background								
RecAbr (n=20)	*82.0*	8.0±3.1 (2.56-12.5) 8.0	*76.8*	16.5±7.7 (3.6-30.7) 14.0	*952.5*	7.2±6.0 (0.47-30.7) 5.8	*25.4*	0.4±0.7 (0-2) 0
RecDom (n=19)	*51.3*	5.2±2.6 (2.0-12.0) 4.7	*59.8*	12.5±7.0 (3.8-28.0) 10.8	*765.9*	5.2±4.4 (0.26-28.0) 3.8	*39.9*	0.8±0.8 (0-2) 1
NotRec (n=73)	*51.7*	5.1±2.7 (1.0-15.8) 4.8	*50.9*	11.5±8.1 (1.5-36.2) 9.5	*755.6*	4.9±4.1 (0.15-36.2) 3.8	*69.9*	2.3±1.4 (0-6) 2
Significant differences	***RecAbr>(RecDom=NotRec)***		***RecAbr>NotRec***		***RecAbr>(RecDom=NotRec)***		***NotRec>(RecDom=RecAbr)***	

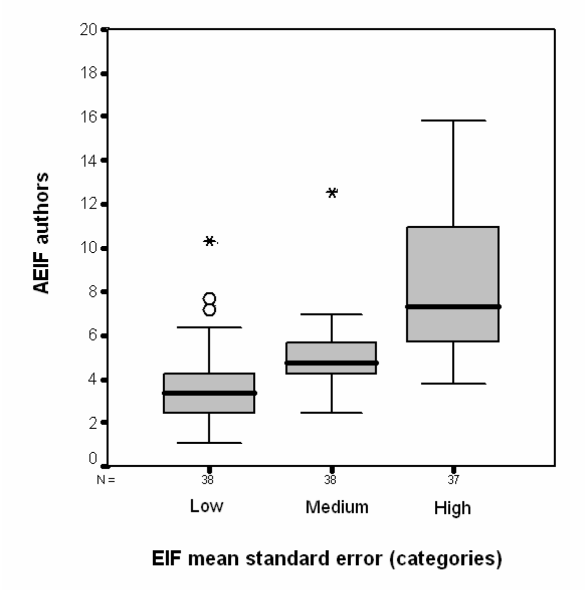
AEIF: average expected impact factor: MaxEIF: maximum expected impact factor: EIF expected impact factor: RecAbr: researchers recently returned from abroad who had recently joined the CSIC staff; RecDom: scientists who had recently joined the CSIC after holding another domestic position; NotRec: individuals who had joined CSIC staff before 1996.

To study the effect of past organizational context and background we created a variable called 'background' to group individuals on the basis of the duration of their employment by the CSIC and their previous background. We recorded the date when scientists joined the permanent staff of CSIC, and the time elapsed between the date of return to Spain for researchers with stays abroad and the date when they joined the CSIC staff. Scientists were considered 'recently joined' if they became CSIC staff members during the study period or the two years immediately previous to this period (i.e., from 1996 to 2002), and as 'recently returned' when they joined the CSIC staff in the same year as when they returned from a stay abroad, or during the two subsequent years. Scientists were then grouped into three categories: a) researchers recently returned from abroad who had recently joined the CSIC staff, b) scientists who had recently joined the CSIC after holding another domestic position, and c) individuals who had joined CSIC staff before 1996.

Collaboration was recorded here as the number of collaborations with domestic and foreign teams, as reported by scientists in the survey. Although querying scientists through surveys or personal interviews has some disadvantages (such as the difficulty in obtaining large, representative samples, and the subjectivity inherent to any survey study), surveys make it possible to analyse the phenomenon of scientific collaboration from a wider perspective than is possible through bibliometric studies based on co-authorship (KATZ & MARTIN, 1997).

Three different measures of impact were used, as described below. First we calculated the average expected impact factor of publications. The expected impact factor (EIF) was assigned to each article published by each participant in journals covered by the *Journal Citation Reports* (JCR) of the ISI, and was taken as the IF of the journal of publication (in the year when the journal was published) according to the JCR. Secondly, the average EIF (AEIF) for each author was also calculated as the average of the EIFs for each article. To determine to what extent the AEIF could be assigned to each individual without losing variability, we checked for a statistically significant dependence between the AEIF for a given researcher and the dispersion of IF values for papers authored by that researcher (indicated by the corresponding mean standard error, $S/\sqrt{n}$). The average value was assigned to each author together with the corresponding mean standard error. Next, 33.3% percentiles were calculated to delimit three categories based on high, medium and low standard error, then the average IF was calculated for each category. Significant differences were found between the IF of each of the three categories (Mann-Whitney's test), a result that indicated limited dispersion (Figure 1a). Differences between categories were also found for the mean standard error (Figure 1b).

