論文

Essay on the New Regime of Doctoral Training and Knowledge & Competence Transfer between Academia and Industry: The cases of USA and Europe (Germany, Great Britain, France)

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Abstract: This study first aims to observe how the recent 'hybridization' of academic and industrial rationales (Gibbons et al. 1994) exerts its influence over the new formation of doctoral students, and second, seeks to apprehend the different ways young scientists are socialized within a specific —societal— set of institutional arrangements, by comparing four OECD countries (USA, France, Great Britain and Germany). The formation of young scientists brings into play a multiplicity of institutions at local or national levels and mobilizes the various resources available to them. These complex institutional interactions require them to adopt a variety of behaviors based on a diversity of animating principles. Thus, in order to uncover the so-called 'societal' modes of the construction of new scientific knowledge and competence, we are led to analyze simultaneously the socialization of young scientists and the various institutional configurations. For this purpose, we will scrutinize some of the essential elements that structure this process, such as the funding system, the nature of the contract between doctoral students and their supervising institutions, the rules governing the academic community, training-job transition, career paths etc.

Key words: competence; knowledge transfer; academia-Industry relationship; research training system; labor market for PhDs; post-doc position; occupational career; precarious trajectory

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I. Introduction

In order that they can flow between academic and industrial spaces, knowledge and competences must take on a tangible form: scientific articles, data, patents, technical objects, computer programs, engineers, post-docs, etc. Although it is the task of the scientific community to formalize or codify knowledge, some knowledge remains tacit: a part of the new knowledge generated remains embodied in human actors in the form of competences (Callon 1986). Since knowledge is fundamentally 'sticky' (von Hippel 1988, Lee 2000) and tacit knowledge is context-dependent, it cannot easily be separated from the contexts or individuals that generated it.

It is why we need to pay attention to human actors such as doctoral students, young researchers, post-docs, professors, experts, engineers, technicians and so on, in order to fully understand the knowledge diffusion in society. These human actors are sole capable of mixing the codified knowledge and tacit knowledge to produce innovation. They are then privileged tools for the analysis of the structuration of the hybrid space that is emerging at the interface between academia and industry (Ezkovitz and Leydesdorf 2000, Etzkowitz 2008). In view of the importance of human actors in the circulation of knowledge, the formation and mobility of the competences embodied in research 'workers' becomes a decisive factor in any analysis of technology transfer. In other words, compared with the authors of actor-network theory (Callon 1986, Latour 2005) who consider the interaction, without any distinction, of human and non-human actors in the boundless social world, we will clearly prioritize the former one in our analysis(1).

In this regard, S&E (science & engineering) PhDs seem to play a crucial role among other categories of actor, by the fact that they account for the highest share of the annual flows of scientists between academia and industry. In fact, we observed a rapid growth of doctorates graduates' flows in all the OECD countries and in all field of education. The number of doctorates in S&E has doubled over the last twenty years or so in countries like France, Germany, and United Kingdom (NSF 2012). Explanation of this expansion could be linked to the stimulus of higher education and research policies based on the premise that the production of high-level scientific diplomas was a key to future economic growth. The stakes are high, especially in the IT-related engineering, medical and biological sciences.

Yet, the number of doctoral students in these fields—at least who are origins of advanced

countries—is now tending to stagnate, a trend which is however offset by the arrival of students from other developing countries (internationalization of doctoral training). Europe is the biggest producer of doctoral degrees in 2012 with just over 68,000 (of which UK and France accounted respectively for 10,000 and Germany 25,000). The United States award over 41,000 doctorates in all fields, so that Europe trains more PhDs than USA. In addition, almost half of the doctoral degrees are awarded in science and engineering, including 28,000 in the US and some 31,000 in three European countries. Natural sciences and engineering alone accounted for more than 80% of S&E doctorates in both the USA and Europe[i]. At the same time, difficulties appeared on the labor market for PhD graduates, confronted both with rigidities of the academic labor market and with a lack of professional opportunities in the industry, as recent studies have underlined (Stephan 1996, Mangematin 2000, Cyranoski et al. 2011, Lanciano-Morandat, Nohara 2013) for OECD countries.

In this paper, we will attempt to compare the conditions under which PhDs are produced and integrated into the labor market in USA and several European countries (France, Great Britain and Germany)(2), while taking into account the recent changes in labor market for scientists.

PhD's research training and integration into the labor market brings into play a whole set of public and private institutions in the sphere of science and innovation. Thus, our aim here is to focus on the way in which PhDs are produced in a given national research and higher education systems. In other words, although the 'hybridization' of academic and industrial spaces is taking place everywhere, it takes different forms depending on the characteristics of the national context whose pre-existing institutional arrangements exert a strong influence over the selection, formation and professional trajectory of PhDs. In this sense, our analysis based on the 'societal approach' (Maurice, Sorge 2000) might be in line with the framework of the institutionalist theoretical school known as 'the national system of innovation' schools (Nelson 1992, Edquist 1997, Lundvall 2007).

This paper will be composed of the first part focused on the institutional environment of PhD research training system in each country and the second part that aims to describe the dynamics of labor market for PhDs on the basis of the concept of knowledge/competence circulation.

II. Analysis of PhD's Research Training Models in USA and Europe

From our analytical perspective, the function of PhDs—and of doctoral students—is three-

fold: they are the resources used to produce the scientific output of the teams within which they operate, the pool from which the next generation of scientists will be drawn and the primary vector for the transfer of knowledge between academia and industry.

