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**A Comparative Study of R&D Staff in France and Japan :
Skill Formation, Career Patterns and Organisational Creation of Knowledge**

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abstract

This paper attempts to interpret the interrelated dimensions of learning between technological professions (technicians, engineers, researchers) and the dynamic process of innovation on the basis of an international comparative analysis. One of the main hypotheses is that scientific and technological professions, far from constituting a universal and homogeneous category, are "social constructs" which embody a specific mode of knowledge creation in Japan and France and thus tend to structure national patterns of innovation. On the basis of our Franco-Japanese comparative research (three couples of firms in the chemical, the electric/electronic and software service sectors), we focus our analysis on some facts in the construction of the engineer category which offer sharp contrasts from one country to another: a clear difference in the way engineers in France and in Japan are certified by higher education systems; a difference in the way their career patterns (mobility, training, incentive system) are organised. The nature of innovative capacity seems finally to be closely linked to the way that the career patterns of engineers/scientists are managed, at both the national and the firm level, in order to create the linkage between individual learning and the collective accumulation of knowledge.

Introduction

The effectiveness of learning economies is clearly linked to their efficient coordination of individual and collective learning processes, and also to their capacity for rapidly transforming new ideas into a product, a production process or an organisation. Engineers/scientists naturally find themselves right in the centre of such activity. It is therefore vital to analyse the interdependence between the way these professionals are "socialised" in societal (national) contexts, the nature of the knowledge they generate and the form their technical creativity takes.

Our main hypothesis is that scientific and technological professions, far from constituting a universal and homogeneous category, are "social constructs" which embody a specific mode of knowledge creation in each country and thus tend to structure national patterns of innovation. The societal approach adopted here places great emphasis on the interdependence between the nature of the actors and the societal (and national) "space" within which they are shaped: engineers/scientists are considered as actors who, at the same time, are generated by and determine the national configuration of an innovation system, which is itself made up of various institutions such as the higher education system, the training system, firms, public research laboratories and so on. In other words, while an innovation system is obviously structured by the interaction between these institutions, the engineers/scientists play the main role in their linkage and mutual commitment through their own interaction. Indeed, from the epistemological point of view, learning or knowledge creation through interaction essentially occurs on an individual rather than institutional basis. The analytical bridge between the individual and institutional levels can be made only by the introduction of the concept of actors.

This societal approach seems very close to some institutionalist schools of thought in the Economics of Innovation, in particular evolutionary theory (Nelson and Winter 1982), which, based on the concept of "routine", emphasises the relative coherence of the "national system of innovation" (Freeman 1987, Lundvall 1992, Edquist 1997) in a country and its specific trajectory along its historical time path. All these schools stress the importance of the tacit dimension of knowledge, as pointed out some time ago by insightful economists such as Hayek, Polanyi and others, who gave prominence to the process of knowledge creation embedded in the routines of economic activities. In this case, knowledge is considered in the context of the institutional arrangements within which it is contained. Since it is shaped by a set of shared habits, routines, established practices and representations, knowledge is considered to be more or less local or idiosyncratic in nature. For this reason, the circulation of knowledge requires individuals to be in reasonably close proximity to each other and to have shared norms, conventions and, more generally, "mental models". Thus, some authors speak of the "social shaping of knowledge" (Williams and Edge 1992) or even of the "institutional nature of knowledge" (Foray 1994). Although the writings of these schools show great analytical quality and rich scientific interest, it is somewhat difficult to locate the micro-foundation of learning or knowledge creation in such institutional analyses, which are conducted principally at the macro level. This is why it is of great importance to understand the way that various institutions concretely build mutual commitments and the way that individuals learn by interacting with each other at the micro level, so as to stimulate innovation.

The originality of our approach lies in introducing the notion of an actor, which permits us at once to develop a more comprehensive analysis on the basis of empirical research and to interpret the interrelated dimensions of learning between actors and the dynamic process of innovation. Our basic assumption is that the creation of knowledge results

as much from the investment (Becker 1962) or the "translation" via socio-technical networking (Callon 1989) as from the construction, through socialisation and learning, of the actor in whom the knowledge is embodied.

In this paper, the theoretical and methodological aspects of our approach will not be fully discussedⁱ. On the basis of our Franco-Japanese comparative research, we shall focus our analysis on some stylised facts in the construction of the engineer category which offer sharp contrasts from one country to another.ⁱⁱ We shall first attempt to show a clear difference in the way engineers in France and in Japan are certified or produced by higher education systems. Second, we propose to link the national mode of socialisation not only with their career patterns but also with the nature of the innovation which they tend to promote.

I. Socialisation through education and training systems

I.1. Statistical Comparison of "Engineers"

In France, the category of "engineer" is ambiguous and heterogeneous, since this title is used for both an educational qualification and a post. Thus, not all qualified engineers hold engineering jobs, and conversely, not all those who are in engineering have an engineer's qualification, attested by the State diploma, after five years of schooling in the "Grandes Ecoles" (selective engineering schools). In Japan, the category of *guijutsusha* is even broader than that of "engineer" in France. It is associated neither with a specific type of qualification nor with a professional status. The national census defines this category as "those who have received scientific or technical training, generally in the higher education system such as universities, or those having an equivalent level with respect to capabilities and professional experience. . . ." Such a definition encompasses scientists, engineers and technicians in the French sense and thus corresponds more closely to the French definition of "corporate R&D staff (*ingénieurs et cadres techniques*)". These differences in the statistical or status-based definition make the quantitative comparison of engineers very delicate. If, in spite of possible statistical bias, we compare the stock of "engineers" defined as such by the national censuses, we obtain the percentages of "engineers" in the working population, which are respectively 2.9 % (659,000 persons in 1997) in France and 3.7% (2,370,000 persons in 1995) in Japan: the larger proportion of Japanese engineers is not surprising, since it may also include part of the "technician" category in the French sense.