a)



b)

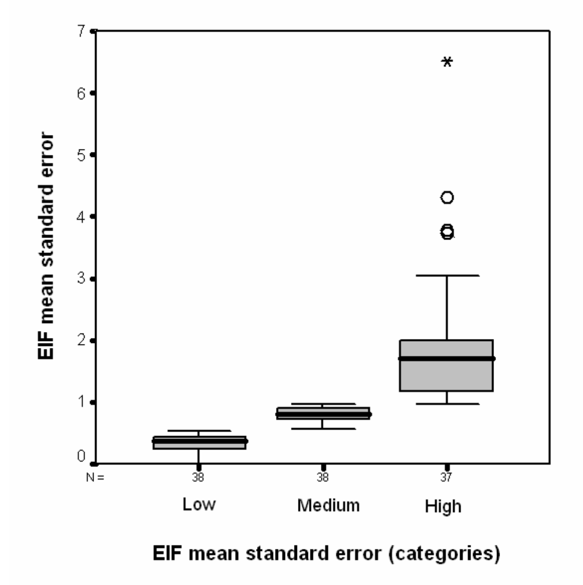


Figure 1. Box plots showing statistically significant dependence between the average expected impact factor (AEIF) for authors and the dispersion of IF values for their papers

We therefore concluded that there was dependence between the average IF and the dispersion of IF values, that is to say, categories of average values were not the result of differences in dispersion. This means that an average IF can be assigned to each individual researcher without loss of variability. The third IF measure studied here was maximum EIF for each author.

Prestige of scientists was investigated through three different indicators: a) the number of international journals for which they served as reviewers or members of the editorial board during the five-year study period, b) the number of times they had served as evaluators or members of peer review panels for international R&D projects or programmes, and c) the number of scientific awards received during their entire professional career. These parameters have been considered indicators of eminence by some authors (LONG & MCGINNIS, 1981; PRPIĆ, 1996).

Statistical analyses

Principal components analysis for categorical data (CATPCA) was used to identify and summarize relationships between the different variables. This analysis generalizes principal components analysis to accommodate variables of mixed measurement levels (numeric, ordinal or nominal). This makes it possible to reduce the original set of variables into a smaller set of non-correlated components that represent most of the information found in the original variables. The outcome of CATPCA is interpreted by reading a two- or three-dimensional plot in which component loadings are shown as the orientation of lines along the principal axes. The relationships between variables represented by their correlations with the principal components are displayed by vectors pointing towards the category with the highest score. The length of a vector reflects the importance of the variable: the longer the vector, the more variance the variable accounts for. The angle between two vectors reflects the correlations between the variables they represent: the more orthogonal the vector, the less correlated the variables are. The analyses were carried out with variables that showed significant differences between categories. These differences were found by comparing samples with non-parametric tests, as the data did not follow a normal distribution. For qualitative variables, chi-square values were obtained with exact methods using the Monte Carlo test. For quantitative variables we used the Kruskal-Wallis H test and the Mann-Whitney U test.

Statistical analyses were done with the Statistical Package for Social Sciences (SPSS) for Windows. Descriptive statistics are given as the average ± standard deviation, the range (in parentheses) and the median. Differences were considered significant when $\alpha < 0.05$.

Results

Almost three quarters (73.2%) of the researchers surveyed considered themselves part of a consolidated, well-established research team (C team), whereas 25.2% of them reported belonging to a non-consolidated team (NC team), and a nominal 1.6% indicated they were not members of a research team. Because this latter category contains only two individuals, it was not considered in subsequent analyses.

Teams were composed of about eight members on average, most of them either researchers with a permanent position or pre-doctoral fellows (Table 1). C teams were significantly larger than NC teams, the differences being mainly due to the number of permanent researchers, support staff and post-doctoral fellows. Members of C teams also had more support staff per permanent researcher. The correlation between the level of research team consolidation and its size and composition is summarized by principal components analysis (CATPCA), as shown in Figure 2. Consolidation of teams was mainly determined, in terms of professional status, by the number of permanent researchers and support staff (and the ratio of these two values), and to a lesser extent by the number of post-doctoral fellows.

