Università degli Studi di Bergamo

Productivity, Career and Collaboration in Science:

Three Studies on French and Italian Physicists

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Summary

Chapter 1 Introduction

In recent years, most European governments have been trying to reform the university and public research systems. Frequent objectives have been enhancing the competition for funds between departments and individual scientists, and promoting the collaboration between academic research and industry. The ability to evaluate the scientific standing of individual scientists and departments has therefore become a key aspect not only for policy makers facing budget constraints, but also for companies that need to take decisions on their scientific and funding priorities. At the same time, little is known on the determinants of scientists' productivity, career advancements and collaboration in specific institutional settings. Therefore policy changes are often proposed in an empirical vacuum.

The main motivation of this work is therefore to study scientific productivity, career advancements, and collaboration of individuals by means of a large panel dataset of Italian and French physicists from both universities and public research organizations (namely, CNRS for France and CNR for Italy). The dataset includes personal and environmental information on each individual, as well as detailed bibliometric data. Its depth and scope allows for three takes on the topic, each of which is presented in a separate chapter, of this dissertation.

Following a brief survey of the literature (in this chapter), chapter 2 examines the determinants of scientific productivity at the individual level. Particular emphasis is placed on distinguish between classical determinants (which have been examined by the existing literature, and apply to any country) and country-specific ones. It is argued that the national specificities of the French and Italian academic labour market make it necessary to pay special attention to cohort effects. In particular, it is remarked that state-controlled, heavily centralized academic systems such as the French and Italian ones are characterized by an alternance of "recruiting booms" and long "dry spells". The latter are time intervals during which universities can offer to young scientists only very limited chances of entry in the tenured staff ranks, and of promotion therein, either because of limited public funding or administrative stalemates due to impending and laborious reforms. An hypothesis is tested, according to which scientists who are promoted or recruited during the "recruiting booms", are persistently less productive than their peers.

Chapter 3 focuses on the determinants of career advancements in the two countries. Besides classical determinants of career advancements, I account for the impact of the scientist's social capital represented by the position in the national social network of academics. Once again, it is suggested that this type of social capital is particularly important in the French and Italian recruitment systems, due to the control exercised by national disciplinary associations in the recruitment and promotion processes.

Chapter 4 analyses the outcomes of collaboration among scientists. In particular, it focuses on some empirical evidence on differences between French and Italian scientists, with respect both to individual productivity and to propensity to multi-authorship.

All chapters make use of econometric methods and statistical concepts which lie at the core of the economics of science, a field of enquiry which has reached a high disciplinary status and widespread recognition within the economic profession only in recent years. Despite its short history, however, the economics of science has deep roots in psychological and sociological studies that date back to the nineteenth century. The following section aims to give a picture of the evolution from such classic studies to the modern economics of science.

1.1 Scientific productivity studies: From Sir Francis Galton to the economics of science

The first systematic enquiries on the measurement and explanation of scientific productivity date back to Sir Francis Galton (1822-1911), now remembered both the father of eugenics (a now disreputed discipline) and a key figure of modern statistics (credited, among other things, of having introduced terms such as correlation and regression in our vocabulary). According to Godin (2007), Galton's book on "*Hereditary Genius"* (Galton, 1869) is possibly the first study that makes use of systematic measures and statistical tools. Galton's work aimed at measuring the frequency and characteristics of "eminent men" (the men recognized by the society as *geniuses*) in a population. The principle taken for granted was that the more eminent men are present, the more will be the contribution to the development and the welfare of society. Galton identified his "eminent men" by ranking the most illustrious people according to the information on the bibliographical handbook *Man Of Time*. His explanation of the reasons why a man becomes eminent focused on heredity and eugenics transmission of intellectual capabilities. Galton strongly believed that the talent and capacities of exceptional man are handed down genetically among individuals. In order to prove this theory he assessed the family histories of the individuals to whom he attributed non-common intellectual ability in several fields, the latter being renowned judges, statesman, commanders, literary men, poets, musicians, painters, and divines and men of science. One of the main hypothesis in the Galton's work is that intellectual ability is normally distributed in the population.

Another notable work of Galton is the *English Men of Science* (Galton, 1874), based on a survey submitted to a selected list of eminent man. From this survey, according to his interpretation, emerges that the large part of eminent man have an innate taste for science genetically driven and that the number of children of eminent men is lowering if compared to the children of the previous generation. From this two facts he concludes that there is an unequivocal trend of extinction of the eminent families. One of the greatest merit of Galton' work is the idea of systematic collection of data on men of science and the regular statistical analysis conducted.

Following the lead of Galton's ideas, the US experimental psychologists James McKeen Cattell (1860-1944), editor of the scientific journal S*cience*, started collecting data in the directory *American Man of Science.* Cattell put more emphasis on the activities of observation, classification, measure, ranking and comparison, but preserved the focus of the analysis on the number of "eminent man", as Galton did. In the following years sociologists and economists of science will privilege measures of productivity and quality according to the count of scientific articles and citations. This approach allows to include in the analysis not only the "eminent man", but to bring into the analysis also the scientists of lower reputation, that however contribute to the production of scientific knowledge.

Cattell put side by side the importance of heredity and environmental factors in generating eminent man of science. He accounted also for the information on country, university and department of affiliation to assess productivity. Thanks to the survey questions about birthplace and residence he partially contradicted Galton's conclusion on hereditary of intellectual ability, by showing that men of science are concentrated in specific areas of the country and are rare in others, which is evidence of the influence of socio-economic conditions on the "productivity" of eminent men (Cattell et al., 1906). Cattell's conclusion, according also to other studies on other non-hereditary causes of the genius, was that hereditary explanation is not exclusive, like it was for Galton, but other socio-economic and environmental factors are at play.

Another intuition, formalized later on by Alfred Lotka (1880-1949), was that individual qualities of scientists are not normally distributed, as hypothesized by Galton, but follows an exponential distribution. The functional form representing such productivity distribution dates back to Lotka (1926) and has been confirmed after by several later studies. Lotka's law shows that few eminent scientists are responsible for the large part of the scientific productivity or, in other words, that the distribution of scientific productivity is extremely skewed. Finally, a contribution by Cattell was also to rank for the first time the institutions tabulating the universities according to the merit of their affiliated scientists (Cattell et al., 1906).

The eugenic explanation considered by Galton and Cattell was progressively abandoned by the largest part of sociologists and economists of science in the following years, in favor of other explanations related to three major categories: individual-level characteristics (without reference to heredity), environmental characteristics, and processes of cumulative advantages.

Nowadays, one of the most studied determinants of productivity is the impact of career life-cycles on research activity (Levin and Stephan, 1991; Stephan, 1996; Hall et al., 2007). Publications count is widely used as a proxy for research activity, but isolating the impact of life-cycle (economists and sociologists often use age as a proxy) rises problems mainly due to the fact that it is difficult to identify three mixed, but logically separate effects: age, cohort and period[1]. The issue bases on the fact that *"…there is an obvious impossibility of observing two individuals at the same point in time that have the same age but were born in different years…"* (Hall et al., 2007). To disentangle the three effects is a not trivial issue and needs large panel data to be analyzed. Levin and Stephan (1991) show that there is a life-cycle effect in science common in many fields, in particular the publishing activity increases, reaches a peak and, finally, declines. The peak and the rate of growth and decline of publication activity is different according to the field. Although life-cycle explanation is generally accepted as one of the determinants of productivity the low explanatory power of these models shows clearly that other important factors are at play in affecting productivity. A number of alternative hypotheses have been advanced to account for observed productivity decline (Fox, 1983).

Another important line of research refers to the gender effect on productivity (Fox, 2005; Long, 1992; Levin and Stephan, 1998). When looking at descriptive statistics, it is often found that women appear to be less productive than men, and also to progress less in career and remuneration. Econometric studies try to assess the relative weight of three possible explanations: differences in ability and motivations, family engagements, and explicit discrimination. Fox (1981) documents the impact of gender on salaries controlling for other characteristics like age, position, race and education. Levin and Stephan (1998) find little evidence of gender discrimination in terms of rewards controlling for scientific productivity. According to Cole and Zuckerman (1984) women are excluded from the most relevant social network of scientists. Fox (2005), instead of accounting only for the simple gender effect, examines how related characteristics of the family like marital status, presence and age of children, impact on scientific productivity. Several other reasons have been put forward to explain why women appear to be less productive than men: lower graduation rate from prestigious universities, family engagements, less interest in pure research.

Another branch of studies focuses on the role played by the university department in affecting scientific productivity of scientists (Crane, 1965; Allison and Long, 1990). In the US there is a strong heterogeneity of the quality of the departments among universities. The stratification is so strong that the impact on scientific productivity of the scientist is not negligible. One of the main point of this analysis is the possible endogeneity between scientist's productivity and the department where she works. Long and Allison (1990)

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[1]We refer to age as the biological age of the individual. Individuals belonging to the same cohort are those who pass some crucial stage approximately at the same time. Cohort is usually intended as cohort of birth but may be also defined according to job market conditions, year when PhD is granted, marriage. An example of cohort in economics of science is that of the scientists who got their PhD during 1960. Those scientists experienced their first employment during a period of particularly favorable conditions of the scientific labor market. Period is the calendar year observed. All the cohorts of scientist, for example, may experience incentive in publishing activity according to the emergence of electronic journals, or some specific events that affect all the cohorts in a specific calendar year. The identification problem is related to the fact that in a linear model we cannot disentangle the three effects because one variable can be expressed as a liner combination of the other two: age=year-cohort of birth.

discuss the difficulty of identifying a clear causal link: is it the case that good departments encourage and facilitate research productivity, or that productive scientists managed to get hired by good departments? Although the latter explanation (known as *selection hypothesis*) is the more frequent in the sociological literature, the former one (*departmental effects hypothesis*) should be considered for at last three reasons, as listed by Long and Allison. First, best departments own best facilities and equipments, therefore, this could facilitate the productivity of the scientist. In some disciplines, like physics, the need of large and expensive equipments is one of the substantial driver of the productivity of the research. Moreover, research resources in science are not only tangible but also human resources. The importance of the contribution of qualified workers, like post-docs and graduate students, is not negligible. Second, better departments manage to provide more intellectual stimulation and denser networks of interactions precisely because they hire better scientists. Third, the motivational effect has to be taken into account, which consist in the stronger pressure that better departments exercise on their scientists in terms of publications required. Long and Allison show, by making use of panel data instead of the cross-sectional figures prevailing before their contribution, that the departmental effects are stronger than selection ones. Diane Crane (1969 and 1972) proposes, instead of focusing only on formalized structures like university departments, to account also for informal patterns of interpersonal contact defined as “invisible colleges”. For example, the members *Royal Society of London* do not belong to a formal institution but are geographically close and have regular meetings.

Finally, one of the most diffused processes in recent years that impacts on individual productivity, is the sharing of scientist’s specific knowledge and skills in large research teams to gain from specialization of the tasks. This is showed by the empirically observed dramatic growing trend of the average number of authors in the scientific papers.

Another appealing explanation of the heterogeneous performance of scientists is the so called *Matthew effect* proposed by Robert K. Merton, who is regarded as the founding father of sociology of science as a specific discipline. In economic jargon, the Matthew effect consists of increasing returns to scientific reputation. When commenting a number of interviews to Nobel laureates by Harriet Zuckerman, Merton remarked that *“…eminent scientists get disproportionately great credit for their contributions to science while relatively unknown scientists tend to get disproportionately little credit for comparable contributions…*” (Merton, 1968). It happens in the case of collaboration, for example in coauthored papers, where the scientist of established reputation gains more recognition. It also happens in the case of independent multiple discoveries, where the reward for the discovery is probably given to the most famous scientist. Merton named this process of misallocation of credit for scientific work “Matthew effect” from the parable of St. Matthew that, paraphrased in the scientific context, *“…consists in the accruing of greater increments of recognition for particular scientific contributions to scientists of considerable repute and the* *withholding of such recognition from scientists who have not yet made their mark…"* (Merton, 1968). Merton proposed also an institutional interpretation of Matthew effect, according to which the centers of scientific excellence are more likely to attract resources, funds, and better scientists according to their past reputation. Many later sociologists generalized the Matthew Effect by speaking of a more generic process of cumulative advantage that attributes productivity differences to the differential resources assigned to the scientists because of their earlier productivity. Therefore, according to cumulative advantage, scientists who experienced early success are able to obtain more time, facilities, and support for their research (Allison and Stewart, 1974).

In recent years, economists have stepped in side by side to sociologists in contributing to the systematic study of social mechanisms within science. Economists of science have inherited from sociologists of science the long tradition of quantitative studies focused on the description and explanation of mechanisms acting in the scientific reward system. In this field, another important contribution of Merton, is related to the study of priority and the self-developed system of reward in science. In particular he suggested that the reward system in science incentives the production of knowledge as a public good, that is as a good characterized by non-excludability and non-appropriability. The non-market system autonomously developed in science gives to the scientists a strong incentive to disclose their findings quickly and widely to fix priority, being the first scientist who discovers the only one rewarded. In particular it is crucial that in science evolved a non-market system that provides incentives to the scientists to behave in socially responsible ways disclosing the information on research results from which society can benefit (Stephan, 1996). The most important mechanism that incentives the scientists is the fact that the reward is assigned by the scientific community to the first who discovers. Therefore, the priority is something that has to be established quickly through the publication of results on scientific journals (Merton, 1957). Moreover publication *"…allow(s) scientists to verify the reliability of information, to acquire a sense of the relative importance of a contribution, and to obtain a critical response to work…"* (Fox, 1983). The whole mechanism is clearly a winner-take-all process where only the first who make the discovery gains the reward. Stephan (1996) lists three kinds of reward for scientists. First is financial remuneration in form of monetary prizes or, more indirect, in terms of influence on the wage variable part and the scientist's career (e.g. stock of publications influences career advancement). There is also a strong anecdotal evidence that, for scientists, part of the reward given by research activity is the pure taste of the solution of the puzzle. Last form of reward is the recognition given to the scientist by peers (i.e. the scientific community).

The imbalance in this brief introduction in favor of studies on scientific productivity reflects the same imbalance found in literature. Few studies, almost based on US data, focus on career advancements and collaboration in science. According to the classical view, scientists with high productivity should be rewarded, among other things, by career advancements. Therefore the main cause of career progress should be the scientific productivity. This interpretation could be suitable in US institutional setting where the flexibility of the labour market and autonomy of universities are higher than in Europe, although several studies have shown that it is not always the case. In more centralized institutional settings like Italy and France, other mechanisms could be at play in determining the chances of promotion.

Collaboration among scientists is another field do not explored intensively. The large part of the studies are strictly related to the evaluation of technical issues to account for multi-authored papers when measuring scientific productivity. The entire literature is again based on US data although some exceptions (Mairesse et *al.*, 2005).

Chapter 2 Scientific Productivity and Academic Promotion[1]

2.1 Introduction

Countries exhibit very substantial differences in their scientific productivity that are often attributed to a large extent to differences in the institutional settings of research activities (May, 1997; King, 2004). However, most of the available studies on scientists' productivity and careers are based upon US data and the theoretical insights and policy implications that they suggest take for granted the institutional characteristics of the US universities (Long, 1978; Allison and Long, 1990; Levin and Stephan, 1991; Lee and Bozeman, 2005). Little is known in fact on the determinants of scientists' productivity in European countries and their institutional settings. European academic governance and organisation differ substantially both from what they are in the US and among themselves, the most important differences being related to the degree of autonomy of universities and the magnitude of their resources, the size and flexibility of the academic job market, and also the relative weight and quality of universities and public research organizations (PROs) within national science systems.

In this paper we study various determinants of scientific productivity of physicists in French and Italian universities in the explicit context of the academic career mechanisms typical of the two countries. In both France and Italy, professors (both junior and senior) are civil servants recruited and promoted through centralized procedures controlled by the State. Universities have in fact very limited autonomy and have also to compete for human and research resources with large PROs (especially important in France). We hope that our investigation will contribute in assessing to what extent individual scientist productivity and career are affected by similar determinants in the French and Italian settings and beyond that it will help in understanding whether and how such determinants can shape them very differently than in the US.

We thus investigate the effects of age, gender, cohort of entry and productivity of past research activity both on the current productivity of the academic physicists in the two countries and on their probability of being promoted. We also consider the role of size and international nature of projects and the influence of co-authors productivity on individual productivity. We analyse in particular whether the frequent stop-and-go policies of recruitment and promotion, which are typical of the Italian and French centralized systems of university governance, have led to significant long-lasting cohort effects on productivity.

We have constructed a panel of about 3600 academic physicists in France and Italy, covering most of the physicists active in academic year 2004-05 in the two countries, with the exception of nuclear and astro-physicists. To measure their productivity, going back to their first publications for the younger ones and to 1975 for the older ones, we make use of the information from the ISI-Web of Science pertaining to a set of

[1] This chapter is largely based on joint work with Francesco Lissoni, Fabio Montobbio, Jacques Mairesse; see Lissoni et al. (2009)

some 360 journals covering most specialized journals in physics with some reputation (i.e., with at least a five-year impact factor of 0.5 in average). We assess their productivity both in terms of “quantity” and of “quality”, respectively by the total number per year of their articles in this set of journals, and by the average impact factor per article per year of these articles computed on the basis of the impact factors of the specific journals in which they have been published.

We consider five productivity regressions, both in terms of quantity and quality, one for each main position in the academic ranking of the two countries from assistant to full professor: precisely Maitre de Conférence (MCF) and Professeur (PR) in France, and Ricercatore Universitario (RU), Professore Associato (PA) and Professore Ordinario (PO) in Italy. We also specify three selection probit equations accounting for the individual scientist’s probability of promotion from respectively MCF to PR, RU to PA and PA to PO. The three productivity regressions for PR, PA and PO are estimated jointly with the three corresponding promotion equations as a generalized Tobit model by means of Heckman two-step method. Estimating a productivity regression for each rank, and jointly with a promotion probit equation for professors helps in controlling for unobserved individual heterogeneity across ranks and in correcting for selectivity in promotion to professorship. We also take care of individual heterogeneity among individual physicists by including past productivity variables in all equations: three year average lagged productivity in the promotion probit equations, and average productivity before recruitment (for MCF and RU) or promotion (for PR, PA and PO) in the productivity regressions.

As expected from previous literature, our results confirm the existence of age and gender effects both on the probability to be promoted professor and on productivity conditional on academic rank, although with some differences between ranks and the two countries. They also confirm that physicists’ own past productivity has very significant positive impacts on promotion probability and current productivity. We find that the size and international nature of collaborative projects and coauthors’ past productivity are also influential determinants of current productivity. Finally, we provide significant evidence that the physicists recruited or promoted in 1980 in Italy and in 1985 in France (when massive recruitment and promotion waves took place after several years with limited career opportunities) are on average less productive than the other physicists, showing the damaging and long-lasting effects of the stops-and-goes in recruitment and promotion policies typical of the two centralized academic systems.

The remainder of the paper is organized as follows. In section 2.2 we very briefly outline the background literature, and in section 2.3 we present the institutional features and relevant historical developments of the French and Italian academic systems in the past 30 years. In section 2.4 we explain our data and justify our choice of econometric specification, and in section 2.5 we comment in detail our results. Section 2.6 concludes.

2.2 Background literature

Interest in the determinants of individual scientist productivity goes back to the XIX century[2]. From the very start, enquiries on scientific productivity were meant to cast light on a two separate issues: the soundness of eugenic principles proposed by Sir Francis Galton, whose studies on the "hereditary genius" had been largely based on the demographics of "eminent men of science"; and the impact of academic institutional arrangements and incentive schemes on a country scientific performance, as measured by the number of outstanding scientists from that country (Cattell, 1903; Godin, 2006; Godin 2007)[3]. Both the issues have been debated ever since and are still present in today's studies, although quite often in a disguised manner.

Since the 1960s, sociologists of science have tested whether increasing returns to scientific reputation and productivity (presently referred to as "Matthew effect") may explain Lotka's law better than the unequal distribution of intelligence in the population (Merton, 1968; Merton, 1988; David 1994). A typical result in this direction has been obtained by Long and Fox (1995), who find that, other things being equal, graduates from prestigious universities have a higher chance to get their first job at institutions in the same league, with substantial advantages in terms of present and future research productivity. As for individual determinants, gender is the one that has attracted most of the attention, with cognitive and genetic explanations of gender differences (as opposed to social ones) being still debated (Etzkowitz *et al.*, 2000; Fox, 1999; Spelke, 2005).

Understanding the relationship between academic institutions, incentive schemes, and scientists' performance has become increasingly important over the last 30 years or so. This surge of interest can be explained by the policy makers' wish to measure and increase the effectiveness of the public funding of science. Leading research universities and scientists, facing possible budget cuts, have also actively lobbied in favour of a higher concentration of resources on the basis of publication and citation-based indicators of excellence (Graham and Diamond, 1997).

An important line of research explores the impact of age and tenure on scientists' productivity. In particular, many studies have explored the possibility that individual scientific productivity follows a life cycle: productivity increases when the scientist is young, reaches a peak at/before middle age, and declines afterwards (Levin and Stephan, 1991). At the same time, studies on tenure have tried to clarify whether observable life cycles are due to biological factors or to the incentive structure, such as the reduced "publish-or-perish" pressure on senior scientists with tenured positions. In a rare study on a non-US

[2] James Cattell published in 1903 the first systematic data collection on scientific papers per author and provided strong evidence of the existence of large differences across individuals, a result later systematized by Alfred Lotka's well-known "power law"(Lotka, 1926).

[3] A third purpose served by these early enquiries was the study of disciplines, from their birth to consolidation. This is still a very much beaten path, although recent studies add to simple paper counts increasingly sophisticated applications of network analysis (Crane, 1972).

sample, Turner and Mairesse (2002) find that while promotion has a positive effect on the quantity and quality of publications, the time spent on the same tenured senior position has a negative impact on both variables. They also show that being a member of a highly productive laboratory fuels individual productivity. This confirms that some institutional variables, such as the stratification of universities according to prestige and funding, may generate increasing returns in science.

2.3 Recruitment and careers of academic scientists in France and Italy

Most of the available literature on scientific productivity is based both theoretically and empirically on the US case. This is an important limitation, because the latter is not representative of university systems worldwide[4]. The centrality of universities for public science, the degree of academic job mobility, and the clear stratification of universities according to research intensity are typical characteristics of the US (Ben-David, 1992; Clark, 1993). In countries such as France and Germany, for example, large public research organizations such as CNRS (*Centre National de la Recherche Scientifique*) or the Max Plank Institute have been regarded by policy makers as the main pillars of the public research system; Italy also followed this model for many years with CNR (*Consiglio Nazionale delle Ricerche*).

As for job mobility, we observe that US universities select candidates for professorial jobs in total autonomy, with no control from the central (federal) or state governments. Professors of all ranks are university employees who can bargain for their wages and working conditions on an individual basis; in addition, the existence of a proper academic job market allows scientists with a strong publication record to move across universities in search of better paid or better funded research positions (Ehrenberg *et al.*, 1990). This is hardly the case in France and Italy. In these centralized systems university staffs are considered civil servants, who are employed by the government and selected by commissions of senior peers, chosen by national members of the relevant discipline or nominated by government. In these countries, there is not a strong competition between universities for recruiting or promoting the most promising or productive scientists.

At the same time, strict dependence of universities on government funding (which tend to be highly pro-cyclical) and the frequent reforms of the recruitment procedures tend to make career perspectives highly erratic. Italy, for example, has a long history of prolonged periods during which universities do not recruit any new scientist, due to funding shortages or ongoing policy revision, followed by sudden waves of strong recruitment and promotion, often under the political pressure exerted by the large number of scientists seeking a tenured position after many years of temporary contracts.

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[4] Noteworthy exceptions are Turner and Mairesse (2002), Bonaccorsi and Daraio (2003), Hall et al. (2005), Mairesse and Turner (2006), and Breschi *et al.* (2007, 2008).

2.3.1 Academic careers in France and Italy

The French academic system has two main positions: "*Maitre de conférence*" (MCF; roughly equivalent to the US rank of assistant professor) and "*Professeur*" (PR). In Italy there are three positions: "*Ricercatore universitario*" (RU), "*Professore associato*" (PA) and "*Professore ordinario*" (PO). In French physics, MCF amount to around two thirds of tenured faculty, while in Italy RU, PA and PO each amount for around one third of tenured faculty (see figure 1).

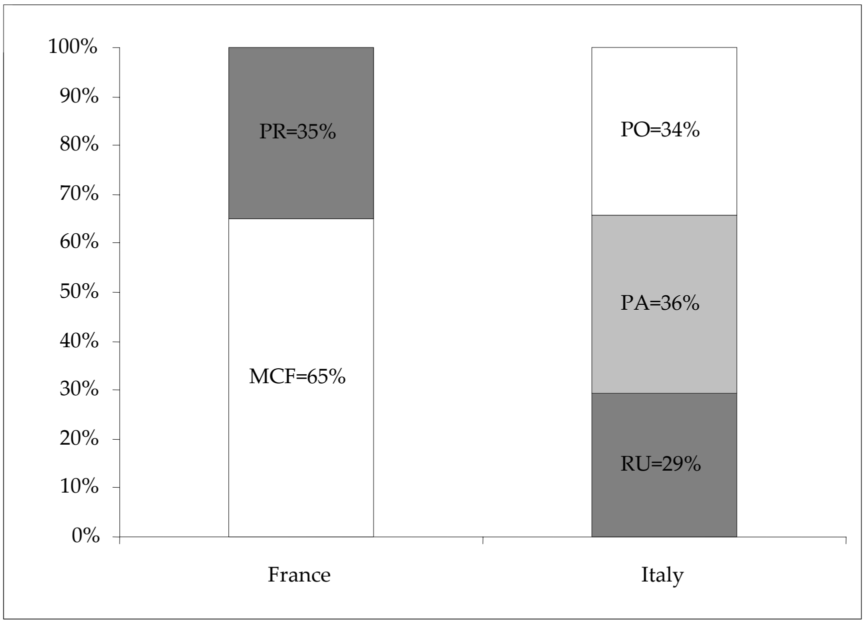

Figure 1 Rank distribution of physicists active in 2004-05 in France (MCF, PR) and in Italy (RU, PA, PO)

All positions are tenured, and for all of them the teaching and research duties, as well as the wages, are defined by national laws, with limited possibility of negotiation at the local level. Whatever their rank, academics are classified by the government according to their discipline. Such disciplines act very much as professional guilds, since their members (and not individual universities or department) control the recruitment process[5]. Before accessing any of the above-mentioned positions (most often RU in Italy and MCF in France) young scientists go through post-doc positions of various lengths. Universities that wish to recruit a young scientist or promote any member of the academic staff are subject to a series of administrative constraints, which limit their freedom to allocate funds to recruitment or career progress in the absence of governmental approval, and require them to follow a set of complex procedures to place a job call and collect the related applications. In addition, the job calls may be suspended by the government

[5] Notice also that the US system is openly stratified according to the research *vs*. teaching intensity of institutions. On the contrary, both the Italian and French laws forbid universities to differentiate openly their mission, and to assign different research versus teaching loads to the faculty.

at any time for either financial or regulatory reasons, forcing universities to delay their recruitment or promotion plans.

In Italy and France, these constraints have often clashed against an increasing demand for higher education instruction, whose growth was particularly intense in the 1960s and 70s. Both countries answered to the growing number of students of those years by hiring a large number of young assistants with fixed-terms contracts or when tenured weak prospects of promotion (p*rofessori incaricati* as well as *contrattisti* and *assegnisti* in Italy, and *assistants* and *maitres assistants* in France). In early 1980s, two reform acts were passed: law 382 in Italy (in 1980) and the Higher Education Act in France (in 1984). Both laws reformed the recruitment process by introducing the ranking system we described above, and by changing the hiring rules. At the same time, a number of *ad hoc* measures were passed along with the new laws, which were meant to allow many *professori incaricati* and *assistants* to obtain tenured positions as *ricercatori* or *professori associati* in Italy, or *maitres de conférence* in France. In Italy, the *ad hoc* procedures were merely formal and candidates did not face any selective competition[6] (Clark, 1977; Moscati, 2001). As a result, in each country there was a massive recruitment wave (respectively in 1980 and 1985), followed by a prolonged period without any recruitment in Italy, and by a sensible decline in recruitment in France. Figures 2 and 3 illustrate this effect for the field of physics: they report the number of scientists - who were on active duty in 2004-05 - by year of recruitment (for RU and MCF) or year of the last promotion (for those in professorial positions). The 1980 and 1985 entry/promotion peaks are clearly visible.

