Are Italian Physicists More Productive Than French Physicists? Prima-Facie Evidence On The Importance Of Collaboration In Scientific Research

Preliminary draft

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Abstract

In this paper we investigate why the productivity of physicists as defined on the basis of publications (in terms of numbers and average journal impact factor) appears in average higher in Italy than in France, specially so in recent years. We are thus led to compare separately the productivity of physicists working in universities and in the two main public research organizations in the two countries (CNRS *Centre National de la Recherche Scientifique* and CNR *Consiglio Nazionale delle Ricerche*). We also have to abstract from differences in the participation of physicists to "big research projects" resulting in publications with numerous co-authors. Finally, we are led to analyze the different styles of cooperation between physicists in the two countries, where collaboration is defined on the basis multiple-authored scientific articles.

Collaboration and Productivity In Scientific Research[1]

1 Introduction: scientific productivity and collaboration

Bibliometricians, economists and sociologists of science but also policy makers and peoples in institutions are all interested in evaluating scientific productivity in order to assess its determinants at individual level, and also with the aim of ranking, candidates for new jobs or research funding, as well as universities, both nationally and worldwide[2]. Despite this multiplicity of objectives, publication counting is still nowadays the basic ingredient of all evaluation exercises, based as it is on the strong *a priori* that a scientist's or an institution's number of the articles is a good proxy for the latter's productivity. Since Lotka's statement that productivity of scientists distributes as an inverse square law (Lotka, 1926) it has been often stressed that productivity at individual level and collaboration of scientists are strongly related (Price and Beaver, 1966). In their seminal work De Solla Price and Beaver state correctly that *"…the most prolific man is also by far the most collaborating…"* (Price and Beaver, 1966). Moreover, following the success of large scale collaborative projects typical of US military research during second world war, collaboration has been incentivized by all policy makers and institutions, according to the perception that it is a "good thing" *per se*. The general feeling is that the more collaborative is the scientist the better it is, both for her productivity and for the outcome of the projects trusted to her.

According to Katz and Martin (Katz and Martin, 1997), there are at least four categories of studies related to research collaboration. First, there are studies which test how sound is using multiple-author articles as proxies of collaboration. Second, there are studies which explore the forces that push scientists to collaborate more, these studies being typical of recent years. Third, there are studies on the role played on both collaboration and productivity by communication costs, which include those influenced by social and physical proximity. Forth studies that aims to assess what is the effect of collaboration on productivity. In this paper we take as granted that multi-author papers are the best available measure of collaboration. Co-authorship in fact is invariant and verifiable, inexpensive and practical method for qualifying collaborations, moreover in the short run the measure does not affect the behavior of the measured subjects.

[1] This paper, joint work with Jacques Mairesse, is also a chapter of my Ph.D. thesis

[2] Most famous, discussed and recent ranking of the universities is the Shanghai ranking, edited by Shanghai Jiao Tong University.

The gradual transition from *Little science* to *Big science*[3] (Price, 1969) has increased the need for collaboration in research activities. Especially in the last 50 years, the rate of collaboration among scientists has persistently increased. Several forms of collaboration have been introduced, many of which bear little resemblance with the original meaning of the term (collaboration as "working together"). This is especially true in the hard sciences. Large teams, for example, are characterized by shared rules among scientists according to which individuals or sub-teams manage independently their work and participation to the research projects. The presence of dozens or hundreds of scientists that have to work together needs a more formalized and well-framed organization than the simple willingness of working together to achieve a common target. In particular, large teams represents a new paradigm for the organizational structure of research (Beaver, 2001; Adams et al., 2005). For Beaver (2001), the main advantages of teamwork on a large scale are: efficiency, speed, breadth, synergy, reduced risk, flexibility, accuracy and visibility. On the other hand there are also disadvantages, such as: lack of visibility for individual contribution and the project managers' loss of touch with direct research activity.

Katz and Martin (Katz and Martin, 1997) states that six forces push scientists to collaborate more and more. First, especially in applied disciplines, the progress of science requires expensive and complicate equipments and technical tools which sometimes cannot be bought even at national level but requires an international coordination in funding. Therefore, collaboration intended as sharing of resources is a matter of economies of scale and scope. A second force, widely cited in literature but not suitably evaluated in a quantitative way, consists of decreasing travel and communications costs[4]. A third force bases on the principle that what two scientists can do together is more than the sum of what they can do alone. Productivity of the two benefits from sharing ideas, discussing and interacting. Therefore scientists tend not to isolate. Collaboration and interaction of scientists can be based on tangible (university departments) or intangible ("invisible colleges" (Crane, 1972)) frameworks. The fourth force is related to increasing need of specialization in specific fields, due to impossibility for any individual to master all the growing number of necessary competencies and skills for any given project, in particular in hard sciences. The emergence of interdisciplinary fields where two or more disciplines are merged together in research projects makes the need of collaboration even stronger, and can be counted as the fifth force behind the growth of collaboration. Finally, the perception of the funding institutions that collaboration is a "good thing" pushes scientists to group together, in the hope that this would get more funds (Lee and Bozeman, 2005).

[3] Big changes that involves the work style of the scientists. From scientists that primarily works alone or in small groups with few resources, to big projects like Manhattan Project or Cape Canaveral rocketry

[4] A notable exception is (Waverly W. et al., 2009)

Several other contributions to the existing literature identify other forces that push scientists to collaborate, such as scientific popularity, visibility and recognition, need to gain experience, close physical proximity to benefit from the tacit knowledge. Speaking of the division of credit between notable scientists and junior scientists collaborating, Robert Merton, stressed the substantial trade off between the visibility given to a paper by the presence of the famous scientist among its authors, and the disproportionally low credit given to the junior authors (Merton, 1968). On the other hand, young scientists benefit from the collaboration with famous scientists, in terms of access to equipments and resources awarded by the scientific community to their mentor. In a study on French scientists at a large public research organization, Mairesse and Turner identify physical proximity, as the key determinant of collaboration, along with the size, productivity and specialization of the laboratories (Mairesse et al., 2005). Some research practices may lead to co-authorship, but do not arise from collaboration. This is the case of honorary authorship and the practice of authorship exchanges, aimed at increasing the assessment of individual productivity and popularity by the scientific community. Journal editors, universities, and research institutions all try to fight this practice, sometimes by imposing limits and guidelines to authorship assignment (LaFollette, 1996).

Scientists who are involved in research collaboration are usually defined as collaborators. The definition of collaborators however is not trivial and usually in literature is taken as granted its representation through co-authorship. Katz and Martin (1997) gives two definition of collaborators, one weak, that includes a several kinds of relationships between scientists and one stronger. The former include as collaborators *"…anyone providing an input to a particular piece of research…"*, the latter defines collaborators as "*… those scientists who contributed directly to all the main research tasks over the duration of the project…*". They state that the real definition of collaboration in research lies between this two extremes. It is reasonable to think that definition of collaborator is closer to one or the other extreme, depending on the discipline. Big science projects in high-energy physics, for example, requires specific knowledge in several disciplines and almost nobody contributes to all the main research tasks. On the other hand, in mathematics it seems more reasonable to presume that two scientists who try to prove a theorem both contribute directly to the whole project. A final remark on the literature is that the largest part of the data on which these studies are based are US-centric, starting from the seminal work of De Solla Price on *US Chemical Abstracts* (Price, 1969). Other institutional settings and more centralized systems, like the Italian or the French, could present different incentives to collaboration and different collaboration strategies by the scientists.

In section 4.2 we investigate the relationship between collaboration and productivity, with the aim of explaining the observable differences between individual productivity of Italian and French physicists. In section 4.3 we classify the scientists according to the characteristics of their collaboration and perform two counterfactual exercises in order to answer the following question: how much does productivity of French scientists change if they collaborated as Italians, and *vice versa*? We restrict the analysis to two windows of time, 1985-1990 and 2000-2005.

2 Are Italian physicists more productive than French ones?

This section is based on some empirical evidence that popped up when working on chapters 2 and 3, namely that Italian academic physicists apparently exhibit higher individual productivity than their French colleagues, where productivity is measured by number of articles per scientist (per year). We will show that the phenomenon is strictly related to collaboration practices. Information on collaboration is derived here from co-authorship data, so that if two or more scientists sign the same article they are considered collaborators. The usual correction adopted by scholars who deal with co-authorship related issues, but are interested to individual measurement, is the so-called *fractional count* of articles. In this case fractional count, as shown below, explains only part of the difference and is rather misleading for two main reasons: (1) it doesn't account for peculiarities of coauthors, but it treats them as homogeneous and (2) it gives disproportionate credit to scientists who do not collaborate and sign only or chiefly single-authored papers (i.e. penalizes to much scientists who collaborate).