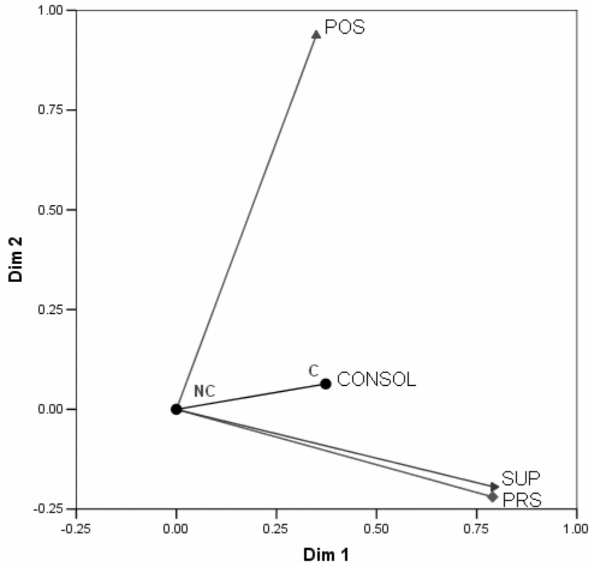


Figure 2. Relationships between 'level of team consolidation' and size and composition of research teams
POS: post-doctoral fellows; SUP: support staff; PRS: permanent researchers; CONSOL: level of team consolidation; C: consolidated team; NC: non-consolidated team.
CATPCA model summary: Cronbach's alpha: 0.86. Variance accounted for: Total (eigenvalue) 2.3; % of variance 77.9% (Dimension 1 = 45.8%; Dimension 2 = 32.1%). Variance accounted for (variables): POS 1.0; PRS 0.67; SUP 0.67; CONSOL (Supplementary variable) 0.14. Correlations (of transformed variables) with CONSOL (with NC=1, C=2): SEN 0.32; SUP 0.24, POS 0.19.

Table 2 shows the percentage of researchers who collaborated with other teams, along with the average number of collaborations. Almost all participants were involved in at least one collaboration with another research team during the five-year period studied here. Most of them (96%) collaborated with Spanish teams, and more than 93% collaborated with foreign teams. Researchers belonging to C teams collaborated significantly more, on average, that those in NC teams. The differences reflected fundamentally the significantly higher number of collaborations with other Spanish teams by C researchers. In contrast, belonging to a C or an NC team did not seem to have significant repercussions on the number of collaborations with foreign teams.

With respect to collaborations with private companies or institutions, the picture was slightly different from collaborations with other research teams. Of note was the difference in the percentage of individuals involved in collaboration with foreign companies, which was much higher among C researchers, although no significant differences were found in the average number of collaborations per researcher (the U-value was at the limit of statistical significance, at $\alpha = 0.05$).

Scientific productivity showed a positive correlation with the level of research team consolidation. Researchers in C teams were more productive, as reflected by the higher number of articles they published during the five-year study period in journals covered by the JCR (Table 3). In contrast, belonging to a C or an NC team did not seem to be significantly related with the number of patents granted and other documents published, with the number of contributions to conferences and congresses, or with the number of participations in funded R&D projects or contracts, although the figures for scientists in C teams were generally higher than for their NC colleagues.

Higher production was not accompanied by higher visibility, as indicated by the EIF. On the contrary, the EIF of articles by C researchers, as well as the average EIF of individual scientists and the maximum EIF they attained, were found to be significantly lower than for NC researchers (Table 3).

Scientists in C teams were more actively involved in training new researchers. Although the proportion of pre-doctoral fellows to every permanent senior researcher was the same in both types of team (Table 1), scientists in C teams supervised significantly more dissertations during the five-year study period (Table 3). This shows that dissertation run time was lower in C teams, and suggests that the rotation of pre-doctoral students through these teams was higher.

Researchers in C teams performed better in all of the prestige indicators considered here. During the five-year study period, C researchers reviewed for twice as many international journals as their colleagues in NC teams, and served as evaluators or members of peer review panels for international R&D projects fivefold as many times. They also received an average of three times as many scientific awards as their NC colleagues during their career. (This was expected considering that C researchers are significantly older, on average, than their colleagues in NC teams).