The process of completing a doctorate formation enables students, firstly, to acquire knowledge of the latest scientific advances in each discipline. In return, they contribute to the collective scientific output by specializing in a specific area within their team. The presence of doctoral students is absolutely indispensable to the performance of the team as a whole, since research at this level requires a very high degree of specialization, synergy between the various individual elements and a gradual accumulation of scientific results.

Secondly, it serves to produce the next generation of lecturers and researchers whose task it will be to provide leadership in the scientific research of the future; this equates of course to the reproduction of the academic community. The reproduction of that community is based on large sums of money allocated by governments, on peer co-opting or selection, etc.

Finally, the flows of doctoral students and PhDs between Higher Education and Research System (HERS) and firms are the means by which the new knowledge produced in academic research institutes is diffused beyond the boundaries of academia. This diffusion of knowledge through the exchange and mobility of scientists usually takes place just after completion of the PhD or in the post-doc phase within the collaborative networks that form the basis of the organizational and cognitive proximity between publicly-funded research institutes and firms.

Thus, the production of PhDs brings into play a multiplicity of institutions at local or national levels and mobilizes the various resources available to them. The interaction between them requires the actors involved to adopt diverse behaviors based on a diversity of animating principles. Hence, to reveal the different 'societal' modes of the construction of new scientific knowledge and competences, we should simultaneously analyze the socialization of the actors and the various institutional configurations. To this end, we will continue by analyzing some of the key elements that underpin this process, such as the funding system, the contract between doctoral students and their supervising institutions, the rules governing the academic community, etc.

II-1. The funding of doctoral programs

The United States has the most highly systematized PhD programs, although they are decentralized and differ from university to university. The power of the graduate schools run by the research universities, which are characterized by their autonomy, the competitive environment in which they operate and, above all, their concentration (there are about 50 research

universities of international standing), gives this model the status of an international reference point in this regard. The American system produces slightly more than 20,000 new PhDs in science and engineering each year. Its scale makes it possible to rationalize academic programs and to manage research funds, to tap the various sources of funding and to create the conditions for the efficient production of scientific output and PhDs based on economies of scale. As far as funding is concerned, many students receive assistance from research funds gathered outside the university system but managed directly by the universities (and the individual research teams). These funds are used to establish assistant teaching or research posts. On the other hand, relatively little use is made of national or federal core funding. In other words, the quality—and the reputation—of individual research teams and universities depends to a large extent on their ability to tap the various sources of funding (federal, military and private) that make it possible to put the 'best' doctoral students to work on promising topics. Thus reputation plays an essential part in effecting the match between financial resources and 'talent'.

In Europe, doctoral programs are much less systematized than in the United States and still reflect the various national institutional heritages (Clark 1993). Nevertheless, the three European countries under consideration here did initiate reforms during the 1990s, albeit in their own different ways.

The system in **France** is characterized by the fragmentation of university research teams and the dichotomy between the universities, on the one hand, and the elite *Grandes Ecoles,* on the other. In recent years, however, doctoral programs have been reformed in order rapidly to increase the number of PhDs produced. The universities have tended to set up research schools in order to take advantage of economies of scale. The *Grandes Ecoles* have also expanded the part they play in the production of PhDs by strengthening their 'engineer-PhD' programs. Funding for doctoral students is based to a large extent on the various grants awarded by government ministries, and in particular MENRT (*Ministère de l'Education Nationale et de la Recherche,* or Ministry of National Education and Research)[3]. Thus 85 to 95% of doctoral students in science and engineering, depending on the discipline, are funded by one or other of these grant-awarding bodies (MENRT 2005). The distribution of these grants among the various research units seems to remain relatively stable, at least in the medium term. Similarly, the grants awarded by organizations such as the DGA (General-Directorate for Armaments), the CEA (Nuclear Energy Centre), the CES (Space Studies Centre), France Télécom and so on go mainly to a certain number of laboratories with whom they have established good working relations. In contrast to the USA, the funding of doctoral stu-

dents is relatively unconnected to direct academic competition; the system of grant allocation tends rather to be administrative in nature (MENRT-type awards) or to be based on long-term partnerships.

Although the Humboldt model, in which teaching and research is seen as an indivisible whole, has been the basis for the effectiveness of German universities, little distinction is made between doctoral research and other advanced training programs and the production of PhDs is relatively unsystematized. In other words, the selection process, courses and pedagogic content are not highly structured, as they are in the American system. In consequence, the career paths for students embarking on a doctorate are not very well signposted, particularly since the length of time they take to complete their theses remains highly variable.

Three quarters of doctoral students are employed as junior staff in universities, although their conditions of employment (full-time/part-time, length of contract and so on) seem to differ considerably from one field to the next. These posts are funded partly from local (*Länder*) and national (*Federal*) government grants provided for in annual budgets and partly from the public or private research funds that selectively finance projects on which doctoral students can apply for assistantships. Particularly in this latter case, they are dependent on the reputation of the professor/PhD supervisor, who often manages scientific projects involving both the university and research institutes, on the one hand, and the university and industry, on the other. As a result, many doctoral students are from the outset members of research teams in which their personal work forms part of the team's collective program.

In the **United Kingdom**, as in Germany, PhD students can take a number of different routes. Entry conditions for those who have completed the 3-year undergraduate degree, the length of time taken and the way in which the doctorate is obtained differ from discipline to discipline, even though efforts are being made to formalize programs and the final assessment. As far as funding is concerned, the research councils distribute the major share of grants on the basis of individual academic merit, with other public organizations, notably the universities themselves, accounting for most of the remainder. Thus three quarter of full-time PhD students have their tuition fees(4) paid by public bodies. Half of them receive money from the research councils and a quarter from the universities, government ministries or local authorities; firms seem to make only a very limited financial contribution to the production of PhDs. On the other hand, more than half of all part-time doctoral student are self-funding because of their restricted access to government grants or funding from business and industry. However, the general trend in the funding of doctoral students is towards a gradual withdrawal by the state, which is forcing the universities and the research councils to diversify their sources of finance.