2.1 Methodology

We define two methods to measure productivity, both based on count of publications. First is the *micro* level, where the entire article is assigned to all the co-authors. The basic justification for this count method is that we cannot distinguish each co-author's distinctive contribution, nor we can approximate by fractional counting, due to heterogeneity of the individual contributions. This is also the most intuitive method and largely used in evaluation of productivity at scientist level (Gauffriau et al., 2008). Once the articles are assigned, scientists are grouped according to two main criteria, their affiliation (either to a university or a PRO) and their nationality (Italian vs. French[5]). For each organization *o* (or nation *n*), we measure micro productivity (m_prod_o; or m_prod_n for a nation) as the ratio between the sum of articles published in each year *t* ($n\_articles_{i,t}$) by each scientist belonging to the organization (or nation) and the sum of active scientists ($n\_scientists_{t,o}$) per year *t* of evaluation (Equation 1). *Last_y* and *First_y* are respectively the last and first year of evaluation, and

[5] To be more precise. Here we not refer to the scientist's nationality, but the nationality of the institution she appears to be affiliated to.

they define the window of evaluation[6]. Micro productivity measure (or average individual productivity), is therefore the average number of articles per scientist per year of evaluation.

$$\mathrm{m\_prod}_{\mathrm{o,\,last\_y,first\_y}} = \frac{\sum_{t=First\_y}^{Last\_y} \sum_{i=1}^{\mathrm{n\_scientists}_{o,t}} \mathrm{n\_articles}_{i,t}}{\sum_{t=First\_y}^{Last\_y} \mathrm{n\_scientists}_{o,t}} \qquad \mathrm{m\_prod}_{\mathrm{n,\,last\_y,first\_y}} = \frac{\sum_{t=First\_y}^{Last\_y} \sum_{i=1}^{\mathrm{n\_scientists}_{n,t}} \mathrm{n\_articles}_{i,t}}{\sum_{t=First\_y}^{Last\_y} \mathrm{n\_scientists}_{n,t}}$$

[Equation 1]

The second level of analysis is *macro*. It is the count of publications with at least one author affiliated to the organization *o* (nation *n*). The average macro productivity is the ratio between the bulk of publications assigned the organization *o* (nation *n*) and the sum of active scientists per year of evaluation (Equation 2). The point of view is that of the organization *o* or the nation *n*.

$$\mathrm{M\_prod}_{\mathrm{o,\,last\_y,first\_y}} = \frac{\sum_{t=First\_y}^{Last\_y} \mathrm{n\_articles}_{o,t}}{\sum_{t=First\_y}^{Last\_y} \mathrm{n\_scientists}_{o,t}} \qquad \mathrm{M\_prod}_{\mathrm{n,\,last\_y,first\_y}} = \frac{\sum_{t=First\_y}^{\mathrm{Last\_y}} \mathrm{n\_articles}_{n,t}}{\sum_{t=First\_y}^{Last\_y} \mathrm{n\_scientists}_{n,t}}$$

[Equation 2]

Difference between macro and micro productivity clearly depends only upon the rates of co-authorship within organizations (nations), being the two measures exactly the same only when one and only one scientist affiliated to the organization *o* (nation *n*), signs each article. Higher rates of co-publications within organization (nation) generate increasing differences in productivity measures, by increasing micro productivity and leaving macro unaltered. In the following sections we will assess the differences between the two defined productivity measures, moreover we will compare them also to the usual fractional count of articles used by bibliometricians.

[6]When productivity is evaluated year by year like in the following graphs, for example productivity in 2005, the ratio is simply between articles published in 2005 and number of active scientists in 2005

2.2 Data

The data used in this chapter come from four lists of Italian and French physicists active in the year 2004-2005. The data includes all the academic physicists (2152 French; 1769 Italians) and all the physicists affiliated to two important public research organization (PROs), CNRS (1255 physicists) in France and CNR (307 physicists) in Italy. While CNRS employs almost all the non-academic physicists working in public sector, the Italian picture is more fragmented. Besides CNR there are other two centers with substantial numbers of employees in the field of physics: INFN ("*Istituto Nazionale di Fisica Nucleare*") and INFM (*"Istituto Nazionale per la Fisica della Materia"*). INFN operates in the field of nuclear physics (or high energy physics) and is not included in the sample. Second operates in the field of physics of the matter and, in principle, is part of CNR from 2003. It was founded in 1994 and in 2005 employed about 188 scientists, part tenured and part with fixed-term contracts[7].

In both countries physicists are classified in sub-disciplines according to their research interests. Unfortunately the classification is not standardized across Europe, so that we decided to choose similar sub-disciplines of physics for comparability. For Italian universities we consider three fields: *Fisica sperimentale (FIS01)*, *Fisica teorica, modelli e metodi matematici (FIS02)* and *Fisica della materia (FIS03);* For French universities: *Milieux dilués et optique (30)* and *Milieux denses et matériaux (28).* The CNR official definition of fields matches exactly the definition in academia (i.e. FIS01, FIS02, FIS03). For CNRS we include in the analysis: *Physical theories methods, models and applications (2), Atoms and molecules-Lasers and optics-Hot plasmas (4), Condensed matter physics: structure and dynamics (5), Condensed matter physics: structures and electronic properties (6)*.

In principle our aim is to exclude nuclear physicists because of their peculiar research style founded on big teams membership, large laboratories and equipments like particle accelerators. Publication data are available for each scientist from 1975 to 2005. The database includes several personal details like gender, year of birth, affiliation in 2005 (for academics), and the year of last promotion to the rank observed in 2005 (see also chapter 2 and chapter 3 for descriptions of the dataset). Before the analysis we processed the data to solve homonymy problems. Moreover, due to the lack of the information about the year when Ph.D. is granted to the scientists, we consider for everyone the beginning of scientific career at the age of 25.

[7] Source: INFM website (http://www.infm.it//index.php?option=com_content&task=view&id=39&Itemid=53).

2.3 *Prime facie* evidence on productivity of French and Italian physicists

In chapter 2 and 3, based largely on the same database used here, Italian academics show up a dramatic increase in average individual productivity during the 1990s, which has no correspondence on the French side. According to the micro productivity measure defined in the previous section, French academics share with the Italians only the earlier trend, before the 90s, although with about half an article less per year (Figure 1). In 2005 Italian academics publish on average 4.5 articles per year, against 1.5 articles of French academics.