[6] See article 59 Décret n 84-431 du 6 juin 1984 for France and article 50 and 57 DPR 382/1980 for Italy. These laws can be found (in original language) on the following French and Italian websites: http://www.legifrance.gouv.fr/ and http://www.pd.infn.it/infn_ric/GruppiLavoro/Stato_Giuridico/Stato%20Giuridico%20Universitari_DPR382_1980.html

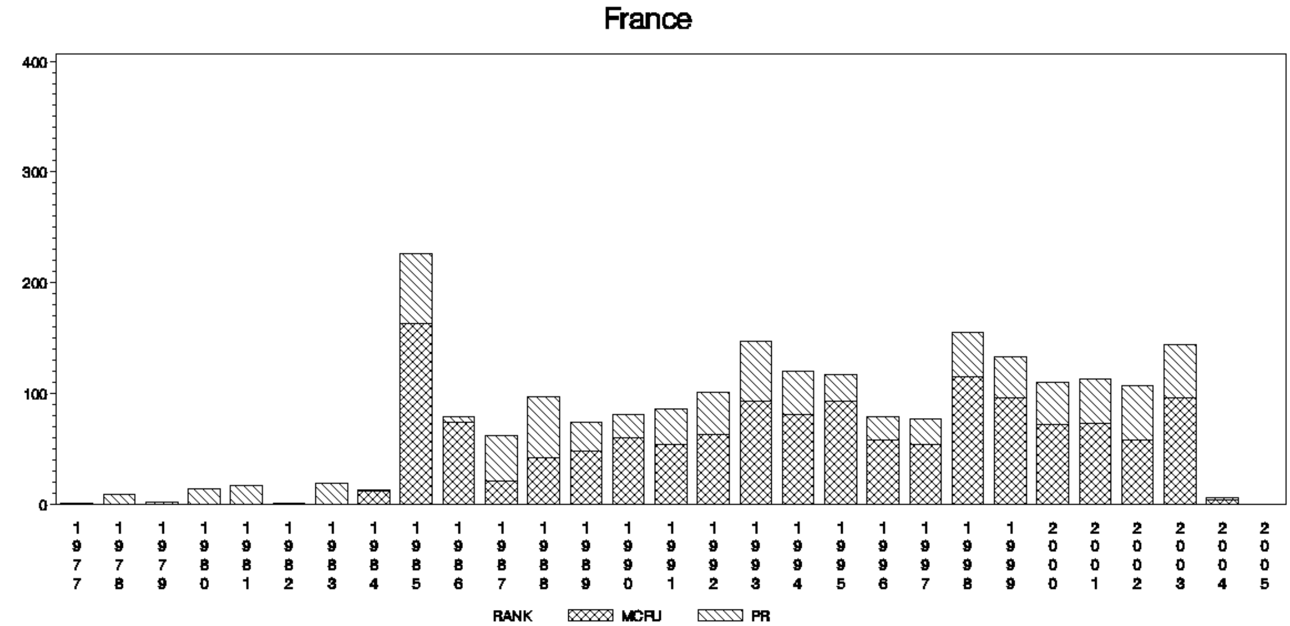

Figure 2 Distribution of physicists active in 2004-05 in France by year of recruitment (MCF) or year of last promotion (PR)

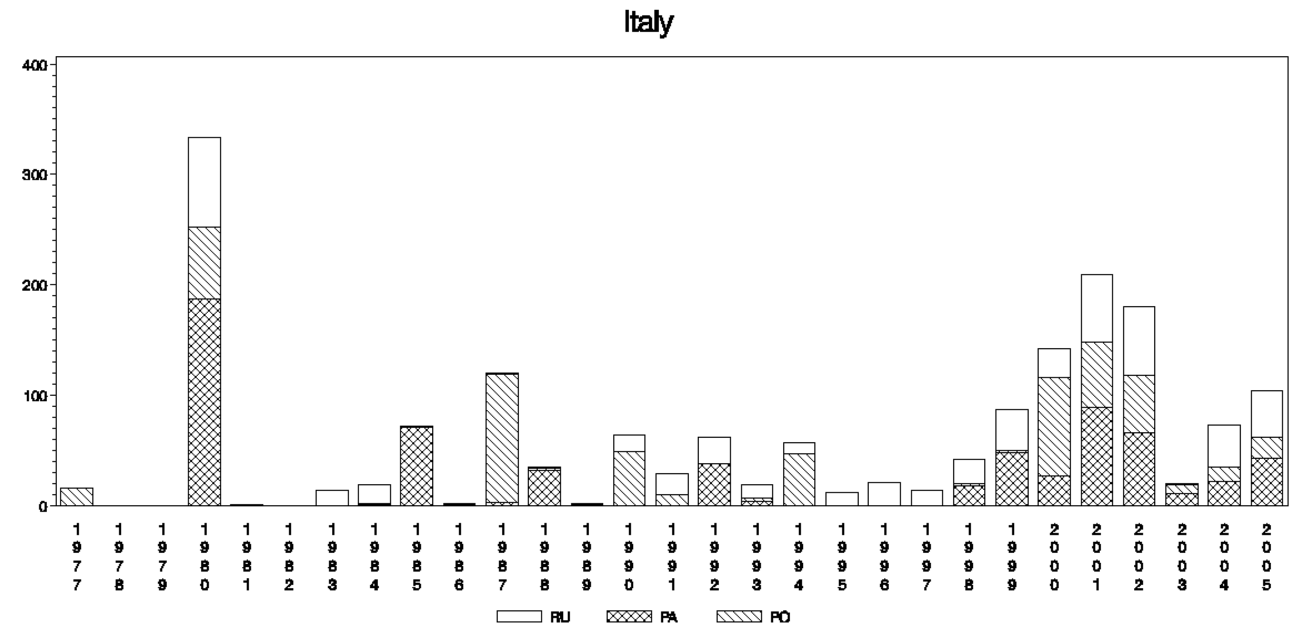

Figure 3 Distribution of physicists active in 2004-05 in Italy by year of recruitment (RU) or year of last promotion (PA; PO)

The 1980 and 1984 laws also had lasting effects on the selection procedures. In Italy, it was established that the promotion to PA and PO had to occur at a national level, for a number of positions issued every other year by the ministry, and managed by a professors' committee whose members were first chosen by all peers in each discipline, and then further selected by the ministry. As for RU, these were selected at the university level by a committee of three PA and PO, all appointed by the ministry. Together with the universities' lack of financial autonomy, this highly centralized system soon became responsible for a number of difficulties in speeding up the recruitment process by universities throughout the 1980s and early 1990s (see again Figure 3).

In 1998 a new recruitment system was introduced, which was still in place at the time of our study[7]. The system allows each university to offer new positions by launching its own call for applications (*concorso*), and to set up an examination committee. All the committee members, however, must belong to the same discipline for which the position is offered and (with the exception of just one member) not selected by the university, but elected by all the discipline affiliates at the national level. Nominally, the commission has not the task to pick the most suitable candidate for the university that launched the call (on the basis, for example, of the coincidence of the candidate's and the university's research interests), but the best possible candidate in absolute terms, who should be the one with the best publication record (called "*idoneo*", which means *fit-for-the-job*). In principle, if the university does not like this candidate, it can always refuse to nominate him/her and launch a new job call. In practice, most commissions try to steer the selection process towards suitable candidates for the university.[8] Once again the introduction of the new law coincided with a new wave of recruitment; although less dramatic than the 1980 one, it is still visible in Figure 2, over the years between 1999 and 2001.

The French recruitment system is also very centralized and discipline-centred[9]. Every year, the central government issues a list of vacancies, by discipline and institution, both for the MCF and PR positions. The applicants need first to get a *qualification* certificate, which is granted by the CNU (*Conseil National des Universités*) – whose members are partly elected and partly designated by the Ministry of Education. Once obtained, the *qualification* is valid for four years and the qualified candidates are the only ones who can apply for the vacant positions. Applications will then be examined at the university level, by disciplinary commissions, composed both of local and non-local members[10].

Both the Italian and the French recruitment systems have undergone severe criticism over the years, which resulted in a succession of reforms that shifted the balance of decision power in recruitment matters back and forth between the national and local level (Chevaillier, 2001; Moscati, 2001; Musselin, 2005). None of these reforms, however, has gone as far as to grant universities total freedom in recruitment matters, nor has it diminished much the power of disciplines. More importantly, the procedural uncertainty created by

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[7] While we revised the paper, the Ministry of Education announced a new change in the recruitment laws, which by June 2009, however, had not yet been entirely disclosed to the Parliament.

[8] This requires many behind-the–scene manoeuvres by the university, aimed at steering the election of the committee members in favour of friendly candidates. For a more in-depth discussion of this point, and of its consequences for academic careers in Italy, see chapter 3

[9] In August 2007, the Sarkozy presidency initiated a number of much debated and still on-going reforms which are aimed at giving autonomy to universities by shifting powers and administration of resources from the Ministry to them.

[10] These disciplinary commissions are made up of 10 to 20 members, coming both from the discipline or possibly other disciplines in the university, and from the discipline in other universities. These commissions, in which PR and MCF sit in equal number, are elected for 4 years; they meet to deliberate on the recruitment of MCF in plenary formation, and on the promotion of PR in a formation restricted to PR.

this succession of reforms, combined with repeated cuts in the public spending for universities, has made the recruitment process very irregular over time.

Time irregularities in recruitment and career advancement mechanisms determine the age composition of the academic workforce. Table 1 reports the number of physicists in France and Italy in 2004-05 by rank and decade of birth. As expected, the lower academic ranks are populated by younger scientists in both countries. However, in Italy the top academic rank (PO) is populated by much older scientists than its French equivalent (PR): while in France 19.6% of the full professors (PR) were born in the 1960s, in Italy the percentage of PO from the same decade is only 2.6%. Although less striking, such differences in age composition hold also for the lower ranks: only 11.6% of Italian RU were born in the 1970s, as opposed to 25.0% of French MCF. This is a very likely consequence of the higher emphasis on seniority-career links in Italy, and of the higher irregularity of the Italian recruitment process.

	COHORT					
	1930s	**1940s**	**1950s**	**1960s**	**1970s**	**Total**
France-Ranks:						
PR	23	423	179	153	3	781
% by cohort	*2.94*	*54.16*	*22.92*	*19.59*	*0.38*	*100*
MCF	12	341	134	586	357	1430
% by cohort	*0.84*	*23.85*	*9.37*	*40.98*	*24.97*	*100*
						2211
Italy-Ranks:						
PO	168	301	137	16		622
% by cohort	*27.01*	*48.39*	*22.03*	*2.57*		*100*
PA	72	222	177	187	3	661
% by cohort	*10.89*	*33.59*	*26.78*	*28.29*	*0.45*	*100*
RU	1	54	115	301	62	533
% by cohort	*0.19*	*10.13*	*21.58*	*56.47*	*11.63*	*100*
						1816
Total	276	1341	742	1243	425	*4027*

Note: Computed on French and Italian overall samples (before cleaning) see Section 4.

Table 1 Number of physicists active in 2004-05 in France and Italy by cohort of birth and rank.

Finally, an important institutional feature of both the French and the Italian research systems is the role of large PROs such as CNRS and CNR, respectively. In France, CNRS has been traditionally regarded as the most important actor of the research system (even more so in physics, with the exception of nuclear physics, where that role is contended by CEA, a special agency for atomic energy). As such, it has often out-competed universities in attracting the best and most motivated young scientists, who may perceive the academic position of MCF as overloaded with teaching and administrative duties (not so much the professor's position, which is often targeted by CNRS *Chargés de recherche*). In Italy, the history of CNR starts similarly to that of CNRS, which indeed was taken as a model for its creation, in the late 1930s. Badly hit by successive budget cuts, the CNR has progressively lost its centrality in the Italian research system, as well as the possibility to offer permanent positions to young scientists. This implies that while French universities have at least one competitor in the academic labour market, Italian universities have none.[11]

2.3.2 Implications for scientific productivity

The analysis of the recruitment process in the two countries, and of the relative balance of universities and PROs inside the research system, suggests some observations on the factors affecting scientific productivity. In principle, productivity is a key determinant of career advancement in both countries, at least for senior positions. In a related paper we show that this is indeed the case in France for moves up to PR positions, and in Italy for promotion from RU to PA but less so for promotion from PA to PO (see chapter 3). As a consequence, other things being equal, we should expect scientists who are currently on higher positions to be more productive than those in lower ones. We should also expect such scientists to exhibit a less pronounced life cycle that is to be highly productive over a longer time spell, and to incur a productivity slowdown at a later age. However, especially for Italy, informal recruitment and promotion practices push in the direction of career by seniority and can give great advantages to local candidates, no matter their productivity. If these effects were dominant, they would significantly weaken the effectiveness of incentives to high productivity.

We also expect to find strong effect for the different years of entry/promotion both in Italy and France, for at least three reasons. First, access to tenured academic positions has increasingly become more difficult over the 1980s and 1990s, so we may presume that scientists who have been recruited over these two decades are more productive than their predecessors. Second, late generations of scientists have more international experience and may be expected to find it easier to publish in international journals, which in our data are better represented than the national journals. Last, cohorts of scientists recruited *en masse* over short periods of time (after periods of no recruitment) could be either more productive or less productive than the average. We expect the RU, PA and MCF that entered the university system in 1980 in Italy and 1985 in France (or reached their last academic rank), to be less productive, due to the explicit lack of selective pressure in those two years. We do not have any *a priori* on the effect of the 1980 and 1985 entry waves on the productivity of scientists in higher positions (PO and PR), which were much less affected by these legislative changes.

We expect productivity to grow over time (calendar years) for at least three reasons. First, both in Italy and in France public research funding has been increasingly distributed on the basis of competitive grants. Second, physics, as any other discipline, has enjoyed decreasing publishing cost, thanks to new procedures

[11] Note also in France the existence of institutions of higher education called “Grandes Ecoles”, such as “Ecole Normale Supérieure” and “Ecole Polytechnique” to cite two oldest and most prestigious ones. They are of very small size compared to universities, but they select excellent students, and have also developed good research activities in the last twenty years.

and media. Finally, and especially in physics, "big science" and large projects have favoured teamwork, which tend to increase productivity, as measured by publishing (Price and Beaver, 1966)[12].

As for the gender, no apparent reason exists to think of peculiarities for France and Italy with respect to the US, so we expect to find evidence of a statistically significant gender effect in both countries. Stratification effects may also exist, which we try to capture with information on the affiliation and productivity of our scientists' co-authors.

2.4 Data and methods

2.4.1 Data collection and sample

Our data collection is based on confidential lists of all tenured academics in Italian and French universities, active in academic year 2004/2005. Both lists were provided by the Ministries of Education of the two countries, alongside with the disciplinary affiliation of the individuals and some limited information. As indicated in Table 2, we cover all fields of physics with the exception of astro-physics and nuclear physics, although some nuclear physicists may belong to the selected fields[13]. We know the physicists' dates of birth, gender and university, as well as their rank in 2004/2005 and seniority in these ranks. We thus know when they were last promoted before 2004/2005 for PR, PA and PO, or when they were recruited for MCF and RU, but we ignore when they were recruited as MCF or RU for PR, PA and PO, or promoted to PA for PO.

We gathered the information on scientific publications from the ISI Web of Science, from Thompson-Darwent, by matching the surnames and names of the physicists with the surnames and initial of names (as coded by ISI) for the authors of all articles published in physics journals going back to 1975. We considered a total of 363 journals classified as mainly physics journals in the ISI records and with a minimum reputation as defined by an average five year impact factor of at least 0.5[14]. This list of journals includes all the main international journals specialised in physics and covers well all its subfields[15]. Note that we have preferred not to take in our list such generalist journals like Science and Nature[16].

[12] : "..It is especially noteworthy that nobody who worked without collaborators or with only one co-author succeeded in producing more than four papers in the five-year period, whereas everybody with more than twelve collaborators produced fourteen or more papers in the same time.." (Price and Beaver, 1966, p. 1014)

[13] Not all the scientists classified in one discipline, in fact, have homogeneous research interests. In addition, it is often the case that some scientists are pushed to join (nominally) the discipline with the highest opportunities of promotion at a given point in time. Face-to-face interviews to Italian physicists show that some nuclear and particle physicists are classified as *Fisica Sperimentale* (Field FIS/01), which enters our study, instead of being classifies as *Fisica Nucleare e Subnucleare* (Field FIS/04), which we excluded from our study.

[14] This means in other words that we excluded the physics journals which have regularly received over a five year period less than 0.5 citations per article. It is also the case that ISI does not cover as well those low reputation journals.

[15] The list of the 20 journals with the larger number of publications in our database is reported in the Appendix Table 6. Interviews with a few physicists have confirmed that no top journals specialised in physics are missing.

[16] Including generalist journals such as Science and Nature may create even more problems of homonymy than the ones we already have (if there are several "Smith J." in physics, there must plenty when considering all disciplines!). Moreover, we believe there are

	French Universities	Italian Universities
Fields	28 Milieux denses et matériaux 30 Milieux dilués et optique	Fis/01 Fisica Sperimentale Fis/02 Fisica Teorica, Modelli E Metodi Matematici Fis/03 Fisica Della Materia
Ranks	(PR) *Professeur* (MCF) *Maitre de Conférence*	(RU) *Ricercatore Universitario* (PA) *Professore Associato* (PO) *Professore Ordinario*

Table 2 Disciplinary fields and ranks

<u>Overall sample</u>

	FRANCE		
	Women	**Man**	**Total**
MCF	410	1020	1430
PR	80	701	781
Total	490	1721	2211

	ITALY		
	Women	**Men**	**Total**
RU	132	401	533
PA	102	559	661
PO	40	582	622
Total	274	1542	1816

Note: Computed on overall French and Italian samples (i.e. before cleaning).

<u>Study sample</u>

	FRANCE		
	Women	**Men**	**Total**
MCF	299	912	1211
PR	50	655	705
Total	349	1567	1916

	ITALY		
	Women	**Men**	**Total**
RU	124	387	511
PA	93	525	618
PO	38	550	588
Total	255	1462	1717

Note: Computed on French and Italian study samples (i.e. after cleaning for homonymy and "zero-productive" academics).

Table 3 Number of physicists in France and Italy, active in 2004-05 by gender and rank in overall sample (before cleaning) and on study sample

Such a collection strategy is the only one compatible with the publication data gathered from the Web of Science, but it generates problems of homonymy for the small group of physicists with the same surnames and initial of names in the ministerial lists, as well as for those with very common surnames. Ignoring these problems may lead to over-estimating the productivity of these physicists. In other cases there are homonyms in the ministerial databases and it is impossible to correctly attribute papers. Therefore after some trials we finally dropped from our search all homonyms in the ministerial lists and all physicists with an apparent productivity record far too high for being credible as well as quite common surnames. This

strong correlations between publishing in specialized journals of good quality and generalist journals of outstanding reputation as Science and Nature. Such generalist journals are few and they are not alternative outlets to specialist physics journals. Top physicists who manage to publish the results of their research in Science and Nature also publish these results in specialized physics journals. In terms of descriptive statistics on "quantity" productivity, the errors we introduce should be more or less negligible. On "quality" productivity, the absence of a few very-high-impact-factor journals such as Science and Nature probably results in chopping up slightly the long tail of the productivity distribution of scientists. In terms of biases in our econometric analysis, one can expect that they will not be sizeable. At the same time, it is very unlikely that a physicist with a small publication record in specialized journals will publish many papers in Science or Nature.

resulted in dropping in total about 3% of surnames from the original lists, leaving us with 2151 French (instead of 2211) and 1769 Italians (instead of 1816) [17]. Note also that unless one would think that the spelling of surnames could in some way be related to the scientific productivity, cleaning our study sample from homonyms should not introduce any biases in our econometric results.

Looking at our publications data, found that about 3% (52) of the academic physicists in Italy and about 11% (235) in France had no articles at all before and after recruitment or promotion, and hence a computed zero productivity throughout their observed careers. This significant difference between the two countries could reflect that French academics tend much more than Italian to write in journals not included in the ISI Web of Science, and be involved nearly exclusively in teaching, and/or administrative, advising and consulting activities. Given the impossibility for lack of specific data to investigate why these "zero-productive" physicists self-select as "non researchers", we thought it was better to simply leave them out from our analysis[18]. Our final study sample is thus made of 1916 French and 1717 Italian academic physicists, for which have a corpus of respectively 44100 and 52919 articles published from 1975 up to 2005 in 363 physics journals. Table 3 gives the number of physicists in France and Italy, active in 2004-2005, by gender and rank in the overall sample (before cleaning) and on our study sample. All the statistics and econometric estimates reported in the following sections of this paper are obtained for our study sample.

2.4.2 Specification and estimation problems and solutions

Our data constitute an unbalanced panel, where individual physicists for most of them are observed from their year of first recorded publication to 2005, that is for the oldest ones from 1975 to 2005, or where they are observed for the few MCF and RU without any recorded publication before their known year recruitment from this year to 2005. To assess sensibly and with reasonable confidence the impacts of the various determinants of their scientific productivity that we can consider, we have to worry about three major kinds of interrelated specifications errors: selectivity, endogeneity, and unobserved (correlated) individual heterogeneity. All three are potential sources of biases in our estimates, as well as uncertainty in their proper meaning and correct interpretation. We have tried here to take care of them in a specific and particular cautious way.

First, we have considered five productivity regressions, both in terms of quantity and quality, one for each main position in the academic ranking of the two countries: MCF and PR for France, and RU, PA and PO in Italy, which we estimate on the subsamples of physicists who have reached these ranks in 2004-2005, restricted to the years after their promotion to these ranks. Our estimated impacts of productivity

[17] Most of the surnames of physicists we discarded are the homonyms in the ministerial lists. Otherwise we have had in fact to discard only 4 names of physicists for France and 2 for Italy because their computed productivity appeared much too large to be credible (with 30 papers or more for at least 10 years!) and they had also widespread surnames (e.g., CHEN or WANG).

[18] Following a referee's request, we have also replicated our econometric analysis for the sample including the "zero-publications" physicists. Our main results do not change significantly, with the exception of the estimated effects of the 1980 and 1985 entry waves on productivity and promotion, which appear to be stronger. The tables showing these results are available on request.

determinants are thus conditional on ranks. This helps in controlling for selectivity and endogeneity as well as unobserved heterogeneity of physicists across ranks.

Second, we also consider three selection probit equations accounting for the individual physicist probability of promotion from respectively MCF to PR, RU to PA and PA to PO. These equations are specified jointly with the corresponding productivity regressions as three generalized Tobit models, one for each of the professor ranks. To estimate consistently such Tobit models we have simply relied on Heckman's two-step method, where the probit equation is estimated in the first step, and the productivity equation estimated in the second step including as an additional explanatory variable in the equation the inverse Mill's ratio of the probability of promotion as predicted by the probit equation (Heckman, 1979; Dubin and Rivers, 1989; Wooldridge, 2002).[19] Besides of providing interesting information per se on the determinants of promotion, estimating jointly a model of promotion and productivity also contribute in controlling for selectivity, endogeneity and unobserved heterogeneity.[20]

Last, we also control for individual heterogeneity in both the promotion and productivity equations by specifying past productivity variables in all of them. In our analysis, individual heterogeneity mainly corresponds to individual characteristics such as ability and motivation which are not directly observable, but have a major impact on individual performance. In so far as these individual characteristics are mostly permanent, they are bound to be strongly correlated with past productivity. Thus the presence of past productivity in the promotion and current productivity equations will take care of the most likely unobserved heterogeneity biases to a large extent if not fully.[21]

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[19] Note that while the productivity equations are estimated for the professor subsamples restricted to the observations after promotion, the promotion probit equations are estimated on all the observations, both before and after promotion, of these subsamples. We have preferred to use the two-step Heckman method to the maximum likelihood, which encountered in some cases problems of convergence due apparently to our very large number of variables (including in particular in both the promotion and productivity regressions interactions of cohort of entry and year dummies, as explained in the next sub-section).

[20] Note that we might have also considered two probit equations accounting for the individual physicist probability of being recruited as respectively MCF and RU. That was not, however, really possible because of a much too short history of publications before recruitment (or even none) and for lack of other background information, such as on graduate studies. Moreover, that also seemed a priori less relevant than concerning promotion to professor.

[21] The standard approach in a panel data setting as ours is to control for permanent unobserved heterogeneity by including fixed individual effects in the equations. Although we may want to go back to this approach in future analysis, our first attempts were not promising. The advantage of our approach here is that past productivity variables largely correct for the likely heterogeneity biases by picking-up the correlated components of individual fixed effects, while being more informative than fixed effects per se and preserving, contrary to them, the relevant cross-sectional information in the data.

2.4.3 The determinants of promotion and scientific productivity

The exercise requires estimating two equations: a selection equation in which the dependent variable is promotion of the scientist to the present position (PO, PA, PR), with past scientific productivity as the key explanatory variable; and a productivity equation in which the dependent variable is productivity, for all scientists in the same position. Each estimation exercise of the productivity equation is run twice, for two different dependent variables that measure respectively the quantity and quality of the scientific productivity of each individual scientist:

- *Quantity:* log(1 + number of articles in year *t*)
- *Quality:* log(1 + average 5-year impact factor of journals with articles in year *t*)

We do not correct the number of articles, and the related quality measure, by the number of co-authors of each article; that is, we do not try to capture the individual scientist's contribution to the article. We have two reasons for doing so. First, almost all articles in physics are co-authored, often by quite a large number of scientists. Papers written in isolation or by a few authors may be either theoretical ones or, if applied, they may reflect the isolation of their authors from the rest of the scientific community, rather than a larger individual contribution. Introducing arbitrary corrections according to the number of authors would have meant giving greater weight to theoretical papers or, possibly, to papers by peripheral authors. Instead, we control for the productivity of co-authors before *t*, which we expect to be correlated to the number of papers at time *t*[22].

The key explanatory variables in both the selection and productivity equation are related to the scientists' age, the historical conditions of the academic labour market at the time of their recruitment or promotion, and time trends in productivity[23]. Additionally, promotion is explained by productivity, which enters the regression through two distinct variables: *Quantity flow* and *Quality flow.* These are the average number of papers published by the scientist between *t-4* and *t-2*, and the related average value of the five year impact factor of journals[24]. Finally, promotion is also a function of the *Academics per year*, which is the number of individuals who achieved promotion in year *t*.

Introducing age, cohort, and historical time in the promotion or the productivity equation creates the identification problem discussed by Hall *et al.* (2005). In particular, it is impossible to take simultaneously into account age, time and birth cohorts, one variable being a linear combination of the other two (age = year – birth cohort). In line with Hall *et al.* (2005) we attack this problem by using a semi-parametric model

[22] We have also produced a series of ancillary regressions with author-weighted measures of quantity and quality, whose results do not differ substantially from those reported in this paper, and are available on request.

[23] It is common knowledge that bibliometric measures of productivity exhibit an increasing trend over time. Our data do not escape this regularity, both for quantity and quality.

[24] Publications in *t-1* are excluded because the recruitment procedure (*concorso* in Italy or *concours* in France) can take many months, up to one year or so. Therefore, some publications appear after a candidate has filed for the job and are not considered by the commissions relevant for the appointment.

in which these effects enter linearly, and are represented by variables the least affected by identification problems.