An increasingly large share of doctoral students are being co-funded by industry and the universities within the framework of programs such as CASE[5] and PTP.

II-2. Characteristics of the Doctoral students; reflect of institutional forms of University system

Doctoral students in the **United States** constitute a very heterogeneous population, reflecting the great diversity within the university system itself. The freedom each university has to fix its own rules or procedures for awarding PhDs, combined with the relatively large numbers of students who interrupt and then return to their studies, means that the socio-demographic characteristics of doctoral students are fairly disparate. The absence of any centralized (federal) certification for doctoral programs also has the effect of making the quality of the degrees awarded less than transparent. Furthermore, the number of foreign doctoral students and post-docs, which varies from discipline to discipline (34% in natural sciences, 49% in engineering, according to the NSF 2012), is still very high, as we have already seen. The large numbers of foreign students is proof of the attraction exerted by certain American research universities; at the same time, they constitute a pool of skilled labor on which the scientific labor market, particularly that for post-docs, can draw[6].

For slightly different reasons, the **United Kingdom** also has fairly diversified populations of doctoral students. Since specialization begins at a very early stage here, from the age of 16 onwards, and the total time spent in higher education can be relatively short (6 years may be sufficient to reach PhD level), some students obtain their doctorates at a young age, around 25. On the other hand, a significant share of doctoral students, working part-time for their PhDs, take a very different path through the education system, in terms both of time spent in the system and scientific background or motivation. According to one estimate, a quarter of new entrants in a university year could be part-timers. This category of students, many of whom have previously worked or are continuing to work while studying, accounts for a not insignificant of the total doctoral student population in the United Kingdom. Moreover, as in the USA, foreign students account for a significant share of the new doctorates awarded (30-50%). This diversity, combined with that of the universities themselves, makes quality standards a little difficult to assess (Lee, Miozzo, Laredo 2010).

On the other hand, the PhD populations in the other two countries are relatively homogeneous, although this homogeneity is not of the same kind. In **Germany**, many students embark on a higher education course in a technical or scientific subject on completion of an apprenticeship begun after obtaining the Abitur at age 19[7]. Even though they may subsequently

leave higher education at various levels, the professional experience acquired during the 2 to 3 -year apprenticeship serves as a sort of common basis for creating a professional identity that facilitates cooperation among technicians, engineers and researches. Graduates tend to obtain their degrees late because of the relatively long time taken to complete the bachelor's and master's programs, which have no real cut-off point. For example, the average age at which a university student becomes a graduate engineer is 29, and 31 for students in the *Fach-hochschulen.* Consequently, those who prolong their studies beyond the graduate engineer level in order to obtain a PhD are delaying still further their entry into the labor market. Doctoral students tend to complete their doctorates between the age of 31 and 35, which seems late compared with the French average of 29. Even though the funding arrangements mean that their academic careers are slightly different, the PhD population retains a certain homogeneity, which is further reinforced by the fact that Germany attracts significantly fewer foreign students (less than 10%).

France on the other hand, is characterized by the relative coherence of its doctoral student populations: virtually all PhD students in these countries study full-time, apart from some of the foreign students in France. In this country, students' progression through the system follows a relatively linear path from high-school graduation to PhD. The procedure for completing theses is standardized and takes a relatively short time, with students often completing before age 30. This normative procedure creates a certain coherence among each cohort of doctoral students, although in France of course there is the duality between universities and *Grandes Ecoles.* Foreign students, mainly originating from Africa, account for around 20-25% of doctoral students in France.

III. Deployment of PhDs and Career Formation as a Mechanism of Knowledge & Competence Transfer

As yet noted, some difficulties appeared recently on the labor market for PhD's graduates. With a growing supply (doctorates diplomas) and a trend to a decrease in the number of academic jobs offered, the labor market for PhDs could be characterized more and more as inefficient, because of a mismatch between the supply and the demand side, while in the past, there existed a traditional matching between doctorate graduations and academic positions. Obtaining a tenure job in public research labs becomes longer after graduating, leading to multiplication of fixed term contract, post-doctoral positions and precarious life. This situation could explain the higher attractiveness of United States for junior researchers, doctorates students,

graduates and post-doctorates. Besides the traditional academic labor market, we observe that more and more doctorates turn to business sector. They may still remain not enough well-suited to the need of firms, although they are crucial in the innovation process and in a knowledge-based economy. Yet, apart from these common trends, each country attempts to resolve these difficulties in a different way, putting in place a new form of training-job transition or career paths.