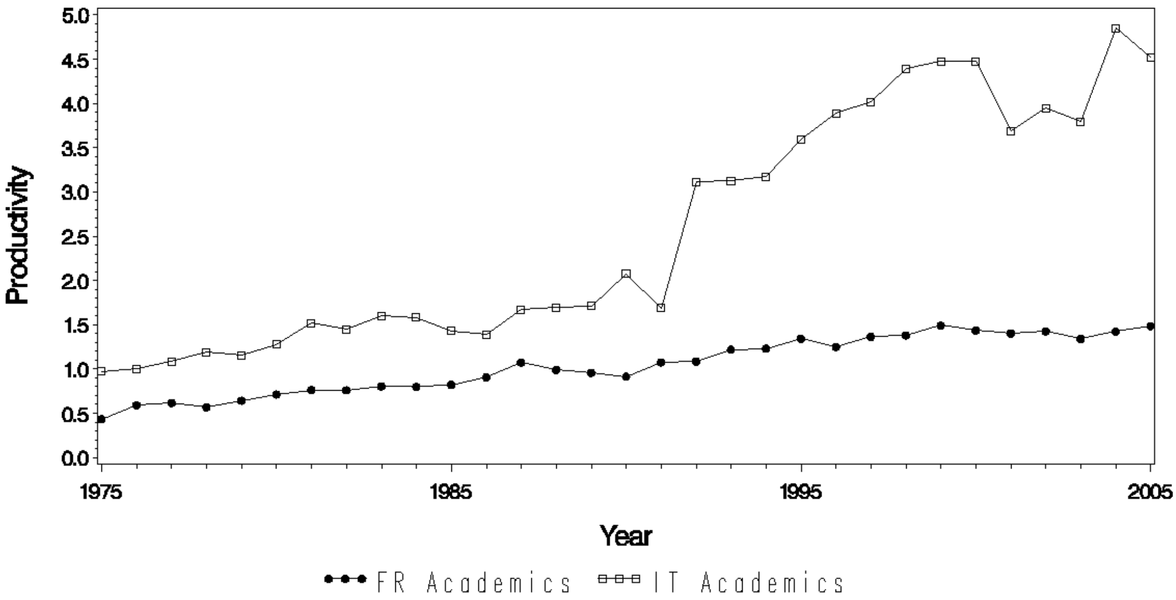


Figure 1 Micro productivity, Italian and French academics

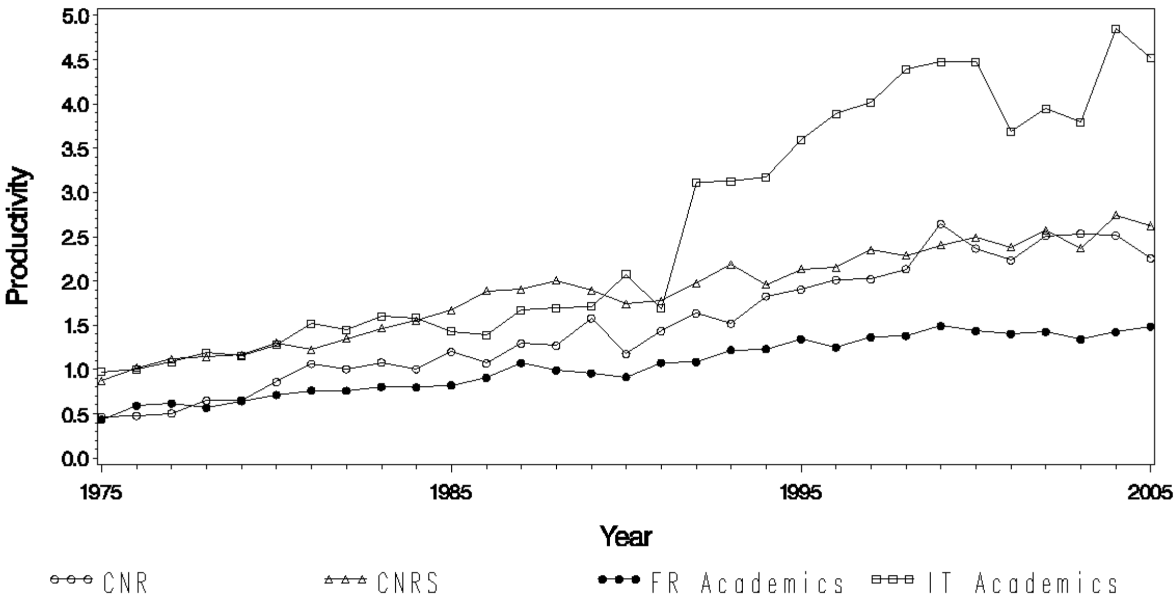


Figure 2 Micro productivity of organizations

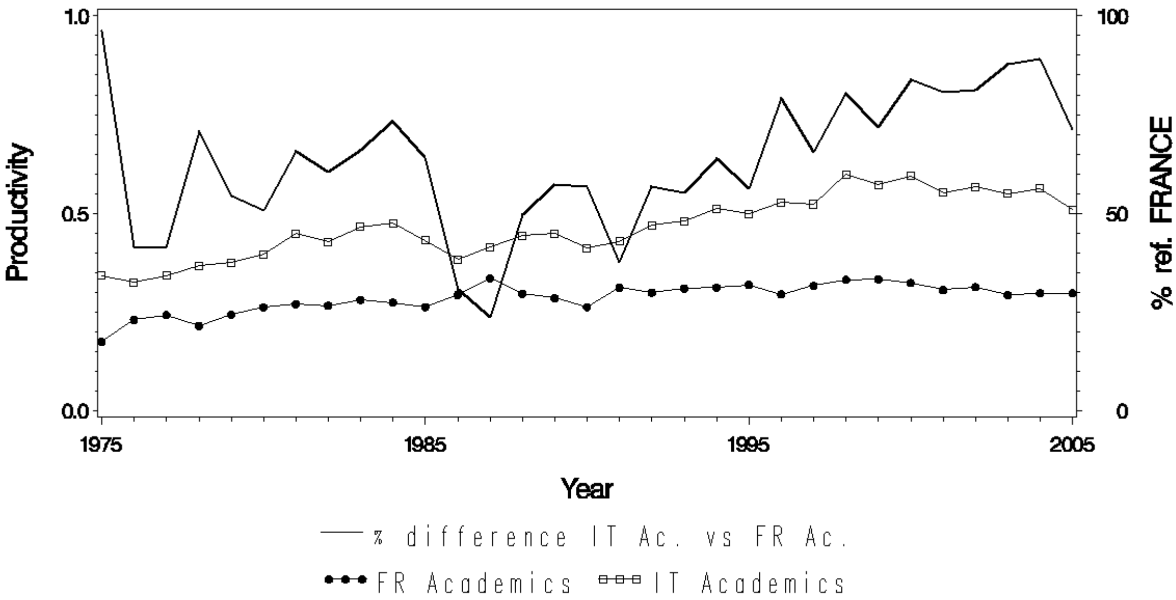


Figure 3 Micro productivity of French and Italian academics weighted by authors

Given that a prominent role in national research system is played by PROs, the analysis has been extended also to such institutions. Academics, in both countries, are supposed to dedicate part of their time in teaching generating a trade off with the time dedicated to research. On the other hand, CNR and CNRS scientist are supposed to be full time researchers. An approximate hypothesis, is that academics dedicate half of their time to research and half to the teaching duties. Accordingly, their productivity should be nearly half if compared to the scientists belonging to PROs, at least according to the more limited amount of time. Figure 2 shows that this proportion is roughly valid for productivity of French academics if compared to CNRS scientists, but does not apply to Italian academics. Italian academics' productivity is permanently over that of CNR scientists, both before 1990 and even more so after then. Italian academics do even better than CNRS scientists (who, in turn, do only slightly better than CNR scientists).

Even using fractional count method, Italian academics' productivity is between 22.8% (1987) to 85.5% (2004)[8] higher than its French equivalent (Figure 3). Fractional count of articles, in fact, does cut large part of the Italian academic's productivity excess, but don't explain away all of it. Decreased difference by using fractional count is an evidence of the relevant role played by collaboration in enhancing the productivity of Italian academics. Dividing each article by the number of authors gives less weight to the articles with several authors and more to the articles with few. Therefore, from the empirical evidence that fractional count decreases much more the productivity

[8] We do not consider in the comments first year (i.e. 1975) because we don't have much observations if compared to other years

of Italian academics, we can infer that they publish more often than French articles with a large number of authors. Surprisingly the number of average authors per article is comparable for Italian and French academics, showing up for French academics the highest level of authors per paper in 2005 (Figure 4). From Figure 3 one could expect that a dramatic decrease in the individual productivity computed according to fractional count would be caused by a considerable higher number of coauthors for Italian academics' articles, that is not the case (Figure 4).

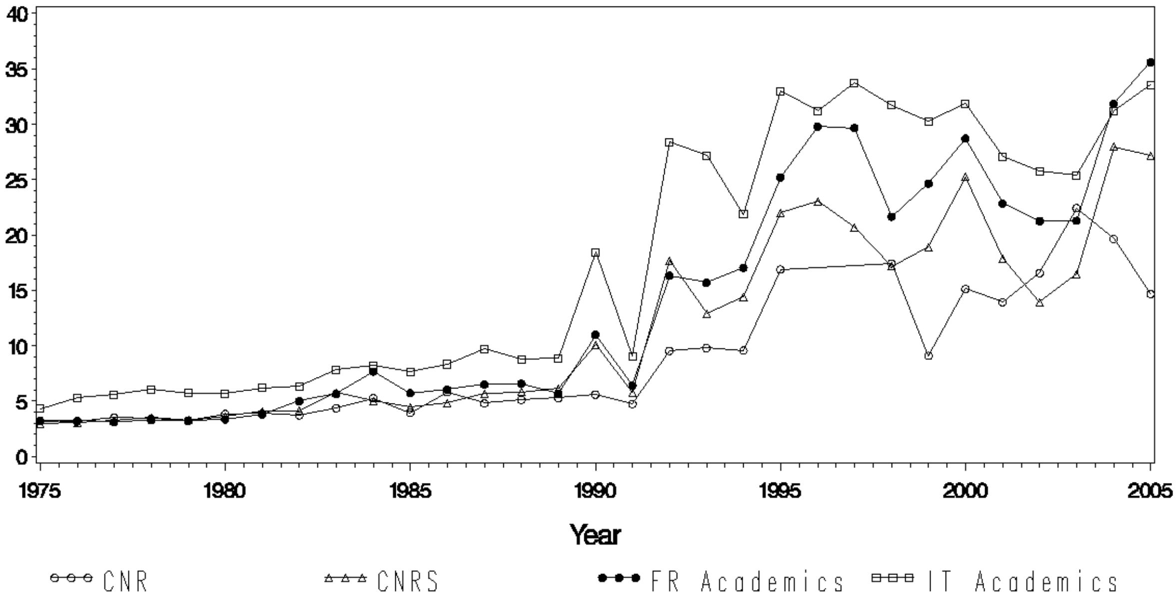


Figure 4 Average number of authors per article according to organization

2.4 Macro productivity

Micro level productivity (i.e. individual productivity) is often taken into account by bibliometricians, economists and sociologists of science, but rarely used by policy makers and institutions in processes of evaluation and ranking. Macro measure is more likely to be used to evaluate productivity in the latter contexts. Macro productivity measure, decreases the differences in productivity of Italian and French universities, not duplicating the articles co-authored by scientists belonging to same organization. According to this measure the difference at macro level for Italian and French academics is between 3.2% (1987) and 54.5% (2004) (Figure 5).

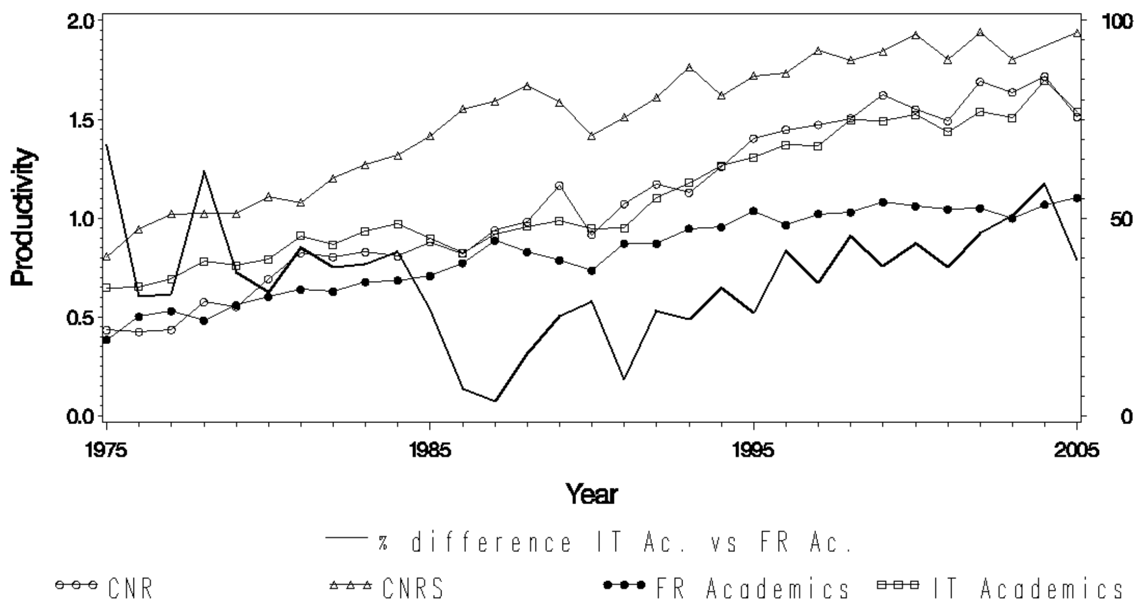


Figure 5 Macro productivity of organizations

Moreover productivity of CNRS is well above the Italian academics and, on average, CNR scientists are as productive as academics. French academics are the least productive physicists in any year. Another way to assess macro productivity is to change the point of view from organizations to national level. In this case scientists are grouped according to their nationality, irrespective to the organization they are affiliated. The bulk of publications with at least one Italian or French scientist listed among the authors in the period of observation, is the numerator of equation 2 to compute the macro productivity index at national level.