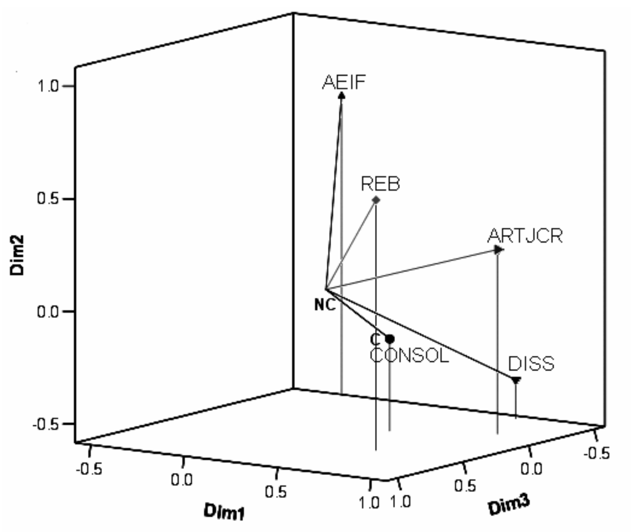


Figure 3. Relationships between 'level of team consolidation' and scientific productivity, impact, contribution to the training of new researchers, and prestige of scientists
AEIF: average expected impact factor of authors; REB: reviewer or editorial board member of international journals; ARTJCR: articles in JCR journals; DISS: dissertations supervised; CONSOL: level of team consolidation; C: consolidated team; NC: non-consolidated team.
CATPCA model summary: Cronbach's alpha: 0.95. Variance accounted for: Total (eigenvalue) 3.4; % of variance 86.0% (Dimension 1 = 38.1%; Dimension 2 = 26.3%; Dimension 3 = 21.6%). Variance accounted for (variables): AEIF 0.99; REB 0.87; DISS 0.87; ARTJCR 0.72; CONSOL (Supplementary variable) 0.17.
Correlations (of transformed variables):

	ARTJCR	REB	AEIF	DISS
CONSOL	0.17	0.21	-0.26	0.35
ARTJCR		0.33	-0.05	0.31
REB			-0.03	0.06
AEIF				-0.17

The three-dimensional model of the relationships between consolidation of research teams and indicators of activity, productivity, impact and prestige of scientists is shown in Figure 3. This plot illustrates how team consolidation correlated with scientific productivity in numbers of articles in JCR journals (ARTJCR), impact (indicated by the author AEIF), and training of new researchers (in numbers of doctoral dissertations supervised) (DISS), as well as with prestige. For the present analysis, serving as a reviewer or editorial board member for international journals (REB) was used as an indicator of prestige, instead of serving as a evaluator or peer review panel member for international R&D projects and the number of awards received, for two reasons: reviewing for journals correlates better with the level of team consolidation and is referred to the five-year period of analysis, whereas the number of awards is referred to the individual's entire career. The component loadings plot obtained from principal components analysis shows that the higher the team consolidation level, the higher the value of all variables (positive correlation) except average expected IF (negative correlation). Belonging to a C team was therefore associated with higher productivity, higher professional prestige, and higher training activity, but not with a higher impact of publications. The average expected IF was the most significant of these variables in terms of explained variance, whereas the number of dissertations supervised was the variable that best discriminated between individuals in C and NC teams, as it showed the highest absolute correlations with consolidation level. On the other hand, scientific output (in terms of number of JCR articles) was the variable that contributed the least to the differences between scientists, with the lowest values for explained variance and correlation with consolidation level.

Membership in a C team rather than an NC team correlated significantly with the age and seniority of scientists, as well as with their professional background. Researchers in NC teams were significantly younger, on average, than their colleagues in C teams (42.4±5.4 [34-60] 41 vs. 49.1±7.6 [35-68] 48 years; mean ranks 35.9 vs. 68.7), and had held their doctorate for significantly less time (14.3±5.3 [6-30] 14 vs. 20.8±7.6 [7-41] 20 years; mean ranks 34.1 vs. 64.7). Most NC researchers were 'recently joined' staff members: 70% of them joined the CSIC staff during the study period (60%) or during the two previous years (10%). The percentage of 'recently joined' individuals was lower in C teams, accounting for 22% (17.1% + 4.9%) of the members. These NC researchers were individuals who, instead of joining a C team, decided to establish their own line of research and form a new team. In fact, 80.6% of NC researchers were members of teams consisting of themselves as the only permanent senior researcher, together with a number of support personnel and fellows. In C teams, although the proportion of individuals who were the only permanent senior researcher in the team was smaller, it was nonetheless a far from negligible 45.6%.

A large number of these young NC researchers (61.9%) joined the CSIC staff after a stay abroad, and returned during the same year as when they obtained their permanent position or in the two previous years. Person who joined the CSIC staff soon after they return from abroad (recently returned) were more likely to establish a new team than to become a member of an already established team. In fact, of the 20 individuals surveyed who were both 'recently joined' and 'recently returned', 65% did not join a C team. The average age of individuals who joined a C team and who belonged to an NC team was similar: 39.6±4.2 (35-45) vs. 39.9±4.1 (34-48) years.