As far as the comparison of the annual flow of young qualified graduates in the science and engineering disciplines is concerned, the quantitative production of young "engineers/scientists" is very similar in the two countries. Both Japan and France make an effort to develop technical and scientific human potential through the higher education system: young graduates with more than four years of higher education represent 1.99 per thousand of the working population (128,000 first-level university degrees) in Japan and 1.90 (43,000) in France. But most significantly, the latter puts a strong priority on the production of engineers/scientists with a long initial training period (more than five years after the high school *baccalauréat*) particularly through the "Grandes Ecoles". This French situation

ⁱ For the theoretical and methodological discussions on the "societal" approach, see M. Maurice, J.-J. Silvestre and F. Sellier (1986), *The Social Foundations of Industrial Power : A Comparison of France and Germany*. (Cambridge, Mass.: MIT Press.)

ⁱⁱ See our research reports on the comparative study of Japan and France: "Engineers, Organizations and Innovation: Training Systems and Organization of Technical Skills in Japanese and French Firms" LEST and JIL (Japan Institute of Labour), 1995. The most recent report concerns the software industry : "A Comparative Study of the Software Industries in Japan and France", LEST and Gakushuin University, 1998. See the Annex for the details of companies surveyed.

contrasts with the Japanese one, where a four-year period of university training (bachelor's degree) remains predominant, although there has been a rapid increase of students in masters programmes (six years of training) in the most renowned universities. Similarly, there is a considerable difference between the number of scientific doctoral theses produced annually: 0.28 doctors per thousand of the working population (6,387 PhDs) in France for 1995, but only 0.08 (5,152 PhDs) in Japan.ⁱⁱⁱ

These indicators show that France invests heavily, and with considerable cost, in high-potential human capital, while Japan seems to opt for the mass production of fairly undifferentiated engineers/scientists.

1.2. Educational and Training Systems in France and in Japan

In France, higher education offers various routes to qualification. There are both engineering schools ("Grandes Ecoles") and university science faculties. The former adopt a system of entrance examinations (*numerus clausus*) and screen students mainly by numbers, while the latter accept all the students holding the *baccalauréat* but apply a progressive selection process through annual examinations. Each institution is designed to "rank" and train a particular category of students. Thus, university graduates traditionally enter either the public and private sector as research workers, whereas engineers from the most famous engineering schools tend to embark quickly on careers as State technocrats (*corps d'Etat*) or in higher management in the private sector. The rationale behind training and qualification opportunities corresponds to a French way of management characterised by marked differences of status among employees. Furthermore, a very fine distinction must be made between engineers who have graduated from engineering schools with various technical specialities (software, robotics, aeronautics etc.) and those graduating from university with a more academic background. Those obtaining a diploma with only 2, 3 or 4 years in higher education will not automatically be given the "title" of engineer at the beginning of their career: they correspond to the "senior technician" category, which has a status inferior to that of engineer. The logic behind this distinction is based on the strength of the educational frame of reference and leads to separate professional identities, which in turn serve to legitimise hierarchically ordered functions or "territories" within the firm.

In Japan, by contrast, higher education maintains the character of mass education with a relative homogeneity of academic programs. The university system therefore stresses a very general and broad-based curriculum rather than professional or scientific specialisation.^{iv} In this sense, the labour supply is not very differentiated. On the other hand, this educational system is characterised by a hierarchical order of establishments. Such a hierarchy works as a filter for ranking the students on the basis of their potential. The way that graduates from different universities are distributed in the labour market depends on a matching mechanism between the rank of each university in this hierarchy and the reputation of each firm, rather than on individual signalling (academic speciality, particular expertise etc.). Moreover, compared with the French situation, the Japanese one involves a continuum from one university level to another, without any radical breaks between them. Three-quarters of the graduates in scientific or engineering fields spend four years in higher education. Their qualification level therefore constitutes a clear reference point for the whole engineer category. Length of time spent in higher education with the reference to this dominant period

ⁱⁱⁱ In the case of Japan, half of the PhDs are accorded to corporate scientists actively involved in industry. The figure does not include the hundreds of Japanese students who obtain their PhDs in the US each year.

^{iv} This situation is somewhat paradoxical, because Japanese scientific training has historically been dominated by the engineering faculty. The engineering faculties enrol 461,000 students and the natural science faculties only 73,000 (1992 figures). Engineering training in Japan does not give much importance to student specialisation.

and seniority in the company have equal weight; a six-year training period, for example, represents an extra two years as far as seniority is concerned. Such assimilation means that the management of all university qualifications by year of entrance into the firm is both homogeneous and compatible with competitive career advancement. Nonetheless, if qualifications are accepted as equivalent at the beginning of professional career in Japan, the effects of the university hierarchy remain. They reveal themselves only gradually during the graduate's career, in contrast with the almost immediate effect of the hierarchy of the French "Grandes Ecoles".

1.3. Transition Between the Educational System and the Labour Market

Another particularity of the French training system is the existence of the engineer "status". Indeed, in France, an engineer's status is clearly defined by his or her "title" and the fact of belonging to the category of *cadre* (this French concept includes not only management but also highly qualified professionals). French legislation makes a clear distinction between engineers who graduate from State-accredited schools and "in-house" engineers who are promoted within a single firm. This "title" of engineer attests to both general and technical knowledge and gives them social legitimacy and professional autonomy alike.