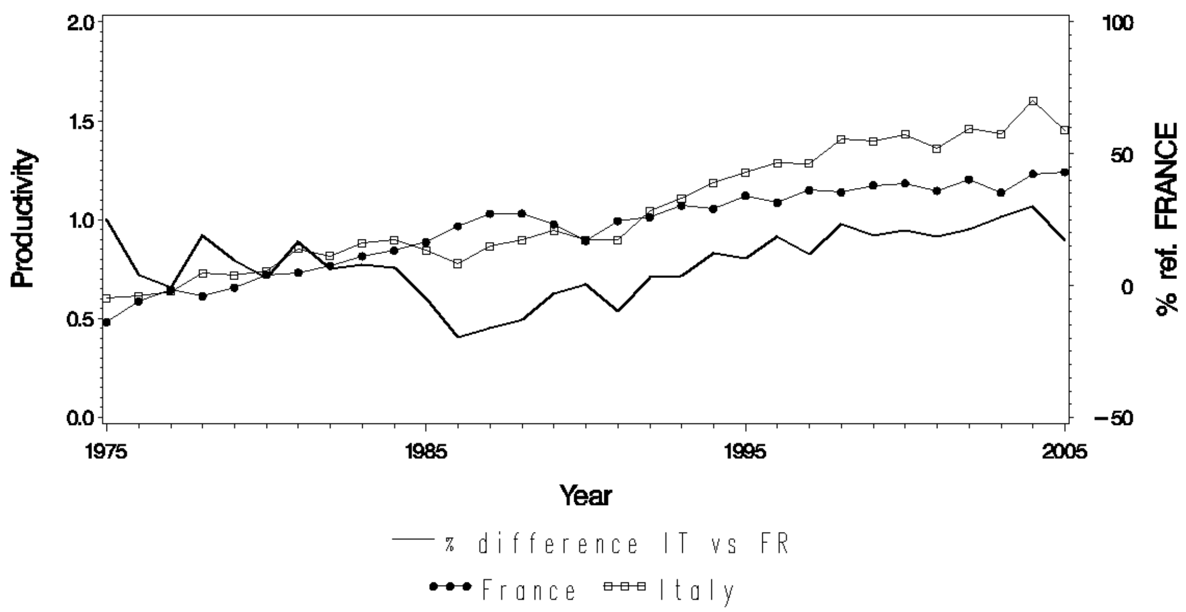


Figure 6 Macro productivity at national level

Figure 6 shows that according to macro productivity at national level, France is, for the years between 1985 and 1990, more productive than Italy. The compensation effect between the low productivity of French academics and high productivity of CNRS scientists increase the national scientific output in favor of France. Differences in macro productivity range from -20.35% (1986) to 29.3% (2004). It is useful to bear in mind that, at national level, all the articles with mixed co-authorships between PRO and university are not repeated in the count of publications, downsizing the productivity of both countries in absolute levels (left axes values in figure 6). At national level Italy is still more productive than France only in recent years, before 1985 productivity of the two countries is almost the same (Figure 6).

From the qualitative analysis of the Figures 1-6 we can reach the conclusion that the high productivity of Italian academics at individual level is largely due to an higher rate of collaboration in terms of co-publication of articles among Italian scientists. Compared to the other groups considered here, this collaboration is more likely to take place among scientists from the same nation[9], which explain why macro measures for Italian academics differ so much from micro ones[10]. Moreover usual correction of fractional count does not explain wholly the difference in productivity between Italy and France, especially in recent years, showing that, at least in this case, it is not the most appropriate tool to account for multi-authored papers. This is strictly related to the fact that the increase in number of authors per article in recent years is roughly the same for Italian and French academics (average number of coauthors per article, Figure 4).

Therefore the usual fractional count correction tends to hide, the real causes of the higher micro productivity of Italian physicists, that is related only to the intra-national collaborations or, in other words, the large part of the difference between individual productivity of Italian and French physicists can be explained by the different amount of articles co-authored by Italian scientists with Italian and French scientists with French. We define as *intra-national* collaborators, the number of co-authors per article belonging to the same nation as scientists *i*, where *i* is the subject of analysis. We can identify correctly the intra-national authors, that corresponds to the part of information useful to explain the difference in productivity between Italian scientists and French scientists. On the other hand we cannot disentangle inter-national coauthors, or co-authors coming from non-academic or public research institutions (such as industrial researchers) or technicians. Figure 7 shows the fractional count of articles according to the strategy of weighting the articles only by intra-national authors.

[9] At the level of organization high rate of coauthorship is shown among Italian academics.

[10] It's important o bear in mind that the only difference between macro and micro measure of productivity is the repetition of coauthored articles among scientists belonging to the same nation in the count of publications.

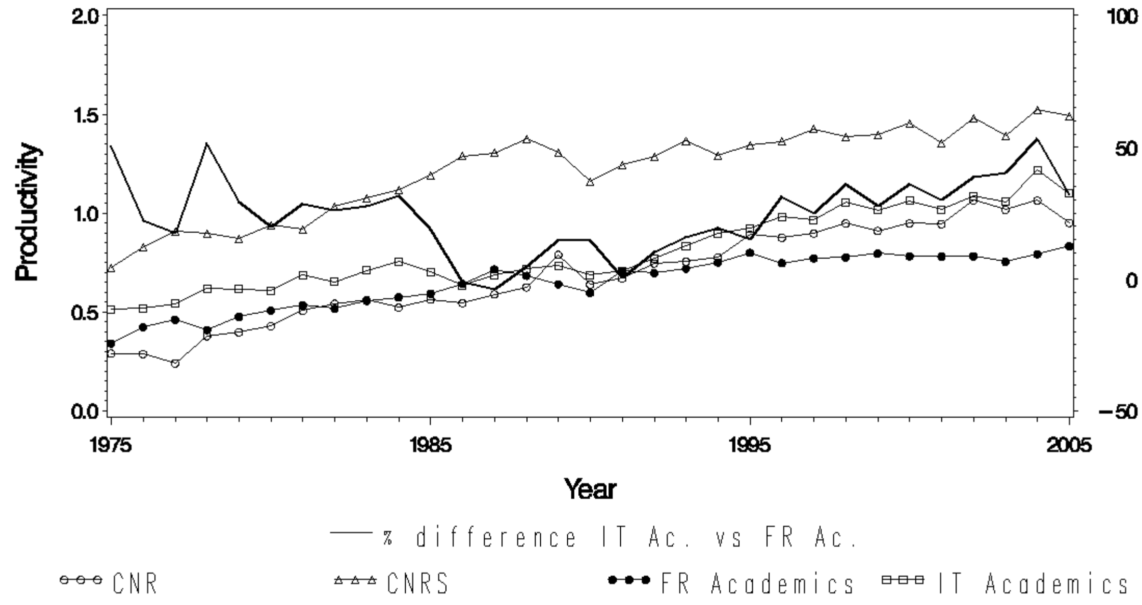


Figure 7 Micro productivity of organizations weighted by national authors

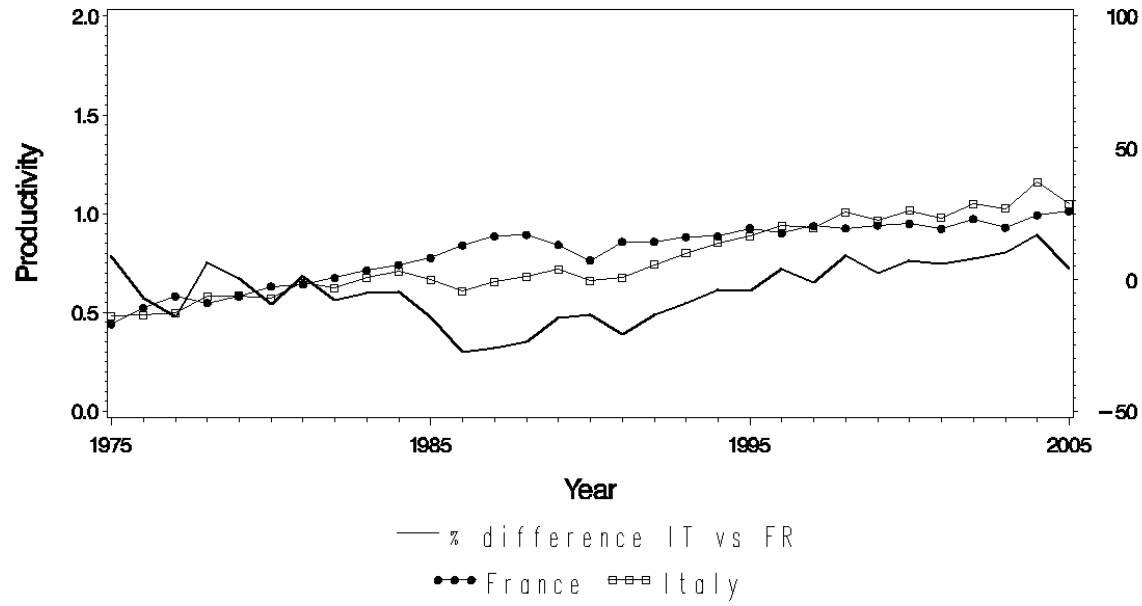


Figure 8 Micro productivity of countries weighted by national authors

Differences between Italian and French academics range from -4% in 1987 to 51% in 2004. Weighting for intra-national authors increases also the distance between average productivity of CNRS scientists and academics, leaving behind also the average productivity of CNR scientists. Average micro productivity at national level weighted by national coauthors (Figure 8) shows an higher productivity of the French research system (academics and PROs) in the years before 1995. The effect of compensation between French universities and CNRS is again evident.

A first conclusion we can reach through our qualitative analysis is that differences we observe in micro productivity, across nations and organizations, appear to be reduced when we move to macro productivity measures. This is due to the substantial higher rate of national co-authorship of Italians, in particular, at the organization level, Italian academics show the most intense collaboration. The usual fractional count of articles explains not completely the observed differences in productivity, although it contains useful information on number of national coauthors. Finally, when we account for the entire research system in countries, both according to macro measure and weighted productivity by national coauthors, the difference in productivity becomes rather negligible.

A second conclusion we can reach is that while CNRS higher productivity compensates the lower of French academics at national level, the same does not apply to CNR in Italy. According to this observation, we can define the French research system as dual, with the CNRS getting the lion's share of productivity. On the contrary, the Italian scientific productivity is supported largely by academics, due to the small size and low productivity of CNR (if compared to its counterpart in France). CNR in Italy in fact is only 14% of the whole Italian research system, while CNRS in France is 38%. Given role played by CNRS scientists and academics in French research system, in what follows, we will consider national productivity as a whole.