First, we do not consider *birth* cohorts, but only *entry* cohorts. That is, our *Cohort* dummies refer to the scientists' years of entry in the academic workforce, namely the first year in which the individual scientist published an article or, if the scientist does not have publications before last promotion, the date of last promotion. This is similar to the approach used by Levin and Stephan (1991) which define as cohort the year in which a scientist received her PhD. It also captures more precisely than the year of birth the influence of changes in the importance of research fields or legislation on a cohort's productivity. The entry cohort dummies are interacted with a full set of *Period* dummies that refer to calendar years; in other words, our semi-parametric model includes a dummy variable for each cohort-period combination (*Cohort* x *Period*).

In addition, we estimate the impact of being recruited or promoted in 1980 in Italy and 1985 in France. We expect scientists belonging to these recruitment waves to display, other things being equal, lower productivity levels than scientists from all other cohorts, due to lack of selective pressure. Notice that the share of scientists recruited as RU, PA, and PO in 1980 in Italy and as MCF and PR in 1985 in France account for respectively 34%, 52%, 19%, 20% and 13% of the observations in the productivity regression samples (see Appendix Table 2 and 3), and therefore they represent a substantial share of the academics active in 2005[25]. In both the selections and the productivity equation we identify these scientists with the W*ave 1980* and W*ave 1985* dummy variables. Besides, in the selection equation, we control for the ease of entry into academia by counting, in each year *t*, the number of scientists promoted in that year and still active in the same rank in 2005 (*Academics per year*).

As for the scientist's age, we address the above-mentioned identification problem by using age groups; more precisely, we introduce in both the selection and productivity equations five *Age* dummy variables, representing ten-years age-intervals of our scientists (see Table 4)[26]. Our expectation is to find a negative impact of scientist's age on productivity (Levin and Stephan, 1991; Hall *et al.*, 2005). On the contrary, when considered as a determinant of promotion (selection equation), *age* is expected to have a positive impact: the older the scientists, the higher her chances to be promoted (as in Long, 1993).

[25] It's worthwhile remarking that we do not have the full career profile of the scientists and therefore we do not know how many PR, PO and PA - that were promoted after 1980 in Italy and after 1984 in France – were previously recruited or promoted in the *wave 1980* and in the *wave 1985*.

[26] We have also tried different specifications using directly the age variable and age squared and the results do not change substantially.

Variable	**Definition**
<u>*Dependent variables in promotion and productivity equations*</u>	
Promotion	Step indicator for being promoted in year *t(p)*: =0 if promoted [i.e., *t>=t(p)*], and =1 if not promoted [i.e., *t<t(p)*].
Quantity-productivity	Logarithm of the numbers of articles published in year *t*, plus *1*
Quality-productivity	Logarithm of the average five years impact factor in year *t* for the journals in which articles have been published in that year, plus *1*
<u>*Explanatory variables in the promotion equations only:*</u>	
Quantity-productivity lagged flow	Logarithm of the average number of articles in the three years *t-2,t-3* and *t-4,* plus *1*
Quality-productivity lagged flow	Logarithm of the average five years impact factor of the journals in which articles have been published in the three years *t-2, t-3* and *t-4,* plus *1.*
Zero lagged flow	Dummy=1 when *Quantity flow*=*Quality flow*=0 (and =0 if not).
Academics per year	Estimates of the number of academics promoted in year *t* as PR, PA or PO.
<u>*Explanatory variables in the productivity equations only:*</u>	
Quantity-productivity before promotion	Logarithm of the average number of articles per year published before the year of recruitment or last promotion, plus *1*
Quality-productivity before promotion	Logarithm of the average impact factor of the journals in which articles have been published before the year of recruitment or last promotion, plus *1*.
Co-authors quantity	Logarithm of the moving average of co-authors' number of articles (with other scientists than the author) in the three years *t-1, t-2* and *t-3,* plus *1*.
Co-authors quality	Logarithm of 1 plus the moving average of average impact factor of the articles published by the co-authors (with other scientists than the author) in the three years *t-1, t-2* and *t-3,* plus *1*.
Co-authors quantity and quality zeros	Dummy=1 when *co-authors quantity* is 0 (and=0 if not); and Dummy=1 when *co-authors quality* is 0 (and =0 if not).
Co-authors number and affiliation dummies	*Large Project Dummy*=1 if in the three years before *t* (*t-1,t-2* and *t-3*) scientists have at least one article with 30 or more co-authors (and=0 if not); *Small Project with Foreign co-authors Dummy*=1 if in the three years before *t* (*t-1,t-2* and *t-3*) scientists have no articles with 30 or more co-authors and have at least one article with an address indicating at least one foreign co-authors (and=0 if not); *Small Project with only national co-authors Dummy*=1 if in the three years before *t* (*t-1,t-2* and *t-3*) scientists have no articles with 30 or more co-authors and have no articles with addresses indicating foreign co-authors (and=0 if not); *Small Project with co-authors of unknown affiliations Dummy*=1 if in the three years before *t* (*t-1,t-2* and *t-3*) scientists have no articles with 30 or more co-authors and have only articles with missing addresses (and=0 if not).
Zero in three preceding years	Dummy=1 when scientists published 0 articles in the three years *t-1, t-2* and *t-3* before year of observation (and=0 if not).
Zeros before promotion	Dummy=1 when *Quantity before promotion*=*Quality before promotion*=0 (and =0 if not).
Zeros after promotion	Dummy=1 when scientists published 0 articles after recruitment or last promotion (and=0 if not).

Explanatory variables in both the promotion and productivity equations:	
Wave 1980/1985	Dummy=1 if academic experienced last promotion in 1980 in Italy or in 1985 in France
Gender	Gender dummy variable: Female=1, Male=0
Age group dummies	Dummy= 1 if academic belongs to a specific age class: age group 1 (age<30), age group 2 (30<=age<40), age group 3 (40<=age<50), age group 4 (50<=age<60), age group 5 (age>=60)
Field *(28, 30, FIS01, FIS02, FIS03)*	Country specific fields of affiliation of physicists in French and Italian universities. In France 28= Milieux denses et matériaux and 20= Milieux dilués et optique. In Italy Fis01= Fisica Sperimentale, Fis02= Fisica Teorica and Fis03= Fisica Della Materia.
(Year) and (cohort of entry) interactions dummies	Interactions between dummies for year of publication and cohort of entry defined as the first year we see the scientist publish (or in case of zero publications before entering or being promoted the year of entry or of promotion)
Promotion before 1975	Dummy variable for the (small) subset of professors promoted before 1975. The inclusion of this dummy in the productivity equations controls for the fact that the publication history of this subset of professors is unknown between promotion and 1975. Its inclusion in the promotion equations is equivalent to eliminating them in the estimation of these equations (the dependent step indicator of being promoted is always equal to one for them).

Table 4 Dependent and explanatory variables in promotion and productivity equations

In both the selection and productivity equations we test for gender effects (G*ender* dummy is 1 if the physicist is a woman). In our sample, women represent respectively the 23% and 27% of the French MCF and Italian RU. At the same time they are the 7% and 6% of the French and Italian full professor. The literature typically indicates that women publish less than men (Levin and Stephan, 1998). However this result often depends on cross-sectional data that cannot control for individual heterogeneity.

Moreover, in both the selection and productivity equations, we control for the scientist's specific *research fields* through a set of dummies reflecting ministerial classifications of disciplines *(Field 28* and *Field 30* for France; *Field FIS/01*, *Field FIS/02,* and *Field FIS/03* for Italy). We expect the probability to be recruited or promoted to be field-specific for two reasons. First, resources to hire new employees are not distributed homogeneously among all the disciplines. Second, some disciplines could be more prolific in terms of new discoveries and research paths, thus attracting more junior scientists. As for productivity, this can also be affected by the scientist's specific field of research, due to differences in the resources needed to produce a paper.

In order to characterize the work environment in the productivity equations, we also control for our scientists' relationship with other members of the scientific community. First, we consider the past productivity of each scientist's co-authors in year *t (Co-author's quantity* and *quality)*. The co-authors we consider are only those who also belong to our sample (that is, we ignore all co-authors who are neither French nor Italian physicists for which we have no publication data). Their overall *Quantity* and *Quality* is calculated over the interval *[t-3, t-1]* and divided by the number of years in the interval. We expect both variables to bear positive effects on the scientist's productivity, however measured, to the extent that working contacts with other productive individuals provide access to knowledge and information[27].

Second, we consider the size and geographical reach of the projects in which our scientists are involved. We produce four time-varying and mutually exclusive dummy variables that summarize information on the number of co-authors and their addresses, as reported by the ISI publication records (in this case we consider all co-authors, not only the French and Italian scientists)[28]. In order to do so we consider the scientist's publications from *t-3* to *t-1*. The variable *Large Project* dummy, then, takes value one if the scientist has at least one article (among this set of lagged publications) with 30 or more authors[29]. All these large projects are international, that is for all papers with 30 or more co-authors, the ISI records reports several non-Italian and non-French addresses. Alternatively, in case the scientist's lagged publications do not come from any large project, we check whether there is at least one publication resulting from an international project, although of a smaller scale. As a result the *Small_project_with_foreign_co-author* dummy takes value one if the scientist has no publications with 30 or more authors over [*t-3*,*t-1*], but she has at least one publication with at least a foreign co-author.

A third dummy variable, named *Small_project_with_only_national_co-authors* signals that none of the co-authors has a foreign affiliation[30]. Finally since in many cases the information on affiliation and addresses reported by ISI is incomplete, we control for the possibility that none of the scientist's articles contains information on its authors' affiliation or addresses (*Small_project_with_co-authors_of_unknown_affiliations* dummy). Scientists with no publications over [*t-3*, *t-1*] constitute the reference case.

In order to capture unobserved heterogeneity in the productivity equations, we control for the scientist's productivity before promotion, that is the yearly average quantity and quality since entry year *(Quantity before promotion; Quantity before promotion*).

Finally, we control for problems arising from data design. First, in the productivity equation we deal with the left truncation problem due to the unavailability of information on publications before 1975. To this end, a dummy variable *Promotion before 1975* is inserted, which takes value one for scientists who reached the present position before the first year of observation. As for the promotion equation, we simply do not

[27] In order to avoid endogeneity problems, we do not consider the co-authors' publication to which the observed scientist also contributed.

[28] The information on affiliation and related addresses provided by ISI is not precise. For each publication, in fact, the authors' names and affiliations are reported in separate fields, with no one-to-one matching between the two. So there is no way to know how many authors of a publication come from a university or research institute among those listed; but only that at least one authors comes for sure from such university or institute.

[29] The share of articles with 30 or more co-authors is higher in Italy (8.57%) then in France (5.95%). Appendix Table 4 shows the percentage of large projects in the two countries and the information available about the affiliations (addresses) from the ISI database. Moreover, Appendix Table 5 reports the average number of authors (per article) according to a list of 22 nationalities and PROs. US, German and English scientists are quite frequent co-authors in Large Projects publications, both in Italy and France.

[30] This dummy is an approximation since the addresses of the authors are not always reported in the articles.

consider observations affected by this problem. Second, we deal the presence of zero values in all measures of quantity and quality when used as explanatory variables by inserting a number of dummies which take value 1 in case of absence of any publication[31]. Appendix Tables 1, 2 and 3 report summary statistics for all the regressors, by rank.

2.5 Results and discussion

In what follows we comment separately the results from the estimation of the selection and productivity equations. In the case of RU and MCF we do not see enough history of the individual to explain the promotion with a *probit* model. For example, many RU and MCF published very few or no articles before being promoted to their present rank; and the latter may have been achieved mainly thanks to the candidates' graduate work or educational attainments, which we also do not observe.

2.5.1. Promotion equation

Results from the selection equation for Italy and France are reported in Table 5. Cohort-period interactions are included in the estimation, but not displayed. As expected, the promotion probability of both Italian and French scientists increases with age, which confirms the role of seniority in both academic systems. Note however that for full professorship in both countries (PO in Italy and PR in France), the estimated coefficient for *Age group 5* (that is, for academics who are more than 60 years old) is smaller than the coefficient for *Age group 4*. This suggests a non-monotonic effect of seniority on promotion probability

[31] In the promotion equations we include a *Zero lagged flow* dummy indicating when past quantity and quality-productivity are zeros, while in the productivity equations we include a *Zeros before promotion* dummy. The reasons for including these two dummies is to allow for some functional form flexibility without imposing that a strict linearity through the value of zero for the effects of the corresponding variables which are measured in terms of log(1+x) (i.e., respectively the *Quantity-productivity lagged flow* and *Quality-productivity lagged flow* variables and the *Quantity-productivity before promotion* and *Quality-productivity before promotion* variables). The reason for the inclusion in the productivity equations of the *Zeros after promotion* dummy is different one. It is to fully abstract from the information that will be conveyed in the estimation of the productivity equations if we did not include it. It is thus simply

	PR (FR)	PO (IT)	PA (IT)
Quantity flow	0.018	0.048***	0.059***
	(0.011)	(0.012)	(0.0074)
Quality flow	0.060***	-0.0050	-0.025***
	(0.011)	(0.014)	(0.0088)
Zero flow	0.15***	0.18***	0.12***
	(0.013)	(0.022)	(0.0079)
Academics per year	0.0046**	0.0023***	0.012***
	(0.0018)	(0.00090)	(0.00061)
Wave 1985 (FR)/ Wave 1980 (IT)	0.18***	0.40***	0.38***
	(0.0095)	(0.0084)	(0.0097)
Gender	-0.11***	-0.15***	-0.068***
	(0.021)	(0.024)	(0.012)
Age group 1	n.r.	n.r.	n.r.
Age group 3	0.27***	0.50***	0.15***
	(0.012)	(0.018)	(0.0093)
Age group 4	0.37***	0.68***	0.22***
	(0.013)	(0.014)	(0.0097)
Age group 5	0.23***	0.56***	n.r.
	(0.010)	(0.011)	
Field 30 (FR)/Fis01 (IT)	0.022**	0.0020	0.029***
	(0.0092)	(0.013)	(0.0088)
Field Fis02 (IT)		0.13***	0.0090
		(0.014)	(0.011)
Constant	-	-	-
Observations	14094	14114	12165
Number of physicists	705	588	618

*See Table 4 for the precise definitions of the variables. The coefficients given in the Table are the marginal effects. Their standard errors are given in parentheses, and the corresponding P-values if less than 0.01, 0.05 and 0.10 are respectively denoted by ***, ** and *.The equation include controls for the (year) and (cohort of entry) interactions and for the promotion before 1975 dummy variable; their coefficients are not reported in the Table.*

Table 5 Probit equations for professor promotion

The positive sign and absolute size of the coefficients for *wave 1980* and *wave 1985*, confirm that in those two years a scientist's chances of being promoted were much higher than at any other time in recent history. This result holds despite we also controlled for the (positive) effect of *Academics per year* on the probability of promotion. For example, the estimated marginal effect for *Academics per year* in the PO equation suggests that one more PO promoted in year *t* gives any (Italian) candidate to the same position 0.23% more chances of success (1.2% for PA and 0.46% for PR). On top of this, being a candidate to the same position in 1980 meant a 40% higher probability of success (38% also for PA and 18%, in 1985, for PR). Overall, in 1980, 62 individuals reached the PO position, for a combined increase in the probability of promotion of around 54%, other things being equal (40% from the *Wave 1980* dummy, plus 62x0.23% from *Academics per year*).

The *Gender* effect is strongly negative in both countries and confirms that, other things being equal, women in physics face more difficulties than men to be promoted. Field effects are also significant, with some relevant differences across ranks[32].

As for productivity, its effect on the probability of being promoted is captured by the two variables *Quality flow* and *Quantity flow*, whose estimated coefficients differ across countries. In Italy, promotion seems to be affected largely by quantity, the impact of quality being negligible for promotions to PO but negative to PA position[33]. In France quality, but not quantity flow, affect positively and significantly the probability of promotion to PR[34].

2.5.2 Productivity equation

Results from the productivity equations for Italy and France are reported in Tables 6 and 7. In Table 6 the dependent variable is *quantity* while Table 7 refers to *quality*. As expected, the age of academics has a negative impact on both the quantity and quality of articles published. In all equations, this is captured by the age groups coefficient, which are all negative and significant (with the exception of *Age group 1*) and increasingly larger when moving from *Age group 3* to *Age group 5*[35].

32 In Italy, promotion to PO appears to be easier in *Fisica teorica (Field FIS/02)* rather than *Fisica della materia (Field FIS/03,* the reference dummy*)*. On the other hand the chances of being promoted to a PA position are higher in *Fisica sperimentale (Field Fis/01)*. In France, promotion to PR are more likely in *Milieux dilués et optique (Field 30)*, compared to *Milieux denses et matériaux (Field 28)*.

33 Variables quality and quantity flow are highly correlated

34 Notice that the variable *Zero flow* is positive and statistically significant in all the selection equations. At first sight this result looks puzzling, but in fact it depends on the design of the pooled-probit exercise. In such exercise the dependent variable is a binary one, which takes value one from time t onward, for all scientists who are promoted at time t. After t many scientists may stop publishing altogether, so the value one of the dummy *Zero flow* is often coupled with unitary model outcome. This variable should be considered as a control for the zeros and its omission does not affect the estimates of other regressors.

35 In a separate regression exercise we have tested the effect of age on productivity of Italian PO, in the absence of controls for participation to large and/or international projects. In this case, the impact of age on productivity (quantity) appears to be negligible. One interpretation is that PO suffer of a productivity loss at the individual level, which they compensate by participating to large international projects.

VARIABLES	PR(FR) Heckman	MCF(FR) OLS	PO(IT) Heckman	PA(IT) Heckman	RU(IT) OLS
Quantity before promotion	0.45***	0.33***	0.57***	0.37***	0.48***
	(0.019)	(0.017)	(0.022)	(0.020)	(0.023)
Quality before promotion	0.080***	0.058***	-0.094***	0.00038	0.013
	(0.020)	(0.012)	(0.022)	(0.019)	(0.023)
Co-authors quantity	0.036*	0.13***	0.047**	0.0095	-0.041
	(0.019)	(0.015)	(0.020)	(0.021)	(0.025)
Co-authors quality	0.069***	0.028	0.018	0.036	-0.021
	(0.026)	(0.021)	(0.028)	(0.028)	(0.036)
Co-authors zero Dummy	-0.017	0.099**	-0.13**	-0.083	-0.27***
	(0.053)	(0.044)	(0.060)	(0.058)	(0.077)
Large Project Dummy	1.09***	1.14***	1.13***	1.18***	0.96***
	(0.049)	(0.038)	(0.039)	(0.032)	(0.045)
Small Project with Foreign co-authors Dummy	0.55***	0.43***	0.68***	0.55***	0.39***
	(0.023)	(0.015)	(0.035)	(0.025)	(0.037)
Small project with only National co-authors Dummy	0.33***	0.21***	0.39***	0.34***	0.18***
	(0.024)	(0.016)	(0.035)	(0.024)	(0.035)
Small Project with co-authors of unknown affiliations Dummy	0.22***	0.14***	0.22***	0.24***	0.082
	(0.035)	(0.024)	(0.075)	(0.050)	(0.072)
Wave 1985 (FR)/ Wave 1980 (IT)	0.028	-0.032**	-0.061**	-0.080***	-0.14***
	(0.024)	(0.016)	(0.027)	(0.025)	(0.047)
Gender	-0.11***	-0.079***	0.047	-0.024	-0.11***
	(0.029)	(0.012)	(0.038)	(0.021)	(0.021)
Age group 1		0.097**			-0.015
		(0.043)			(0.16)
Age group 3	-0.19***	-0.060***	-0.42***	-0.11***	-0.078**
	(0.047)	(0.020)	(0.095)	(0.034)	(0.032)
Age group 4	-0.26***	-0.11***	-0.64***	-0.27***	-0.25***
	(0.061)	(0.027)	(0.11)	(0.043)	(0.057)
Age group 5	-0.31***	-0.074*	-0.77***	-0.38***	-0.40***
	(0.066)	(0.040)	(0.12)	(0.048)	(0.12)
Field 30 (FR)/Fis01 (IT)	0.0011	0.054***	-0.13***	0.011	-0.013
	(0.015)	(0.010)	(0.021)	(0.021)	(0.024)
Field Fis02 (IT)			-0.20***	-0.039	-0.055**
			(0.023)	(0.024)	(0.027)
Constant	0.19	0.37	0.46***	0.056	0.26
	(0.18)	(0.53)	(0.16)	(0.10)	(0.25)
Rho	-0.33		-0.30	-0.27	
lambda	-0.20***		-0.21***	-0.17***	
standard error lambda	(0.06)		(0.047)	(0.041)	
Observations	14094	12057	14114	12165	5106
Uncesnsored observation	9018		8332	8089	
Censored observations	5076		5782	4076	
Number of physicists	705	1211	588	618	511
Sigma	0.61		0.69	0.62	
R-squared		0.344			0.526

*See Table 4 for the precise definitions of the variables. We control for the (year) and (cohort of entry) interactions dummies, for the Zero after promotion dummy variable and for the promotion before 1975 dummy variable, all three not reported in the Table. The Zero in preceding years is normalized to be the reference group for the co-authors number and affiliation dummies. Standard errors are given in parentheses, and P-values less than 0.10, 0.05 and 0.01 are respectively denoted by *, ** and ***.*

Table 6 Quantity-productivity equation.

VARIABLES	PR(FR) Heckman	MCF(FR) OLS	PO(IT) Heckman	PA(IT) Heckman	RU(IT) OLS
Quantity before promotion	0.37***	0.21***	0.30***	0.18***	0.21***
	(0.026)	(0.026)	(0.025)	(0.026)	(0.029)
Quality before promotion	0.34***	0.14***	0.15***	0.093***	0.11***
	(0.027)	(0.019)	(0.025)	(0.024)	(0.030)
Co-authors quantity	-0.057**	0.067***	-0.027	-0.053**	-0.083***
	(0.025)	(0.024)	(0.022)	(0.026)	(0.032)
Co-authors quality	0.19***	0.20***	0.25***	0.25***	0.20***
	(0.034)	(0.033)	(0.031)	(0.036)	(0.047)
Co-authors zero Dummy	0.14**	0.32***	0.21***	0.20***	0.052
	(0.071)	(0.070)	(0.067)	(0.074)	(0.099)
Large Project Dummy	1.04***	0.96***	1.24***	1.18***	0.95***
	(0.066)	(0.061)	(0.044)	(0.041)	(0.059)
Small Project with Foreign co-authors Dummy	0.84***	0.71***	1.04***	0.88***	0.73***
	(0.031)	(0.024)	(0.039)	(0.032)	(0.047)
Small project with only National co-authors Dummy	0.61***	0.43***	0.72***	0.58***	0.46***
	(0.032)	(0.025)	(0.039)	(0.031)	(0.045)
Small Project with co-authors of unknown affiliations Dummy	0.47***	0.28***	0.49***	0.38***	0.35***
	(0.047)	(0.038)	(0.084)	(0.064)	(0.093)
Wave 1985 (FR)/ Wave 1980 (IT)	0.075**	-0.0039	-0.028	0.024	-0.18***
	(0.032)	(0.026)	(0.030)	(0.032)	(0.061)
Gender	-0.15***	-0.11***	0.021	-0.019	-0.10***
	(0.039)	(0.019)	(0.042)	(0.027)	(0.028)
Age group 1		0.16**			-0.085
		(0.069)			(0.20)
Age group 3	-0.16**	-0.090***	-0.17	-0.037	-0.065
	(0.063)	(0.031)	(0.11)	(0.043)	(0.042)
Age group 4	-0.22***	-0.11**	-0.34***	-0.15***	-0.27***
	(0.081)	(0.044)	(0.12)	(0.055)	(0.074)
Age group 5	-0.27***	-0.059	-0.45***	-0.31***	-0.55***
	(0.088)	(0.064)	(0.13)	(0.061)	(0.15)
Field 30 (FR)/Fis01 (IT)	0.029	0.076***	-0.15***	-0.071***	-0.081***
	(0.020)	(0.017)	(0.023)	(0.026)	(0.032)
Field Fis02 (IT)			-0.094***	-0.073**	-0.018
			(0.025)	(0.031)	(0.035)
Constant	-0.013	-0.070	-0.23	-0.13	0.13
	(0.24)	(0.85)	(0.18)	(0.13)	(0.32)
Rho	-0.25		-0.15	0.052	
lambda	-0.20***		-0.11**	0.040	
standard error lambda	(0.081)		(0.052)	(0.052)	
Observations	14094	12057	14114	12165	5106
Uncesnsored observation	9018		8332	8089	
Censored observations	5076		5782	4076	
Number of physicists	705	1211	588	618	511
Sigma	0.81		0.76	0.78	
R-squared		0.288			0.402

*See Table 4 for the precise definitions of the variables. We control for the (year)x(cohort of entry) interactions dummies, for the Zero after promotion dummy variable and for the promotion before 1975 dummy variable, all three not reported in the Table. The Zero in preceding years is normalized to be the reference group for theco-authors number and affiliation dummies. Standard errors are given in parentheses, and P-values less than 0.10, 0.05 and 0.01 are respectively denoted by *, ** and ***.*

Table 7 Quality-productivity equation.

Elaborations on the estimated coefficients in Table 6 tell us that over-60 Italian PO produce around 2.25 articles per year less than their colleagues (also PO) in their thirties; a similar comparison suggests that over-60 French PR produce 0.65 articles less per year[36]. As for quality (Table 7), Italian PO seem the most affected by age, with over-60s exhibiting a loss of average impact factor per year equal to 1.99. Since we observe the productivity conditional to the scientist's ranking in 2005, our estimates capture on one side the life cycle effect, as discussed in section 2.4.3 on the other side, only for RU, PA and MCF, the effect of less productive scientists that are not promoted and remain at lower academic ranks.

Gender impacts differently in Italy and in France, and across academic ranks. With reference to quantity estimates in Table 6, we observe that Italy exhibits a negative gender effect only for RU: Italian *ricercatrici* publish 0.27 papers less than their male peers, per year; on the contrary, women in PA or PO position are not less productive than their male equivalents. As for France, we observe a negative gender effect on quantity both for PR and for MCF, where women produce respectively 0.26 and 0.13 papers less than men, per year. Results for quality are similar, the women's gap in average impact factor per year is: -0.49 for PR, -0.24 for MCF, and -0.39 for RU. In the absence of additional data, we can provide intuitive explanations for such results. In particular, we notice that, for Italy, the existence of a gender effect only for the most junior position (RU) is consistent with the possibility that gender matters more at the early career stages, when familiar engagements may also be demanding. Thus, a self-selection process may take place, by which only the best or most motivated researchers try to access the higher ranks, at which the gender effect appears to be less remarkable or even not significant. If this was the correct interpretation, we need then to explain why we observe a gender effect also at the senior level of French PR. In this respect we note that women in France are the 10% of PR (as opposed to 6% of Italian PO). Moreover going back to the selection equation (Table 5), we notice that the negative gender effect on promotion is smaller for PR relatively to PO. One possibility is therefore that French women face less difficulties in the promotion to full professorship (thanks, for example, to the first centralized step managed by CNU), which may explain why we observe the negative gender to persist at the top academic rank.