III-1. The training-career transition in academia

Obtaining a PhD has traditionally been regarded as preparation for an academic career, either in universities or in publicly funded research institutions, where the careers of teaching and research staff are governed by strict rules: recruitment based on academic publications record, peer evaluation, tenure or employment guarantees and so on. The tenure system often emerges as a major issue in academic careers, particularly in the English-speaking world, since it serves both as an incentive mechanism for those starting their careers and as the boundary marker beyond which job stability in the internal market allows academics to specialize and extend their knowledge without the threat of academic obsolescence or dismissal (Carmichael 1988). This canonic model of the academic labor market seems to be largely a fiction, however, if only because, in reality, it functions very differently in different societal contexts. In order fully to understand its diversity, we will need to consider two mechanisms: the first concerns the internal workings of universities, while the second relates to the nature of the implicit contract between doctoral students and their supervisors, who fix the rules governing the balance to be struck between students' contribution to collective research and the development of individual careers. The first influences the rules or practices governing recruitment, while the second tends to shape the strategies PhD students adopt in respect of their own career aims.

a) In the **United States**, the academic labor market is characterized, firstly, by extensive segmentation between two types of university, teaching universities and research universities (public research institutions), with teaching and research staff being managed in accordance with the different missions of the two types of institution[8]. It is characterized, secondly, by the tenure system, which offers young academics an incentive to produce knowledge, particularly in the second category of university, among which there is intense competition. This dual competition at the individual and collective (inter-establishment) level is based on the '(academic) reputation system' which functions as a sort of stock market quotation in a quasi-

commercial marketplace and is the basis for the hierarchy that characterizes the American university system. Unlike in France or Germany, *'where the discourse is egalitarian and where the universities are all supposed to be of comparable quality and to award degrees of the same value'* (Brisset-Sillon 1997), universities in the USA are systematically ranked, which has the effect of hierarchizing and segmenting the academic labor market. The main differentiating factor in this hierarchy is research: the best institutions are those that have a high level of academic/scientific output and manage both to tap the available financial resources to the fullest extent possible and to attract the best talents. The careers of teaching and research staff tend to espouse the same principle of competition based on reputation.

In accordance with this same principle, the contract between doctoral students and their supervisors seems to be based on a reciprocal commitment to a relatively explicit form of exchange. PhD students undertake, while working on their theses, to contribute to the production of new knowledge within the group research directed by their supervisors or professors, while the latter agree to provide them with an academic environment as conducive as possible to the production of interesting findings and, above all, of articles for publication in the leading academic journals, which in turn guarantees their academic future. However, this mutual commitment is limited in both time and space, since a PhD thesis is only one staging post on the route to academia, access to which remains highly uncertain. The allocation of research funds, including assistantships, is extremely competitive, the process of obtaining tenure is both lengthy and selective and mobility between projects or research teams is the rule. It is important for young academics, therefore, to adopt a strategic approach to constructing their academic reputation by accumulating positive signals as they work with various research teams, collaborate with various professors and help to run a variety of different projects. Each commitment to these various contracts is intended to create a positive dynamic.

Currently, slightly fewer than two thirds of PhDs are employed in university or academic positions three years after obtaining their doctorates, while only one quarter are employed in firms (NSF 2010). Thus PhD students in the USA are being prepared mainly for careers in the 'academic space', and particularly in the university system. Nevertheless, the vast majority of new PhDs find themselves accepting temporary posts and thereby joining the queue for tenured or tenure-track positions. This selectivity, which has become more intense in recent years, makes the situation of young academic precarious to some extent, which reduces the attractiveness of academic careers and tends to restrict enrolment on PhD programs, at least in some subject areas (Cyranoski et al. 2011). For example, in Silicon Valley, there are many cases of biotechnology researchers with doctoral degree starting their own businesses after

gaining work experience in firms (Fujimoto 2012).

b) The situation in the **United Kingdom** is not dissimilar to that in the USA. Here, the higher education system comprises a total of 113 university institutions and has been unified since 1992. Nevertheless, these institutions can be divided into two distinct categories, the 'old', or pre-1992 universities, and the 'new', or post-1992 universities, which grew out of the former polytechnics. Universities in the first category, which forms the basis of the British system, provide courses at all levels, with teaching and research being closely linked. It includes the ancient universities as well as technological universities and the so-called '*red-bricks*', founded in major cities such as Manchester and Leeds in the late 19th and early 20th centuries. The post-1992 universities concentrate more on undergraduate teaching. They have a significant number of part-time students and students on sandwich courses. Although current policy in Britain is aimed at creating a homogeneous system by increasing the number of crossover points between the two categories, the academic labor market is highly segmented between the new universities, which concentrate mainly on teaching, and the traditional universities, in which most research is conducted. Although they are less autonomous than American universities, the most prestigious British universities enjoy a not-insignificant degree of freedom, far more in any event than their French and German counterparts, in matters of recruitment, promotion and incentives for teaching staff. The allocation of public research funds on the basis of the Research Assessment Exercise increases competition between universities, which in turn influences academics' career paths, as it does in the USA. Furthermore, although the tenure system was formally abolished in the late 1980s, the goal of most young academics is to obtain a permanent lectureship, which offers far greater job security than that enjoyed by contract research staff, the vast majority of whom are employed on fixed-term contracts. The contract researcher category, which accounts for almost 30% of faculty staff and provides support for university research activities, acts as a sort of 'airlock' in which young academics destined for lectureships are sorted out from the rest, who are likely to seek work in the private sector.

The implicit contract between doctoral students and their supervisors, which is based on a mutual commitment, is intended here, as elsewhere, to ensure that the work students do for their theses also adds to the research teams' output and reputation, with benefits for both parties. Doctoral students appear to enjoy greater room for maneuver here in constructing their individual strategies, since most of them receive grants to support their studies. In this sense, British PhD students are able to adjust their level of involvement in their teams' research in

accordance with the likelihood of their obtaining a position in the academic community. Nevertheless, those seeking such a position have to go through a lengthy selection process which forces them to take part in a sort of protracted knock-out tournament. By way of illustration, a survey carried out by the *Wellcome Trust,* a private research foundation, shows that, after completing their theses, 80% of young PhDs in the biological sciences find their first jobs on fixed-term contracts in academia; however, only 60% remain after three years and this figure falls further to 47% beyond the four-year mark (Lee, Miozzo, Laredo 2010).