Finally, a substantial change in the regime of collaboration is observed around 1990 (Figure 4, average number of authors per paper, see also Adams et al., 2005). It is common to both countries even if the dramatic increase in average number of coauthors per paper affect mainly the academics' publications.

3 The role of intra-national collaborations and windows of evaluation

As stated in the previous section, many studies about individual productivity of scientists with the aim of taking into account the issue of multi-authored articles, use fractional count methods. As qualitatively shown this does not solve completely the issue of differential in productivity between France and Italy especially in recent years. Moreover, given the empirical evidence of the dual research system in France, in what follows we will group scientists only according to their nationality, leaving the organizational level analysis. Finally, one of the qualitative conclusion of the previous section is that around 1990 is identifiable a substantial change in regime of collaboration. According to this evidence we define two windows of *evaluation* of scientists, first from 1985 to 1990 and second from 2000 to 2005, before and after the empirically detected change in of regime of collaboration. Related to windows of evaluation we define two windows of *observation*. The first is between 1975 and 1990, the second runs from 1990 to 2005. Windows of observation overlap the window of evaluation they refer to. Windows of observation will be used in what follows to categorize the scientists according to their "history" in terms of collaboration based on their national network of relationships with other scientists. This section, instead of changing the measure (i.e. from micro to macro) to explain the gap in individual productivity values, aims to explain differences by assessing the impact of national collaborations features on micro productivity.

The analysis starts from a more quantitative evaluation of what emerges from the analysis of figures 1-8 (Table1).

	(macro level) 1985-1990			(macro level) 2000-2005		
MACRO	**France**	**Italy**	**Ref.FR**	**France**	**Italy**	**Ref.FR**
Number of articles	11644	8582	-26.30%	24004	17962	-25.17%
Number of scientists	2291	1792	-21.78%	3375	2056	-39.08%
Years of evaluation	12074	9815	-18.71%	20157	12328	-38.84%
Productivity	0.96	0.87	-9.33%	1.19	1.46	22.35%
Avg. Impact factor(IF)	7.39	7.02	-5.01%	7.35	7.25	-1.36%
Avg. Authors	6.11	10.06	64.65%	19.69	27.02	37.23%

	(micro level) 1985-1990			(micro level) 2000-2005		
MICRO	**France**	**Italy**	**Ref.FR**	**France**	**Italy**	**Ref.FR**
Number of articles	15465	15929	3.00%	36828	48719	32.29%
Number of scientists	2291	1792	-21.78%	3375	2056	-39.08%
Years of evaluation	12074	9815	-18.71%	20157	12328	-38.84%
Productivity	1.28	1.62	26.71%	1.83	3.95	116.30%
Avg. Impact factor(IF)	7.43	7.25	-2.42%	7.52	8.93	18.75%
Avg. Authors	7.19	34.84	384.56%	29.71	157.4	429.79%

Table 1 Windows of evaluation

In the first window (i.e. between 1985 and 1990) at macro level, the average quality of articles, measured according to the impact factor of the journals, is rather the same, 7.39 in France and 7.02 in Italy. The average number of authors per article is 64.65% higher in Italy, if compared to France. In the most recent window, at macro level, (i.e. 2000-2005) the difference between average impact factor of the journals is still only 1.36% in favor of France. Moreover the difference between the average number of authors reduces to 37.23%. Therefore, according to the macro measure defined, the differences in quality of publications and average number of authors in the two countries decrease when moving to the most recent windows. On the contrary, differences in productivity increase from 9.33% in first window to 22.35% in the second. Generally speaking, as observed in section 4.2, the differences between countries at macro level are quite small, both in terms of publications' features (average impact factor and average number of coauthors) and scientific productivity.

On the other hand, micro productivity measures give a different picture. The difference in productivity between Italy and France in first window is 26.71%; then, in the most recent window, it increases up to 116.30%. Moreover the average number of authors per article in recent window is more than four times higher in Italy. This means that publications with a large number of authors are assigned several times to Italian scientists or, in other words, that the publications most often shared among Italians are those with many authors. This conclusion is not trivial considering that in France the increment of authors between micro and macro measure is negligible in the window 1985-1990 and of around 50% in the last window (well below the Italian values, 247% in 1985-1990 and 482% in 2000-2005).

What is shown by the statistics on windows of evaluation replicates the differences between macro and micro already seen in the qualitative graphs. France and Italy are much more different in terms of productivity at micro level than at macro. In what follows we will assess two possible causes of differences in micro productivity and the role of collaboration.

3.1 Micro productivity difference: zero productive and nuclear physicists

From section 4.2 we can infer that the differences between macro and micro measures derive largely from the intensity of intra-national collaboration of scientists. This section focuses on explaining differences in micro productivity by changing in collaboration strategies of scientists, but other determinants could be at play. We check for the presence of two categories of scientists that can influence micro productivity: (1) scientists who do not publish at all during the evaluation period and (2) scientists who are classified in the fields of our interests, but actually do research in other fields, where the average productivity is different. In principle we should exclude both categories from the analysis of collaboration. The first category should be excluded because it represents scientists who are not involved in research activities for various reasons, the second because it introduces a hidden composition effect in our averages.

Productivity measures in Table 1 include also scientists without any publication during the window of evaluation. We define them as “zero productive”. Table 2 shows that in recent years (i.e. second window) 677 scientists are classified as non-productive in France and 229 in Italy representing respectively the 20% and 11% of the whole sample. Large part of these physicists are French academics 74.7%. If compared to the whole sample of academics in France a not negligible part of physicists is zero productive (26%), well above the percentage in CNRS (9%). Italian academics include in recent years only 11% of zero productive, while CNR 13%. Therefore French micro productivity measure is more affected by zero productive scientists; this helps considerably to bring down the average productivity values (in the micro productivity equation, zero productive scientists are considered as active scientists but they do not contribute with publications).

	1985-1990		2000-2005	
	France	Italy	France	Italy
Number of scientists	2291	1792	3375	2056
Zero productive	763	363	677	229
% of zero productive	33%	20%	20%	11%

Table 2 Zero productive scientists according to the two windows

Table 3 shows the increase in individual productivity at micro level obtained by excluding scientists classified as zero-productive. In recent years the increment in micro productivity for France is 25% while in Italy is 13%. In the first window French increment is 41% and Italian 21%. As expected what France gains in terms of individual productivity is more than what Italy gains by excluding category of zero productive. It contributes to decrease the difference in micro productivity.

	productivity 1985-1990		productivity 2000-2005	
	FRANCE	ITALY	FRANCE	ITALY
MACRO	0.96	0.87	1.19	1.46
MICRO	1.28	1.62	1.83	3.95
(reference MACRO)	*+33%*	*+86%*	*+53%*	*+171%*
without zero-pr.	1.81	1.96	2.29	4.45
(reference MICRO)	*+41%*	*+21%*	*+25%*	*+13%*
without nuclear	1.76	1.75	2.08	2.98
(reference MICRO)	*+38%*	*+8%*	*+14%*	*-25%*

Table 3 Summary table

Interviews with Italian physicists have suggested a possible problem of national misclassification according to the disciplines. Several physicists, in particular in FIS01, doing research on particles, nuclear physics and related topics are *de facto* classified in discipline *fisica sperimentale* instead of being included in FIS04, more closer to their research interests (*fisica nucleare e sub-nucleare*).

From this empirical evidence we define two alternative measures to identify, first article in nuclear physics and, once determined the articles, nuclear physicists. First measure defines articles in nuclear physics according to the classification of journals where they are published, second, according to the fact that nuclear physicists do research mainly in large teams. The latter reflects in the high number of authors per article due to the rules about the attribution of the authorship in this field. Usually every component of the team is listed among the authors even if she contributes directly for a small part of even simply because she is part of the project.

First definition of articles in nuclear physics bases on journals. We identify, according to their ISI classification, all the journals which presumably should host articles in nuclear physics. They are journals classified as “particles”, “nuclear” or “multidisciplinary” or a combination of these. Table 4 reports the result of excluding from the sample all the articles published on that journals. Total sample of publications in both countries is drastically reduced mainly due to the exclusion of articles in multidisciplinary journals. Micro productivity is now more comparable between Italian and French academics (0.77 and 0.68) and productivity of PROs is higher with 1.05 for CNR and 1.08 for CNRS. Average impact factor is between 6.09 and 6.88 and the average number of coauthors is around 5. Even thought exclusion of articles in nuclear physics, according to the definition based on journals' classification, significantly decreases the difference in productivity of academics, it also decreases dramatically the size of the publication sample for each organization (Table 4).

Second definition of articles in nuclear physics bases on the peculiarity of working in large teams. We define as large projects all the articles with 30 or more authors (the same definition as in chapter 2). According to this definition we exclude these articles from the sample. Average impact factors are similar for French and Italian academics (6.43 and 6.87), higher for CNRS (7.79) and lower for CNR (5.8). Average number of authors is between 5 and 5.92 for academics and CNR, only CNRS shows a lower value (Table 4). In what follows we adopt the second classification of articles in nuclear physics to define nuclear physicists, mainly because size of the whole sample of publications is less reduced if compared to the first approach based on journal classification.

According to the definition of articles in nuclear physics, we define as nuclear physicists the scientists with more than 20% of her scientific productivity made by large project articles (i.e. articles in nuclear physics). This definition allows to classify nuclear scientists by looking at their productivity. Table 5 shows, as expected from face to face interviews, that the misclassification problem affects mainly Italy, where nuclear physicists are 20% of the sample in recent years and 11.2% from 1985 to 1990. French percentages of scientists active in nuclear physics, on the contrary, are negligible shares (0.7% and 2% in recent years). Scientists active in nuclear physics are characterized by a notably high individual productivity given by their participation to several big research projects at the same time (in recent years around 9 articles per year, 0.75 articles per month!!). Relative close values of productivity between Italian and French nuclear physicists suggest that we are classifying as active in nuclear physics at least comparable scientists.