The estimated coefficient of the *Wave 1980* and *Wave 1985* dummies is negative and significant in the quantity model, for all positions (with the exception of French PR; see Table 6), while it is still negative, but

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[36] Throughout Section 5 we express the impact of the covariates on quantity (the number of articles) or quality, (average impact factor) by means of marginal effects, which we compute on the basis of the estimated coefficients in Tables 6 and 7. The marginal effect of any dummy covariates is given by: $\Delta y = e^{\overline{R-D}} \cdot (e^{\beta} - 1)$ where $e^{\overline{R-D}}$ is the average predicted value of the model minus the dummy D effect and β is the coefficient of D. As for the marginal effects of a continuous or discrete covariate, this is given by: $\frac{d(1+y)}{d(1+x)} = \frac{dLog(1+y)}{dLog(1+x)} \cdot \overline{\left(\frac{1+y}{1+x}\right)}$ where $\overline{\left(\frac{1+y}{1+x}\right)}$ is the average value of the ratio between the dependent variable and the covariate and $\frac{dLog(1+y)}{dLog(1+x)}$ is the coefficient (elasticity) estimated in the regressions.

never significant in the quality model (with the exception of Italian RU where it is significant and PR and PA where is positive; see Table 7). As for quantity, PO promoted to such rank in 1980 publish 0.20 articles less per year than other PO. Similarly, PA and RU last promoted in 1980 publish respectively 0.19 and 0.35 articles less per year than colleagues last promoted in more recent years. The effect for France is still noticeable, but less pronounced: MCF who were recruited in 1985 (and never promoted to PR) produce 0.05 articles less than other MCF, per year. Bearing in mind that we do not observe how many scientists, among those who entered the academic system as RU or MCF in 1980 and 1985, have been subsequently promoted to higher positions (as opposed to having retired or left Italy), the interpretation of our results may be as follows: the 1980 and 1985 big recruitment waves in the two countries filled up the RU, PA, and MCF positions with less productive scientists, who did not progress much further in their careers, and are now responsible for the negative signs we observe in Table 6 and (for RU) in Table 7. We can estimate the total scientific productivity loss due to the entry wave of 1980 in Italy, where the effect is stronger, comparing the total number of papers published by scientists promoted in these entry cohorts, with the estimated number of papers published by scientists from other entry cohorts, other things being equal. This exercise suggests that the 62 Italian PO promoted in 1980 have published about 314 articles less than what expected by similar PO from other cohorts, over the same years of activity. Similar calculations suggest a production gap of 785 articles by PA and of 639 articles by RU from the 1980 wave, for a total scientific loss of around 1738 articles. Our calculations may under-estimate the effects of the massive entry waves, since they are based on a sample which includes only academics who published at least one article since 1975. A large share of the French and Italian unproductive scientists, excluded from the regression sample, comes precisely from the 1985 and 1980 waves [respectively 17% (40/235) and 36.5% (19/52)], so that their inclusion increases further the size of the estimated coefficient for the two wave dummies[37].

These figures suggest that the percentage of unproductive scientists over all scientists hired during the 1980 and 1985 waves is at least two (for MCF) or three times higher (for PA and RU) than the same percentage for the rest of the sample[38].

Some descriptive statistics help understanding why the “wave effect” appears to be stronger in Italy than in France. In Italy, over 10% (62/588) of PO, 26% (166/618) of PA and 14% (73/511) of RU active in 2005 were promoted to such positions in 1980. In France, only less than 8% (55/705) of PR and 10% (121/1212) of MCF reached their present position in 1985. In other words, the 1980 wave in Italy was bigger and

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[37] More precisely, among the Italians hired during the 1980 wave the unproductive PO, PA and RU are respectively 1.6%, 6.7% and 7.6%. In France 21.9% are MCF and 9.8% are PR. Notice that, following referee request we rerun all the regression including all scientists with zero publications. The effect of the waves is confirmed and become even stronger.

[38] Another peculiarity of the waves is that in Italy were hired considerably younger academics if compared to the average age of hiring in other years; this is true also for PR in France but not for MCF with an average age of 41 instead of the usual age of 32 in other years. In general there are no big differences for the gender composition of the academics promoted during the waves except for the rank of RU where, during the wave were promoted 14% more women (36% instead of 22%).

produced more enduring effect than its French equivalent. As for Italian RU, this effect is also visible for the quality-based measure of productivity.

As explained in the previous section, we control for the individuals' unobservable heterogeneity by means of lagged measures of productivity (*Quantity before promotion* and *Quality before promotion*). As expected, all such controls bear a positive and significant sign (the only exception being the negative sign of the impact of past quality-productivity on current quantity-productivity in the case of PO.

Productive co-authors impact positively on individual scientists' productivity. For quantity measures of productivity, estimates in Table 6 suggest that Italian PO and French PR and MCF produce 0.08, 0.06 and 0.18 extra articles per year for every additional article produced by their co-authors over the three preceding years. The marginal effect of co-authors' quality on the scientist's quality output per year is positive for all ranks and countries, and it ranges between 0.37 for Italian RU and 0.53 for PR.

Involvement in large and/or international projects affects strongly a scientist's yearly productivity. This is especially true for Italian PO, where the dummy *Large project* produces a marginal effect on quantity of more than 5.5 articles per year. Similar results hold also for PA and RU, it grows strongly their productivity (4.40 and 3.43 more articles per year; the reference group is given by scientists with no publications in the three years before *t*). The effect of *Large projec*t for France, albeit high if compared to the effect of others covariates, is weaker than in Italy, the marginal effects for PR and MCF being respectively equal to 4.63 and 3.33. Even quality is affected by participation to large international projects, with increases in the average impact factor per year comprised between 3.54 (for MCF) and 9.09 (for PO). Scientists who are not involved in large projects, but had at least one foreign co-author in the three years before *t*, also have larger quantity and quality scores than the reference group (but lower than their peers participating to large projects). Italian PO with dummy *Small_project_with_foreign_co-authors* equal to one, for example, publish 2.41 more papers per year than the reference group; On the other hand, PO with participation to *Small_project_with_only_national_co-authors* publish 1.50 papers more than the reference group. Similar results hold for all position in both countries.

Controls for field effects also prove significant. Italian PO belonging to *Fisica sperimentale (Field Fis/01)* and *Fisica teorica, modelli e metodi matematici (Field Fis/02)* publish respectively 0.46 and 0.65 articles less than colleagues from *Fisica della materia (Field Fis/03)*, per year. The quality of the publications is also lower. In France MCF belonging to *Milieux dilués et optique (Field 30)* publish more and higher quality articles if compared to *Milieux denses et matériaux (Field 28).*

Tables 6 and 7 show also the estimated inverse Mill's ratio (lambda) produced by the Heckman procedure to correct for the problem of selection bias. Its negative sign means that the probability of not being promoted affects negatively the individual scientific productivity. The coefficient is significant for PR, PO and PA in the quantity regressions and for PR and PO in the quality regressions. Lack of significance for PA in the quality regression means that the two equations, selection and productivity, could have been estimated separately, without any kind of correction for endogeneity of the academic rank.

2.6 Conclusions

In this paper we have investigated the determinants of scientific productivity for a sample of most of academic physicists active in French and Italian universities in 2004-2005. We have performed this analysis both conditional on being in an assistant or professorial position (MCF and PR in France and RU, PA and PO in Italy) and together with a joint analysis of the determinants of promotion to professor (from MCF to PR in France and RU to PA and PA to PO in Italy). We have followed this approach to be more informative and enrich our study, as well as to address the interrelated econometric problems of endogeneity, selectivity and unobserved heterogeneity.

Our estimates of promotion equations show that the probability of a French or Italian physicist to be promoted professor increases with age until he reaches his sixties and that "other things being equal" it is also significantly lower for a woman than a man. In Italy promotion is influenced by the quantity of past publications (quantity-productivity lagged flow), and in France, it is influenced by their quality (quality-productivity lagged flow). In both academic systems we observe big recruitments waves, in 1980 and 1985, which affect significantly the probability of promotion.

In the productivity equations we show that the age of academics has a negative impact on the quantity and quality of articles published by French PR and Italian PO publications. For the other academic ranks the age effect is mixed with the other effect of not being promoted, due to the database design. French MCF and Italian PA and RU are characterized by a strong negative impact of age.

As for gender effects, Italian, women at the early stage of their careers (for example RU) are penalized in their publication activity. However, if Italian women manage to be promoted to higher ranks, then they publish as much as their male colleagues. On the contrary, in France we observe a negative gender effects across all ranks. We find evidence that the work environment is very important for individual scientists' productivity. In particular being involved in large projects, or at least having an international collaboration has a strong and positive effect on quantity and quality of published articles

Finally we show that the big recruitment and promotion waves of 1980 and 1985 had negative and lasting effects on the average scientific productivity of the two countries, especially so for Italy. Such big waves came after a prolonged spell with no recruitment of new scientists and few promotions, and were the result of policy provisions aimed at providing permanent positions for many scientists with temporary assignments. Many of the physicists recruited in these years appear not to have progressed much in their careers, and to have persistently scored as less productive than the average physicists of the same rank recruited or promoted in other years.

Our results on age, gender and the importance of promotion probability confirm many of the results found in the literature. Findings on the enduring negative effects of *en masse* recruitment, on the contrary, are more specific of France and, most notably, Italy. They suggest that tight governmental control over academic careers, such as when governments can prevent universities from recruiting or promoting scientists for a long time, and then intervene with sudden and massive waves of job creation, can create persistent damage to the national academic system. Although never equalled in terms of size, such provisions are still typical of the French and Italian systems, which makes our results particularly relevant for the ongoing reforms in those two countries.

Appendix to chapter 2

	PR (obs. 14094)				PO (obs. 14114)				PA (obs. 12165)			
	mean	sd	min	max	mean	sd	Min	max	mean	sd	min	max
Promotion	0.64	0.48	0	1	0.59	0.49	0	1	0.66	0.47	0	1
Quality flow	0.87	0.61	0	4.01	1.21	0.71	0	3.78	0.97	0.74	0	3.65
Quantity flow	1.42	0.75	0	3.00	1.72	0.70	0	3.16	1.46	0.81	0	3.02
Zero flow	0.14	0.35	0	1	0.08	0.27	0	1	0.16	0.36	0	1
Academics per year	26.97	15.84	0	55	19.12	29.40	0	109	22.24	30.21	0	166
Wave 1985 (FR)/ Wave 1980 (IT)	0.10	0.30	0	1	0.12	0.32	0	1	0.35	0.48	0	1
Gender	0.07	0.25	0	1	0.06	0.25	0	1	0.15	0.35	0	1
Age group 1	0.01	0.08	0	1	0.00	0.07	0	1	0.01	0.09	0	1
Age group 3	0.38	0.49	0	1	0.35	0.48	0	1	0.37	0.48	0	1
Age group 4	0.29	0.45	0	1	0.32	0.47	0	1	0.23	0.42	0	1
Age group 5	0.06	0.23	0	1	0.16	0.37	0	1	0.08	0.27	0	1
Field 30 (FR)	0.30	0.46	0	1								
Fis01 (IT)					0.52	0.50	0	1	0.62	0.49	0	1
Fis02 (IT)					0.23	0.42	0	1	0.18	0.38	0	1
Promotion before 1975	0.02	0.14	0	1	0.05	0.22	0	1				

Appendix Table 1 Summary statistics of dependent and explanatory variables in promotion equations

	PR (obs. 9018)				MCF (obs. 12057)			
	mean	sd	min	max	Mean	sd	min	max
Productivity(Quantity)	0.81	0.75	0	4.26	0.48	0.64	0	4.89
Productivity(Quality)	1.21	0.98	0	3.19	0.81	0.98	0	3.18
Productivity(effort)	0.15	0.14	0	0.69	0.09	0.13	0	0.69
Quantity before promotion	0.81	0.47	0	2.82	0.60	0.44	0	2.81
Quality before promotion	1.63	0.65	0	2.73	1.34	0.74	0	3.11
Co-authors quantity	0.58	0.75	0	4.04	0.48	0.72	0	4.19
Co-authors quality	0.84	0.98	0	3.11	0.68	0.95	0	3.11
Co-authors zero Dummy	0.56	0.50	0	1	0.64	0.48	0	1
Large Project Dummy	0.02	0.15	0	1	0.02	0.14	0	1
Small Project with Foreign co-authors Dummy	0.52	0.50	0	1	0.36	0.48	0	1
Small project with only National co-authors Dummy	0.24	0.43	0	1	0.23	0.42	0	1
Small Project with co-authors of unknown affiliations Dummy	0.05	0.22	0	1	0.06	0.24	0	1
Wave 1985 (FR)	0.13	0.33	0	1	0.20	0.40	0	1
Gender	0.06	0.23	0	1	0.23	0.42	0	1
Age group 1	0.00	0.00	0	0	0.02	0.13	0	1
Age group 3	0.40	0.49	0	1	0.28	0.45	0	1
Age group 4	0.43	0.50	0	1	0.21	0.40	0	1
Age group 5	0.09	0.28	0	1	0.04	0.20	0	1
Field 30 (FR)	0.29	0.46	0	1	0.34	0.47	0	1
Zeros before promotion	0.09	0.29	0	1	0.15	0.36	0	1
Promotion before 1975	0.03	0.18	0	1	0.00	0.00	0	0
Zero after promotion	0.03	0.18	0	1	0.09	0.28	0	1

Appendix Table 2 Summary statistics of dependent and explanatory variables in productivity equation for France

	PO (obs. 8332)				PA (obs. 8089)				RU (obs. 5106)			
	mean	sd	min	max	mean	Sd	min	max	mean	sd	min	max
Productivity(Quantity)	1.16	0.89	0	4.36	0.82	0.88	0	4.38	0.94	0.88	0	4.43
Productivity(Quality)	1.55	0.95	0	3.76	1.16	1.02	0	3.17	1.34	1.02	0	3.57
Productivity(effort)	0.15	0.15	0	0.69	0.13	0.16	0	0.69	0.13	0.15	0	0.69
Quantity before promotion	1.00	0.59	0	3.24	0.86	0.53	0	3.32	0.82	0.63	0	3.31
Quality before promotion	1.65	0.81	0	3.11	1.52	0.66	0	2.80	1.35	0.80	0	2.86
Co-authors quantity	1.06	0.79	0	3.50	0.81	0.83	0	3.89	1.00	0.85	0	3.43
Co-authors quality	1.47	0.96	0	3.62	1.09	1.03	0	3.12	1.32	1.01	0	3.11
Co-authors zero Dummy	0.28	0.45	0	1	0.46	0.50	0	1	0.35	0.48	0	1
Large Project Dummy	0.22	0.42	0	1	0.16	0.37	0	1	0.20	0.40	0	1
Small Project with Foreign co-authors Dummy	0.48	0.50	0	1	0.33	0.47	0	1	0.39	0.49	0	1
Small project with only National co-authors Dummy	0.19	0.39	0	1	0.26	0.44	0	1	0.24	0.42	0	1
Small Project with co-authors of unknown affiliations Dummy	0.01	0.11	0	1	0.02	0.15	0	1	0.02	0.14	0	1
Wave 1980 (IT)	0.19	0.39	0	1	0.52	0.50	0	1	0.34	0.47	0	1
Gender	0.05	0.21	0	1	0.13	0.34	0	1	0.28	0.45	0	1
Age group 1	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.06	0	1
Age group 3	0.25	0.44	0	1	0.44	0.50	0	1	0.38	0.49	0	1
Age group 4	0.47	0.50	0	1	0.34	0.48	0	1	0.13	0.33	0	1
Age group 5	0.27	0.44	0	1	0.12	0.33	0	1	0.01	0.09	0	1
Fis01 (IT)	0.49	0.50	0	1	0.64	0.48	0	1	0.50	0.50	0	1
Fis02 (IT)	0.27	0.44	0	1	0.20	0.40	0	1	0.24	0.43	0	1
Zeros before promotion	0.15	0.36	0	1	0.08	0.27	0	1	0.17	0.37	0	1
Promotion before 1975	0.08	0.28	0	1	0.00	0.00	0	0	0.00	0.00	0	0
Zero after promotion	0.01	0.09	0	1	0.02	0.15	0	1	0.01	0.08	0	1

Appendix Table 3 Summary statistics of dependent and explanatory variables in productivity equation for Italy

	France	Addresses				
		0-5	6-10	11-20	>20	
Authors	1-5	65,66	0,16			*65,82*
	6-10	23,25	0,85	0,01		*24,11*
	11-20	2,63	0,77	0,05		*3,46*
	21-29	0,32	0,27	0,06	0,00	*0,66*
	Large projects	0,28	0,67	1,12	3,88	*5,95*
		92,15	*2,72*	*1,25*	*3,88*	*100,00*

	Italy	Addresses				
		0-5	6-10	11-20	>20	
Authors	1-5	65,61	1,27	0,01	0,00	*66,89*
	6-10	15,61	1,86	0,02		*17,49*
	11-20	3,21	1,82	0,15		*5,18*
	21-29	0,60	0,95	0,33	0,00	*1,87*
	Large projects	0,65	1,27	2,56	4,08	*8,57*
		85,68	*7,16*	*3,06*	*4,09*	*100,00*

Appendix Table 4 Two ways distribution of number of co-authors and of addresses explicitly listed in the articles.

	France		Italy	
1	USA	4.39	USA	2.60
2	GERMANY	1.70	INFN	2.30
3	INFN	1.28	ITALY	2.00
4	ENGLAND	1.28	GERMANY	1.25
5	ITALY	1.06	ENGLAND	1.08
6	CNRS	0.83	FRANCE	0.61
7	FRANCE	0.72	CNRS	0.54
8	RUSSIA	0.51	CERN	0.46
9	CHINA	0.48	JAPAN	0.35
10	BELGIUM	0.41	RUSSIA	0.34
11	CERN	0.31	BELGIUM	0.25
12	GREECE	0.29	SPAIN	0.24
13	JAPAN	0.29	SWITZERLAND	0.24
14	INDIA	0.23	CHINA	0.22
15	NORWAY	0.19	GREECE	0.21
16	SPAIN	0.19	NORWAY	0.16
17	SWEDEN	0.11	INDIA	0.13
18	SWITZERLAND	0.08	SWEDEN	0.09
19	DENMARK	0.07	DENMARK	0.08
20	CNR	0.02	CNR	0.04

** List limited to the 20 of most frequently cited countries or PROs.*

Appendix Table 5 Average number of authors per nationality or affiliation to CERN, CNRS and CERN, for Large Project articles, based on the addresses explicitly listed.

N.	Journal	Entry date	Exit date	Publications Italy	France	Total
1	PHYSICAL REVIEW B	1975	2005	4225	3424	7649
2	PHYSICAL REVIEW LETTERS	1975	2005	3000	2566	5566
3	PHYSICS LETTERS B	1975	2005	4129	1045	5174
4	NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION A-ACCELERATORS SPECTROMETERS DETECTORS AND ASSOCIATED EQUIPMENT	1984	2005	2446	552	2998
5	JOURNAL OF APPLIED PHYSICS	1975	2005	1245	1542	2787
6	APPLIED PHYSICS LETTERS	1975	2005	1178	1347	2525
7	NUCLEAR PHYSICS B	1975	2005	2039	308	2347
8	PHYSICAL REVIEW A	1975	2005	1281	1036	2317
9	JOURNAL OF CHEMICAL PHYSICS	1975	2005	875	1376	2251
10	PHYSICAL REVIEW D	1975	2005	1586	499	2085
11	PHYSICAL REVIEW E	1993	2005	1207	811	2018
12	SOLID STATE COMMUNICATIONS	1975	2005	831	938	1769
13	JOURNAL OF PHYSICS-CONDENSED MATTER	1989	2005	726	945	1671
14	EUROPHYSICS LETTERS	1986	2005	778	858	1636
15	JOURNAL OF MAGNETISM AND MAGNETIC MATERIALS	1977	2005	535	1060	1595
16	JOURNAL DE PHYSIQUE	1975	1990	257	1193	1450
17	OPTICS COMMUNICATIONS	1975	2005	625	810	1435
18	JOURNAL DE PHYSIQUE IV	1991	2005	264	1140	1404
19	NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION B-BEAM INTERACTIONS WITH MATERIALS AND ATOMS	1984	2005	731	652	1383
20	PHYSICS LETTERS A	1975	2005	960	349	1309

** The Table shows the first and last year in which we observe an article published on a journal (Entry date of the journal in the database and exit date of the journal from the database). It also gives the number of publications (Italian, French and the sum) available in the database for each journal.*

Appendix Table 6 Total number of articles by the French and Italian physicists in the 20 first journals listed in terms of decreasing numbers of articles*

Chapter 3 Career progress in centralized academic systems: an analysis of network effects[1]

3.1 Introduction

In the past 15 years or so, the number of empirical contributions to the economics of science has grown considerably (Audretsch et al., 2004). This literature has focused especially on the rate and direction of university research and on how the latter may be affected by changes in university funding patterns (Geuna, 1999) as well as by the spread of commercialization practices (see surveys by Geuna and Nesta, 2006; Siegel et al., 2007). Several essays have also dealt with the issue of scientific productivity and its determinants at an individual level (Stephan and Levin, 1992; Azoulay et al., 2007; Breschi et al., 2007; Hall et al., 2007). None of these studies, however, has examined explicitly the issue of academic careers (for an exception, see Ehrenberg, 2003); only if we leave the economics of science literature do we find isolated contributions from economists who are interested in the analysis of recruitment examinations in their own discipline (Perotti, 2002; Ginther and Kahn, 2004; Combes et al., 2008).

More generally, such economic studies in the economics of science have taken on board, without much discussion, the classical sociological analysis proposed by Merton (1957), as reformulated by Dasgupta and David (1994). Indeed, the coupling of classical sociological assumptions and economic analysis is a distinctive mark of what many now identify as the “new economics of science” (Stephan, 1996). According to such a perspective, scientists progress in their career to the extent that they are given credit for their contribution to knowledge advancement. Credit for such a contribution must be obtained from one’s own academic peers, who rely for their judgement on each individual scientist’s publication record (so that an incentive system comes into place that forces the disclosure and diffusion of data, methods and discoveries).

Although generalizing along these lines is still valid, this theory is not without limitations. Issues related to gender, stratification (by departmental prestige), and social capital may have a part in explaining the progression of scientific careers. These factors may combine with increasing returns to reputation (the ‘Matthew effect’) to create career trajectories that reward disproportionately those scientists who obtain early success (Merton, 1968 and 1988). While a few empirical studies have explored such issues for the US academic labour market (most recently, Long et al., 1993; and Long and Fox, 1995), almost no work has

[1] This chapter is largely based on joint work with Valerio Sterzi and Francesco Lissoni; see Pezzoni et al. (2009)

been carried out in European countries, where the institutional setting is both heterogeneous and altogether different from that in the US.[2]

In this paper we aim to fill this empirical gap. In order to do so, we update the conceptual framework of the Mertonian sociology of science (as received from the new economics of science), and examine the cases of France and Italy. This requires tailoring the notions of stratification and social capital to the institutional features of academia in the two countries. In both countries, academic advancement is heavily controlled by central government *via* disciplines, the latter to be intended as state-sanctioned guilds of professors, over which universities and departments exercise little control. In addition, both countries host large and powerful public research organizations (the CNRS, *Centre Nationale de la Recherche Scientifique*, in France; and the CNR, *Centro Nazionale delle Ricerche*, in Italy), which act as important channels of funding and legitimization for academic research.

In Section 3.2, we provide a brief summary of the relevant literature and the key determinants of academic careers it proposes; we also discuss briefly the specificities of Italian and French academic career paths and the consequences they bear for our analysis. In Section 3.3 we describe our data and methodology. In Section 3.4 we illustrate the results of our empirical analysis, and Section 3.5 concludes.

3.2 Determinants of academic careers: background literature and the cases of France and Italy

In this section, we discuss the key determinants of rank advancement in science, as they emerge from the empirical literature and from our own interpretation on the specificities of the recruitment processes in France and Italy. From the discussion, we derive a number of hypotheses to be tested by the regression analysis that follows.

3.2.1 Background literature

Both the classical sociology of science and the new economics of science have devoted considerable effort to examining the determinants of *scientific productivity*. The latter is considered to be affected both by biographical variables (such as a scientists' age and gender) and by several "institutional" or "social" variables, such as departmental prestige and the role of 'invisible colleges' (Crane, 1965; Hargens and Hagstrom, 1967; Clemente, 1973; Allison and Stewart, 1974; Reskin, 1977, 1978; Long 1978; Cole, 1979; Allison and Long, 1990; Levin and Stephan, 1991; Xie and Shaumann, 1998; Hall et al., 2007). However, much less attention has been paid to the effects of productivity on academic careers, possibly because of

[2] Again, a few exceptions are the occasional self-referential studies by economists on the career prospects within their own discipline, such as Checchi (1999) and Perotti (2002) for Italy, Combes et al. (2008) for France, and Coupé et al. (2005) for the US.

data constraints or because of the common assumption that productivity and career are inextricably linked (Hollingshead, 1940).

Only a few studies have analysed the two concepts separately, and highlighted explicitly the mechanisms that drive the recruitment process. As Caplow and McGee (1958, p. 109) observe: *"A distinction must be made between the two kinds of recruitment in general use "open", or competitive, hiring and "closed", or preferential hiring. In theory, academic recruitment is mostly open. In practice, it is mostly closed."*

Four dimensions of career success can be considered: participation, position, productivity, and recognition (Long and Fox, 1995). In this paper, we focus mainly on position, expressed by rank advancement within or across organizations. In this respect, most of the empirical work has focused on either biographical or individual determinants (seniority, productivity, gender). More rarely, some consideration has been given to institutional and social variables (departmental reputation, sponsorship, inbreeding).

Seniority and scientific productivity

In many jobs, career progress is a matter of time: seniority is rewarded (either formally or informally) with promotion. Academic jobs are no exception (Long et al., 1993, Modena et al., 1999). The time spent by a scientist at a given academic rank is always found to be one of the most important factors determining chances of promotion, either directly (more senior researchers stand higher chances of being promoted, ceteris paribus) or indirectly, via scientific production (more senior scientists stand a chance of accumulating a longer list of publications, which may be of help in getting promoted).

Scientific productivity

Classical sociologists of science have long studied scientific productivity, and invariably confirm Lotka's (1926) original results: whenever a large or random sample of scientists is considered, the distribution of scientific productivity is found to be highly skewed to the right. This means that a small minority of highly productive scientists is responsible for the majority of scientific publications, especially of those with large or at least meaningful impact (as measured by citations).

Productivity therefore has also been analysed in relation to rank advancement in academic careers, in particular to try and distinguish the effect of quality versus quantity.

While the impact of quantity is beyond doubt (see, for example, Clemente, 1973), the role of quality is more controversial, usually measured by citations to a paper or journal (impact factor). Hargens and Farr (1973) find that the number of citations received is positively associated with promotion, but their results are not confirmed by other works (such as Long et al., 1993).

Gender

The finding that women are at a disadvantage in terms of career progress is a recurrent one (Everett, 1994; Modena et al., 1999). Gender affects the probability of promotion both indirectly, through the channel of scientific productivity[3], and directly. Long et al. (1993) find that even after controlling for productivity, women scientists have a lower promotion probability. Similar results have been found by Cole (1979), Everett (1994) and Modena et al. (1999).

Departmental prestige

Many empirical studies show the importance of departmental prestige for a successful career. On the one hand, graduating and working in a prestigious institution gives visibility and access both to information and to knowledge embedded in other productive scientists, which makes promotion easier, especially if associated with mobility across universities. On the other hand, more prestigious university departments apply more stringent criteria for promotion, which makes internal promotion harder to achieve (Long et al., 1993). Longitudinal studies find evidence that departmental reputation affects productivity and that changes in departmental location are associated with changes in productivity (Allison and Long, 1990). They also find that the ranking of PhD education is one of the most useful predictors of success in academia, where success means getting a job in a highly-ranked academic institution, even after controlling for productivity (Hargens and Hagstrom, 1967).

Stratification by PhD-granting institutions may also be interpreted as a consequence of the Matthew effect, according to which scientific credit is more easily recognized by those scientists who already enjoy it, than by non-tested or less-tested ones (Merton, 1968). Long et al. (1979) find evidence that entry into an academic career does not depend on scientific productivity, if one controls for the effects of doctoral origins and the prestige of a junior scientist's mentor.

Mentoring

The "mentor" is typically a senior member of an organization who commits to facilitating the careers of his (or less often her) students or junior colleagues (Kirchmeyer, 2005). Mentors may influence the career success of their students and colleagues either indirectly by improving their protégés' performance, and/or directly by introducing the protégés to their own social network and providing contextual signals of reputation and ability (Kram, 1985; Ferris and Judge, 1991).

[3] Gender differences in productivity have attracted the attention of both sociologists and economists (Reskin, 1978.; Cole, 1979; Stephan and Levin, 1992; Prpic, 2002; see also Modena et al., 1999). Several reasons have been put forward to explain why women appear to be less productive than their male counterparts (Xie and Shaumann, 1998; Zainab, 1999): more limited access to relevant social networks (woman are more isolated and excluded from "old boys'" social circles; Cole and Zuckerman, 1984); less interested in pure research; lower graduation rate from prestigious universities; more severe family-career trade-offs.