On the contrary, there is no formal recognition of the title of either engineer or scientist in Japan as a prerequisite for entering a firm. Such recognition is built up gradually from the time that the young university graduate is recruited. The form of recruitment involves a collective type of contracting which ties young graduates to the firm. They are all subject to the same procedure and enter employment at the same time. They automatically accept this collective commitment without negotiating individual conditions, while French engineers individually negotiate the conditions of their contracts and professional commitments with the firm. The latter are chosen by the employer on the basis of both the school from which they graduated and their specialisation. The former are not recruited because of their particular skills but because of their potential, measured roughly by the level and the reputation of their universities.^v Both parties commit themselves to a strict relationship involving mutual obligations. The firm invests in training, taking its chance on the graduate's long-term potential. As for the graduates, they agree to learn the art of engineering and wait for deferred recognition in terms of wages and promotion to a management position. Such a tacit contract on the basis of mutual commitment shapes a particular form of internal labour market in Japan and structures the learning behaviour of Japanese engineers which constitutes the base of firm's capability.

II.- Construction of R&D Staff's Capacity: Division of Labour, Hierarchy and Career Patterns

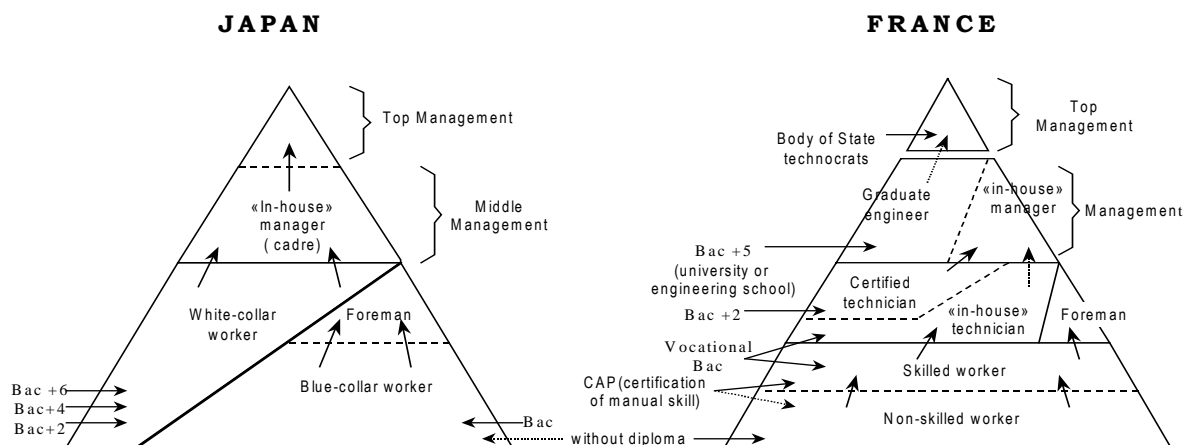
Innovative capacity depends on the way that the career patterns of engineers/scientists are managed--at both the national and the firm level--in order to create the linkage between individual leaning and the collective accumulation of knowledge. The organisation of career patterns is, nevertheless, very closely associated with the structure of the labour market, the social division of labour and the hierarchy in the firm. In other words, the learning attitude of engineers/scientists and the way that they coordinate with each other and create shared knowledge are dependent on the form of incentive system within which they are integrated

^v The introduction of students to the company by the university professor plays a very important role as a first job search channel, because the mechanism of individual signalling does not work well in the Japanese labour market. This channel of communication constitutes a major link organising relations between university and industry in the case of Japan.

(Aoki 1988). In this regard, France and Japan show different institutional frameworks (see figure I). In particular, the French firm, through interactions with the educational system, elaborates a very specific form of combination between incentive and coordination mechanisms which cannot be assimilated to the typology developed by Aoki.^{vi}

The models presented here correspond to an “ideal-type” in the Weberian sense which has been established by gathering the most significant stylised facts collected in our case studies. As a result, they do not reflect local variations which might exist according to the sector or size of firms. We assume, however, that the different aspects put together in a model make a meaningful system of coherence which helps us to understand the complex reality.

Figure I. Comparison of Hierarchies in Japan and France



Source: H. Nohara (1995), LEST-CNRS

Note: The level of education corresponds to the number of years of schooling after the *baccalauréat* (high school graduate).

II.1. Access to the Hierarchy: Skill Stratification and Learning

The hierarchy in French firms is based essentially on the job-classification system--the key factor in both the technical management of production and the social management of labour--to which employees gain access through a variety of routes and strategies. In other words, the hierarchy is sustained by both external and internal mobility. Thus, at all levels of the hierarchy, including the highest ones, both employees holding the formal qualifications stipulated for that particular level and self-taught individuals promoted from the lower levels coexist. It is as if these two categories of actors were constantly competing with each other for vacant jobs by enhancing their human capital in their own particular ways.

These two modes of access to the hierarchy naturally have their own internal logics:

^{vi} Based on a theoretical comparison of the A-type firm (American) and the J-type firm (Japanese), his approach is very stimulating and coherent as a theory of the firm, but it appears mechanical from an empirical standpoint. Our interpretation is based on the premise that the firms are deeply embedded in the social structure (incentive and coordination mechanisms), which would explain the national diversity of firm organizations and the way that these evolve. This position is much more in line with the evolutionary theory.