	Publications 1975-2005				(A) Small projects (<30 authors)				(B) no nuclear journals (Nuclear, particles or multidisciplinary)			
	CNR	CNRS	UN. (FR)	UN. (IT)	CNR	CNRS	UN. (FR)	UN. (IT)	CNR	CNRS	UN. (FR)	UN. (IT)
Number of articles	11742	52519	52880	125945	11196	50012	50041	75160	7184	27852	31172	34437
Years of evaluation	6819	25678	46078	44576	6819	25678	46078	44576	6819	25678	46078	44576
Productivity	1.72	2.05	1.15	2.83	1.64	1.95	1.09	1.69	1.05	1.08	0.68	0.77
Avg. impact factor(IF)	5.93	7.95	6.73	8.53	5.8	7.79	6.43	6.87	6.09	6.88	6.44	6.76
Avg. Authors	13.87	19.04	20.54	137.13	5.57	4.82	5	5.92	5.37	5.06	4.89	5.22

Table 4 Definition of articles in nuclear physics

	FRANCE 1985-1990							FRANCE 2000-2005						
	Productivity			Weighting				Productivity			Weighting			
	Total	Average per physicist	Prod.	Number of Physicists	Avg obs.	Y. of obs.	W	Total	Average per physicist	Prod.	Number of Physicists	Avg obs.	Y. of obs.	W
N Nuclear	584	36.50	6.28	16	5.81	93	0.7%	4373	52.69	8.85	83	5.95	494	2%
TOTAL	15465	6.83	1.28	2291	5.27	12074	100%	36828	10.91	1.83	3375	5.97	20157	100%
	ITALY 1985-1990							**ITALY 2000-2005**						
N Nuclear	3617	18.45	3.26	196	5.65	1108	11.2%	23545	56.60	9.43	416	6.00	2496	20%
TOTAL	15929	8.89	1.62	1792	5.48	9815	100%	48719	23.70	3.95	2056	6.00	12328	100%

Table 5 Nuclear physicists

Empirical evidence observed according to the percentage of nuclear physicists is compatible with the picture described in interviews with Italian physicists. Therefore we can infer the conclusion that there is a substantial misspecification of Italian academics being disciplines biased by the presence by nuclear physicists, that, in principle, should be classified in FIS04 "*fisica nucleare e sub-nucleare"*. Taking out from the sample all zero productive and nuclear physicists increases the comparability in recent years being micro productivity in France 2.08 articles per year and 2.98 article per year in Italy. Although the difference in window 2000-2005 is still 43% in favor of Italy. In the first window, micro productivity without nuclear physicists and zero productive is rather the same (difference 0.6%), 1.76 articles for France and 1.75 for Italy (Table 3). In the remaining of the section we will assess how much of the difference in micro productivity, still present in recent years, (0.9 articles per year per scientist) can be explained by re-classifying scientists according to their collaboration strategies.

In chapter 2 we have taken into account the presence of zero productive and nuclear physicists by excluding the former from productivity evaluation and by identifying the latter according to the *large project* dummy. Therefore we have kept nuclear physicists in the sample but controlling for their presence. In chapter 3, we have based social capital measures on the co-authorship network made by articles with less than 30 authors, excluding, from relationships between individuals, those due to articles in nuclear physics. On the side of determinants of promotion we have tried different measures of productivity, weighting articles by the number of authors (or functions of number of authors).

3.2 Classes of collaborations

Zero productive and nuclear physicists largely explain the difference in micro productivity before the emergence of large teamwork (before 1990), although in second window of evaluation remains a non-trivial difference in productivity values. On average, the Italians publish 0.90 (+43%) articles more per year per scientist than the French, that is a non-negligible difference. In this section we will classify scientists according to two dimensions of collaboration and we will assess the impact of each class on micro productivity. We account only for national collaborations given that, as shown in section 4.2, it is the main cause of the difference between Italy and France.

We define strategies of collaboration among scientists focusing on person-to-person collaborations in terms of size (how many different collaborators) and length (how long a collaboration lasts on average). Therefore the analysis based on the national networks of Italian and French physicists is built upon co-authorship information. According to network terminology two scientists who sign the same article are connected. We define each connection a couple. One scientist could have more than one connection with another during her/his career. If the same couple is present in more than one year we define them as years of collaboration. Collaboration between scientists *i* and *j*, where *i* is the subject under analysis and *j* is one of her/his collaborators, may be more or less durable according to the amount of years *i* and *j* collaborate. To standardize the duration of collaboration we compare it to the whole years of observation of *i*. Therefore, we define persistence of collaboration according to equation 3, where *years of collaboration*$_j$ is the amount of years of collaboration between scientist *i* and scientist *j* and *collaborators*$_i$ is the number of collaborators of scientist *i* during the observation window.

$$\text{Persistence}_i = \frac{\sum_{j=1}^{\text{collaborators}_i} \frac{\text{years of collaboration}_j}{(\text{Last\_y - First\_y})_i}}{\text{collaborators}_i}$$

[Equation 3]

Persistence values are in the range [0,1] and can be interpreted as the average percentage of the *i*'s career when *i* and other scientists (*j=1*, *j=2*, *j=3*…) collaborate. This is the first dimension we consider to define classes. The other dimension of collaboration bases on the number of different national collaborators of scientist *i* during the years of observation (i.e. the number of different couples). Extent is defined as the ratio of the number of different scientists collaborating with *i* (i.e. *j=1*, *j=2*, *j=3*…) and the periods when scientist is observed (Equation 4). The index is in the range [0, ∞).

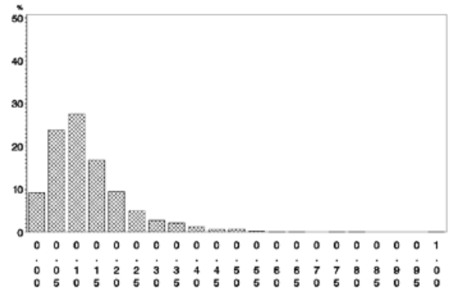
$$\text{Extent}_i = \frac{\text{collaborators}_i}{(\text{Last\_y - First\_y})_i}$$

[Equation 4]

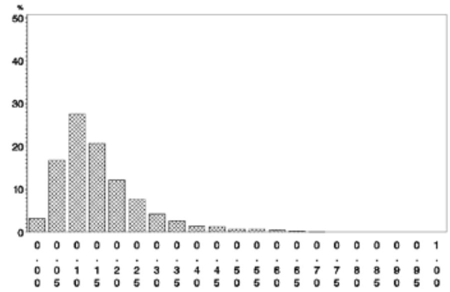
Thresholds, based on values of extent and persistence, are fixed according to the distributions of the two dimensions of collaboration (Figure 9). They are respectively 0.3 for extent, that means 3 different collaborators during 10 years of observation, and 0.15, that means that average collaboration lasts for 15% of the career length of scientist *i* observed. Both variables have an asymmetric distribution at national level (Figure 9).

Persistence of collaboration

France

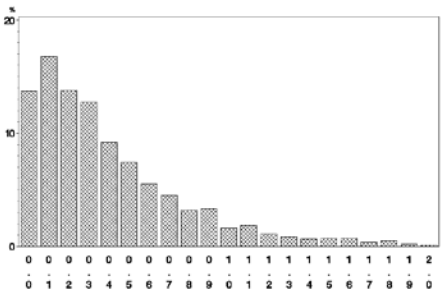


Italy



Extent of collaboration

France



Italy

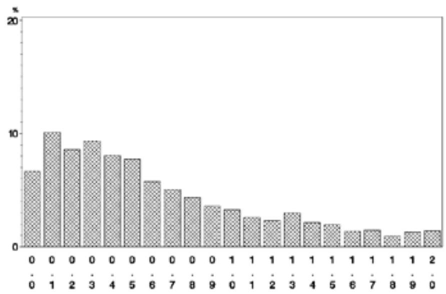


Figure 9 Definition of classes according to the thresholds of 0.3 for extent and 0.15 for persistence

The same thresholds are applied in all the following exercises making the classes always comparable. When scientists are not included in the national collaboration network (i.e. they have only publications alone or coauthored with international scientists) their extent and persistence are null, therefore they are grouped in a specific class (E no-collaboration). First collaboration class (A) groups all the scientists with an extent less than 0.3 and persistence less than 15%. Second class groups scientists who have several different collaborators per year but low persistence of collaboration (B). Third class, on the opposite, groups scientists with low extent but collaborations that last for large part of the career (C). Finally, when scientists are very persistent in their collaboration with several colleagues per year (more the 15% and more than 0.3), they are grouped in class D. According to classification we have ten classes: A,B,C,D,E for Italy and A,B,C,D,E for France. Table 6 shows detailed statistics of the classes.