In the other two European countries, the higher education system is managed by centralized supervisory bodies whose management procedures are more or less bureaucratic. The market mode of coordination based on reputation or 'share price' is replaced here by an administrative mode. While it is true that certain establishments are more 'recognized' than others, the inter-institutional competition and hierarchies are not as explicit or as transparent as in the USA or the UK[9]. Thus the doctorates awarded in these countries, regulated and controlled as they are, reflect a certain quality standard.

c) In **Germany**, the academic labor market is organized by the supervisory authorities, which operate on two different levels:

'the federal government lays down a general framework of rules and procedures governing the university system, a framework within which the individual Länder or states are able to develop a certain number of options. The Länder are also very active in negotiating professors' salaries, since they are requested by the universities to find the necessary funds' (Musselin 1994).

Although university teaching staff in Germany are civil servants, as they are in France, they do not generally obtain a permanent position until the age of about 40, when they are appointed to a professorship following completion of their *Habilitation,* a second doctorate that confers entitlement to teach in a university. Moreover, the system attaches a certain number of supplementary conditions to the recruitment procedure: candidates already in post cannot be promoted unless they change institution; once selected, they may negotiate additional payments and working conditions with the university, in particular research budgets (including assistantships). Compared with the conditions in the French market, young assistant staff have to be mobile in order to obtain a permanent position and also have to go through a lengthy apprenticeship and selection process under a professor's authority that lasts until the age of about 40. The status of professor is the central pivot around which the German university and research systems are organized. Indeed, unlike in France, where university staff and public-

sector researchers have separate career paths, it is the university career path leading to the status of professor that is the obligatory route for all academics and allows them subsequently to be considered for positions of responsibility in extra-university research institutions funded by the state or by industry, such as the Max-Planck Institute, the Helmholtz Centers, the *Fraunhofer Gesellschaft* etc. It is through these public or semi-public research organizations that German industry receives a steady flow of professors, doctoral students and post-docs as part of a process of cross-fertilization that reflects the close cooperation between science and industry.

In view of the importance of the status of professor, the implicit contract is based more on the individual relations between professors and PhD students, or even on a master/pupil relationship along the lines of the classic *Humboldt* model in which they come together around a common research object. This type of personalized relationship, based less on the value of the student's immediate performance, tends to restrict the scope for young academics to adopt individual strategies. As a result, they seem to be more dependent on the relational networks established by their professors in order to gain a toehold on the various professional career paths. This is particularly true of those who embark on academic careers.

d) In **France**, the higher education and research system is an archetypal example of a system controlled by the central state, even though the state is currently seeking to reduce its financial commitment and to give establishments greater autonomy under local management. It is further characterized, over and above the university/*Grande Ecole* duality(10), by a clear distinction between the universities and public research establishments, which each have their own separate missions, namely teaching and research respectively. This distinction has served to create two separate professions, researchers and lecturers. Thus the academic labor market is divided into separate segments between which there is little mobility. Nevertheless, the same rules govern the service of all academics, whether teaching staff or full-time researchers, since virtually all of them are civil servants. In France, therefore, the rules governing the service of university staff and researchers are laid down by the state. The distribution of posts is managed by the central administration within each system. The management of individuals—recruitment and promotion—is the responsibility of the relevant corporate body. University teaching staff and researchers become civil servants on obtaining their first permanent lecturing position (*maître de conference*) or research post (*chargé de recherché*). Having gained tenure around the age of thirty, university teaching staff and researchers enjoy job security, behave as 'insiders' in the internal market and display a propensity to shut themselves off from

its economic environments.

As far as the nature of the contract governing relations between doctoral students and their supervisors is concerned, there is a not insignificant element of personal commitment, as in Germany. In France, however, these relations are shaped more by the institutional aspect of the contract that links PhD students to their laboratories or research units. Indeed, since the conditions under which they complete their theses, particularly the allocation of grants or the industrial contracts under which support is provided, depend to a very large extent on the laboratory to which they are affiliated, they feel themselves more involved in the workings of their institutions. This tendency is further reinforced by the fact that the competitive procedures by which young academics are recruited to teaching or research posts frequently go beyond the selection of individuals to become competitions between individual laboratories. Individual strategies certainly exist, but they have to be implemented, in the form of co-option, within a space shaped by the constraints imposed by wider institutional strategies.

III-2. The recruitment of PhDs in the private sector

Labor market transactions are characterized by uncertainty caused by informational asymmetries. One of the ways in which this uncertainty can be reduced is to evaluate individuals and their competences on the basis of the signals they transmit in the form of qualifications, experience, areas of specialization, research topics, institutional affiliation, etc. (Spence 1973). These signals include, on the one hand, more or less objectified elements, such as degrees and publications record, which constitute a form of certification of competence and quality and, on the other, subjective elements, interpreted by the actors, which provide the basis for reputations. Thus ‘certification’ and ‘reputation’ are two major modes of coordination around which the encounter between supply and demand in the labor market is organized (Stephan 2012). Nevertheless, these modes of coordination become increasingly less satisfactory as subject corpora evolve ever quicker and the boundaries between disciplines become blurred in certain areas of academic and scientific specialization (Lam 2000). Nor do they any longer provide an absolutely sound basis for matching supply to demand in certain R&D activities. As a result, an alternative mode of adjustment is emerging at the interface between the academic and industrial spaces; networks make it possible not only to identify, contact and sift the talents that best match specific needs but also, and above all, to co-produce them through university/industry collaboration (Lam 2007). The recruitment of PhDs depends to a fairly large extent on these types of mechanisms. However, these mechanisms, which are intended to reduce uncertainty or to bring the two spaces closer together, are deployed within a set of national institu-

tional arrangements.