The match between formal qualifications and jobs is based on the collective agreement negotiated between the social partners and legitimated by the State. These rules are external givens to which French firms have to acquiesce. At the same time, the educational system selects students for its various levels and courses, thereby preparing them for specific occupational categories: those with five years of higher education are graduate engineers (or *cadres*), those with two years of higher or further education are technicians, those with the vocational *baccalauréat* or CAP are manual workers, and so on. This labour supply, which is already extremely hierarchical, is also finely ranked and highly specialised, as mentioned above: science graduates from the universities are often destined to become researchers, engineers from the major "Grandes Ecoles" to be senior managers or executives, engineers from the minor "Grandes Ecoles" to work in R&D functions, and holders of lower-level qualifications (the two-year university curriculum) to be senior technicians. This evaluation of individuals, carried out on the basis of educational selection, extends directly into the hierarchy and remains very much in evidence throughout an employee's entire career. The importance attached to educational qualifications gives rise to various occupational identities that are used to legitimate both the existence of hierarchically arranged "territories" and the strategy of external mobility in the labour market. This segmentation gives rise to a certain imbalance of power in the organisation of creativity in manufacturing industry: those engaged directly in manufacturing (i.e., technicians and manual workers) are rarely allowed to play as large a role as possible in the technical aspects of product design and manufacturing, since R&D staff tends to "parachute" their ideas onto the shop floor with little consultation. In other words, the existence of hierarchical "territories" hinders the development of wide-ranging dialogue between the R&D, design and manufacturing functions as well as that of sufficiently rigorous compromises between technical "inventiveness" and manufacturing feasibility.

"Graduate engineers design a new product . . . and they have never mixed with production workers, they cannot imagine how the product they design is going to be manufactured . . ." (head of production).

"People in the R&D department are so concerned with the basic product functions that they attach greater importance to the concept design than to subsidiary details. . . . Thus they seek to solve these fundamental aspects without worrying about the manufacturing problems that this may pose during the industrialization process. . . . The technicians in charge of industrialization often have to say that the device is not completely finished, although the engineers say it is. . . . It turns into a dialogue of the deaf. . . (industrialization manager).

Faithful to the doctrine of scientific management, France tends to produce a hierarchy characterised by both a separation between science and technology and a clear split between design (thinking) and production (manufacturing). The former function is overvalued, while the latter is not given sufficient consideration.

Over and above the influence on organisational structures exerted by educational qualifications, firms also have some leeway to take the initiative in constructing their hierarchy. In so doing, they are explicitly recognising the allegiance that employees without formal qualifications develop through the stabilisation of their position within the firm. This interaction between firm and employees is based on highly personal strategies. The ambition of technicians is clearly to be promoted to the engineer or *cadre* category. This system of internal promotion serves as an incentive mechanism for those wishing to become involved in their work or to invest in continuing training. The mechanism thus creates groups of self-taught employees, such as the so-called "in-house" technicians or engineers, who coexist with their formally qualified colleagues: according to a French survey (Ministry of Research and

Technology 1998), 10 % of researchers in the industrial corporate laboratories have PhDs and 15 % are considered "self-taught" researchers, while the majority of them (58%) are engineering graduates.

To sum up, the French engineering graduates gain access to a firm with recognised skills and a "title" of engineer. In this way, they may be considered a "quasi-finished product" having a generic technical expertise, although they naturally have to be initiated into the particular codes--formal and unwritten--of engineering functions (rules of design, procedures of programming, scheduling etc.). They learn such technical matters on the job. However, this professional initiation does not last very long. Their entry into the first job is accompanied by an adaptation of their skill to the working environment but not by an "apprenticeship" in the Japanese sense.

"Someone who starts straight out of engineering school will be considered an apprentice for three or six months. . . . They learn on the job in the technical service. . . . Confronted with the concrete approach to daily problems, they can observe what happens on the technical side and learn how to supervise technicians and their work. . . ." (head of technical service).

Thus, they integrate a pre-established division of skills characterised by a "Taylorist" principle of separation between design and manufacturing: the engineer's task is conceptual in nature as opposed to the technician's, which consists of resolving empirical problems. We can cite many examples showing a clear-cut division of labour between engineers and technicians throughout the firm: at laboratory level, at manufacturing level and in a project team.^{vii}

"The only authority is an authority of competence in the laboratory. Those people have technician training, they can only solve problems at a technical level. As soon as a scientific reflection is required, they cannot. . . . For my part, I bring new ideas based on scientific fact . . ." (R&D engineer).

"The engineer is, in his function, a sort of expert-system which generates algorithms, whereas the technician applies these algorithms to concrete technical problems. . . ." (executive).

Thus, from the very beginning of their career, the superiority of intellectual work leads the engineers/scientists to fulfil control functions which make them take initiatives and identify themselves as managers. Indeed, young French engineers/scientists frequently take responsibility at an earlier stage of their career, although they are not sufficiently prepared. The following remark made by a young project leader is revealing:

"The fundamental part of an engineer's work, that is, all aspects of the organisation and management of people, isn't taught in engineering school. . ." (young project leader).

But they are not faced with the problem of gaps between the management function and the technical or scientific function, as is frequently reported in a case study of English

^{vii} According to the French survey of employment in 1997 (Enquête Emploi, Insee), the category of engineers and technical managers includes 292,000 persons and that of technicians 408,000 in industry. As far as the former is concerned, 44 % are engineering-school graduates, 11 % engineers graduated from universities, and the others considered "in-house" engineers. Within the technician category, one-third have a diploma superior to two-year training in higher education, and another third have vocational training certificates.

industry (Lam 1998). The engineers' role in French organisation naturally integrates these two functions.

"Engineers are multi-skilled. They must be able to speak the language of technology, marketing and management, and to manage a budget. This is not required either of technicians or of commercial managers who are not engineers" (head of technical service).