Figure 4 shows the relationships between the variables 'team consolidation level' and age, seniority and background. All had a positive component loading on the first dimension, i.e., a common factor correlated positively with all variables. The second dimension, in contrast, separated the variables. Age and seniority correlated highly and formed a bundle with negative loading on the second dimension. The vectors in this bundle were orthogonal to the team consolidation vector (which had large positive loading on the second dimension), thus reflecting low correlation. Background, although correlated with the other variables, was strongly associated with the first dimension and may therefore provide useful information about the 'common factor'.

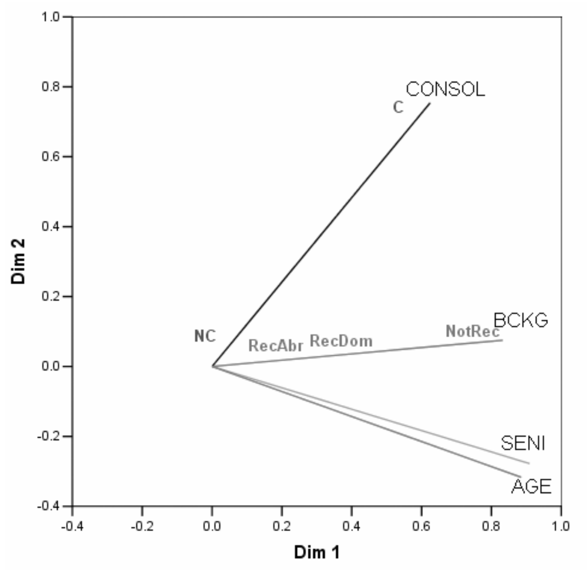


Figure 4. Relationships between 'level of team consolidation' and age, seniority and background of scientists BCKG: background; SENI: seniority; AGE: age; RecAbr: researchers recently returned from abroad who had recently joined the CSIC staff; RecDom: scientists who had recently joined the CSIC after holding another domestic position; NotRec: individuals who had joined CSIC staff before 1996; CONSOL: level of team consolidation; C: consolidated team; NC: non-consolidated team.
CATPCA model summary: Cronbach's alpha: 0.95. Variance accounted for: Total (eigenvalue) 3.4; % of variance 86.1% (Dimension 1 = 67.3%; Dimension 2 = 18.8%). Variance accounted for (variables): CONSOL 0.96; SENI 0.90; AGE: 0.88; BCKG 0.70.
Correlations of transformed variables:

	AGE	SENI	BCKG
CONSOL	0.36	0.39	0.46
AGE		0.86	0.60
SENI			0.65

Univariate analysis of the relationship of seniority, age and background with indicators of scientific activity, performance and prestige revealed a number of statistically significant differences (Table 4). Most senior and older researchers attained lower IF values than the rest of their colleagues. On the other hand, most junior and younger researchers supervised significantly fewer dissertations during the five-year study period. With regard to recent background, both 'recently joined' and 'recently returned' scientists had a higher average expected IF, whereas scientists who joined CSIC staff before 1996 supervised significantly more dissertations. No significant differences were found in any of the other indicators.

To further elucidate the role of research team consolidation, we considered the joint effects of variables that showed significant correlations individually. Principal components analysis for categorical data was used to find interactions between the level of team consolidation, individual characteristics of their components (age, seniority and background) and indicators of performance, productivity and prestige. Age and seniority were found to be highly correlated, and because their effect on the overall relationship was similar, only the latter was included in the analysis.

Figure 5 shows the results of this analysis. The three-dimensional object scores showed a positive component loading on the first dimension for all variables (indicating a common factor that correlated positively with all of them) except average expected IF of authors, which correlated negatively with the other variables. Team consolidation level was strongly associated with the first dimension and may therefore provide useful information about the 'common factor'.

The second dimension, in contrast, separated the variables. Reviewing for international journals and publication in JCR journals were highly correlated and formed a bundle with positive loading on the second dimension. The vectors in this bundle were orthogonal to the team consolidation vector, thus reflecting a low correlation.

Seniority and background were highly correlated and formed a bundle with negative loading on the second dimension. The number of dissertations supervised also showed negative loading on this dimension. Vectors of these variables showed high correlations with team consolidation level.

In short, the correlations between level of team consolidation and the dependent variables (i.e., number of articles in JCR journals, average expected IF of authors, number of dissertations supervised, and reviewing for international journals) were similar to those found in the previous analysis (Figure 3) in the absence of the other two prediction variables (seniority and background). The effect of these variables was in the same direction as that of team consolidation level. Of note was the high correlation between background and the number of dissertations supervised, and the almost null correlation with reviewing for international journals found for both seniority and background.