Reskin's (1979) study on academic chemists suggests that the direct effect of mentoring is quite relevant during the early years of a scientist's career. Kirchmeyer (2005) obtains similar results for a sample of American accounting academics.

Inbreeding

Academic "inbreeding" occurs whenever an academic institution tends to recruit its scientists chiefly from among those who took their degrees within it, either at the undergraduate and/or at the graduate level. Inbreeding has been viewed as an expression of academic particularism. However, McGee (1960), through an investigation of the junior faculty of the University of Texas, found that 29 per cent of the full-time professors had a University of Texas degree and justified the use of inbreeding for financial reasons and geographical isolation. In this view, inbreeding can be seen as an efficient way for selecting people, in proper circumstances.

The relationship between academic inbreeding and scientific performance has been examined by Hargens and Farr (1973). For scientists in their first academic job, no relationship appeared to exist between their academic origins and scientific performance (either at the quantity or quality level). For scientists at their second and/or successive career step, it is found that those "who have been inbred throughout their careers [..] tend to be less productive" (Hargens and Farr, 1973, p. 1392). Hargens and Farr (1973) also look at how many years it takes for an assistant professor to be promoted to an associate position, and find that inbred scientists wait for longer than others, even after controlling for differences in terms of productivity.

Social capital

The existing literature suggests that social connections affect promotion chances indirectly through productivity. Gonzalez-Brambila et al. (2006) find that networks promote the creation of new knowledge, by granting greater access to resources and information: the individuals who occupy central positions in their academic network have a propensity to create more knowledge, while the number of ties has a positive impact on future productivity.

It is possible to hypothesize a direct relationship, in particular through two different channels:

1. Following again Gonzalez-Brambila et al. (2006), it is reasonable to assume that universities, after deciding to fill a vacancy, give positive consideration to the candidates' academic networks, to the extent that the latter may add to the university's visibility and access to resources; however, no author has apparently investigated this possibility, either theoretically or empirically.

2. The individual with a strong network position may be perceived as more influential within the scientific community (Kilduff and Krackhardt, 1994). As individual performances are often hard to

evaluate only on the basis of past scientific production and citations (especially when recent publications are considered), prospective recruiters may look for other signals of quality, such as the position of the scientist in his or her community, and the influence he/she is expected to exert on his/her peers.[4]

One should note, however, that when it comes to the empirical analysis of junior scientists' careers it may be hard to distinguish these network effects from mentoring. Junior scientists working in association with influential mentors will tend to occupy a more central position in the social network than other colleagues of the same age and with similar productivity. As a result, it will be hard to say whether their higher promotion chances are explained, ceteris paribus, by the recruiters' consideration of their social capital, or by the influence exercised by their mentors on the recruiters.

An important issue related to social capital is that of measurement. Social network analysis based upon co-authorship data has a long tradition of application in the sociology of science, dating back to the early identification of 'invisible colleges' (Crane, 1969 and 1972), up to the recent application of small-world theory to the description of collaboration patterns (Newman, 2001)[5]. Co-authorship is usually seen as proof of collaboration and knowledge exchange between two or more scientists. However, more complete measures also take into account sociometric information, such as the individual scientist's dependence on another for advice or mentoring. In our study, in the absence of sociometric data, we will make use of refined bibliometric indicators aimed at capturing (at least partially) the same type of information.

3.2.2 Academic careers in France and Italy

As one can easily gather from checking the references in the previous section, most of the applied and quantitative literature on academic careers derives from US scholars, whether economists or sociologists. As stressed by many authoritative studies (Ben-David, 1977; Clark, 1993) however, the US system has unique features in terms of university autonomy and academic labour market mobility. Universities select candidates for professorial jobs in total autonomy, with no control from the central (federal) or state governments. Once selected, professors become university employees and can bargain for their wages and working conditions on an individual basis (as opposed to many of their colleagues in Europe, who are civil servants in the public administration, whose wages are set or capped by law). In addition, the sheer number of US academic institutions, together with a competitive funding system, allow US-based scientists with a strong publication record the opportunity to move from one university to another in search of better paid, or better funded research positions (Ehrenberg et al., 1991). Finally, the system is openly stratified according to the research vs. teaching intensity of the academic institutions, and the latter's wealth: two-

[4] For some evidence in this direction, albeit not within the academic realm, see Seibert et al. (2001)
[5] For a different approach to the social network analysis of science, see Mullins et al. (1977), who base their graphs on co-citation patterns. For a different use of co-authorship data, see Gonzalez-Brambila et al. (2006)

and four-year colleges follow different recruitment criteria to the 200 or so "research universities"[6], and the latter differ widely in terms of financial resources, with private institutions most often being in a better-off position than the public ones.

On the contrary, both the Italian and French academic recruitment processes derive from a mix of state control and professional corporatism. As such they represent, at an extreme level, the common situation throughout Europe. All French and Italian professors are civil servants, whose recruitment regulations, duties and wages are fixed by national laws, and cannot be bargained for at the local level, let alone the individual one. The French academic system has two main positions called "*Maitre de conférence*" (MCF) and "*Professeur*" (PR). In Italy there are three positions called "*Ricercatore universitario*" (RU), "*Professore associato*" (PA) and "*Professore ordinario*" (PO). Here we are concerned mainly with career advancements, from MCF to PR in France, and from RU to PA or PO in Italy.

All positions are tenured, and for all of them salaries are defined by national laws. All academic personnel are classified by the government according to their discipline. Disciplines fulfil a role similar to professional guilds: their members, and not individual universities or departments, retain formal control over the recruitment process.

In Italy, disciplinary classification is very detailed, and it is negotiated periodically between the Ministry and the leading senior professors of the country. Over the past 20 years, the classification system has grown larger and more fragmented, and at present it includes more than 170 disciplines just for science, medicine and engineering alone[7]. Any university wishing to fill a vacancy or simply to offer a new position has first to specify for what discipline the position is offered; then it has to launch a call for applications (concorso) and set up an examining committee. All the committee members must belong to the same discipline for which the position is offered; one of them is chosen by the university, most often from among the internal faculty, and two to four others are elected with a national secret ballot by all professors ranked as high, or higher than the position on offer, also from the selected discipline. Nominally, the commission does not have the task of picking the most suitable candidate for the university that launched the call (on the basis, for example, of the candidate's and the university's research interests coinciding), but the best possible candidate in absolute terms, who should be the one with the best publication record (called "idoneo", which means fit-for-the-job). In principle, if the university does not like this candidate, it can always refuse to nominate him/her and launch a new job call. In practice, most commissions try to steer the selection

[6] Research universities are commonly identified as those granting PhDs, and are ranked according to a number of criteria. The original classification was proposed in 1970 by the Carnegie Commission of Higher Education, which has updated it since then (http://www.carnegiefoundation.org/classifications/)

[7] Overall there are no less than 300 disciplines; some of them, such as "Naval Architecture" and "Naval and Marine Engineering" – notice they are considered separately - counted less than 30 affiliates in 2005.

process towards candidates who they know will be acceptable to the university[8]. In some job competitions, the commissions are also allowed to declare two winners (two idonei), only one of which will be selected by the university[9].

The French recruitment system follows different procedures for different disciplines, the most notable differences being between the natural sciences and the social sciences, including humanities and law. Differences also exist between procedures for the recruitment of "*Maitres de conférence*" (MCFs) and "*Professeurs*" (PRs). For MCFs seeking promotion to PRs in physics (who are studied in this paper), the so-called *concours* runs over two phases. The first phase, called "*qualification*" is centrally managed by the National Council of Universities (*Conseil National des Universités*, CNU), an overseeing body under governmental control. The second phase, on the contrary, is up to the individual universities that have to fill the vacant positions[10].

The CNU is divided into sections and each section has to evaluate the candidates in each single discipline. Each CNU section is made up both of members elected by the professors in the discipline, and of members appointed by the minister. All members serve for more than one year. As in the Italian system, professors are classified according to their disciplines, although the latter are not divided up into as many categories (there are 73 of them overall). Each year, the CNU releases a list of "qualified" candidates on the basis of their publication and teaching records.

In the second phase of the recruitment process, the qualified candidates apply for professorial jobs at local institutions (after four years, candidates who have not found a job lose their qualification). Each university has recruitment committees (*commissions de spécialistes*) devoted to the evaluation of applicants, one for each discipline or at least for each group of related disciplines in small universities. The committees, elected every four years, are composed of members of the faculty and invited members from other institutions or disciplines.

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8 This requires a lot of political background work to be done by the university, in order to steer the secret ballot in the direction of selecting at least a majority of external commissioners on good terms with the university. Once that result has been achieved, those commissioners will take care of letting some prospective candidates know their presence would be an embarrassment to the commission (these are typically those candidates who have a strong publication record, so that they could be potential winners, but are not considered suitable by the university issuing the *concorso*). On the long-standing importance of such practices in the Italian academic system, see Clark (1977).

9 In this way, the examining commission is free to let both the strongest candidate and a local insider win. Then the latter will be chosen for the job, and the former will possibly be called by some other university. A controversial rule, in fact, allows fit-for-the-job (*idonei*) candidates, who have not been recruited, to be offered a job position by other universities, which in this case will be exempted from the duty of launching a national call for applications. Needless to say, this possibility is often exploited for more political bargaining among the professoriate: external commissioners may agree to trade the nomination of a local candidate from the university which has issued the job call, in exchange for a 'fit-for-the-job' certificate for another candidate, who they wish to recruit in their own university (Moscati, 2001).

10 For the physical or natural sciences, in France, promotion from MCF to PR can be granted only to prospective candidates who have obtained a qualification to act as PhD supervisors (*Habilitation à diriger des recherches* or HDR). MCFs obtain such a qualification from the same university where they are employed, upon presentation and discussion of a synthesis of the research work they have produced over the years. However, holding a HDR does not change the scientist's wage and duties, nor does it guarantee promotion to PR. In social sciences and law, the HDR requirement is superseded by the possibility of sitting a special examination at a national level (*Concour d'agrégation*) which leads directly to the PR position.

So, the main difference between Italian *concorsi* and French *concours* lies at the qualification stage. While French candidates achieve it through a committee which is both national and under some degree of ministerial control, in Italy the qualification has to be obtained through strategic agreements among members of the many commissions scattered across the individual universities.

Both the Italian and the French recruitment systems have been severely criticized in recent years, resulting in a succession of reforms shifting the balance of decision-making in recruitment matters back and forth between national and local levels (Moscati, 2001; Musselin, 2005). None of these reforms, however, has gone as far as to grant universities total freedom in recruitment matters, or to re-establish total control by government. As for the role of disciplines, this has possibly increased in Italy, due to progressive fragmentation, which makes it easier to control elections.

This brief examination of the recruitment process in the two countries suggests a few observations on the factors affecting academic careers, as derived from the US-centric literature we examined.

Length of career, in principle, should not affect rank advancement chances, since seniority does not enter the examination criteria of *concorsi* either. On the contrary, productivity should be a key determinant of career advancement in both countries, and more so in Italy than in France.

The egalitarian norms typical of French and Italian legislation forbid the consideration of departmental prestige as a factor to be evaluated by the examining commissions: all PhD titles have to be considered equal, since no official ranking of universities or department exists, and no unofficial information can be deemed as relevant by examiners. Similarly, mentoring should have no role, since no reference letters are admitted into the process. However, in the Italian system, mentors may either lobby in order to be elected onto the examination committee, or ensure that some close colleagues of theirs are elected in their place, so they can exert direct influence on the recruitment process. In France, this result is also possible but harder to achieve, as the national examination committee is not entirely elected, and the disciplines are too large for their members' voting intentions to be easily steered. Both in France and in Italy, in addition, departments are visibly ranked according to the strength of their ties to the two largest public research organizations, respectively the CNRS (Centre Nationale de la Recherche Scientifique) and the CNR (Centro Nazionale delle Ricerche). In France, the CNRS has traditionally played a more important role in research than universities. It receives the largest portion of research funds from the government, some of which it redistributes to academic scientists via collaborations and partnerships. However, since the 1970s, policy-makers have pushed for a better integration of the CNRS and academic research structures. Nowadays, the CNRS operates mainly through laboratories located within universities, and universities compete to host such laboratories. As a result, departmental laboratories are nowadays ranked according to a vertical hierarchy: at the top (by prestige and resources) we have the laboratories staffed only by CNRS personnel and funded directly by the CNRS and the Ministry of Education; then, those staffed by both CNRS and university personnel (known as UMR, Unité Mixte de Recherche); and finally those exclusively staffed by university personnel, with little or no access to CNRS funds (Mustar and Laredo, 2001).[11] In Italy, CNR laboratories do not, in general, have the same importance as their CNRS equivalents. However, in nuclear physics, the CNR often controls key research tools and infrastructures, so that participating in their research programmes is, for academic scientists, a necessary precondition of conducting research. In material physics, a similar role is played by the INFM (Istituto Nazionale di Fisica della Materia), a research organism that was for a long time independent of the CNR (it was absorbed by the latter only in 2005). The INFM operates via a network of laboratories, all except one of them located within different universities and staffed by academic personnel. Such a modus operandi creates a hierarchy not dissimilar to the one we described above for the CNRS in France.

Inbreeding is a major force behind recruitment in both countries. Again, in principle, it should not be so, but in practice all peripheral universities face the problem of fending off candidates who, although qualified, would not be dedicated to the institution. This situation is due to the civil servant status of professors in both countries: a professor's salary profile over time does not depend upon the university's decision, but is fixed by law and linked exclusively to seniority; universities have no power to fire absentee professors, or to moderate the balance between their research and teaching duties according to the university's needs (teaching loads are also determined by law). So, brilliant scientists from top universities (or foreign ones) are seen by peripheral, teaching-oriented universities as a threat: once recruited, they try to spend as little time as possible locally, in order to maintain informal research ties with their *alma mater* (Musselin, 2005). Accordingly, more peripheral universities will try to play the system in order to push forward their internal candidates, rather than recruiting external ones.

As for gender, no apparent reason exists to think of peculiarities for France and Italy with respect to the US-based evidence at hand. However, a quick look at available statistics show women are under-represented at the higher levels of the academic ladder.

Finally, as far as social ties are concerned, one should note that in the French and Italian systems they do not only serve the purpose of information sharing and knowledge creation. Prospective candidates for professorial positions have an incentive to nurture ties with senior members of their discipline, the latter being very likely to sit on their examination boards. This ought to be especially true of Italy, where both stages of the recruitment process are in the hands of local committees. When attempting to measure the importance of junior scientists' social capital, an effort should be made to distinguish between contacts

[11] In the life sciences, the role of the CNRS is often taken by INSERM (*Institut National de la Santé et de la Recherche Médicale*). Similarly, in more applied disciplines other public research organizations may play a similar role (as is the case of INRA, *Institut National de la Santé et de la Recherche Médicale*, for agricultural studies). We insist on the role of the CNRS due to its dominant influence on physics, to which our data will refer.

that have the potential to increase a scientist's productivity, and those that are more instrumental, and serve the purpose of linking up with decision-makers at a disciplinary level.

3.3 Data and methodology

This section provides a description of the data and the model we will use to assess the determinants of academic promotions in France and Italy. Section 3.4 shows the statistical models estimated.

3.3.1 Data

The data collected for this paper are drawn from the complete list of Italian and French academics active in the academic year 2004/2005, which we obtained from the Ministries of Education in the two countries. In particular, we focus our attention on physics, with particular emphasis on material physics. Due to the need of reconciling differences in the French and Italian classification system of disciplines, we were forced to use quite broad disciplinary categories, so that our sample ended up including also a large number of nuclear physicists (although not the majority of them; no astrophysicists were included).[12] We concentrate on rank advancements between 2000 and 2005 for Italy, and between 2000 and 2003 in France (that is, our dependent variable is the promotion for which a scientist may apply).

We recall from Section 3.2.2 that steps in an academic career are country-specific. The French academic system has two main positions called "Maitre de conférence" (MCF) and "Professeur" (PR). In Italy there are three positions called "Ricercatore universitario" (RU), "Professore associato" (PA) and "Professore ordinario" (PO). Since a direct comparison between the careers of academic scientists in the two countries cannot be made without an aggregation of two of the three Italian positions, we decided to compare the promotions from MCF (in France) and RU (in Italy) to higher ranks; and to examine separately the promotion from PA to PO (which applies only to Italy).

The main reason for this choice is that academic careers (acquisition of the MCF or RU rank) start roughly at the same age (33 years, on average) in both countries (see Appendix table 1); this allows us to consider a uniform starting point for admission to higher ranks. However, the age structure of MCFs and RUs is not the same, the former usually being younger than the latter. Therefore, in order to increase comparability, we excluded from both the MCF and RU samples those scientists who were either too young or too old to be considered for promotion, namely those younger than 30 or older than 50. This leaves us with a total number of scientists in our sample of 1285, of which 816 French and 469 Italian. Of these, less than 14 per

[12] The disciplinary fields we considered, as described by the extant classifications, are, for France: *Milieux denses et materiaux* (28) and *Milieux dilues et optique* (30); for Italy: *Fisica Sperimentale* (Fis/01), *Fisica Teorica, Modelli e Metodi Matematici* (Fis/02), *Fisica della Materia* (Fis/03) (codes in brackets are from the classification systems). Other physics-related fields which are present in the two countries' classification system, and which we excluded, are, for France: *Constituants elementaires* (29) and *Astronomie & Astrophysique* (34); and, for Italy: *Fisica Nucleare e Subnucleare* (Fis/04), *Astronomia e Astrofisica* (Fis/05), *Fisica per il Sistema Terra e il Mezzo Circumterrestre* (Fis/06), *Fisica Applicata* (Fis/07). For Italy, we also did not consider a number of classes within the engineering disciplines.

cent were promoted to a professorial position in France, as compared to 45 per cent in Italy, with differences across disciplines for Italy (see Appendix Table 1 and Table 2). Most of the promoted scientists did not change affiliation after promotion: only 20 per cent changed university in France, and less than 6 per cent in Italy (Table 1). Some gender gap also appears to be significant, and it is more visible for France.

	FRANCE			ITALY		
	Total	**Men**	**Women**	**Total**	**Men**	**Women**
No. of scientists [MCFs-France; RUs-Italy]	816	601	215	469	365	104
Promoted*, no. and % over no. of scientists	110 (13.5%)	95 (15.8%)	15 (7%)	211 (45%)	172 (47%)	39 (39%)
Mobile**, no. and % over promoted	22 (20%)	19 (20%)	3 (20%)	12 (5.7%)	11 (6.4%)	1 (2.5%)

**MCFs and RUs promoted to professorial positions (aged between 30 and 50) **MCFs and RUs who changed university affiliation when promoted*

Table 1 Promotion and mobility

We then went on to build three classes of explanatory variables: individual (productivity, inbreeding, age, and gender), stratification-related (that is, proxies of departmental prestige), and mentoring- or social capital-related (which we derive from analysis of co-authorship patterns). A complete list of these variables is reported in Table 2.

2a. Productivity and individual characteristics	
Gender	Gender dummy (=1 for women scientists)
Age	Scientist's age in year 2000
Productivity (α)	Cumulative sum of impact factors of the journals where articles are published, weighted by the number of co-authors (see Equation 1)
Articles	Gross number of publications
Relative productivity	Ratio between individual Productivity (α) and average Productivity (α) for each discipline individual i belongs to
Inbreeding	No. of co-authors from same university / No. of co-authors
Field probability	Average probability of being promoted for each field and rank, i.e. % of researchers promoted in each field and rank
2b. Stratification	
CNRS	Percentage of articles published between 1995 and 1999 which list at least one CNRS or UMR affiliation, for each scientist i
CNR	Percentage of articles published between 1995 and 1999 which list at least one CNR affiliation, for each scientist i
INFM	Percentage of articles published between 1995 and 1999 which list at least one INFM affiliation, for each scientist i
2c. Network variables	
Principal Component	Connection dummy (=1 if scientist belongs to principal component of co-authorship network, 1995-1999)
Closeness	Inverse of avg shortest path between the scientist and other scientists in the principal component (co-authorship network, 1995-1999; =0 for scientists outside the principal component)
Credit	Weighted sum of ties with PO or PR, where the ties are a co-publication and the weight is 1 over the total number of PO/PR's articles.
Right Credit	Weighted sum of ties with PO or PR, where the ties are a co-publication and the weight is 1 over the total number of PO/PR's articles times the PO/PR's closeness.

Table 2 Career determinants (explanatory variables for promotion)

3.3.2 Individual covariates

As discussed in Section 3.2, scientific productivity is nominally the main determinant of rank advancement in both Italy and France. Publications in national and international scientific journals are widely recognized to be an indicator of the scientist's research productivity although other measures exist such as, for example, books and book chapters or, in some fields, patents and prototypes. In order to identify those publications we rely upon a database we compiled from the ISI-Web of Science, which contains all scientific articles published between 1975 and 2000, authored by at least one professor of physics active in an Italian or French university during the year 2004/2005. We consider only articles published in journals with an impact factor higher than 0.5. [13]

[13] The impact factor of a scientific journal is calculated by "..dividing the number of times a journal has been cited by the number of articles it has published during some specific period of time. The journal impact factor will thus reflect an average citation rate per published article..." (Garfield, 1972). We consider the average impact factor of each journal calculated as in the latter definition in a time window of 5 years. The first year of observation varies according to the journal and, on average, we observe citations in each journal for a period of 13 years. The complete list of selected journals is available on request, while a selection of the most relevant ones (by number of articles published by scientists in our sample) is reported in the Appendix (Table 3)

We do not distinguish between quality and quantity of the publications, but we use a summary index that accounts for both these features. First, we weigh each publication for the impact factor of the journal. Second, we take into account multiple authorship by assigning to each individual author a fraction of publication, which we calculate as $1/(1-\alpha)^{aut-1}$, where α is a parameter greater or equal to zero, and aut is the number of co-authors of the publication considered. Equation 1 shows the productivity measure of scientist *i* between the time interval (t_0 ,t):

$$Productivity_{i,t}(\alpha) = \sum_{a=1}^{n_t} \frac{imp_a}{(1+\alpha)^{aut_a - 1}}$$

[Equation 1]

where articles are indexed from $a=1$ to $a=n_t$, n_t is the number of articles signed by scientist *i* from the beginning of his/her career up to the year *t* (1999, in our application) $imp_{a,i}$ is the impact factor of the journal where article *a* is published, and $aut_{a,i}$ is the number of co-authors of *a*.

We experiment with different values for α, such as α=0 (each publication is assigned to the scientist in its entirety, no matter the number of co-authors) and α=1 (which is such that a publication with two co-authors counts for exactly half a publication, while a publication with *n*>2 co-authors counts for a fraction smaller than *1/n*, which declines faster than *1/n* as n grows).

We also experiment with the simple count of publications (*Articles*) over the time interval (t_0 ,t), a measure that does not take into account the number of co-authors nor the impact factor of journals. Correlation matrixes in the Appendix Table 4 show that all such measures of productivity are highly correlated.[14]

[14] We also experimented with citation-weighted article counts, where each publication was multiplied by the number of citations it received up to 2008 (our data do not allow us to classify citations according to the year of publication of the citing article). The regression results did not change much (and are available on request).

	Obs.	Mean	Standard Deviation	Min	Max	Median	90° percentile
Individual covariates							
Gender	816	0.26	0.44	0.00	1.00	0.00	1.00
Age	816	36.37	4.77	30.00	50.00	35.00	43.00
Productivity(α=1)	816	19.90	46.20	0.00	563.40	10.31	39.45
Productivity(α =0.25)	816	35.21	76.49	0.00	987.97	19.54	70.09
Productivity(α =0.10)	816	54.14	110.91	0.00	1417.94	30.40	104.27
Articles	816	13.70	30.73	0.00	373.00	8.00	24.00
Prob_field	816	0.13	0.01	0.13	0.14	0.13	0.14
Relative Productivity(α =1)	816	1.00	2.16	0.00	34.06	0.53	2.08
Inbreeding	816	0.30	0.41	0.00	1.00	0.00	1.00
Productivity(α =1)_field *Milieux denses et matériaux*	559	16.40	33.77	0.00	558.66	8.82	36.31
Articles_field *Milieux denses et matériaux*	559	11.90	25.19	0.00	340.00	7.00	22.00
Productivity(α =1)_field *Milieux dilués et optique*	257	27.52	64.99	0.00	563.40	13.50	49.04
Articles_field *Milieux dilués et optique*	257	17.60	40.00	0.00	373.00	10.00	28.00
Stratification covariates							
CNRS	816	3.05	4.84	0.00	71.00	1.00	8.00
Network variables							
PrincipalComponent	816	0.38	0.49	0.00	1.00	0.00	1.00
Closeness	816	0.04	0.05	0.00	0.16	0.00	0.12
Credit	816	0.20	0.34	0.00	1.96	0.00	0.73
Weighted_Credit	816	0.02	0.03	0.00	0.24	0.00	0.05

Table 3a Descriptive statistics (MCF, France)

	Obs.	Mean	Standard Deviation	Min	Max	Median	90° percentile
Individual covariates							
Gender	469	0.22	0.42	0.00	1.00	0.00	1.00
Age	469	40.00	4.75	30.00	50.00	39.00	47.00
Productivity(α =1)	469	53.47	50.14	0.00	326.67	39.28	125.25
Productivity(α =0.25)	469	82.99	86.01	0.00	573.53	57.09	210.95
Productivity(α =0.10)	469	120.31	110.14	0.00	745.27	90.78	268.43
Articles	469	43.06	49.80	0.00	290.00	29.00	87.00
Prob_field	469	0.45	0.07	0.33	0.53	0.44	0.53
Relative Productivity(α =1)	469	1.00	0.85	0.00	6.70	0.80	2.06
Inbreeding	469	0.42	0.39	0.00	1.00	0.33	1.00
Productivity(α =1)_field *Fisica sperimentale*	245	34.22	31.76	0.00	229.13	25.60	70.99
Articles_field *Fisica sperimentale*	245	56.23	63.96	0.00	290.00	33.00	196.00
Productivity(α =1)_field *Fisica teorica, modelli e metodi matematici*	80	95.97	62.92	0.00	326.67	86.68	170.03
Articles_field *Fisica teorica, modelli e metodi matematici*	80	29.01	18.78	0.00	111.00	25.00	49.50
Productivity(α =1)_field *Fisica della materia*	144	62.62	50.90	0.00	237.49	49.30	138.16
Articles_field *Fisica della materia*	144	28.44	17.80	0.00	81.00	26.00	53.00
Stratification covariates							
CNR	469	6.44	9.77	0.00	92.00	3.00	17.00
INFM	469	2.88	4.93	0.00	30.00	0.00	9.00
Network variables							
PrincipalComponent	469	0.70	0.46	0.00	1.00	1.00	1.00
Closeness	469	0.10	0.07	0.00	0.20	0.13	0.17
Credit	469	0.36	0.51	0.00	3.34	0.13	1.00
Weighted_Credit	469	0.05	0.08	0.00	0.49	0.01	0.15

Table 3b Descriptive statistics (RU, Italy)

Table 3 (which reports descriptive statistics for all the covariates) shows that, whatever adjustment we make to the index, the productivity of Italian scientists appears to be more than three times higher than that of their French colleagues, with a higher standard deviation. In a few regressions we also control for cross-disciplinary differences in productivity by adjusting the productivity index for the average productivity in the discipline, as shown in Equation (2)

$$\text{RelativeProductivity}_{i,t} = \frac{\text{Productivity}_{i,t}(\alpha = 1)}{\text{AverageProductivity}(\alpha = 1)_{discipline,t}}$$

[Equation 2]

Other variables of interest at the individual scientist's level are age (which we treat as a proxy for the scientist's career length)[15] and gender. Table 3 shows that French MCFs are on average younger than Italian RUs, even if they reach that position (on average) at the same age of 33 (see Appendix Table 1): this is due to the higher recruitment rates of MCFs than of RUs.