France

	FRANCE 1985-1990							FRANCE 2000-2005						
	Productivity			Weighting				Productivity			Weighting			
	Total (A)	Average per physicist (A/B)	Prod. (A/C)	Number of Physicists (B)	Avg. obs. (C/B)	Y. of obs. (C)	W	Total (A)	Average per physicist (A/B)	Prod. (A/C)	Number of Physicists (B)	Avg. obs. (C/B)	Y. of obs. (C)	W
A less (eq) then 0.3 & less (eq) then 0.15	2734	6.85	1.14	399	6.00	2394	28%	2915	6.22	1.04	469	6.00	2814	18%
B more than 0.3 & less (eq) then 0.15	2536	17.49	2.91	145	6.00	870	10%	10330	14.13	2.36	731	6.00	4386	28%
C less (eq) then 0.3 & more then 0.15	3052	9.66	1.65	316	5.86	1853	22%	3062	9.17	1.53	334	5.98	1996	13%
D more than 0.3 & more then 0.15	5150	14.35	2.90	359	4.95	1778	21%	14981	16.97	2.86	883	5.93	5235	34%
E no-collaboration	1409	4.81	0.91	293	5.29	1550	18%	1167	5.89	0.99	198	5.95	1178	8%
Total	14881	9.84	1.76	1512	5.59	8445	100%	32455	12.41	2.08	2615	5.97	15609	100%

Italy

	ITALY 1985-1990							ITALY 2000-2005						
	Productivity			Weighting				Productivity			Weighting			
	Total (A)	Average per physicist (A/B)	Prod. (A/C)	Number of Physicists (B)	Avg. obs. (C/B)	Y. of obs. (C)	W	Total (A)	Average per physicist (A/B)	Prod. (A/C)	Number of Physicists (B)	Avg. obs. (C/B)	Y. of obs. (C)	W
A less (eq) then 0.3 & less (eq) then 0.15	1314	7.30	1.22	180	6.00	1080	15%	1091	7.47	1.25	146	6.00	876	10%
B more than 0.3 & less (eq) then 0.15	2540	11.60	1.93	219	6.00	1314	19%	6181	17.03	2.84	363	6.00	2178	26%
C less (eq) then 0.3 & more then 0.15	1861	8.99	1.53	207	5.87	1216	17%	2197	12.01	2.00	183	6.00	1098	13%
D more than 0.3 & more then 0.15	6248	11.72	2.16	533	5.44	2897	41%	15474	23.16	3.87	668	5.99	4000	47%
E no-collaboration	349	3.71	0.68	94	5.43	510	7%	231	4.53	0.75	51	6.00	306	4%
Total	12312	9.99	1.75	1233	5.69	7017	100%	25174	17.84	2.98	1411	5.99	8458	100%

Total (A) is the count of articles, Average per physicist (A/B) is the number of articles per physicist, Prod (A/C) is the number of articles per year per physicist, Y. of obs.(C) is the sum of years of evaluation of each physicist, Avg. obs. is the average number of years of evaluation of each physicist, and W is the weight of each class defined as percentage of column (C).

Table 6 Classes of collaboration, details

In both countries we find that the more the scientists collaborate, the more they are productive. Therefore scientists in class E (no-cooperation) are the less productive with only 0.75 articles per year in Italy and 0.99 in France (0.91 and 0.68 during the window 1985-1990). On the other hand, class D scientists are the most productive with the highest average productivity in both countries, in both windows of time. In principle low persistence and more extent rewards in terms of productivity. This view is consistent with the positive influence of being connected with several scientists on the generation process of new ideas, but also with the increasing specialization of science (Katz and Martin, 1997).

Over-representation of classes A and E in France (in terms of percentage weights (W) in table 6) is noticeable. Class C decreaseds size from less recent to more recent window in both countries. The class of scientists with few but durable collaborations decreases its weight from 17% and 22% to 13%. On the other hand class B, physicists with a considerable extent in collaboration but that last for short time increases, from 10%-19% to 28%-26%. Class D increases its representativeness in the recent window and in Italy accounts for the 47% of the sample against the 34% in France. The classes defined are comparable in the two countries and the scientists classified show similar collaboration strategies and productivity. Moreover estimated distributions of productivity by classes are quite well approximated by a log-normal (Shockley, 1957) (Figure 10).

France **Italy**

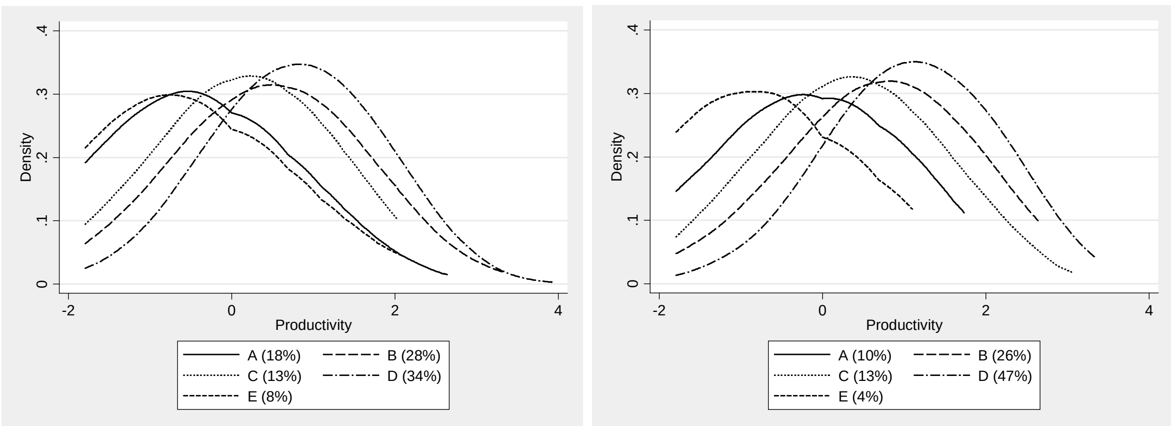


Figure 10 log(Productivity), distribution per class (2000-2005)[11]

Given the hypothesis that part of 0.9 articles per year of difference in productivity between the two countries is given by intensity of national collaborations among scientists, re-weighting the classes

[11] Individual productivity of scientist *i* is computed as in equation 5, that will be presented after

should decrease the differences in productivity measures. In the next section we implement two counter-factual exercises. First is a *re-weighting* of the classes according to sizes (W in table 6) different from actuals. In principle we evaluate France productivity in the case when French scientists act as Italian scientists in terms of collaboration, and *vice versa*. Second counter factual exercise bases on the *re-sapling*. From actual classes we generate new classes of different size by randomly drawing scientists.

3.3 Re-weighting

Given the classification of scientists we aim to reduce the differential in micro productivity between countries by changing the weights of each class. The actual weights of the French classes, in terms of percentage of total years of evaluation (W), will be assigned to Italian classes and *vice versa*. It shows how the French could be as productive as the Italians if they adopted the same collaboration strategies (i.e. same weights of the classes) and *vice versa*. In the most recent evaluation window, classes B and C have approximately the same size in France and Italy according to the weights of counter-factual exercises and actual weights. In a series of different steps we assign respectively Italian and French weights to both countries and finally we will invert the weights. Inversion penalizes Italian scientists by increasing the weights of classes A and E and by decreasing weight of class D. Class D is much more represented in Italy and therefore in the counter factual exercise it increases French productivity. The values of micro productivity, according to the inversion of the weights, are 2.30 for France and 2.63 for Italy (Table 7). Therefore, the difference between the countries in recent years downgrade to 0.33 (14%) articles per year instead of the actual 0.90. Italy is still more productive. Counter factual in first window (1985-1990) increases the difference between the two countries but in favor of France (2.27 against 1.46, -36%). In particular re-weighting France with weights of Italy doubles the size of classes D and B and reduce largely classes A and E.

The counter-factual exercise increases the average productivity of French scientists and decreases that of Italian scientists. We can infer that if French scientists collaborates as much as the Italians, their productivity would be higher in the period before the emergence of large collaborations, and only 0.33 articles per year lower in recent years, between 2000-2005 (Table 7).

	Weights (1985-1990)				Weights (2000-2005)			
Productivity	**Actual**	**Italian**	**French**	**Inverted**	**Actual**	**Italian**	**French**	**Inverted**
France	1.76	2.27	1.76	2.27	2.08	2.30	2.08	2.30
Italy	1.75	1.75	1.46	1.46	2.98	2.98	2.63	2.63
Reference FR	*0%*	*-23%*	*-17%*	*-36%*	*43%*	*29%*	*26%*	*14%*

Table 7 Counterfactual exercise: re-weighting

3.4 Re-sampling

The counter factual exercise in previous section provides an evidence of the impact of collaboration on productivity. However, it is quite simplistic and has at least four drawbacks: (1) We are evaluating only average values of productivity per class, ignoring the distribution of productivity that, in general, is quite asymmetric according to Lotka's law, moreover (2) weights of the classes are defined according to years of evaluation, therefore are not exactly based on the scientist (even if approximation is negligible). (3) We cannot statistically test the differences between productivity values of the two countries and (4) finally we are not evaluating the differences in productivity of organizations (i.e. universities and PROs).

Re-sampling procedure consists in drawing scientists from the 10 classes defined above. Newly created classes differ from the actual one for the number of scientists they include[12]. This procedure preserves approximately the productivity distribution of the original sample and the proportion of scientist belonging to the organizations (shares of academics and scientists belonging to PRO are kept constant as in the actual sample thanks to the random draw). Productivity is expressed as the average number of articles published by the scientist *i* during the window of evaluation years (Last_y-First_y)[13].

$$\text{productivity}_i = \frac{\sum_{\text{y=First\_y}}^{\text{Last\_Y}} \text{n\_articles}_{i,y}}{(\text{Last\_y - First\_y})_\text{i} + 1}$$

[Equation 5]

$$\text{Lprod}_i = \log(\text{productivity}_i)$$

[Equation 6]

[12]For example to generate a class of 100 individuals from a class made by 50, the procedure draws 100 times, randomly and with replacement, from the actual class of 50 individuals.
[13]If the window extend from 2000 to 2005 we are evaluating the scientist for 6 years

Figure 10 shows the actual classes' productivity distributions according to $Lprod_i$ (Equation 6) in windows 1985-1990 and 2000-2005.

The re-sampling counter-factual exercise requires four steps. First is a replication with actual data. We expect similar results as in previous counter-factual exercise at country level, furthermore we are now allowed to test for the impact of being affiliated to a specific organization. Second exercise generates new classes, both in Italy and France made by the same number of scientists as in Italian classes. Third we impose French number of scientists instead of Italian one and finally we invert the numbers of scientists per class in the two countries.

In each case difference in productivity according to nations or organization are tested, taking respectively as references Italians at national level and Italian academics at organization level (Table 8 and Table 9). Exercises are repeated according to the two windows of time. Classes included in the analysis are A,B,C,D and E.