Contrary to France, where the engineering graduates enter managerial positions directly, Japanese engineers/scientists integrate a rank-and-file position.^{viii} Whether they have received two, four or six or more years of higher education, university graduates constitute a more or less undifferentiated population of recruits from which, after a period of between ten and fifteen years, the new generation of senior managers or expert professionals will be selected. In other words, the entire population of new recruits is treated, formally at least, as a single reservoir of human resources from which specific resources are gradually extracted. Thus, the process of differentiation takes place over time and is based more on where the new recruits are allocated and what they learn than on the status or category to which they belong at the beginning of their careers.

Moreover, the "technician" category has neither a place in the classification system nor any real equivalent in Japan. This is why the technician category is not included for Japan in figure I above. The tasks performed by "technicians" in France seem to be allocated to experienced manual workers at the end of their careers and to supervisors, as well as to university graduates with six years of higher training at the beginning of their careers. This breaking-up of the technicians' role may well explain why the boundary between thinking (design) and doing (manufacturing) or the limit between laboratory and factory in the Japanese hierarchy is somewhat ill defined. The separation of tasks that is one of the guiding principles of Taylorism is certainly not eliminated, but it is attenuated to a certain extent, if not modified radically.

"I have been involved, for a few years, with the technical transfer of IC chip manufacturing between Japan and France. I think the French engineers are very conceptual, I mean that they are mainly preoccupied with the conceptual framework and much less interested in technical details. . . . I'm actually a research engineer but I've often had to solve very concrete manufacturing problems in the product development process. So I was obliged to initiate myself, for example, to the micro welding operation. Such know-how, which I used to acquire on the production-site, was very useful. When the French engineers couldn't solve the problems of welding on paper, I could, by operating the equipment, show the technicians how we could determine the operational solutions. . . . They [French engineers] said it was not a good engineering solution, the technicians couldn't solve it scientifically, but the most important thing is that we can produce the chips correctly with the machines" (Japanese head of IC promotion section).

". . . The most important thing for process engineers is to have real experience with operations. If they've learned to operate themselves, they are really capable of decoding the manufacturing language of operators. The most experienced operators can often identify a serious problem by experience. . . . The role of engineers is solely to formalise the operational skills. . ." (head of production).

^{viii} The starting wage of young Japanese graduates is very close to that of production workers of the same age, while the French graduate engineers start their salary career at a level which is twice that of manual workers and equal to that of the highest paid technicians. See H. Nohara (1995), "La comparaison France-Japon des salaires" *Travail et Emploi* no. 62,.

For each graduate, the initial period of work is used to become an engineer through on-the-job training. Not having any immediately useful skills, all these new recruits undergo the same type of occupational and organisational apprenticeship. It is a common process for all young engineers, although they tend to be dispatched to different functions according to the level of university training: those with masters degrees to R&D functions, those with bachelors degree to development and design functions, those having two-year university training to design and manufacturing functions and so on.

"In this laboratory, all young graduates, independent of their degree level, have the status of "apprentice" for two years. During this period, each one, although integrated in a research team, is given his [or her] particular study topic and works on it. At the end, they present the result before a jury composed of senior researchers. Depending on the outcome of this evaluation, their assignment to a post becomes definite. Some of them remain in the laboratory, the others go to the design section or the development centre and so on" (young scientist).

" I was introduced to this company by my professor, with whom I had done a master's course. I studied chemical engineering and vaguely thought I would become a process engineer. But I have been allocated to the lab and assigned to C- mos IC research. . . . It was a new technology both for the company and for me. I knew nothing about it. . . . I had to start from zero and learn with my senior colleague, a person who had some experience in this area. I never worked so hard in my life as during the first four years. . . . I used to do from 100 to 150 hours of overtime a month. . ." (senior researcher in the central laboratory).

Their skills develop during a long process of socialisation: the new recruits begin by exploring technically limited tasks with little responsibility and gradually extend their sphere of competence by moving on to related tasks. Given the quasi-absence of the technician category in Japanese organisation, all young graduates are assigned to concrete technical tasks to resolve problems or develop minor applications under the control of senior engineers/scientists and in cooperation with different categories of workers. Such collaboration or cooperation seems to be largely facilitated by the fact that the boundaries between tasks or jobs are rather ambiguous in Japanese organisation, contrary to the French engineers who tend to build their own "territories". The porosity of task organisation and the ill-defined responsibility of each member generate multiple interactions, mutual adjustment and a certain flexibility vis-à-vis environmental changes (Ishida 1986). Such auto-organisation centred on the local adjustments is a source of information redundancy which can be seen as organisational inefficiency. It favours the sharing of information and knowledge, however. This way of learning, orientated toward empirical problem-solving, contributes to developing tacit knowledge and sharing it collectively.

"In our company, there are many formal training programs for the young graduates. But these programs are not what makes the engineer. The young engineers are initiated to the work on the job (*genba-shugi*). . . . We generally try to arrange things so that there are entry-level jobs in which they can experience the concrete approaches to detailed designs of equipment or technical experiments. They are guided by the section head, but more frequently backed up by the senior colleagues in the team. . . . When they made a stupid error on the blueprint, I told them to go and listen to the operators in the workplace. . . . In any case, they learn informal or unwritten technical knowledge through a sort of osmosis with their working environment. . ." (head of design section).

Nevertheless, these tasks become more complex and comprise more managerial functions in the course of professional advancement. This kind of organisation-driven learning puts the young employees in a situation of dependence and long-term competition with colleagues in the same entry group. Such a slow rate of progression does not encourage initiative and may weaken the originality of the individuals, or even drain their creativity. But this kind of "apprenticeship", as in Germany, forces employees to learn how to work together and to maintain the idea of overall performance.