3.3.3 Stratification by departmental prestige

We measure stratification by means of a set of variables based upon information on scientists' affiliation, as derived from the ISI-Web of Science records.[16] Each ISI record lists, in separate fields, the author's or co-authors' names, and affiliations at the department or laboratory level, with information on whether the department/laboratory is affiliated to the CNRS for France, and the CNR or INFM for Italy. Unfortunately, there is no one-to-one correspondence between names and affiliations. As a consequence, we cannot derive from publication records the exact affiliation of each scientist; at most, we can say that either the scientist and/or one or more of her co-authors belong to such types of research units. However, this is still quite a useful piece of information, because at the very least it signals some connection between the latter and the scientist.[17]

For each French scientist, we build a *CNRS* variable, which represents the percentage of a scientist's papers (from 1995 to 1999) which list at least one CNRS or UMR affiliation. Similarly, for Italy, the *CNR* and *INFM* variables measure the percentage of papers with at least a CNR or INFM affiliation.

3.3.4 Social capital covariates

The most intuitive form of social capital relates to inbreeding, which we defined in Section 3.2.2 as a tendency of several universities to recruit higher-ranked scientists from within their own departments. Data in Table 1 have shown how little mobility we observe in Italy, which is a sign of inbreeding. In order to capture this effect we consider how well positioned a prospective candidate is for promotion in the university to which he/she is affiliated (and where he/she stands the best chances of being promoted, as discussed in Section 3.2). In particular, we measure Inbreeding as the ratio between the number of a scientist's co-authors (of publications up to 1999) still active in the same scientist's university, over the total number of co-authors.

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[15] In the absence of information on their actual date of completion of PhD studies, we assume all scientists start their academic career at 25 (which is the lowest possible age of completion of a PhD, for students who followed standard lower and higher education curricula). As a consequence of assuming the same starting year of careers for all scientists, we have perfect correlation between a scientist's career length (measured in years) and age.

[16] Our lists of scientists, obtained from ministerial records, also list the scientists' affiliation, but only at the university level. That is, they do not provide information on the specific department to which the scientist is affiliated, nor on the association between such departments to the large public research organizations from which prestige and resources may derive.

[17] In particular, for France, affiliation information may contain references to either the CNRS or UMR, which signal respectively the presence of a CNRS laboratory within the university or of a mixed CNRS-university research unit (see Section 2.2). As for Italy, any mention of the CNR in the affiliation field of an academic scientist's publication record signals most often the presence, among co-authors, of one or more CNR employees. Also for Italy, any mention of INFM may signal that either the author and/or one or more co-authors are academic scientists working for an INFM-affiliated laboratory.

While Inbreeding refers exclusively to scientists' relationships within their own university, the importance of disciplinary control over careers, both in France and in Italy, suggests that an analysis should also be carried out of the relationships scientists may entertain with colleagues from the same disciplines, but not necessarily from the same institution. We do so by examining the scientists' co-authorship networks, between 1995 and 1999[18].

In particular, we have built two distinct networks, one for Italy and one for France, each of them having only the academic physicists of our sample as nodes, and the co-authorship ties between them as ties, to the exclusion of any other co-authors. This means that we concentrate on national networks, and deal separately with the publication records of the Italian and French physicists. This choice has both a practical and a theoretical explanation. On practical grounds, the inclusion of all the co-authors of the French and Italian scientists in our sample as network nodes would have required also collecting all the publications of such co-authors, including those written in collaboration with scientists outside our sample. This was well beyond our means. Alternatively, including foreign, retired or student co-authors as nodes of our networks, without including also the co-authorship ties between them, would have meant introducing a severe distortion in our measurements of the network structure.

On theoretical grounds, networks of collaboration may be seen as systems for the distribution of various types of resources: information (on research questions, data sources, methods…); knowledge (such as expertise or tacit skills); and status or power (the scientist's position in the network conveying information on his/her social capital or influence). In this paper, we stress the status/power interpretation. Due to their national dimensions, our networks convey information on the various scientists' standing within the national community, not the international one[19]. In terms of pure scientific reputation and access to knowledge, it is the latter that matters most. But when it comes to getting a job or promotion in France and Italy, where jobs and promotions are decided by the highest ranked and influential members of the discipline, it is the latter that counts[20].

[18] The 5-year window is meant to capture ongoing research partnerships, or at least those partnerships that involve scientists still active between 2000 and 2005. The same time window was used by Newman (2001) and related to work on small worlds in science, so is comparable with our work.

[19] A scientist's position in our national networks is not necessarily correlated to his/her international standing. For example, some isolated nodes in our network could be scientists with limited connections to their national communities, but many co-authorship ties with foreign colleagues (as may happen for young scholars with a PhD from a foreign institution).

[20] However, we have also controlled for the role of international networks, within the limits of our data. In particular, we have controlled our regressions for the number of international affiliations for each researcher's paper over a 5-year window, from 1995 to 1999. This variable plays no role on the probability of being promoted and does not affect the estimated marginal effects of all other covariates. We do not report the results due to space limitations (but they are available upon request).

	ITALY	FRANCE
% of scientists in the principal component (over non-isolates*)	83.2%	64.2%
Size ratio second largest / principal component	1.5%	1.8%
% of isolated scientists over total scientists *	26.7%	65.9%
Network density °	0.0090	0.0057

** isolates=scientists with no publications or no co-authors from the same country ° no. ties /no. of potential ties*

Table 4 Co-authorship networks, 1975-1999 (only national scientists); selected statistics

Table 4 demonstrates that our national networks show both low density and a "giant" component, that is, a principal component (the largest in the network) which collects the vast majority of connected scientists (between 64 and 83 per cent, excluding isolates), many more than any other cluster of scientists (see the very low size ratio between the second largest and the principal component). These are common features to all co-authorship networks in science, as measured in the literature. Notice also that the relative size of the principal component for Italy is quite a lot larger than its counterpart for France. This is explained by the much higher rate of co-authorship in Italy (for a discussion of this, see chapter 2 and chapter 4).

In our regressions, we consider four different synthetic measures of a MCF or RU in his/her national network: *Principal Component*, *Closeness, Credit,* and *Weighted_Credit* (see also Table 2c above).

Principal Component is a dummy that takes the value one if the scientist belongs to the principal component in his/her national network and indicates merely whether the scientist is somehow connected to the core of his/her national scientific community.

Closeness is the reciprocal of the mean geodesic distance between the node and all the other nodes in the principal component (it is set to zero for all nodes that do not belong to the principal component; it has a maximum value equal to one, which can be achieved only by a central node in a star network).[21] More precisely, we measure the *Closeness* of scientist (node) *i* as follows:

$$Closeness_i = \begin{cases} 0 & \text{if } i \text{ does not belong to the principal component} \\ \dfrac{1}{1/V \sum_{v=1}^{V} g(i,v)} & \text{if } i \text{ belongs to the principal component} \end{cases}$$

[Equation 3]

where *v=1…V* are the nodes (scientists) in the principal component and g(i,v) is the geodesic distance (shortest path) between nodes *i* and *v*.

[21] For a definition of geodesic distance and a complete description of closeness, and its relationship to other centrality measures, see Wasserman and Faust (1994).

Credit is a more accurate measure of the social (political) capital because it directly identifies the relationship between prospective candidates to professorial jobs (MCFs or RUs) and professors (PRs or POs). Candidate *i*'s *Credit* is measured as:

$$Credit_i = \sum_{j \in PR,PO_i} \left[\frac{co\_Articles_{i,j}}{Articles_{j,t}} \right]$$

[Equation 4]

where $co\_Article_{i,j}$ is the number of publications signed in by candidate *i* and professor *j* together, while $Article_j$ is the total number of publications of professor *j*. Professors whose recent scientific production owes much to a junior colleague's co-authorship may be expected to act as mentors of the latter. In France and especially in Italy, this may mean making an effort to be elected as a member of the selection committees for PR or PA positions, in order to support the junior colleague's application; or else exerting one's own influence in order to obtain the election of trusted colleagues, who will then act in the same direction. MCFs and RUs who manage to make themselves useful to PRs and POs hold an asset ("credit") which may be repaid by mentoring and political influence on the composition and operation of selection committees[22].

Weighted_Credit explicitly takes into account the amount of influence a professor (PR or PO) may exert within the discipline, by weighting each candidate's credit towards a given professor by that professor's closeness score, to be intended as a proxy for the professor's centrality in the social (disciplinary) network:

$$Weighted\_Credit_{i,t} = \sum_{j \in PR,PO_i} \left[\frac{co\_Articles_{i,j}}{Articles_{j,t}} C_j \right]$$

[Equation 5]

where *i* is the prospective candidate (MCF or PA) and C_j is professor *j*'s *Closeness,* as from equation (3). Table 5 reports the descriptive statistics for all four measures of network position.

[22] This description of an agent's social capital as "credit" to be collected, was first expressed by Coleman (1988, p.S106): "If A does something for B and trusts B to reciprocate in the future, this establishes an expectation in A and an obligation on the part of B. This obligation can be conceived as a credit slip held by A for performance by B. If A holds a large number of these credit slips, for a number of persons with whom A has relations, then the analogy to financial capital is direct." Notice that Coleman's theory of social capital also requires, for credit to be collectable, that agents involved in the exchange belong to tightly knitted ("dense") social networks, so that failure to repay debts can be monitored and sanctioned effectively. Scientific disciplines, such as those considered here, may be described as "dense", one proof of it being our own data on the density of co-authorship ties, and the weight of the principal component. Professors who fail to repay their debt will be quickly spotted by the entire disciplinary community.

	FRANCE		
	MCFU	PR	
Principal_Component	*0.39*	*0.41*	
Closeness	*0.04*	*0.045*	
Credit (to PR)	*0.20*	--	
Weighted_Credit (to PR)	*0.015*	--	
		ITALY	
	RU	PA	PO
Principal_Component	0.70	0.57	0.64
Closeness	0.10	0.082	0.094
Credit (to PO)	0.36	0.28	--
Weighted_Credit (to PO)	0.049	0.038	--

MCFU and RU: ages between 30 and 50 are considered

Table 5 Co-authorship networks, mean by rank

3.3.5 Other controls

Both in Italy and in France, disciplines compete for resources, which allow for cross-disciplinary differences in the availability of new jobs and promotion opportunities. In most regressions we control for this effect by taking into account the average probability of being promoted in a given discipline (*Field probability*).

3.3.6 Models

In order to explore the determinants of the academic rank advancement we proceed in steps. First, we run a regression of the probability of promotion as a function of the individuals' characteristics and departmental stratification (*Model1*). We place special emphasis on the robustness of our results to different specification of the productivity variable.

A second model also takes into account the social network measures presented in Section 3.3.4 (*Model2*). Results for *Models 1* and *2* are presented jointly for French and Italian data. In addition, we test for the overall influence of individual, department, and social network covariates on rank advancements from PA to PO positions in Italy (*Model3*).

Promotion is a binary realization of the dependent variable y_i , where i is the individual. The reported estimations refer to Logit regressions, although we also applied Probit models, with no appreciable differences in the results. Logit coefficients cannot be readily interpreted as partial derivates, so we examine what they suggest in terms of marginal effect with the help of several graphs, with special emphasis on comparisons between our two countries[23]. Tables in the Appendix report the correlation matrixes for all the covariates. No variables show problems of high correlation, except for the various measures of productivity (which never enter the regressions jointly).

[23] We have also run a number of linear probability (OLS) regressions, and checked that the resulting estimating coefficients do not differ much from the marginal effects as calculated from the Logit coefficients.

3.4. Results

3.4.1 Individual determinants

Regression results in Table 6 confirm many of the results already available from the US-centric literature we reviewed in Section 3.2, but also some interesting differences between France (odd-numbered columns) and Italy (even-numbered columns).

Columns from (1) to (10) differ only for the productivity measure. Columns (11) and (12) report also the coefficients for the stratification dummies. Unless stated otherwise, our comments refer to coefficients from columns (1) and (2) for individual variables, and columns (11) and (12) for the stratification ones.

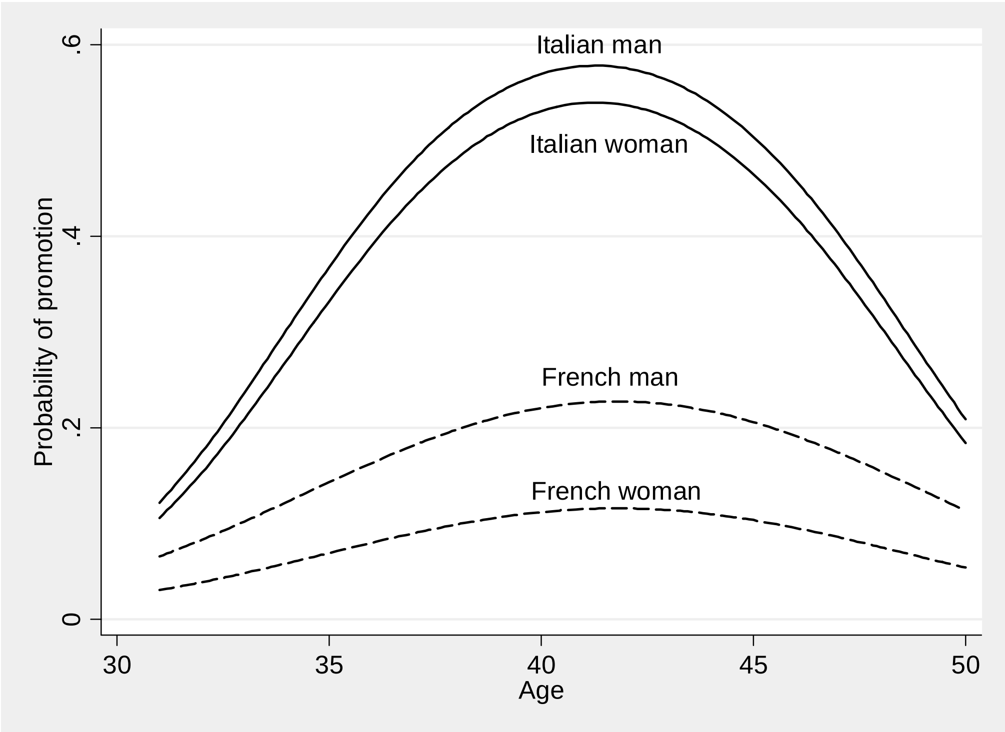
VARIABLES	(1) France	(2) Italy	(3) France	(4) Italy	(5) France	(6) Italy	(7) France	(8) Italy	(9) France	(10) Italy	(11) France	(12) Italy
Gender	-0.81***	-0.20	-0.77**	-0.23	-0.75**	-0.21	-0.82***	-0.34	-0.85***	-0.19	-0.76**	-0.18
	(0.30)	(0.25)	(0.31)	(0.25)	(0.31)	(0.25)	(0.30)	(0.25)	(0.30)	(0.25)	(0.30)	(0.25)
Age	1.03***	1.76***	0.99***	1.74***	0.96***	1.71***	1.01***	1.76***	1.05***	1.74***	1.07***	1.81***
	(0.35)	(0.37)	(0.35)	(0.37)	(0.35)	(0.37)	(0.34)	(0.37)	(0.34)	(0.37)	(0.35)	(0.38)
Age^2	-0.012***	-0.021***	-0.012***	-0.021***	-0.011**	-0.021***	-0.012***	-0.021***	-0.013***	-0.021***	-0.013***	-0.022***
	(0.0044)	(0.0045)	(0.0044)	(0.0045)	(0.0044)	(0.0046)	(0.0044)	(0.0045)	(0.0044)	(0.0046)	(0.0044)	(0.0046)
Inbreeding	0.085	0.43*	0.035	0.36	0.0066	0.38	0.036	0.59**	0.097	0.54**	0.044	0.49*
	(0.26)	(0.26)	(0.27)	(0.26)	(0.27)	(0.26)	(0.27)	(0.26)	(0.26)	(0.26)	(0.27)	(0.26)
Productivity (α=1)	0.020***	0.016***									0.015***	0.012**
	(0.0047)	(0.0050)									(0.0052)	(0.0052)
$Productivity^2$ (α=1)	-3.3e-05***	-3.7e-05									-2.4e-05**	-2.5e-05
	(1.0e-05)	(2.3e-05)									(1.1e-05)	(2.3e-05)
Productivity (α=0.25)			0.015***	0.0090***								
			(0.0030)	(0.0027)								
$Productivity^2$ (α=0.25)			-1.7e-05***	-1.2e-05								
			(4.3e-06)	(7.5e-06)								
Productivity (α=0.1)					0.011***	0.0080***						
					(0.0021)	(0.0022)						
$Productivity^2$ (α=0.1)					-9.4e-06***	-8.0e-06*						
					(2.2e-06)	(4.5e-06)						
Articles							0.038***	0.028***				
							(0.0082)	(0.0073)				
$Articles^2$							-1.2e-04***	-1.2e-04***				
							(3.2e-05)	(3.2e-05)				
Relative Productivity									0.28***	1.15***		
									(0.081)	(0.26)		
$Relative\_productivity^2$									-0.0076**	-0.17***		
									(0.0034)	(0.058)		
CNRS (France); CNR (Italy)											0.052**	0.0044
											(0.024)	(0.011)
INFM												0.074***
												(0.024)
Field probability	0.59	5.07***	-0.33	4.78***	-0.49	4.61***	3.59	4.23***	10.3	4.28***	3.48	4.01**
	(17.4)	(1.48)	(17.5)	(1.47)	(17.5)	(1.46)	(17.3)	(1.45)	(17.1)	(1.47)	(17.4)	(1.57)
Constant	-23.2***	-39.2***	-22.3***	-38.3***	-22.0***	-38.0***	-23.4***	-38.8***	-24.7***	-38.7***	-24.5***	-40.2***
	(7.13)	(7.60)	(7.15)	(7.58)	(7.16)	(7.62)	(7.09)	(7.61)	(7.06)	(7.65)	(7.18)	(7.72)
Observations	816	469	816	469	816	469	816	469	816	469	816	469
Log-likelihood	-293.935	-289.022	-289.304	-287.746	-286.557	-285.108	-291.256	-290.266	-296.017	-285.817	-291.376	-283.525
LR	57.453***	67.411***	66.714***	69.962***	72.208***	75.239***	62.809***	64.922***	53.287***	73.820***	62.569***	78.404***
McFadden's Adj R^2	0.064	0.080	0.079	0.084	0.087	0.092	0.073	0.076	0.058	0.090	0.069	0.090

Standard errors in parentheses: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 6 Logistic model for promotion, 2000-05 (Italy) and 2000-03 (France): individual and stratification determinants

Age and Gender

The age variable (considered here as a proxy of career length) has a significant and non-monotonic impact on the scientists' promotion chances in both countries. The effect of age on the probability of promotion has a concave shape, with an initial increment and a gradual decline as scientists' seniority increases. This result is close to what was found by Long, Allison and McGinnis (1991). Figure 1 is a conditional effects plot, which represents the probability of promotion conditional to the age of an average French or Italian candidate. We notice immediately that age has a stronger impact on Italian scientists' promotion chances than on the French. The position of the promotion probability curves for Italian male and female scientists is persistently higher; at the same time, the rise (and then decline) of the Italian probability curves along with increases in seniority is steeper. While the position of the curves may be explained by the higher chances of promotion for Italian scientists *ceteris paribus*[24], their inclination is the sole effect of seniority.



Notes: Marginal effects calculated on the basis of regressions (1) and (2) in Table 6. All other regressors besides gender and age are set at avg. values

Figure 1 Promotion probability as a function of age and gender*, France and Italy

Considering only the linear component of age, we can also calculate (on the basis of the estimated coefficients) that an additional year of career in the same position generates for Italian scientist an odds ratio double that for a French colleague, which suggests that an Italian physicist's chances of promotion (relative to non-promotion) on the mere basis of seniority are double those of a French colleague.

Gender has a negative impact on promotion chances both in France and in Italy, but such an effect appears to be statistically significant only in France. Being a woman physicist in France means having half the chances of promotion of a man, other things being equal. These results are also evident from Figure 1.

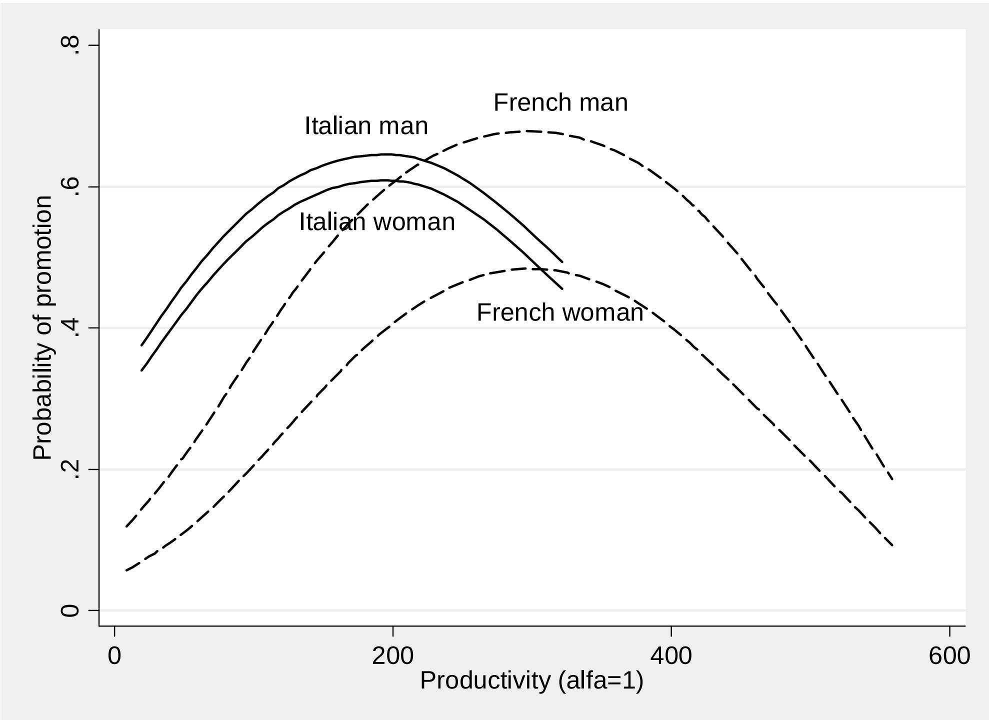
A note of caution is due here. Our data cannot tell whether a scientist does not get promoted because he/she fails a *concorso* or *concours*, or because she does not even try it. So it may either be that French

[24] This is due both to the longer time interval during which promotion may occur for scientists in our sample (5 years in Italy vs. 3 in France) and to the existence of an intermediate career step (PA, associate professor) in the Italian academic ladder, which may facilitate progress off the bottom rung of the ladder.

examination committees discriminate somehow against woman scientists, or also that the latter self-select themselves out of the competition for top jobs (for example, by not even trying to obtain the HDR[25]). It remains to be seen whether the two explanations are complementary (when women scientists do not even try to enter a competition, they are bound to lose) or alternatively, as when women scientists decide that, for many possible reasons, they do not want to get a professorial job.

Productivity

All the measures of productivity have a positive, but diminishing impact on the probability of promotion, including *RelativeProductivity* (i.e. the individual productivity over the average productivity in the discipline). Not all measures, however, exhibit a significant quadratic component in the Italian case (where the component is significant, it suggests that diminishing returns to productivity kick in much sooner than in France). Estimates in columns (1) and (2) of Table 6 suggest that one extra single-authored publication on a journal with an impact factor equal to one may increase the average French scientist's promotion probability of 0.005 (0.002 for an Italian one); an increase of productivity equal to one standard deviation would increase the same scientist's promotion probability of around 0.2 (0.2 for an Italian one).



Notes: Marginal effects calculated on the basis of regressions (1) and (2) in Table 6. All other regressors besides gender and productivity are set at avg. values

Figure 2 Promotion probability as a function of productivity and gender*, France and Italy

[25] See footnote 10 above

Figure 2 shows the promotion probability for men and women scientists in Italy and France. The declining section of the curves is determined by the existence of a few outliers with maximum productivity value. As a matter of fact, most scientists have a productivity value well below the mean (which is around 20 for France and 54 for Italy). This suggests that for almost all scientists the probability for achieving promotion always increases (never decreases) with productivity, although with diminishing returns; and that most scientists have higher promotion chances in Italy than in France.

Stratification and Inbreeding

Our *Inbreeding* variable is never significant in France, while it is so in most regressions for Italy (although never at 99 per cent, and with an estimated coefficient whose value is sensitive to the choice of productivity proxy). This result, albeit not strong, is in keeping with the descriptive statistics which demonstrated that Italian scientists are less mobile than French ones.

As for stratification, French scientists with a high percentage of CNRS-affiliated papers have higher promotion chances. Calculations of the marginal effect suggest that an extra standard deviation of CNRS would add 0.05 to the promotion probability of the average French scientist. The CNR variable does not bear a similar effect in the case of Italy, possibly due to the limited importance of CNR outside nuclear physics (which does not represent the core field of physics considered in this paper). On the contrary, INFM has a positive and significant impact on Italian scientists' promotion chances, due to its importance for all material physicists (who constitute the bulk of our physicists); in particular, an extra standard deviation would add 0.02 to the probability of promotion.

Finally, we note that while promotion chances in France do not depend on the specific discipline to which a physicist belongs, the same does not apply in Italy. Due to the high variability of average promotion chances across Italian disciplines (see descriptive statistics), disciplinary affiliation matters a great deal for a scientist's career.

3.4.2 The effect of social capital, and the promotion to full professor

Table 7 shows the effects of social capital on promotion from MCF to PR (for France) and from RU to PA (for Italy), together with the individual and stratification variables we have already examined. We note that the latter's estimated coefficients are not sensitive to the introduction of new explanatory variables. The only exception is the quadratic effect of productivity for Italy, which becomes not significant.

VARIABLES	(1) France	(2) Italy	(3) France	(4) Italy	(5) France	(6) Italy	(7) France	(8) Italy
Gender	-0.77**	-0.14	-0.76**	-0.15	-0.79***	-0.20	-0.76**	-0.20
	(0.30)	(0.25)	(0.30)	(0.26)	(0.30)	(0.26)	(0.30)	(0.26)
Age	1.07***	1.86***	1.07***	1.87***	1.11***	1.85***	1.09***	1.90***
	(0.35)	(0.38)	(0.35)	(0.38)	(0.35)	(0.38)	(0.35)	(0.38)
Age^2	-0.013***	-0.022***	-0.013***	-0.022***	-0.013***	-0.022***	-0.013***	-0.023***
	(0.0044)	(0.0046)	(0.0044)	(0.0046)	(0.0045)	(0.0047)	(0.0045)	(0.0047)
Productivity (α=1)	0.015***	0.013**	0.015***	0.013**	0.016***	0.014***	0.016***	0.015***
	(0.0052)	(0.0051)	(0.0052)	(0.0051)	(0.0052)	(0.0052)	(0.0052)	(0.0053)
Productivity^2 (α=1)	-0.000024**	-0.000027	-0.000025**	-0.000028	-0.000026**	-0.000030	-0.000025**	-0.000035
	(0.000011)	(0.000023)	(0.000011)	(0.000023)	(0.000011)	(0.000024)	(0.000011)	(0.000024)
Field probability	3.80	3.68**	1.53	3.37**	2.02	3.88**	1.66	3.33**
	(17.4)	(1.61)	(17.6)	(1.65)	(17.5)	(1.60)	(17.5)	(1.61)
CNRS	0.054**		0.056**		0.059**		0.057**	
	(0.025)		(0.026)		(0.024)		(0.025)	
INFM		0.068***		0.063***		0.045*		0.048**
		(0.024)		(0.024)		(0.024)		(0.024)
Principal Component	-0.038	0.44*						
	(0.24)	(0.24)						
Closeness			2.20	3.95*				
			(3.42)	(2.34)				
Closeness^2			-2.82	-0.69				
			(2.99)	(2.14)				
Credit					0.090	2.17***		
					(0.89)	(0.54)		
Credit^{-2}					-0.44	-0.95***		
					(0.75)	(0.29)		
Weighted_Credit							2.44	15.5***
							(7.17)	(3.85)
Weighted_Credit^2							-32.6	-46.4***
							(46.3)	(13.8)
Constant	-24.5***	-41.2***	-24.3***	-41.3***	-25.1***	-41.4***	-24.7***	-42.1***
	(7.18)	(7.70)	(7.20)	(7.73)	(7.23)	(7.82)	(7.20)	(7.84)
Observations	816	469	816	469	816	469	816	469
Log-likelihood	-291.377	-283.638	-290.947	-283.089	-290.485	-276.149	-290.920	-276.034
LR	62.567***	78.177***	63.427***	79.275***	64.352***	93.156***	63.483***	93.386***
McFadden's Adj R2	0.069	0.090	0.067	0.089	0.069	0.110	0.067	0.111

Standard errors in parentheses: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 7 Logit model for promotion, 2000-05 (Italy) and 2000-03 (France); individual, stratification and social capital determinants

Whatever social capital measures we consider, they show a strikingly different impact in the two countries: they are never significant for France and always significant for Italy. At the same time, for Italy, we note that the estimated coefficients of more generic measures of social capital (such as *Principal Component* and *Closeness*) appear to be less significant (90 per cent) than the coefficient for more specific measures (such as *Credit* and *Weighted_Credit*).