1985-1990	**Actual**		**Italian**		**French**		**Inverted**	
	nation	**organization**	**nation**	**organization**	**nation**	**organization**	**nation**	**organization**
UNIVERSITY (FR)		-0.32***		0.10		-0.022		0.45***
		(0.073)		(0.084)		(0.069)		(0.083)
CNRS		0.45***		0.99***		0.80***		1.35***
		(0.079)		(0.087)		(0.077)		(0.086)
CNR		-0.19		-0.29*		-0.082		-0.20
		(0.13)		(0.15)		(0.14)		(0.16)
nation==FRANCE	0.039		0.56***		0.32***		0.90***	
	(0.062)		(0.070)		(0.060)		(0.070)	
Constant	1.73***	1.76***	1.72***	1.76***	1.46***	1.47***	1.44***	1.46***
	(0.046)	(0.049)	(0.052)	(0.055)	(0.044)	(0.046)	(0.052)	(0.054)
Observations	2745	2745	2746	2746	2745	2745	2746	2746
R-squared	0.000	0.032	0.022	0.055	0.010	0.047	0.057	0.089

Table 8 Counterfactual exercise: re-sampling (1985-1990)

2000-2005	**Actual**		**Italian**		**French**		**Inverted**	
	nation	**organization**	**nation**	**organization**	**nation**	**organization**	**nation**	**organization**
UNIVERSITY (FR)		-1.31***		-0.83***		-0.80***		-0.53***
		(0.095)		(0.11)		(0.095)		(0.11)
CNRS		-0.48***		0.0099		0.096		0.38***
		(0.10)		(0.12)		(0.10)		(0.11)
CNR		-0.37**		-0.13		-0.27		-0.094
		(0.17)		(0.21)		(0.18)		(0.20)
nation==FRANCE	-0.90***		-0.45***		-0.38***		-0.13	
	(0.082)		(0.098)		(0.082)		(0.091)	
Constant	2.98***	3.04***	2.91***	2.93***	2.56***	2.60***	2.55***	2.56***
	(0.066)	(0.071)	(0.079)	(0.086)	(0.066)	(0.072)	(0.073)	(0.079)
Observations	4026	4026	4027	4027	4025	4025	4026	4026
R-squared	0.029	0.048	0.005	0.018	0.005	0.026	0.000	0.018

Table 9 Counterfactual exercise: re-sampling (2000-2005)

In the first window 1985-1990 (Table 8) with actual classes, productivity of the two countries is not statistically different. French academics are less productive than Italians and CNRS scientists are more. The compensation effect of the dual system is evident and cancel the difference at country level. Re-sampling according to Italian size of the classes in principle do not affect Italian productivity but favors France giving less scientists to A and E classes and more to B and D. Productivity of France in fact is 0.56 articles higher then Italy, French academics are more productive then Italian academics and CNRS increases productivity up to 0.99 articles more than Italian academics. CNR is significantly less productive, 0.29 articles less. Re-sampling according to the French weights decreases the difference between the countries to 0.32 by penalizing Italy. Academics' productivity does not differ much and CNRS is the best organization in terms of productivity. When we re-sample by inverting the number of scientists per class, Italian academics are significantly less productive than French, and CNR performance is even worse, although being a PRO. CNRS distance from French academics is now 0.90 articles per year more. Figure 11 shows the estimated distribution of (log) productivity of Italian and French according to the actual weights of the classes and the inverted weights.

ACTUAL **INVERTED**

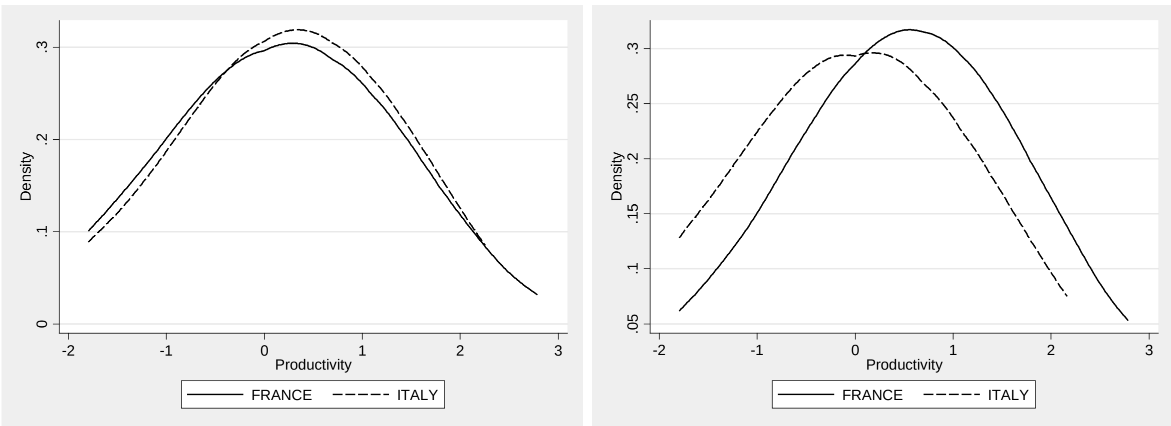


Figure 11 Estimated density of (log) productivity according to actual and inverted number of scientists per class (1985-1990)

In recent window 2000-2005 (Table 9), actual number of scientists per class shows a difference in productivity of 0.90 papers in favor of Italy. Italian academics are by far the most productive, having 1.31 articles more per year than French academics. Moreover they are more productive than both PROs (+0.48 articles if compared to CNRS and +0.37 if compared to CNR). Attribution of the Italian number of scientists per class increase French scientific productivity by 0.45 articles per year. In this case PROs are as productive as Italian academics and French academics are 0.83 articles less productive. The same happens in the case of French number of scientists per class. In the case of inverted number of scientists, the difference between Italian academics and French academics decreases to 0.53 articles and CNRS shows an higher productivity of 0.38 articles. Country difference in productivity downsize to 0.13 articles (not significant). Therefore, the difference in productivity can be explained fully by inverting collaboration strategies, as shown in Figure 12.

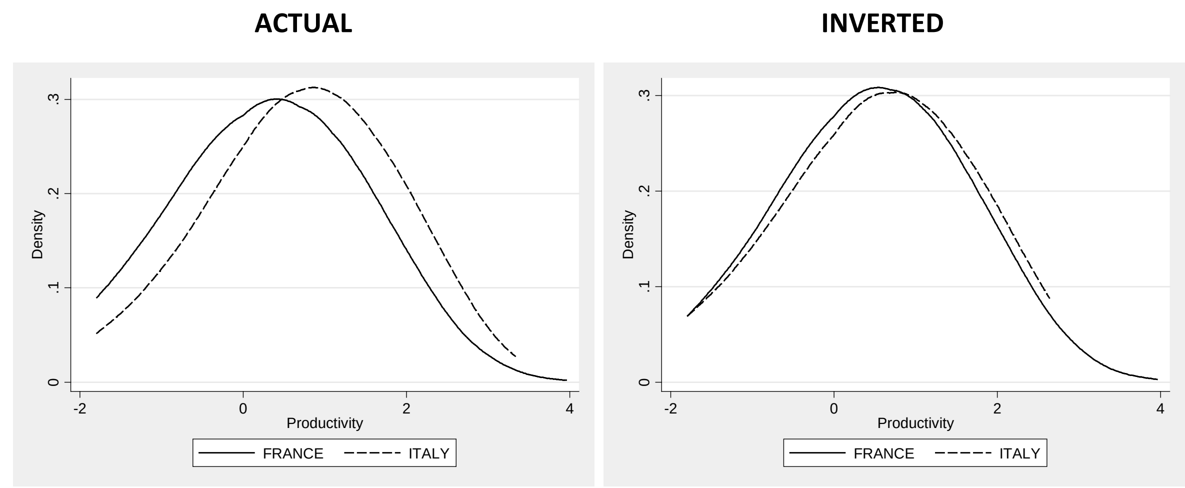


Figure 12 Estimated density of (log) productivity according to actual and inverted number of scientists per class (2000-2005)

In this section we have considered classification of scientists according to the characteristics of their collaboration network in order to explain differences in productivity, but other factors could be at play in influencing productivity. Moreover international collaboration may play a role in influencing productivity in the two countries, although less then intra-national in this case.

4 Conclusions

This chapter is divided in two sections. First section qualitatively explains the differences in individual productivity of the scientists observed in recent years, second section, according to two counterfactual exercises, shows how much productivity of French scientists changes if they collaborate as Italians, and *vice versa*.

Three main conclusions can be inferred from the first section: (1) the difference in individual productivity (or micro productivity) between Italy and France is largely reduced by considering alternative measures of productivity (macro productivity or weighting by national coauthors). The main cause of the difference in individual productivity is the higher rate of national collaboration among Italian scientists if compared to the French. (2) French research system is dual, CNRS gets the lion's share of productivity, compensating for the low productivity of French academics. This is not the case of Italy where scientific productivity of the system is supported largely by academics. (3) Around 1990 there is a substantial change in the regime of collaboration in both countries, according to the dramatic increase in the average number of coauthors per article.

The second section of the chapter evaluates the impact of collaboration strategies on individual productivity of French and Italian physicists through two counterfactual exercises. The analysis focuses on two windows of evaluation, before and after the change in the regime of collaboration (i.e. first window between 1985 and 1990; second window between 2000 and 2005). Two categories of scientists that can influence micro productivity are taken out of the sample before starting the exercises, namely: (1) scientists who do not publish at all during the evaluation period (zero productive) and (2) scientists who are classified in the fields (disciplines) of interest, but actually do research in other fields, where the average productivity is different (in our sample, this is the case of nuclear physicists). An overrepresentation of zero productive scientists is found among French academics and a substantial misspecification of nuclear physicists is found among Italian academics. Exclusion of both categories explains completely the difference in micro productivity during the first window (1985-1990). On the other hand, in the more recent window (2000-2005), the Italians still publish on average 0.90 (43%) articles more (per year per scientist) than the French. Five classes of scientists are defined according to two dimensions of collaboration: persistence (how many year a collaboration lasts on average) and extent (how many different collaborators). Based on the classes we implement the two counter-factual exercises (re-weighting and re-sampling) that aim to explain changing in productivity by changing in collaboration strategies of scientists. The conclusion that can be inferred is that: if French physicists adopted the same collaboration strategy as Italian physicists, and vice versa, the difference in micro (individual) productivity of recent years would be completely explained. In the first window (1985-1990) micro (individual) productivity of the French would be significantly higher than that of the Italians.

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