The negative relationship between AEIF and team consolidation level was determined to a great extent by individuals' recent background. The higher IF for individuals in NC teams was mainly due to the track record of junior individuals who recently joined the CSIC staff on returning from a stay abroad (who, as reported above, were more numerous in NC teams). In fact, all impact values in this group (individuals who had recently joined and had recently returned) were significantly higher than in the rest of the sample (i.e., individuals who joined the CSIC staff before 1996 and those who joined during 1996–2002 after a stay in a domestic laboratory): article EIF was 7.2±6.0 (0.5-30.7) 5.8 vs. 5.0±4.2 (0.2-36.2) 3.8 [mean ranks 924.5 vs. 737.8]; author AEIF was 8.0±3.1 (2.5-12.5) 8 vs. 5.1±2.6 (1.0-15.8) 4.7 [mean ranks 81.1 vs. 51.1]; and maximum author EIF was 16.5±7.7 (3.6-30.7) 14 vs. 11.8±7.9 (1.5-36.2) 9.9 [mean ranks 75.9 vs. 52.3].

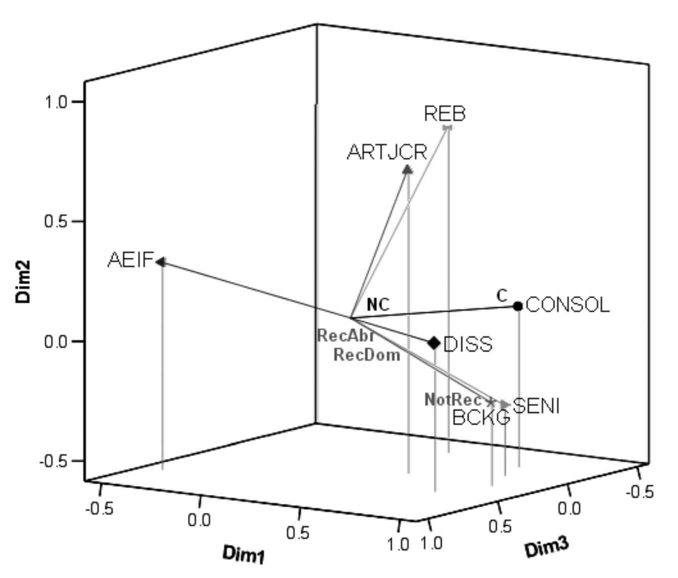


Figure 5. Relationships between 'level of team consolidation', seniority, background, and scientific productivity, impact, contribution to the training of new researchers, and prestige of scientists
AEIF: average expected impact factor of authors; REB: reviewer or editorial board member of international journals; ARTJCR: articles in JCR journals; DISS: dissertations supervised; BCKG: background; SENI: seniority; RecAbr: researchers recently returned from abroad who had recently joined the CSIC staff; RecDom: scientists who had recently joined the CSIC after holding another domestic position; NotRec: individuals who had joined CSIC staff before 1996; CONSOL: level of team consolidation; C: consolidated team; NC: non-consolidated team.
CATPCA model summary: Cronbach's alpha: 0.93. Variance accounted for: Total (eigenvalue) 4.9; % of variance 70.5 (Dimension 1 = 39.4%; Dimension 2 = 18.4%; Dimension 3 = 12.7%). Variance accounted for (variables): REB 0.77; DISS 0.76; AEIF 0.75; ARTJCR 0.65; BCKG 0.81; SENI 0.65; CONSOL 0.53.
Correlations of transformed variables:

	SENI	BCKG	ARTJCR	AEIF	DISS	REB
CONSOL	0.39	0.47	0.18	-0.26	0.35	0.24
SENI		0.64	0.13	-0.34	0.39	0.04
BCKG			0.15	-0.30	0.63	0.05

In summary, the consolidation level of CSIC research teams in the area of Biology and Biomedicine correlated positively with the number of dissertations supervised by individual scientists and, to a lesser extent, with their prestige and productivity in JCR journals, but correlated negatively with their AEIF. The effect of level of consolidation on the average expected IF of authors was influenced by seniority, age and background, as shown by our finding of highest IF values for junior researchers who had recently returned from abroad and who joined an NC team. On the other hand, belonging to a consolidated, well-established team was associated with more training activity. This activity was correlated positively with seniority and background, such that senior scientists who had joined the CSIC staff before 1996 were involved in more training activities than colleagues who joined the CSIC more recently. Serving as a reviewer or editorial board member of international journals was mainly associated with belonging to consolidated, well-established teams; seniority and background had no significant effect on this correlation. Finally, productivity in terms of JCR articles correlated positively with all three predictive variables (team consolidation, seniority and background); nevertheless, these correlations were weak, and the number of articles in JCR journals was the least significant of the dependent variables in terms of the amount of variance explained.