II.2. Incentive Mechanisms, Selection and Career Patterns of Engineers

In the constitution of a "typical" career pattern, the external labour market is of little importance to Japanese engineers/scientists. Some comparative studies (Ishii 1993, Shapira 1995), as well as our own, indicate that they experience much less external mobility than do European or American engineers. Most of them continue their careers within the same firm or industrial group. Their internal mobility, which seems to be closely controlled by the supervisors and the firm, implies a kind of chain-linked movement between tasks or jobs which share some technical proximity.

" . . . Half of the research people will have leave the lab in their mid-thirties and only some 20 percent will remain there after the age of forty These researchers experience transfer to the lab, the design section or the factory, very often accompanying the development of new products as a group. . . . Their main mobility is from upstream to downstream" (assistant-director of a research laboratory).

From the organisational point of view, such mobility has two effects: it tends, on the one hand, to build a hybrid but highly consistent competence focused on managing the various interfaces and, on the other, to facilitate the diffusion of tacit knowledge. During the first half of their careers, Japanese engineers are constantly placed in a learning position where they contribute to the collective development of knowledge by enlarging their own technical competence. At the same time, they gradually acquire the coordination capacity required to assume greater responsibility. Contrary to the French engineers, who have a rational coordination capacity, they develop a highly contextual and idiosyncratic competence which combines technical, relational and managerial know-how. Indeed, given such mobility chains among different jobs, Japanese engineers/scientists are more likely to have varied work experience that covers a wide range of technical areas and to share such experience with others. This situation helps the engineers to overcome communication barriers and transfer tacit as well as explicit knowledge based on their shared experience. In this sense, the mobility among closely related tasks that they experience at the initial stage of their careers contributes to developing an important organisational ability to improve cross-functional integration.

The hierarchy of educational levels and university degrees remains in suspension during this period of apprenticeship. However, its effects make themselves felt as individuals advance along their career paths, and particularly in terms of promotion within the hierarchy. Indeed, although the majority of university graduates advance at more or less similar rates for almost ten years, the principle of selection and competition gradually begins to emerge. The pivotal period falls between 35 and 40 years of age, when the selection for the first rung of the management ladder takes place. This selection is based not on a shot in the dark or a gamble on any particular individual but rather, on the system of assessment that constantly evaluates, on an annual basis, not only each individual's output but also his or her progress in the learning process and ability to cooperate and contribute to the collective effort (Koike and

Inoki 1987). This system encourages employees to incorporate long-term considerations into their career strategies. Nevertheless, sustained and exacting competition of this kind finishes by producing a hierarchy within the 35-40 age group--which leads to the separation of university graduates into managers and non-managers--and continues in an extremely selective way as employees progress towards the upper echelons of the hierarchy. Such structuring of internal career paths ultimately corresponds to the principle of "tournament competition" outlined by Rosenbom (1982). The question that remains, however, is why and how Japanese firms manage to organise such a slow selection process combining cooperation, collective learning and individual competition, which are largely contradictory elements from the European point of view.

Compared to the Japanese situation, individual strategies play a major role in the career patterns of French engineers. There exist, as we have seen, two categories of engineers. One is composed of "in-house" engineers promoted from the technician category, who cultivate allegiance to the firm. Like their Japanese counterparts, they develop a contextual skill, but their empirical know-how, considered inferior to conceptual expertise, is undervalued. Their career paths tend to be limited to low-level technical functions, R&D support or production management in the firm.

“ There is a cultural demarcation between engineers and technicians . . . which creates an identity problem for those who cross the barrier. . . . In any case, technicians do not have access to posts of high responsibility, even when [they have] the title of *cadre* . . . ” (technician passing the test for access to management *cadre* status).

French engineering-school graduates wield a certain bargaining power on the basis of their technical expertise and nationally recognised "title". At every stage of their careers, they negotiate the conditions of their contracts (remuneration, working conditions, etc.) and their professional commitment to the firm. The resulting contract appears explicit and limited in content and in time compared to the Japanese one, which is more implicit or ambiguous. In any case, the firm rapidly puts these engineers to the test and channels them into different careers. Thus, the most competent engineers/scientists are quickly selected, assigned to the management of an important project or promoted to a strategic position.

“. . . There's a natural tendency to be elitist, and at a very early stage we tend to consider natural talents rather than those that have been cultivated. What emerges naturally is more important than what is built up gradually. With the young ones, we very quickly identify the talented ones and put them on a fast track to the hierarchy. And we don't often check on the knowledge they're accumulating. We often take risks . . . ” (Technical Department head).

Although the firm develops interesting career paths in the internal labour market for these engineers/scientists, it always faces the risk of their departure, which represents a loss of technical expertise and organisational knowledge. The mobility of these engineers/scientists both internally and externally seems to be motivated essentially by individual strategic choices, whereas in Japan, the internal transfer of engineers/scientists is closely controlled by the organisation. Moreover, internal mobility occurs more frequently and covers a larger range of functions among French engineers/scientists than among their Japanese counterparts. It corresponds to a progression between functions which are organised according to a notion of "territory". Such a territorial rationale leads to a segmentation of organisation (research, marketing, production etc.), but also to the difficulty of coordination between them and the relatively limited amount of collective learning. This kind of internal

mobility reflects the engineer's ability to fulfil different functions, master them and adapt to them. In France, therefore, engineers' career paths appear discontinuous, with breaks between various types of technical or managerial responsibilities.