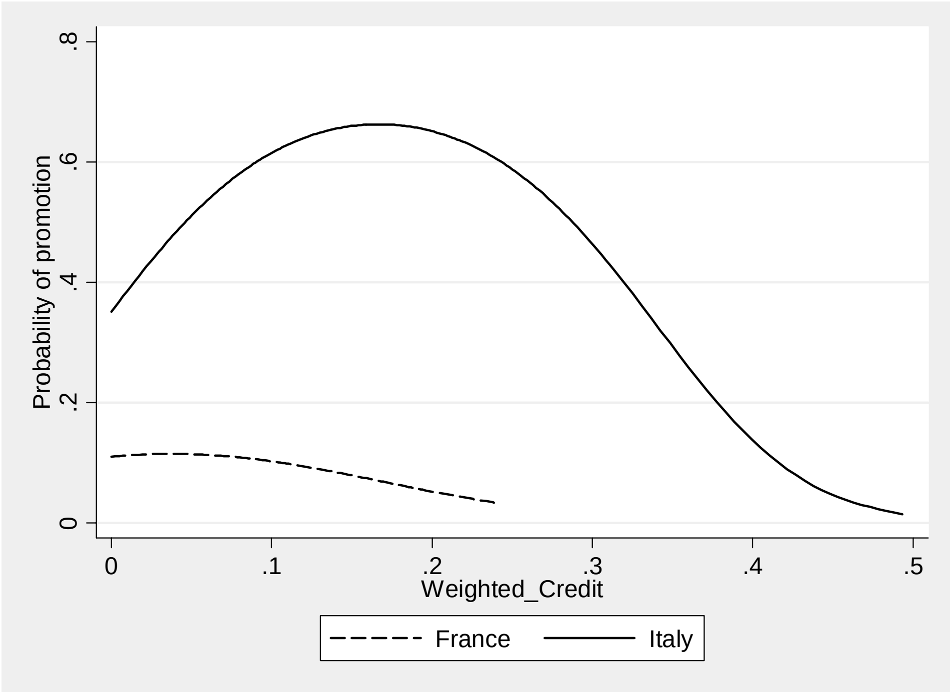
Being part of the principal component of the national scientific network does not affect the promotion chances of French scientists, while it considerably increases those of Italian ones (see *PrincipalComponent* in columns (1) and (2) of Table 7). More strikingly, non-connected scientists in Italy stand almost half a chance of getting promoted compared to those with maximum observed closeness (which is equal to 0.2). Moreover, among connected scientists, those who occupy a more central position in the network have even higher promotion chances, as indicated by the positive and significant value of the *Closeness* variable, in columns (3) and (4) of Table 7.

However, *PrincipalComponent* and *Closeness* provide a generic measure of position of the individual candidate in the network. They do not capture the candidate's ties with the most influential, highest ranked members of the network. This task is better fulfilled by *Credit* and *Weighted_Credit*:, which are found in columns (5) to (8) in Figure 3.

The positive sign of *Credit* suggests that the more valuable a junior scientist proved to be towards full professors the more the chances he/she has of being promoted in Italy, even after controlling for the scientist's productivity and seniority (this is not true in France, where *Credit* bears no relevance on promotion chances). The same result is obtained when considering *Weighted_Credit*, which is the higher the more central the full professors are (to whom the junior scientists can claim *Credit*). *Credit* and *Weighted_Credit* are not only more significant than *PrincipalComponent* and *Closeness*, but considerably improve the goodness of fit of our regression, as measured by McFadden adjusted pseudo-R^2 (different pseudo-R^2 measures give the same result). The latter increase around 20 per cent (for Italy) when moving from columns (2) and (4) to columns (6) and (8).

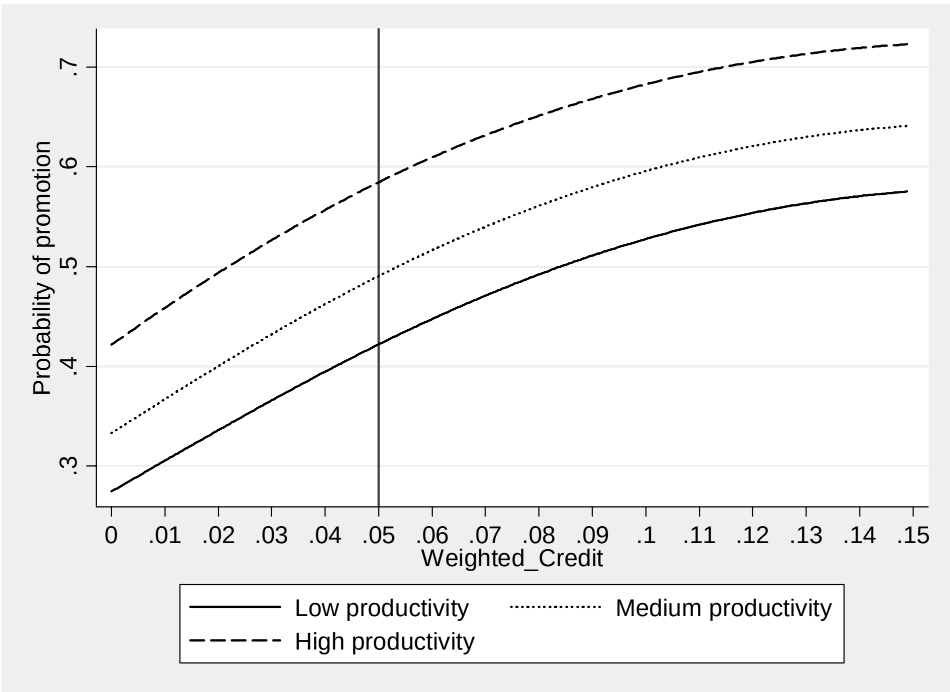
Figure 3 plots the promotion probability in terms of *Weighted_Credit* for two scientists, one Italian and one French, with average values of age, productivity and other regressors. The probability of being promoted for the Italian scientist increases with *Weighted_Credit* reaching a maximum at *Weighted_Credit*=1.8, and declines for higher values. Note that such an inverted U-shape is determined by the existence of a few scientists with exceptionally high *Weighted_Credit* values. The mean and median values for *Weighted_Credit* are respectively 0.5 and 0.1, so most scientists have only to gain by increasing the contribution they make to a full professor's publication record. In the case of the French scientist, no increase in the probability of promotion is associated with an increase in *Weighted_Credit*.

Figure 4 examines the probability of promotion for three Italian scientists with different productivity levels (respectively pointing at the 25%, 50%, and 75% percentiles), as a function of *Weighted_Credit*. The figure suggests that an Italian scientist with low productivity, but a mean value of *Weighted_Credit* (that is *Weighted_Credit*=0.5) has roughly the same promotion probability as a highly productive scientist with a *Weighted_Credit* equal to 0; the latter, in turn, has less probability of being promoted than a mediumly productive scientist with a *Weighted_Credit*=0.5. Note that this comparison makes sense, due to the fact that *Weighted_Credit* and *Productivity* reflect two different characteristics of Italian scientists, as confirmed by the low correlation between the two (see Appendix table 4).



** Marginal effects calculated on the basis of regressions (7) and (8) in Table 7. All other regressors besides gender and productivity are set at avg. values*

Figure 3 Promotion probability as function of Weighted_Credit, France and Italy



Marginal effects calculated on the basis of regressions (8) in Table 7. All other regressors besides gender and productivity are set at avg. values; productivities are calculated at 25% percentile (LOW), 50% (MIDDLE), 75% (HIGH).

Figure 4 Promotion probability as function of Weighted_Credit in Italy

The role of social capital measures in Italy is also confirmed by the analysis of promotion from the rank of associate professor (PA) to the top rank of full professor (PO), which we examine in Table 8. We first note that the estimated coefficients for Age and Productivity are respectively higher and lower than those concerning promotion from RU to PA; apparently, when it comes to reaching the top of the academic ranking (in Italy), seniority matters more, and productivity less than at earlier career stages. No stratification variable is significant, possibly because all PAs are similarly connected to INFM.

As for social capital, *Principal Component* remains highly significant, while *Closeness* does not differ significantly from zero. The coefficients for *Credit* and *Weighted_Credit* remain positive and significant (albeit smaller than in the case of promotion at lower ranks), and the quadratic effects are confirmed.

	(1)	(2)	(3)	(4)
Gender	-0.42	-0.42	-0.40	-0.41
	(0.31)	(0.31)	(0.31)	(0.31)
Age	1.96***	1.97***	1.93***	1.95***
	(0.28)	(0.28)	(0.28)	(0.28)
Age^2	-0.020***	-0.020***	-0.020***	-0.020***
	(0.0028)	(0.0028)	(0.0028)	(0.0028)
Productivity (α=1)	0.0047*	0.0047*	0.0053**	0.0055**
	(0.0026)	(0.0026)	(0.0027)	(0.0027)
$Productivity^2$ (α=1)	-3.4e-06	-3.2e-06	-4.2e-06	-4.4e-06
	(5.4e-06)	(5.5e-06)	(5.7e-06)	(5.7e-06)
Field probability	3.11**	3.30**	3.61**	3.61**
	(1.51)	(1.52)	(1.48)	(1.49)
CNR	0.000087	-0.00094	0.0045	0.0021
	(0.011)	(0.011)	(0.011)	(0.011)
INFM	0.029	0.019	0.028	0.025
	(0.019)	(0.019)	(0.019)	(0.019)
Principal Component	0.73***			
	(0.24)			
Closeness		2.73		
		(2.32)		
$Closeness^2$		2.93		
		(2.30)		
Credit			0.97**	
			(0.40)	
$Credit^2$			-0.27**	
			(0.14)	
Weighted_Credit				8.60***
				(2.89)
$Weighted\_Credit^2$				-17.3**
				(7.28)
Constant	-49.2***	-49.6***	-48.5***	-49.1***
	(6.94)	(7.00)	(6.83)	(6.88)
Observations	578	578	578	578
Log-likelihood	-288.820	-288.317	-290.435	-288.814
LR	145.566***	146.573***	142.336***	145.579***
McFadden's Adj R2	0.174	0.172	0.166	0.171

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 8 Logistic model for promotion from PA to PO (Italy); individual, stratification, and social capital determinants

3.5 Conclusions

Our analysis confirms the importance of seniority and scientific productivity for academic careers, as found in the literature. The older the scientist the higher his/her chances of promotion, but only up to an age between 40 and 45 (for promotion from the bottom to the top/intermediate ranks in France and Italy) or well over 50 (for promotion to the top rank in Italy), after which promotion chances decline. As for productivity, our estimates suggest the existence of positive but diminishing returns, which are considerably higher for French scientists as opposed to Italian ones. Overall, the balance between seniority and productivity, as promotion determinants, seems to be relatively more shifted in favour of the former in Italy, and of the latter in France. Within Italy, such a balance shifts even more in favour of seniority when it comes to moving to the top tier of the academic hierarchy.

We also find that both in Italy and France stratification matters. Such stratification derives from interaction between the universities and the national systems of public research organization (CNRS in France, INFM in Italy). As such, our findings reflect the institutional peculiarity of the two national science systems, and differ from similar findings in the US-based literature (where stratification refers to an internal hierarchy of universities).

A distinctive result of our analysis is the evidence of the importance of a specific type of social capital for Italian scientists. The particular institutional arrangements of the Italian academic recruitment system are such that senior colleagues of those seeking promotion have considerable (and largely unchecked) power on the latter's careers, and are at the same time involved in a web of job commissions, local in nature, but elected by peers on a national basis. As a consequence, proximity to influential decision-makers, as measured by *Credit*, (or the combination of two, *Weighted_Credit*) may be decisive for a scientist's career, at any level of productivity. In this light, even the significance to more generic measures of social capital, such as *PrincipalComponent* and *Closeness*, may be interpreted more as a signal of access to mentoring within the discipline, than as an indicator of scientific potential (access to the scientific community at large).

In France, where job commissions are not entirely elective and stand for several years, this effect does not appear. We are aware that the network effect for Italy could be explained by the recruitment norms as much as by the social norms of the community, with their emphasis on inbreeding and mentoring (which could also be responsible for the existence of such a baroque and easily rigged recruitment system). However, at this stage of our research, we cannot distinguish between social and legal norms. It is also possible that they reinforce each other, to the extent that the latter are a result of the professors' pressure on the legislature.

Besides being of immediate policy interest, our findings on social capital suggest that it is possible to analyse networks of scientists not only in terms of knowledge diffusion (as typical of the recent literature on the economics of science, and of the literature on small worlds), but also in terms of power and brokerage of career opportunities and rewards for exchanges at the dyadic level.

An unexpected result of our study is the differential impact of *gender* on career in the two countries, negative in France and non-significant in Italy. At this stage of our research we can only observe that the French system host more women than the Italian one, and that it is more selective (fewer French *maitres a conférence* become professors, as opposed to Italian *ricercatori*). It may well be that while Italy exhibits its gender effect at the entry level (the number of women who manage to enter the academic system at the bottom rank) France sees the gender effect kicking in only at the promotion level.

Going back to the literature on the new economics of science, our results confirm the role of scientific productivity as a determinant of academic career, but they also suggest that such a role is very much tempered by other determinants, such as seniority, gender, and social connections. While evidence on the importance of seniority and age has also been produced for the US case, we are not aware of studies that have highlighted the role of social connections (of the type we found relevant for Italy).

In the near future, we plan to develop both a more sophisticated theory of the recruitment process in the two countries and a more accurate analysis of network effects on promotion. In France, such an analysis will require taking into consideration the role of CNRS, the National Research Centre, whose influence on the academic system is much greater than the influence exercised by its Italian counterpart, the CNR.

At a later date, we expect that a better understanding of the career process will be instrumental in framing the ongoing debate on the changing economics of universities within a more general model of individual scientists' incentives and constraints.

Appendix to chapter 3

	Number (and % of total physicists) (1)	Age in 2005	Age of nomination (avg)	Promoted to present rank after 2000 [% of (1)]
France				
MCFU	1397 (65%)	43.96	33	21%
PR	758 (35%)	54.29	42	22%
Italy				
RU	524 (30%)	43.55	34	40.5%
PA	640 (36%)	53.29	41	38%
PO	606 (34%)	60.57	47	33%

Appendix Table 1 Rank and age distribution of physicists (in selected disciplines) on active duty in 2000

	Number (and % of total physicists) (1)	% of Promoted after 2000
France: MCFU		
Milieux denses et matériaux	559 (69%)	13.05%
Milieux dilués et optique	257 (31%)	14.39%
Italy: RU		
Fisica sperimentale	245 (52%)	44.08%
Fisica teorica, modelli e metodi matematici	80 (17%)	32.50%
Fisica della materia	144 (31%)	53.47%
Italy: PA		
Fisica sperimentale	369 (64%)	29.53%
Fisica teorica, modelli e metodi matematici	100 (17%)	25.00%
Fisica della materia	109 (19%)	45.87%

NB For MCFU and RU only age between 30 and 50 is considered

Appendix Table 2 Fields and probability of being promoted (MCFU, RU, PA); year of reference 2000

Title	Entry year in ISI-Web of Science	Exit year from ISI-Web of Science	No. of articles by Italians in our sample (1)	No. of articles by French in our sample (2)	(1) + (2)	(1)/[(1)+(2)]	(2)/[(1)+(2)]
Physics letters B	1975	1999	1283	536	1819	11.39%	5.27%
Physical review B	1975	1999	867	716	1583	7.69%	7.03%
Physical review letters	1975	1999	587	561	1148	5.21%	5.51%
Nuclear instruments & methods in physics research section A	1984	1999	667	183	850	5.92%	1.80%
Nuclear physics B	1975	1999	447	136	583	3.97%	1.34%
Journal of applied physics	1975	1999	236	326	562	2.09%	3.20%
Physical review B	1975	1999	296	206	502	2.63%	2.02%
Zeitschrift für physik C	1979	1997	336	129	465	2.98%	1.27%
Physical review D	1975	1999	312	133	445	2.77%	1.31%
Journal of chemical physics	1975	1999	161	278	439	1.43%	2.73%
Solid state communications	1976	1999	198	226	424	1.76%	2.22%
Applied physics letters	1975	1999	149	260	409	1.32%	2.55%
Europhysics letters	1986	1999	166	187	353	1.47%	1.84%
Physical review E	1993	1999	221	110	331	1.96%	1.08%
Journal of physics-condensed matter	1989	1999	145	175	320	1.29%	1.72%
Nuovo cimento della societa italiana di fisica D	1983	1998	298	17	315	2.64%	0.17%
Journal of magnetism and magnetic materials	1979	1999	64	242	306	0.57%	2.38%
Optics communications	1975	1999	136	164	300	1.21%	1.61%

Appendix Table 3. ISI-Web of Science publications used to measure productivity, selected list (≥300 publications in the sample)

		[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]
[1]	Gender	1													
[2]	Age	-0.03	1												
		[0.34]													
[3]	Productivity (α=1)	-0.06	0.1	1											
		[0.09]	[0.00]												
[4]	Productivity (α =0.25)	-0.07	0.1	0.99	1										
		[0.06]	[0.01]	[0.00]											
[5]	Productivity (α =0.1)	-0.07	0.09	0.98	0.99	1									
		[0.04]	[0.01]	[0.00]	[0.00]										
[6]	Articles	-0.06	0.08	0.9	0.89	0.9	1								
		[0.11]	[0.02]	[0.00]	[0.00]	[0.00]									
[7]	Field probability	-0.06	-0.08	0.11	0.12	0.12	0.09	1							
		[0.10]	[0.03]	[0.00]	[0.00]	[0.00]	[0.01]								
[8]	Relative Productivity	-0.07	0.11	0.96	0.94	0.93	0.88	0	1						
		[0.06]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[1.00]							
[9]	Inbreeding	-0.17	-0.07	0.07	0.08	0.09	0.09	0.12	0.06	1					
		[0.00]	[0.05]	[0.06]	[0.02]	[0.01]	[0.01]	[0.00]	[0.11]						
[10]	Comp	-0.12	-0.13	0.16	0.18	0.2	0.19	0.08	0.16	0.35	1				
		[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.03]	[0.00]	[0.00]					
[11]	Closeness	-0.12	-0.13	0.16	0.18	0.22	0.2	0.02	0.17	0.32	0.97	1			
		[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.49]	[0.00]	[0.00]	[0.00]				
[12]	Credit	-0.16	-0.09	0.11	0.13	0.16	0.15	0.02	0.12	0.44	0.37	0.39	1		
		[0.00]	[0.01]	[0.00]	[0.00]	[0.00]	[0.00]	[0.54]	[0.00]	[0.00]	[0.00]	[0.00]			
[13]	Weighted_Credit	-0.11	-0.07	0.12	0.14	0.18	0.17	-0.02	0.15	0.28	0.56	0.61	0.79	1	
		[0.00]	[0.05]	[0.00]	[0.00]	[0.00]	[0.00]	[0.50]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]		
[14]	CNRS	-0.14	-0.09	0.26	0.3	0.34	0.28	0.01	0.33	0.13	0.39	0.46	0.27	0.34	1
		[0.00]	[0.01]	[0.00]	[0.00]	[0.00]	[0.00]	[0.76]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	

(p values in square brackets) **Appendix Table 4a.Correlation Matrix, for French MCFs**

		[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]
[1]	Gender	1														
[2]	Age	0.1	1													
		[0.03]														
[3]	Productivity (α=1)	-0.21	-0.05	1												
		[0.00]	[0.30]													
[4]	Productivity (α=0.25)	-0.18	-0.03	0.95	1											
		[0.00]	[0.50]	[0.00]												
[5]	Productivity (α=0.1)	-0.18	-0.05	0.93	0.98	1										
		[0.00]	[0.28]	[0.00]	[0.00]											
[6]	Articles	-0.09	-0.09	0.2	-0.03	0.03	1									
		[0.05]	[0.04]	[0.00]	[0.53]	[0.45]										
[7]	Field probability	0.09	0.01	-0.16	-0.11	-0.06	-0.04	1								
		[0.07]	[0.84]	[0.00]	[0.02]	[0.18]	[0.37]									
[8]	Relative Productivity	-0.19	-0.06	0.82	0.75	0.79	0.41	0	1							
		[0.00]	[0.17]	[0.00]	[0.00]	[0.00]	[0.00]	[1.00]								
[9]	Inbreeding	0.03	-0.04	0.05	0.09	0.08	-0.11	0.1	0	1						
		[0.52]	[0.40]	[0.27]	[0.05]	[0.09]	[0.01]	[0.03]	[0.98]							
[10]	Principal Component	-0.09	-0.25	0.08	0.12	0.18	0.01	0.16	0.15	0.22	1					
		[0.06]	[0.00]	[0.08]	[0.01]	[0.00]	[0.83]	[0.00]	[0.00]	[0.00]						
[11]	Closeness	-0.06	-0.25	0.05	0.1	0.18	0.02	0.2	0.15	0.17	0.95	1				
		[0.18]	[0.00]	[0.25]	[0.03]	[0.00]	[0.68]	[0.00]	[0.00]	[0.00]	[0.00]					
[12]	Credit	-0.04	-0.21	-0.05	-0.06	0.01	0.14	0.07	0.06	0.12	0.32	0.37	1			
		[0.41]	[0.00]	[0.32]	[0.21]	[0.89]	[0.00]	[0.15]	[0.17]	[0.01]	[0.00]	[0.00]				
[13]	Weighted_Credit	-0.03	-0.2	-0.05	-0.06	0.01	0.16	0.11	0.07	0.07	0.41	0.49	0.94	1		
		[0.53]	[0.00]	[0.31]	[0.19]	[0.79]	[0.00]	[0.02]	[0.13]	[0.16]	[0.00]	[0.00]	[0.00]			
[14]	CNR	-0.11	-0.12	0.14	0.12	0.17	0.12	-0.25	0.15	-0.11	0.27	0.28	0.29	0.3	1	
		[0.02]	[0.01]	[0.00]	[0.01]	[0.00]	[0.01]	[0.00]	[0.00]	[0.02]	[0.00]	[0.00]	[0.00]	[0.00]		
[15]	INFM	-0.07	-0.22	0.15	0.23	0.29	-0.03	0.21	0.24	0.02	0.21	0.3	0.23	0.24	0.04	1
		[0.12]	[0.00]	[0.00]	[0.00]	[0.00]	[0.45]	[0.00]	[0.00]	[0.65]	[0.00]	[0.00]	[0.00]	[0.00]	[0.42]	

(p values in square brackets) **Appendix Table 4b.Correlation Matrix, for Italian RUs**

Chapter 4 Collaboration and Productivity In Scientific Research[1]

4.1 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 chapter is largely based on joint work with Jacques Mairesse

[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.

4.2 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).

4.2.1 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.

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

[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*.

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

[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

4.2.2 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).

4.2.3 *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.

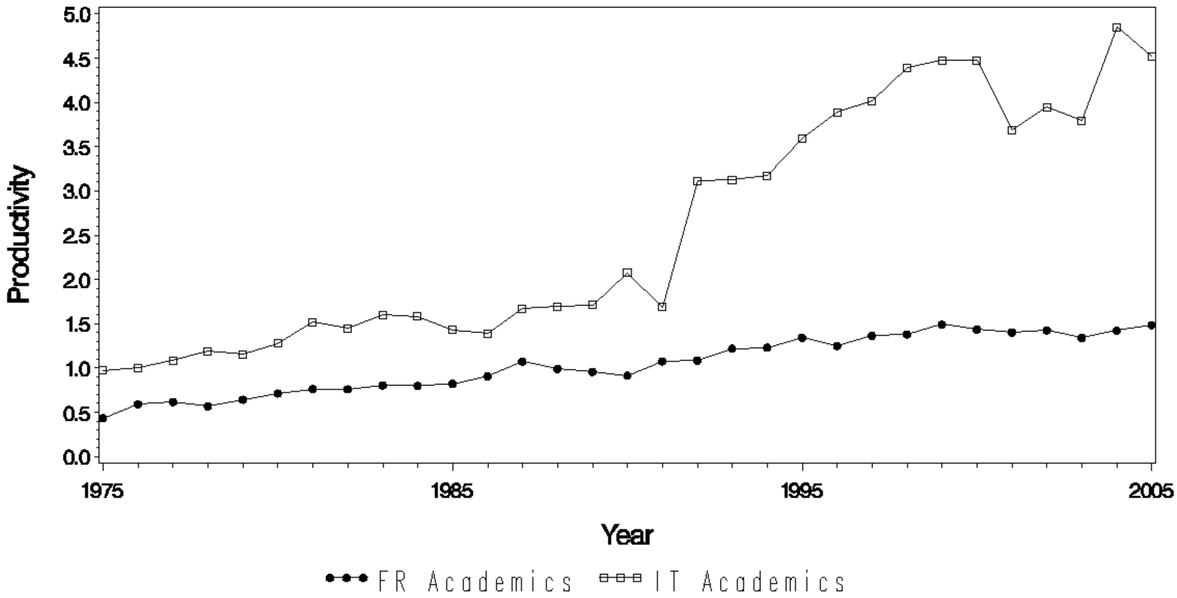


Figure 1 Micro productivity, Italian and French academics

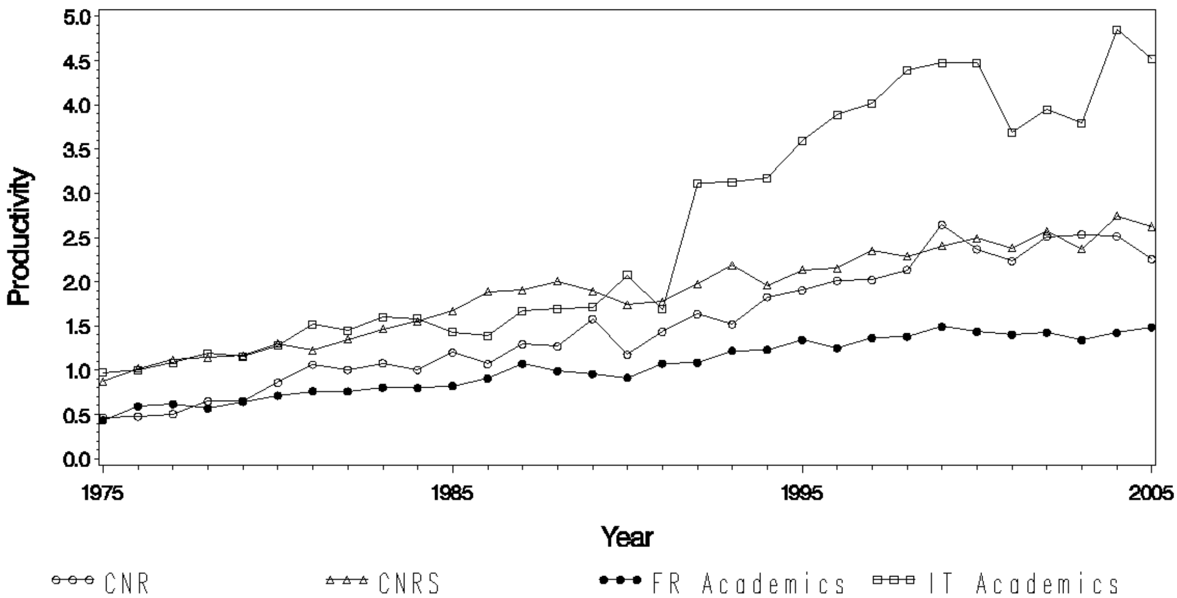


Figure 2 Micro productivity of organizations

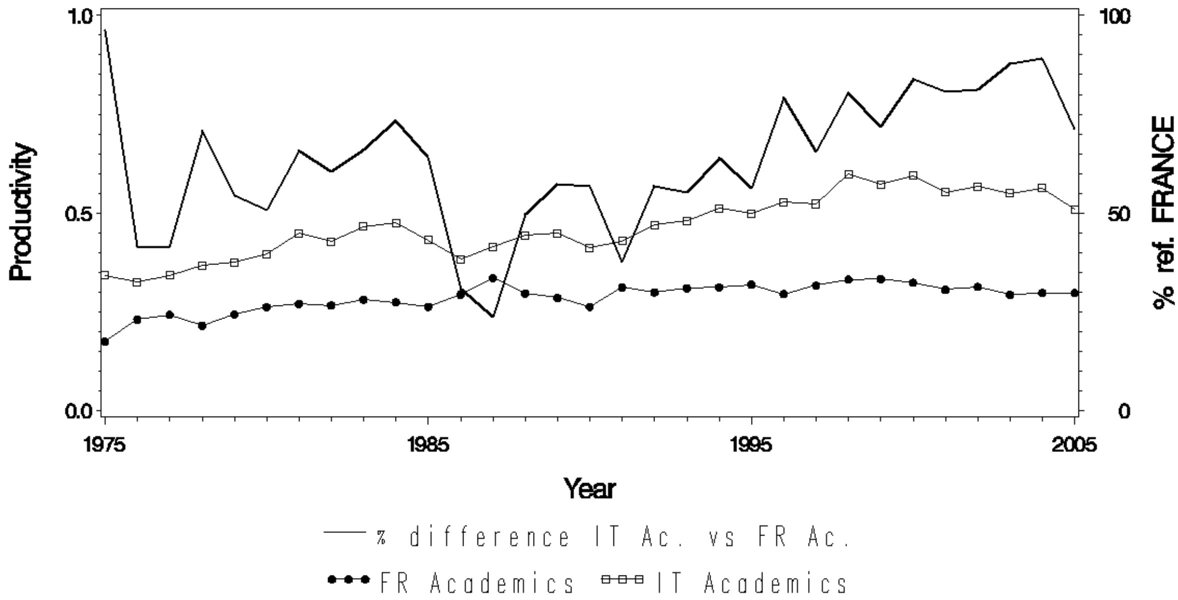


Figure 3 Micro productivity of French and Italian academics weighted by authors

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 of Italian academics, we can infer that they publish more often than French articles with a large

[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

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).