In consequence, they are regulated differently and have meanings that differ considerably from country to country, particularly as far as the recruitment of PhDs is concerned.

a) In the **United States**, the university system can be said to have integrated itself into its economic environment by adopting the principles that animate the business world, that is the provision of commercial services in the marketplace. Thus American universities position themselves in the same competitive arena as firms in order to satisfy their funding requirements. This inter-institutional competition and the provision, on a commercial footing, of various services based on the academic and scientific knowledge at their disposal have helped to legitimate the notion of the 'entrepreneurial' university, a symbol of institutional innovation that dates back to the founding of the Massachusetts Institute of Technology. This type of strategic behavior, duly legitimated and consistent with the American university ethic, enables universities to trade in patents or to establish, on a large scale, high-tech companies as spin-offs from their research activities. It is this general context that shapes the use and flows of doctoral students and PhDs.

According to NSF surveys (S&E Indicators 2000, 2010, 2016 NSF), slightly fewer than two thirds of PhDs are employed in academic jobs three years after obtaining their doctorates, while one quarter are employed in business and industry. Apart from the scale of the academic market, this survey reveals two phenomena.

Firstly, the PhD recruitment rate in industry shows an upward trend over time, although it fluctuates with the business cycle and, even more so, from subject to subject. The share of PhDs in engineering entering industry is greater than that of PhDs in science: around 60 % of those with doctorates in engineering were working in the private sector in 2010, compared with 40% for computer science and 20% for the life sciences.

Secondly, the share of young scientists in intermediate positions at the intersection between academia and industry is growing fairly rapidly. This increase, due largely to the establishment of post-doc positions, reflects a strengthening of the competitive selection mechanism governing entry to the academic market and the increasingly precarious nature of their situation as a result of being employed on a succession of short-term contracts. This phenomenon is most apparent in the life sciences, one of the areas in which American science excels. For example, 60% of new PhDs in this area find themselves in such intermediate positions, and they account for half of all post-docs in the USA. In areas such as this, young high-level scientists employed on extremely flexible contracts alternate between research programs, temporary

posts in industry and academia or even the start-ups established by university teaching staff while they wait to settle down in permanent positions(11): individual mobility of this kind is mediated essentially through reputation, established by formatting knowledge in the form of academic publications, or through socio-professional networks. Fluidity of this kind creates a labor market that is often embedded in a local academic community (Palo Alto, Biotech-Bay in California, Boston etc.) gravitating around a core of university institutions and academic spin-offs that functions as an 'intermediate space' in which scientific knowledge is disseminated (Saxenian 1994, Fujimoto 2011). Combined with the influx of foreign post-docs seeking to familiarize themselves with the latest developments in biotechnology, it also influences the trend towards the externalization of R&D activities by pharmaceutical companies and the constitution of an international space within which certain 'hybrid' actors move, transcending the long-established national and professional boundaries of the university, the industrial researcher or the entrepreneur (Callon 1991).

b) In the **United Kingdom**, there is a tradition of autonomous universities able to manage, at local level, their own relations with the political and administrative authorities as well as with firms. The universities' ability to take advantage of their autonomy in order to establish and sustain local links explains the existence of clusters of innovative companies around certain universities, most notably Oxford and Cambridge. At the same time, the free-market policies of successive governments and its corollary—the reduction of public funding for teaching and research—have further encouraged universities to develop their activities in this area.

Against this background, an increasingly high share of doctoral students is being supported by joint industry/university programs, such as the CASE and PTP programs (see footnote 3). A comparative study of France and Great Britain (Mason et al. 2000) also found that doctoral students in Great Britain seem to be significantly more involved than their French counterparts in industrial projects, particularly in SMEs in the electronics and biotechnology industries. Apart from the fact that many multinationals have established laboratories in the vicinity of certain universities, which in itself creates a strong demand for scientists, British firms are more likely to recruit PhDs to work in their R&D departments than French firms, which display a marked preference for 'engineers' trained in the *Grandes Ecoles.* Consequently, a good number of doctoral students look to industry for employment once they have completed their theses. According to the OST (Observatoire des Sciences et Techniques), one third of the doctoral students funded by the Research Councils find jobs in the private sector on completion of their PhDs in 2005. Whereas it is becoming increasingly difficult to find stable employment

in academia, because of cuts in university funding, the increase in contract research and the drastic reduction in publicly funded research laboratories, industry is seeking to co-produce and reclaim a certain proportion of PhDs by forging strategic partnerships with universities. Similarly, a certain degree of disintegration in the publicly funded research sector and the presence of a significant pool of contract research staff in the universities have helped to create a specific category of 'hybrid' actors made up of professionals and academics who have become self-employed in order to provide services to firms or to act as sources of high-level skills that can be called on for specific scientific/industrial projects. The presence of this category of actors makes the British R&D system extremely flexible (Lee et al. 2010).