“The most brilliant career consists of going from one product department to another or shifting from the production function to marketing, strategic planning, purchasing and so on every three years. If you have such a profile, you're guaranteed to go straight to an executive post . . . ” (Product Department head).

II.3. Work Patterns, Coordination and Innovation Process

Incentive mechanisms and career formation are interrelated not only with work organisation for engineers/scientists, but also with the way the innovation process is conducted. We can thus observe contrasting forms of information flow and coordination associated with the different career patterns in the two countries.

French organisation is characterised by more bureaucratic control, which produces formal project management and numerous management tools accompanying the project. Coordination between project members is basically maintained by formal procedures and explicit rules; information and technical specifications are also more explicitly expressed and recorded in written documents for reducing "territorial" conflicts and transferring the knowledge in a "sequential" manner from one step to another within a project. The flow of information is a vertical one which goes from top to bottom, or from upstream to downstream. This does not, however, imply a simple linear model where no learning occurs in the process of innovation. In terms of the chain-linked model proposed by Kline and Rosenberg (1986), the French approach is closer to long-loop feedback, which generates a formal database and enriches the architectural competence at the top of the organisation.

" Project management is rather linear in this company. . . . It is essential to pass as directly as possible from one phase of product development to the next. Once a phase has come to an end, the file, designs, written documents must be complete and ready to pass to the next. . . . There should be no need to go back to a previous phase. . . . This means that the various phases must not overlap . . ." (project leader).

In certain sectors faced with the economics of variety, implying the necessity of flexible adjustments at the most decentralised level of organisation, this mode of coordination seems to be less efficient, because it is very difficult to introduce retroactive and corrective actions. But it has proven its effectiveness in organising major scientific programmes such as the national nuclear project, the aerospace programme or complex technological projects which require considerable information processing and a massive coordination capacity. The competences of French engineers, and especially those of the engineering elite, correspond to the organisational requisites of a hierarchy-based on vertical coordination.

The Japanese organisational approach seems quite different: coordination is less based on the formal procedure, although the PERT method is often applied to project management. Despite the development of automatic artefacts (CAD/CAM systems), knowledge sharing is more dependent on intensive human interaction and mutual understanding. Project management tends to be organised through reciprocal and “horizontal” communication and mutual adjustment between members (Aoki 1986). It depends less heavily on formal planning and hierarchical control but requires team members' cohesion within the project. The role of the project manager is, as in the French case, to meet the deadline and attain the product-quality level fixed at the beginning of the project. He or she attempts to fulfil these ends, not

by imposing a formal procedure and rigorous work schedule but by encouraging continuous mutual adjustment throughout the problem-solving process. Contrary to the French “rational” approach, the Japanese one might be qualified as “holistic”, insofar as it leads all members to participate in a common experience and to share not only formalised knowledge but also a vast stock of non-coded knowledge. This “holistic” mode contributes to enriching a collective capacity for problem-solving at the local level, but it does not always succeed in formalising the experience at the general level.

"Phases are not always very clear-cut in our project, although we must pass the project review at each step. . . I think these reviews cannot completely check all the technical problems which appear later. The process is much more erratic and non-linear. For example, we must continue to work out some functional details while the product is being tested. It is normal that we, that all development engineers, have to go to the factory in order to find practical solutions for a technical defect, modify the specifications, even few days before the product's date of commercialisation. . . . You know, it's very often anarchic at the final stage of a project. . . . Each member adjusts to the others in a chaotic way under the pressure of the deadline. . . . For each project, it's always the same thing. We repeat it but we consume lot of energy. . ." (project manager).

This form of coordination clearly privileges what is characterised as a short-loop feedback in the chain-linked model, which insists on the central role of feedback of information or new knowledge between a set of linked activities in innovation (R&D, design, trial, manufacturing, marketing etc.). The Japanese approach emphasises immediate and intensive return of information between successive phases. This feedback mechanism, which can be thought of as local learning, is essentially based on a certain continuity of skills among different actors (scientist, engineer, technician and operator) and intensive human networks through which the tacit know-how is transferred. This human-network approach (Ito 1988) means that knowledge and information are more closely associated with the complex social relationships and work groups in which engineers/scientists operate. They are context defined, idiosyncratic and not immediately transferable outside, corresponding exactly to what Aoki terms specific collective assets (Aoki 1988). This type of asset cannot necessarily be divided into individual property, as the human capital theory supposes. Moreover, it can only be mobilised by an adequate incentive mechanism which puts the accent not on individual performance but on the collective commitment of members. As noted above, this mechanism is, more generally, sustained by the practice of long-term employment and the mode of career formation, which generate both long-term competition around internal promotions and cooperation based on shared values.

The human network is obviously one of the elements which facilitates coordination within the French firm as well. But the same concept does not necessarily cover the same reality. In the case of France, the human network is considered more as a tool for a strategic power game: undisclosed or restricted information is a source of power in negotiations (Crozier 1973). Segmented by professional groups and weakened by a logic of "territory", the human network does not necessarily serve as a vehicle for disseminating knowledge within the French firm. In particular, tacit knowledge accumulated by technicians is seldom shared by engineers and remains latent or under-utilised. This is one of reasons that a short loop feedback in innovation cannot be fully mobilised in the French organisation. By contrast, engineers are likely to promote organisational learning on the basis of knowledge that is scientifically objectified, conceptualised or codified into formulas. To the extent that the talent of each engineer is fundamentally associated with the creation of generic concepts,

competence and responsibility can be measured and evaluated on an individual basis. This type of incentive mechanism associated with the immediate career competition favours the diffusion of knowledge through mobility. The interfunctional rotation of engineers within the firm generates long-loop feedback effects on innovation, and their mobility in the labour market helps to spread the inter-firm human networks and diffuse new ideas and knowledge at sector or national level.