Discussion and conclusions

The results presented here suggest that within the CSIC, the 'Biology and Biomedicine' area is characterized by weak development and instability of its research teams. This situation was described in the early 1990s by ESPINOSA DE LOS MONTEROS et al. (1996) in their evaluation of Spanish public-sector biomedical research for 1988–1993. They reported that 'small size and low stability characteristics predominate in groups from the CSIC', whose index for stability and consolidation of groups was found to be lower than that of university- and hospital-based groups. It was suggested then that this difference probably reflected 'the presence of non-staff scientists…amounting to 25% of the total personnel involved in R&D projects'. The results of our study are consistent with this conclusion and document a similar situation one decade later, with one quarter of the scientists working as members of teams in the process of consolidation.

Our findings illustrate the importance, for the development and consolidation of research teams in the area of 'Biology and Biomedicine', of the availability of a minimum number of researchers with a permanent position (the importance of which was also found in our previous studies of university researchers in Earth Sciences), and of a minimum number of support staff and non-staff personnel (mainly post-doctoral fellows). This research team structure does not differ significantly from the usual structure in the field of Biology and Biomedicine, as can be surmised from the results of other studies. Many authors have found analytical support for the effectiveness of small research teams (ZIMAN, 1989). JOHNSTON (1994) reported that 'there is some strong analytical support for the view that, at least in the natural sciences and engineering, and often in the social sciences also, it is the small research team, composed of one or two leaders, possibly other colleagues though usually on a temporary basis, post-doctoral fellows and post-graduate students which make up the effective operating unit'.

On the other hand, in the areas of genetics and cellular and molecular biology, and in other disciplines that require heavy instrumentation and many technicians and engineers, a high proportion of non-researcher members (administrative staff and technicians) of research teams has been found (CARAYOL & MATT, 2004). This kind of team, as noted by JOHNSTON (1994), is highly dynamic, 'with post-graduate students and post-doctoral fellows using it [the group] as a staging post to subsequent career steps, and academic colleagues forming temporary liaisons'. Although this model 'leads to an enormous investment in training', it also 'provides for a steady influx of new ideas and rapid transfer of knowledge' that benefits the group and its members. In line with these considerations, ETZKOWITZ (1992) concluded that 'research groups of graduate students led by teachers [in our case, tenured researchers] and post-doctoral fellows are the academic analogues of the small firm in high technology industries'. These groups are 'recognized as the engine of productivity in research and of effective graduate training in American universities'.

Consequently, a mix of large, consolidated research teams, together with variety of non-consolidated, emerging research teams, and the inclusion of (in the words of NOWOTNY, 1990), 'cunning individuals who carve out niches for themselves within larger research system', may constitute a successful model for a scientific community in the Biology and Biomedicine field. Thus what at first might seem to be a poorly structured scientific community could in fact be interpreted as the basis for success in this area within the CSIC, from an organizational point of view.

Belonging to a consolidated, well-established team facilitates contacts and collaboration with other research teams only on a domestic level, but does not seen to significantly favour the establishment of international collaborations. This should not be surprising: although a certain degree of scientific maturity on a personal and group level is needed to gain access to collaboration with foreign or multinational teams, in most cases participation in these collaborations depends on (or is at least favoured by) the team's attractiveness as a partner, i.e., the extent to which the scientists' or team's specialization or expertise are potentially useful to other projects. It is this 'fit' or complementarity between the skills in each group that makes a team or any of its components attractive to the rest of the project's partners.

The degree of consolidation does not significantly foster participation in funded R&D projects. In this connection it should be recalled that when projects are evaluated for funding, a series of other factors enter into the picture in addition to the scientific quality of the proposal, and these factors could mask the effect of the research team itself. These factors are often influenced by scientific policies and the aims and scope of the grants program, which in turn can depend on whether the program intends to favour young researchers or emerging teams, consolidated, prestigious teams, multidisciplinary teams, or some other group profile.

Nevertheless, the consolidation level of a research team has a clear influence on the more academic-oriented quantitative indicators of scientific activity of individuals, such as the volume of articles published in JCR journals and their impact. It may also have a positive effect on the 'academic prestige' of scientists, and on their capacity to train new researchers. In this connection our results suggest some competitive advantage for researchers working in C teams as compared to their colleagues in NC teams.

Publication in journals for which an IF is available (i.e., those covered by the JCR) is of particular importance as this parameter is frequently used, in Biology and Biomedicine as well as in other scientific fields, as the main criterion for evaluating research activity. As a result of this view, scientists' research activity is, to some extent, governed by and oriented towards publication in JCR journals, particularly those with a high IF (JENNINGS, 1998).