In order to regulate the links between the HERS and firms, the two continental European countries make less use of 'market intermediation' than the USA, where scientific reputation can be as financially profitable in academia as it is in industry, or the UK, where the porous boundaries between the public and private spheres have created an enormous area of great flexibility (Gaughan, Robin 2004). In their different ways, Germany and France have each structured a space in which industry/academia collaboration takes place, the nature of which influences the ways in which PhDs enter the labor market.

c) In **Germany,** close links between academic research and industry have existed for a long time, both in large firms and in SMEs. There are many research centers jointly funded by the state and firms in which university and private-sector researchers work together with a view to developing products up to the pre-competitive stage (the *Fraunhofer Gesellschaft,* for example). In addition to the long-established practice of firms providing periods of training in the workplace for university students, German industry frequently calls on university professors and doctoral students in a process of 'cross-fertilization' that is regarded as the key to its success, particularly in the chemical and pharmaceutical industries. Moreover, these links seem to be forged at local level, since the universities and research institutes, most of which are administered by the *Länder,* are deconcentrated, which encourages the diffusion of academic research within the local industrial fabric.

These close links between industry and academia based on local networks are constructed around a professoriate whose individual members enjoy considerable personal autonomy in managing science/industry relations. This has a direct influence on the integration of German doctoral students into the labor market. Thus PhD students and post-docs are very often involved in the collaborative projects that university professors manage on behalf of firms. Industrial contracts, and the funds they bring in, are an integral part of PhD programs. Profes-

sors are in effect part of the corporate management hierarchy and are responsible for supervising young researchers in both the industrial and academic aspects of their work. Furthermore, post-docs are sometimes strongly encouraged by their professors or other academic associates to launch spin-offs on the basis of their joint research. This type of 'patronage' seems to reduce the probability of young PhDs finding themselves in precarious employment situations in the early stages of their careers.

From a statistical point of view, Enders (2001) shows that one year after obtaining their doctorates, only 60% of PhDs in biology and mathematics stay in the public sector, mainly in the universities. On the other hand, 60% of PhDs in electronic engineering and almost one third in biology are employed in the private sector. Thus the career paths of German PhDs seem to be more diversified than elsewhere.

Whatever their discipline, German PhDs seem to be much less reluctant than their counterparts in other countries to seek careers in industry(12), firstly because of the cognitive proximity between the academic and industrial spaces and, secondly, because of the high status of researchers in industry, which opens up very good promotion prospects.

d) Despite a higher education and research system that is characterized both by state centralism and a certain degree of inwardness—expect in the prestigious engineering schools (*Grandes Ecoles d'ingénieurs*), which have always maintained close links with industry—**France** has developed forms of collaboration between academia and industry that have sometimes proved to be very efficient in the past. Governments have frequently initiated sectoral action programs (such as the Plan Calcul, which was meant to ensure French strategic independence in computers, Plan Télécom etc.) and, adopting a mission-orientated approach to policy, have also provided the impetus for large-scale technological programs (Nohara, Verdier 2002).

In doing so, they looked for support to numerous scientific and technological research organizations as well as to the large national firms, both private and publicly owned, that were the leaders in their sectors. These latter were involved in the large-scale technological programs more as 'purchasers' than as the initiators of scientific collaboration. Thus technological diffusion was conceived in a centralized, top-down way, with companies being little involved in defining objectives. However, this organizational structure, which prevailed until the early 1990s, has begun to change, with greater decentralization helping to break down the boundaries between the public and private spheres. Thus the French system is evolving in two direc-

tions. On the one hand, reduced centralism is giving technological support programs a more regional character and is leading to the development of local networks involving universities, research laboratories and SMEs. On the other hand, there is increasing financial autonomy within the HERS and the financial flows from firms to academia are increasing.

That said, relations between the HERS and French companies are still deeply influenced by the weight of the past in that they remain highly formalized and structured. Thus some large companies continue to maintain long-standing, privileged relations with certain public laboratories or universities; these relations may take the form of jointly operated laboratories, so-called 'economic interest syndicates', or partnerships, or research agreements (Nohara 2017). These forms of links involve mutual, long-term commitment, exclusive 'one-to-one' relations and formalized transactions.

It is within this framework of science/industry relations that PhDs in France are deployed and integrated into the labor market. According to several studies (Cereq 2010, Calmand, Prieur, Wolber 2017), slightly fewer than two thirds of them are employed in the public sector (higher education and public research institutions) three years after obtaining their doctorates, while one third are employed in the private sector. Thus, the academic labor market, which operates in accordance with the rules laid down for the civil service, remains the main source of employment for PhDs. The differentiation between public and private career paths emerges at a fairly early stage, therefore, with each 'space' creating its own relatively impervious segment within the internal labor market (Martinelli 2001). This differentiation is even present at the time when funds are allocated to prospective PhD students(13). Those in receipt of public funding tend to seek employment in the academic labor market, while those supported by industry or the *Cifre* (see the note v) program are very likely to seek employment in industry, possibly even in the companies that have been funding their studies(14).

In this latter case, both the allocation of industrial contracts (or grants) and the labor market integration of those being supported in this way depend on the networks that university or other public research laboratories have established with certain companies. It is the recurrent nature of these relations that encourages the establishment of these networks between the partners. Doctoral students play a central role in maintaining these networks, since they become integrated into them by virtue of the reputation of the institution to which they are affiliated and at the same time function as a key link in their reproduction.

The use of doctoral students in university/industry collaboration in France is further characterized by two considerations of an economic nature. For both partners, it is one of the least costly and least risky ways of organizing such collaboration; a PhD thesis that takes 3 to 4

years on average to complete can serve as an exploratory study of emerging areas or topics. This type of technological wager gives firms a certain degree of flexibility: they can decide whether or not to internalize the co-produced knowledge or competences depending on the potential revealed by the doctoral student's findings.