III. Innovation Patterns

The French engineer/scientist develops scientific and managerial skills around his or her territory. Such a building up of capabilities based on highly professional expertise encourages inventiveness. With its potential for originality, the possibility of a "breakthrough innovation", it can lead to occasional scientific success or even a far-reaching "feat", particularly when the State acts as challenge coordinator. This phenomenon is noticeable in certain sectors such as software system-integration, or the nuclear, aeronautics, or telecommunications industries, where the technocracy composed of "State engineers" (*corps d'Etat*) coordinates a "mission-orientated" policy, or in the chemical industry, where the scientific performance of research upstream of the production process determines its overall competitiveness. However, the fact that the engineers/scientists have a markedly different status from that of technicians or production workers tends to make the sharing of knowledge and/or know-how very difficult, thus calling the collective challenge into question. In France, original creativity appears to show itself in exceptional circumstances or through strong individual personalities, with its spin-offs often poorly capitalised upon or consolidated at the stage of industrialisation. In other words, organisational "routine" in French industry can be characterised both by great capability and high creativity at the top of the organisation and by the difficulty of its "translation" into manufacturing because of the discontinuity of skills between workers.

In the case of Japan, engineers/scientists do not occupy a specific territory right from the start. Their skills and recognition as engineers are built up over time. In a position of apprenticeship, they train themselves by slowly exploring an area of competence collectively covered by the work group to which they belong. Learning is based essentially on the process of interacting with colleagues or more experienced engineers/scientists. Their contribution to the group consists of gradually enriching the current stock of knowledge/know-how. This form of collective learning within the organisation generates the same type of R&D staff having less differentiated cognitive resources and consequently impedes the emergence of individual originality (Sakakibara 1993). The meaning of industrial creativity is thus very different from the French sense: creativity is seen less as the creation of the new than as the consolidation/recombination of existing elements. In this way, the Japanese engineers/scientists tend to develop a very contextual or tacit competence which incorporates two industrial realities. The first concerns the need to combine formalised knowledge with empirical know-how in order to build up R&D efficiency in industry. The second refers to the necessity of creating a complementarity with other categories of actors such as supervisors and operators which goes as far as the distribution of shared knowledge or the overlapping of skills. It is doubtless not by chance that these practices contribute to shaping the Japanese form of "incremental innovation" which efficiently ensures the transition from applied research to design to prototype and on to industrialisation. This type of organisational "routine" appears particularly adapted to such assembly industries as mechanics and electronics which require "productive intelligence" from the shop floor. Nonetheless, such competence has rarely demonstrated its ability in other sectors (software, aeronautics,

pharmaceutical, biotechnology etc.) where creativity is more closely and directly linked to basic research activities or to individual capacity.^{ix} The engineering culture based on *genba shugi*--the empirical approach to learning--evidently faces certain organisational challenges if it is to go beyond the known or generate a change of technological paradigms. This shortcoming is, however, being taken more and more seriously at a time when a move back to basic science is becoming a major challenge in industry.

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This type of international comparison serves to bring out the interdependencies between the socialisation of actors, the mode of learning, the form of competence and the nature of innovation, thus demonstrating that the innovation process is deeply embedded in the societal (and national) context. Both France and Japan have a huge potentiality of cognitive resources which can create a variety of knowledge, but each country has developed a particular configuration of national institutions which tends to shape certain forms of the knowledge-creation process through, among other things, the training of engineers/scientists and their utilisation. This institutional environment functions as a given vis-à-vis the actors and constitutes a "path dependency" the national level. Institutional change is not at all impossible but may be gradual and adaptative, as is indicated by the evolutionary school. As for national economic competitiveness, the comparative advantage of each country ultimately seems to be based on a matching between the industrial/technological requisites of its sectors and the dominant form of knowledge/competence that it is capable of promoting.

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^{ix} According to a Japanese national report based on the DELPHI method (report on the innovative activities in the private sector, 1998), the majority of Japanese companies consider that the competitiveness of Japan is greatly inferior than that of Europe in the software aeronautics, petrochemicals, food-processing, pharmaceutical and biotechnological industries.

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ANNEX

In this Franco-Japanese comparative research, our method was based on qualitative case studies which permitted us de compare three couples of firms in the chemical, the electric/electronic and software service sectors. The firm chosen in our case study corresponds to national leading company in each sector, but its representativity in a statistical term is not guaranteed. Data were gathered by semi-directive interviews (2-3 hours) with managers and technical staff in R&D labs, business units and factories.

Interview sample

Firm	Characteristics	Number of interviews
1 Chemical-F	Nationalised leading company (10000 employees of which 50 % are technical staff); petro and fine chemicals	32(5 managers and 27 staff)
2 Electric/electronic-F	Private leading company (8100 employees of which 49% are technical staff); electricity distribution and transportation equipment, Automatic controller	21(5 managers and 16 staff)
3 Software-F	Private independent company (3500 employees); software applications, system integration	11 (3 managers and 8 staff)
4 Chemical-Jp	Zaibatsu affiliated and leading company (9600 employees of which 41 % are technical staff); general chemistry	11 (6 managers and 5 staff)
5 Electric/electronic-Jp	Private leading company (12000 employees of which 42 % are technical staff); industrial equipment, semiconductors etc.	12 (5 managers and 7 staff)
6 Software-Jp	Private independent company (1400 employees); software applications, telecom services	9 (4 managers and 5 staff)