The results of the present study show that C researchers perform quantitatively better than their colleagues in NC teams in terms of the number of articles published in JCR journals, but not in terms of the impact of these publications. Any analysis aimed at interpreting this situation needs to take into account not only the group context, but also individual factors. In our sample, age and seniority of individual researchers, bound up with their professional record or background, proved to have a significant effect, particularly on the impact factor of publications and the training of new researchers through the supervision of doctoral dissertations. Most researchers in NC teams are young scientists who recently joined the CSIC staff, often upon completing a stay at a prestigious foreign research centre. Most of these individuals decide to create their own team and start their own line of research. They usually initiate innovative lines of research sometimes considered bold or risky. The work involved, along with the effort entailed in forming a new team, makes these younger teams less productive on average than their colleagues in C teams. However, the CV of these newly-incorporated researchers contains papers published during their stay at a prestigious foreign centre, together with those published soon after their return to Spain (to a great extent reporting results obtained during their stay abroad). These publications often attain high international visibility and high impact. Moreover, it should be noted that these young scientists are under greater pressure to publish in high-IF journals. As pointed out by JENNINGS (1998), younger scientists who have not yet established their reputations are particularly obsessed with boosting their IF numbers by whatever means possible.

However, the higher IF for NC researchers should not be interpreted to suggest that their scientific output is more visible, nor does it mean that they are more prestigious as scientists. This oversimplified interpretation is an example of the trend to 'equate prestige with high impact' (GARFIELD, 2001) and to 'rely increasingly on impact factors rather than on more direct methods when evaluating the quality of their candidates' research programs' (JENNINGS, 1998). This view of the findings would suggest, misleadingly, that the greater IF for NC researchers means that they enjoy greater prestige, when in fact the higher values their C team colleagues obtained for the prestige indicators studied here are not only a reflection of their higher seniority but also indicate greater prestige or eminence.

Nevertheless, consolidated teams seem to provide a better environment for training pre-doctoral students, at least from a quantitative point of view, as researchers in these teams supervised a significantly higher number of doctoral dissertations than their colleagues in NC teams. One may wonder what factors result in members of C teams managing to supervise more dissertations than members in NC teams during the study period. One factor is probably the availability of more human resources in C teams, i.e., not only staff scientists but also post-doctoral fellows and support personnel. The latter two collectives are important for pre-doctoral training: post-doctoral fellows help the dissertation supervisor in the pursuit and analysis of new results, and support staff help the student to perfect and apply the techniques required to undertake the work. Another important factor is probably the greater social and intellectual capital in consolidated teams. These advantages make it possible for doctoral students to complete their research and defend their dissertation in less time, so that new pre-doctoral fellows can join the team sooner. This continuous turnover of pre-doctoral fellows benefits consolidated teams by stimulating research, and by producing new papers that arise from research done for the dissertation.

Scientists belonging to C teams probably benefit from economies of scale, both from their larger size and from the selectivity and concentration of resources. The combination of larger size and greater consolidation seems not only benefits *per se* (higher overall team output) but also benefits to individual members (higher personal productivity). Thus, C teams are likely to have greater resources at their disposal, to accumulate experience as a result of members' seniority and job security, and to enjoy a potentially richer flow of information and greater opportunities to exchange experiences. This group context makes it easier to harness the capacities of scientists in C teams, and results in better personal performances. The lower performance of NC researchers might reflect the need to become proficient in all tasks inherent to scientific research, as well as in collateral activities such as manuscript writing, fund-raising, administrative work, relationships with colleagues, and pre-doctoral student supervision. The advantages that consolidated, well-established teams enjoy in terms of human resources are not found in NC teams, where many of the researchers, having joined the institution's staff only recently, face the task of consolidating a team that is undertaking work on an entirely new research line. In other words they need to devote considerable efforts and vast amounts of time to the task of obtaining more personnel and economic resources for the team. These responsibilities prevent them from being more productive, and from devoting more time to the necessary task of training pre-doctoral students.

In conclusion, the results reported here provide evidence that helps explain how consolidated, well-established research teams provide researchers with a context that favours higher productivity and greater activity in training pre-doctoral students. Members of the consolidated teams we identified were also more likely to have attained a higher degree of professional prestige. Nevertheless, membership in a consolidated team as compared to a team in the process of development and consolidation does not seem to influence in the impact of publications. In contrast, impact is influenced to a remarkable degree by seniority, past organizational context, training and professional background, and is significantly greater for young scientists who have spent time abroad at prestigious research laboratories.

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