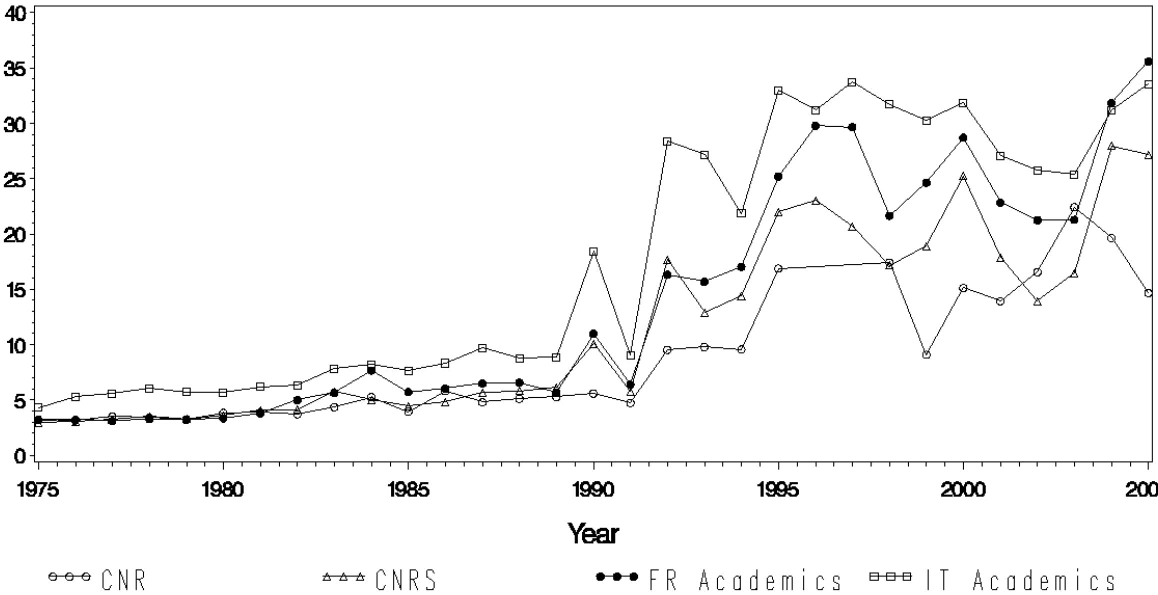


Figure 4 Average number of authors per article according to organization

4.2.4 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).

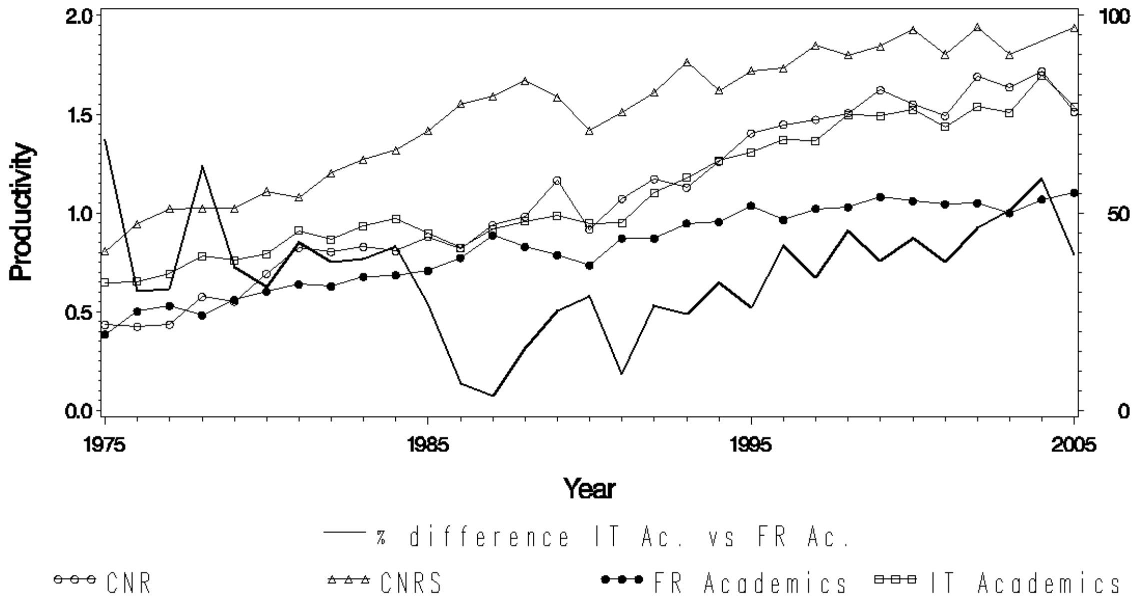


Figure 5 Macro productivity of organizations

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.

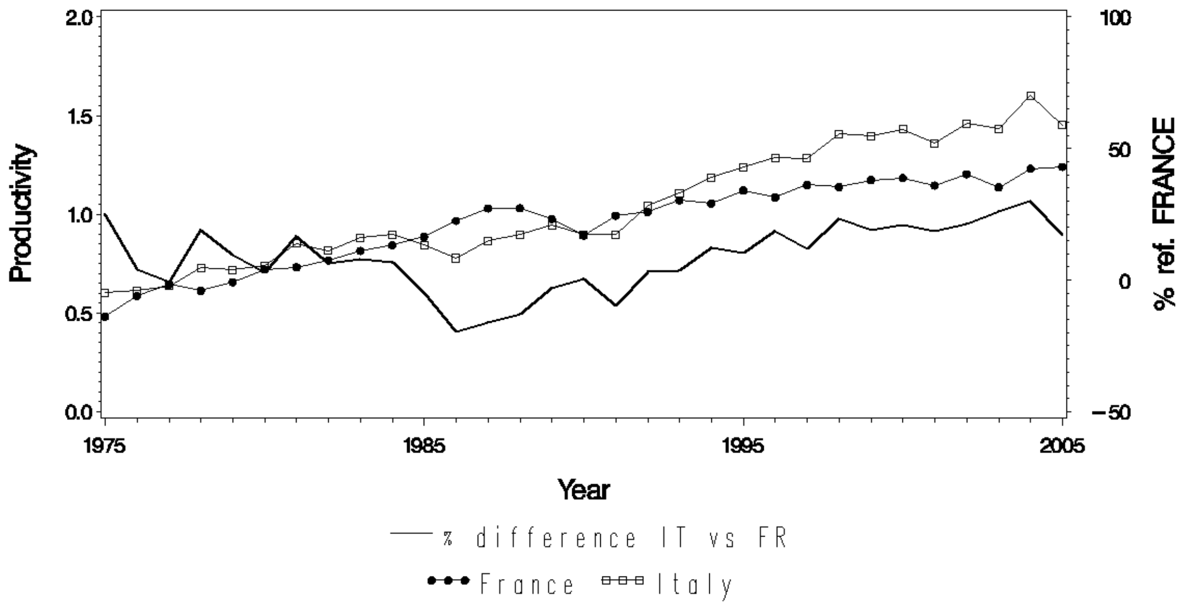


Figure 6 Macro productivity at national level

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.

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[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.

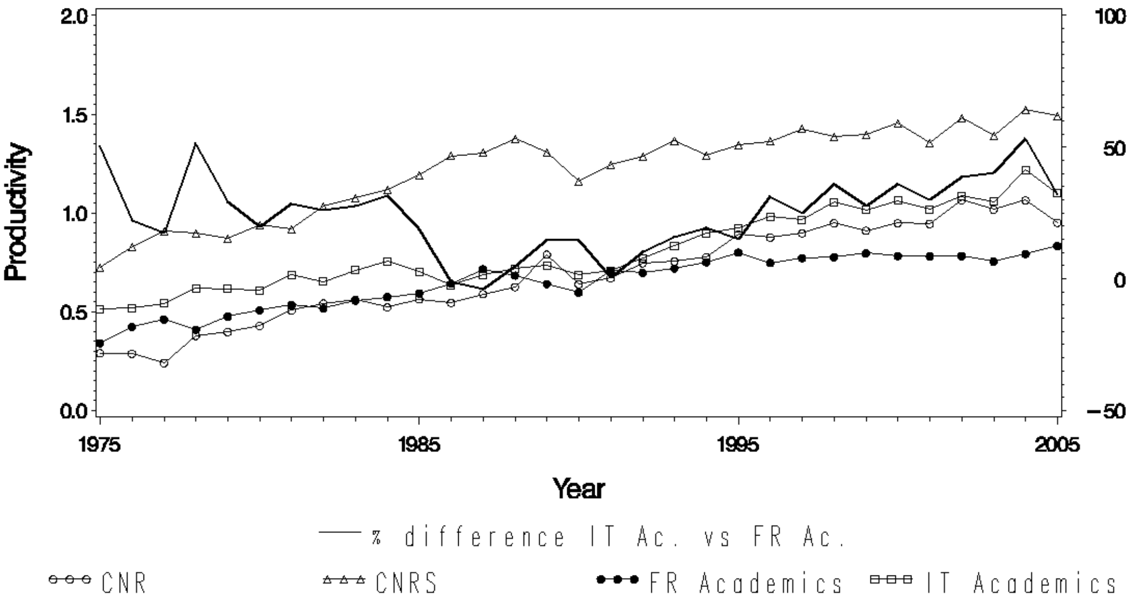


Figure 7 Micro productivity of organizations weighted by national authors

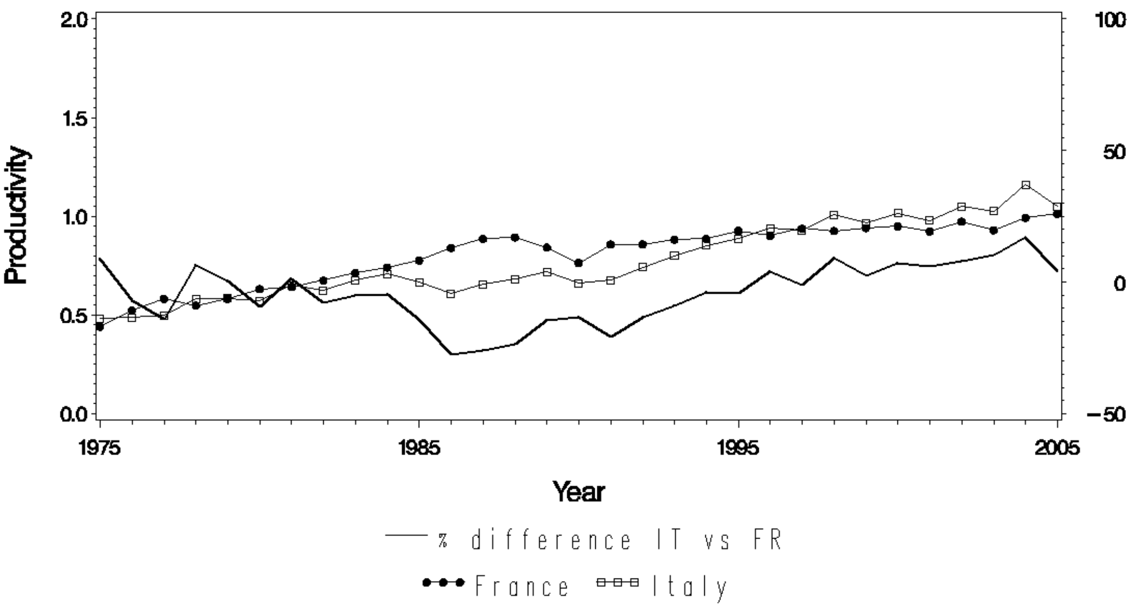


Figure 8 Micro productivity of countries weighted by national authors

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.

4.3 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.

4.3.1 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).

4.3.2 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 $\textit{years of collaboration}_j$ is the amount of years of collaboration between scientist *i* and scientist *j* and $\textit{collaborators}_i$ is the number of collaborators of scientist *i* during the observation window.

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

[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, ∞).

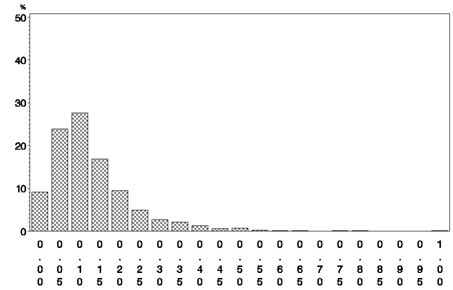
$$\mathrm{Extent}_i = \frac{\mathrm{collaborators}_i}{(\mathrm{Last\_y} - \mathrm{First\_y})_i}$$

[Equation 4]

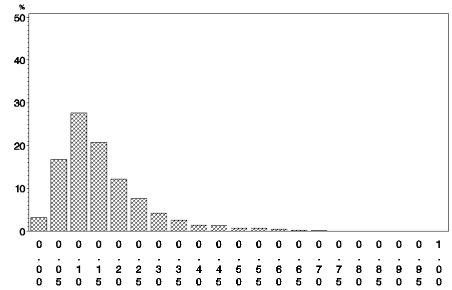
Thresholds, based on values of extent and persistence, are fixed according to the distributions of the two dimensions of collaboration (Figure 9). They are respectively 0.3 for extent, that means 3 different collaborators during 10 years of observation, and 0.15, that means that average collaboration 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

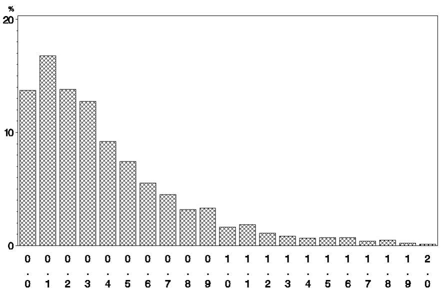


Italy



Extent of collaboration

France



Italy

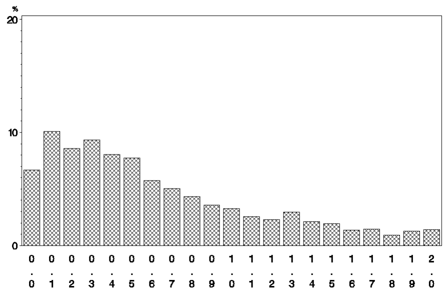


Figure 9 Definition of classes according to the thresholds of 0.3 for extent and 0.15 for persistence

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**

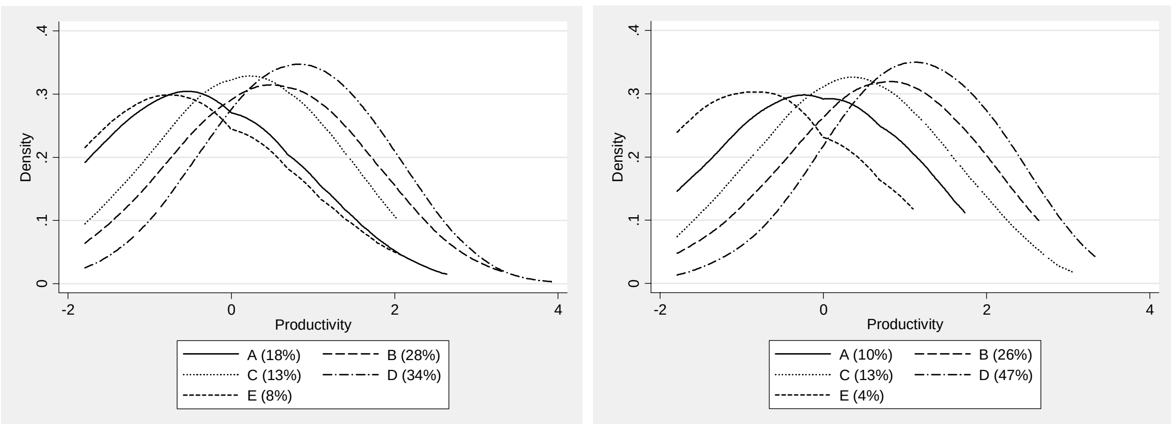


Figure 10 log(Productivity), distribution per class (2000-2005)[11]

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.

4.3.3 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

4.3.4 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**

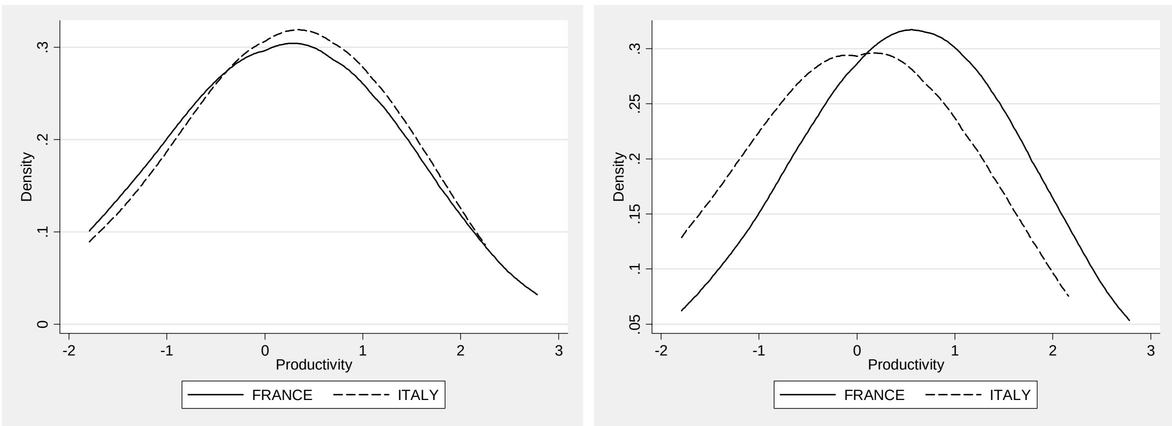


Figure 11 Estimated density of (log) productivity according to actual and inverted number of scientists per class (1985-1990)

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.

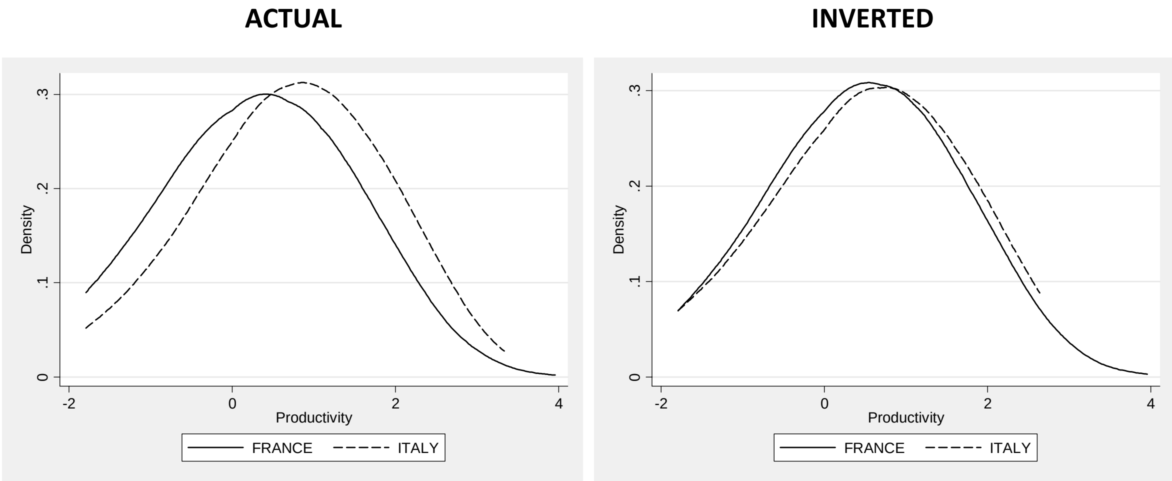


Figure 12 Estimated density of (log) productivity according to actual and inverted number of scientists per class (2000-2005)

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.

4.4 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.

Chapter 5 Conclusions

This dissertation includes three chapters and an introduction (chapter 1). The aim of chapter 2 is to evaluate the determinants of scientific productivity, while chapter 3 focuses on the determinants of career advancements. Individual, environmental and institutional characteristics are the main classes of determinants considered in the analysis. Chapter 2 focuses especially on the negative effect on scientific productivity of *en masse* recruitments, observed in France and Italy during the 1980s. Chapter 3 aims to assess, beside the classical variables, the impact of candidates' social capital on career advancements in academia. The measures of social capital used are based on physicists' national networks of collaboration. Chapter 4 examines the relationship between individual productivity and collaboration of scientists starting from the empirical differences in productivity observed between Italian and French academic physicists.

The three chapters accounts for the entire population of physicists active in specific institutional settings (i.e. France and Italy), both in academia (chapter 2 and 3) and in public research organizations (chapter 4). Most of the available literature on scientific productivity, career advancements and collaboration is based on the US case. This is an important limitation because the latter is characterized by specific features absent in Italian and French research systems: autonomy and explicit stratification of universities, high degree of academic job mobility, individual bargain for wages and working conditions.

Introduction it's a brief summary of the advancements from the first theories to modern economics and sociology of science. Chapter 2 investigates scientific productivity of Italian and French academic physicists. The analysis performed accounts for the interrelated econometric problems of endogeneity between productivity and promotion, selectivity and unobserved heterogeneity among scientists. Two equations are estimated, one for promotion and one for productivity, according to an Heckman two step model. Results in former equation show that in France and Italy promotion is influenced positively by age and negatively by gender. Moreover, in Italy promotion is influenced positively by quantity of past published scientific articles, while in France it is influenced mainly by quality (in terms of average impact factors of the articles published). Big recruitment waves affect significantly probability of promotion by increasing dramatically the chances of being promoted (for "Professore Ordinario" +54%), other things being equal.

In productivity equation age has a negative impact both on quantity and quality of publications. Women are penalized in their publication activity at the early stage of their careers, in both countries. Different impact of gender effect between countries appears in higher ranks, where only French women are penalized. Being involved in large projects (articles with more than 30 authors) has a strong positive effect on individual productivity of scientists (see also in chapter 4). Finally many physicists recruited during the waves of 1980 and 1985, appear not to have progressed much on their careers, and to be less productive than the other physicists of the same rank recruited or promoted in other years. Therefore, stop-and-go policy of recruitment adopted, in particular by Italian government, can create persistent damage, in terms of lost productivity, to the national academic system.

Chapter 3 examines the career advancement processes in Italy and France for academic physicists. In both countries professors are civil servants, whose recruitment regulations, duties and wages are fixed by national laws. All positions are tenured and all academics are classified by the ministry according to their discipline. Members of the discipline retain formal control over recruitment process. Italian and French competitions for promotion, respectively *concorsi* and *concours*, are both made by two steps: *qualification* and *call* from the university that aims to fill the vacant position. The main difference between Italian *concorsi* and French *concours* lies at the *qualification* stage. French candidates achieve it through a committee which is national, while in Italy qualification is obtained at local university level (i.e. *idoneità*). The analysis concentrates on rank advancements between 2000 and 2005 from *ricercatore universitario* to *professore associato* in Italy and from *maitre de conférence* to *professeur* in France.

Seniority and scientific productivity are important determinants of academics career advancements in the two countries and also stratification of universities matters. Four measures of social capital are evaluated, from classical network measures to more sophisticated (i.e. *principal component, closeness, credit, and weighted_credit*). Conclusion is that in Italy proximity to influential decision makers is decisive for scientist's career, in France, where job commissions are not entirely elective and stand for several years, this effect does not appear.

Chapter 4 aims to explain the empirical evidence according to which Italian scientists appear to be more productive than their French counterparts at individual level. The analysis bases on two windows of time, first from 1985 to 1990 and second from 2000 to 2005. Windows are defined with the aim of accounting for two regimes of collaboration, empirically observed before and after 1990.

Two facts can fully explain the difference in productivity during the window 1985-1990: large presence of French scientists without publications (defined as zero productive) and misclassification of Italian nuclear physicists in the selected disciplines. Zero productive scientists are mainly academics, on the contrary CNR and CNRS show lower shares of such scientists. Large presence of nuclear physicists in Italy upward biases the individual productivity, being nuclear physicists' average productivity consistently higher than that of the physicists belonging to the disciplines selected for the analysis. There is no clear reason why scientists active in nuclear physics are not classified according to their research interest (discipline FIS04). Moreover, French academics, CNR and CNRS scientists do not show the same misclassification problem.

In most recent window (2000-2005), 43% (0.9 articles) of difference in individual productivity remains between France and Italy, even correcting for zero productive and nuclear physicists. In order to explain the remaining difference scientists are grouped in four classes (A, B, C, D and E) according to persistence (average length of collaborations) and extent (number of collaborators) of their collaborations. Scientists belonging to classes with higher persistence and extent show, on average, an higher individual productivity. Applying a counterfactual exercise, difference in individual productivity can be fully explained. Precisely, if French physicists adopted the same collaboration strategy (i.e. the same representativeness of each class) as Italians the difference in average productivity of recent years would be completely explained. I propose two version of the counterfactual exercise, one based on the re-weighting and another on the re-sampling of the classes.

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