IV. Conclusion

The 'hybridization' of science and technology is creating a new intermediation space between academia and industry (Gibbons et al. 1994). The creation of this new space has been accompanied by the emergence of new structures, such as academic start-ups, university incubators, technology transfer organizations (TLOs), research consortiums, whose purpose is to facilitate the interactive circulation of knowledge between the academic and industrial spaces (Kline, Rosenberg 1986, Lanciano et al. 1999). The emergence of the PhDs' 'professional' labor market as a mechanism for the co-production and transfer of competences is an important element of this general phenomenon.

More concretely, however, this new type of labor market is also the result of three other basic factors. The first is the development of mass higher education, the second the changing nature of universities themselves (the 'entrepreneurial' university) and the third the needs of business and industry, which result in increased demand for collaboration with the higher education and research system, in which the basic scientific knowledge that is becoming indispensable to the innovation process is produced (Musselin, Teixeira 2014).

These various factors are in evidence everywhere, giving rise to similar trends in all countries investigated. The proposed or partially implemented solutions for dealing with this new situation tend to draw heavily on the American graduate school model, which is thereby acquiring 'universal' legitimation. The increasing number of joint scientific projects involving international teams (research consortia, joint articles etc.) and the globalization of multinationals' R&D functions are further reinforcing these trends (David, Foray 2003).

Nevertheless, more detailed observation shows that this convergence towards the American model, whether assumed or desired, has met with a variety of responses in the different national contexts (Maurice 1989). As our analysis suggests, the labor market for PhDs functions in different ways depending on the particular institutional arrangements associated with the various industrial sectors and disciplines or with national policies on higher education and research system. Higher education and research institutions, which in all countries are the heirs to a considerable national heritage, are in fact shaping the basic architecture on which the ar-

rangements, rules and practices governing university/industry relations are based. In this sense, the 'professional' labor market for PhDs is a 'social construct' deeply embedded in an overall societal context (Granovetter 1985, Maurice, Sellier, Silvestre 1986, Lanciano-Morandat, Nohara, Verdier 2006).

Thus, the coordination mechanisms, such as signalling, reputation and networks, that regulate the scientific labor market must be interpreted in accordance with this societal context. Although the academic world is now 'globalized', with the system of competition and academic reputation being constructed in the international arena, at least at the top level, this does not mean that all academic outputs (articles, patents, PhDs etc.) are evaluated by a few 'universal' criteria. On the contrary, the meaning of each regulatory mechanism can differ greatly depending on the space in which it is functioning. Although we recognize some merits of American graduate school model, we need to avoid evaluating the efficiency of each national research-training system on unique basis of this model.

Notes

(1) We recognize a great analytical value of this school, particularly in the way that they articulate the micro and the macro dimension of actor/network interaction in the seamless social world, while the absence of institution in their analysis seems to weaken such value.

(2) From a different perspective, Barton Clark had conducted a significant comparative study on the research training system at the graduate school level with the same four countries (Clark 1993).

(3) In particular, *Cifre* program—started from the beginning of the 1980s—is a unique French-type scheme. This State program allows firms, in particular SMEs, to benefit from public financial aid to recruit a young doctoral student whose research work, defined by a firm and supervised by a public research laboratory, will lead to the defense of a thesis. Thus, the *Cifre* program associates, under a collaboration contract, three partners: a firm that entrusts a doctoral student with a research project for three years, the subject of his or her thesis, and a public laboratory that provides the scientific supervision of the doctoral student.

(4) In most cases, the grant covers both tuition fees and student's living expenses for 3 years.

(5) Like the *Cifre* program in France, the aim of the CASE scheme is to place PhD students whose work will be supervised jointly by academia and industry. This program is largely funded by the research councils. CASE funding was originally restricted to the universities, but in 1994 the rules were modified to include business and industry. As a result, the research councils can now award grants directly to selected firms on the basis of PhD proposals submitted (Office of Science and Technology 2000).

(6) As well known, Trump Administration restrains and even try to stop the inflow of foreign students at all levels since 2017.

(7) This applies to nearly 80% of new students entering the *Fachhochschulen* (polytechnics) and to approximatively the half in the universities.

(8) This is, of course, a very simplified typology of the 3,600 such institutions in the USA, which can be further distinguished by their nature (public or private), by the length and level of courses offered and by reputation. The classification drawn up by the Carnegie Foundation in fact has 10 categories.

(9) Except for the distinction between universities and *Grandes Ecoles* in France.

(10) The French case is somewhat exceptional, since universities in France are not the centers of excellence that

they are in other countries. They are regarded as the 'second choice' relative to the elitist *Grandes Ecoles* and also as less productive in terms of research output than the public research institutions.

(11) However, this fluidity on the part of candidates does have its downsides: there is a risk that talents will be exhausted and academic careers made to seem less attractive.

(12) And also, in a negative sense, because the trajectories of young academics are lengthy, tortuous and dependent on their professors until they themselves obtain a tenured position.

(13) In addition, there are the engineers graduating from the *Grandes Ecoles* with PhDs who have a dual competence as researchers and engineers that enables them to operate within both the academic and industrial spaces. In itself, the status of researcher has no legitimacy in French industry, unlike in Germany. However, it is the status of graduate engineer that really marks out the elite and opens up prospects of promotion through the management hierarchy.

(14) In the case of the *Cifre* program, participants in which are jointly funded by industry and the state, 78% of new PhDs enter the private sector, with 54% remaining with the partner companies (ABG Formation 2010).

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