SOCIALISATION, HIERARCHY AND KNOWLEDGE CREATION; A COMPARATIVE STUDY BETWEEN FRENCH AND JAPANESE ENGINEERS

Caroline Lanciano and Hiroatsu Nohara
Laboratoire d'Economie et Sociologie du Travail
(LEST-National Center for Scientific Research-France)

The competitiveness of learning economies[1] (Lundvall 1994) is clearly linked to their ability to coordinate efficiently individual and collective learning process, and also to their capacity to bring rapidly new ideas into the product, the production process or the organisation. Engineers naturally find themselves right in the centre of such activity. It is therefore vital to analyse the interdependence between the way engineers are "socialised" in societal (national) contexts, the nature of knowledge they generate and the form their technical creativity takes.

Our main hypothesis is that the engineer, far from constituting a universal and homogeneous category, is a "social construct" which embodies a specific mode of knowledge creation in each country and tends, in that manner, to structure national pattern of innovation. The societal approach adopted here places great emphasis on the interdependence between the nature of actors and the societal (and national) "space" within which they are constructed: engineers are considered as actors who are, at the same time, generated by and determine the national configuration of an innovation system which is made up of various institutions such as the higher education system, the training regime, firms, the public research laboratories etc. In other words, while an innovation system is obviously structured by the interaction between these institutions, it is mainly the engineers who play the major role in their linkage and their mutual commitment by interacting. Indeed, from the epistemological point of view, learning or knowledge creation by interacting occur fundamentally and firstly on an individual basis, not an institutional basis. The analytical bridge between the individual and the 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 the evolutionary theory (Nelson and Winter 1982) which, based on the concept of "routine", emphasises the relative coherence of the "national system of innovation" (Lundvall 1992, Edquist 1995) in a country and its specific trajectory along its historical time path. All these schools stress the importance of the tacit dimension of knowledge, which had some time ago been pointed out by insightful economists such as Hayek, Polanyi etc., who gave prominence to the process of knowledge creation embedded in the routines of economic activities. In such case, knowledge tends to be defined by 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 can also be considered as being 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

[1] Lundvall utilises equivalently the notion of learning economy and of knowledge-based economy. We prefer the former, which signifies explicitly the dynamic nature of innovation, the engine of the economic growth.

nature of knowledge" (Foray 1992). 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. That is why it seems to be of great importance to know the way that various institutions create concretely 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 may consist of introducing the notion of an actor, which permits us both to develop a more comprehensive analysis on the basis of empirical research and to interpret the interacting dimensions of learning between actors and the dynamic process of innovation. We suppose fundamentally that the creation of knowledge is as much the outcome of the investment (Becker 1962) or the "translation" via socio-technical networking (Callon 1991) as of 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 discussed[2]. Based on our French-Japanese comparative research[3], we will focus our analysis on some stylised facts in the construction of the engineer category which seem highly contrasted from one country to another. We attempt to show firstly a clear difference in the way engineers in France and in Japan are certificated or produced by higher education systems. Secondly, 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 both for an educational qualification and a post. Thus, not all qualified engineers hold engineering jobs, and likewise, not all those who are in engineering have an engineer's qualification, attested by the State diploma, after five-year schooling in Grandes Ecoles (selective engineering schools). In Japan, the category of "guijutsusha" is even widerembracing than that of "engineer" in France. It is associated neither with a specific type 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 comprises both engineers and technicians in French sense and corresponds more closely to the French definition of "engineers and technical company staff". These differences in the statistical or status definition make very sensitive the quantitative comparison of engineers. If we compare, despite possible statistical bias, the stock of "engineers" defined as such by the national censuses in France and Japan, we obtain a quite similar proportion in the working population in both countries: the percentage of "engineers" in the working population currently in employment is 2.1% in France and 2.3% in Japan.

Nevertheless, this overall similarity cannot hide a profound difference as far as the institutional setting of engineers' formation is concerned. From this point of view, the international comparison of the annual flow of young qualified gratuates in science and engineering disciplines is interesting. As the table I shows, the quantitative production of young "engi-

[2] For the theoretical and methodological discussions on the "societal approach", see Maurice M, Silvestre J-J, Sellier F (1986): The social foundations of Industrial Power: A Comparison of France and Germany. MIT Press, Combridge.

[3] This comparative study is realised in cooperation with the Japan Institute of Labour. See the research report: "Engineers, Organizations and Innovation: Training Systems and Organization of technical skills in Japanese and French firms", 264 pages, 1995. For this study, a chemical firm and a electronic firm are surveyed in each country.

Table I-Comparison of annual inflows of young engineers

(Year 1989)

Level of educational atteinment	France	Great Britain	Germany	Japan
Five or six years schooling after the baccalauréat (high school graduate), number of persons (X)	16 200 (b)	11 000 (c)	9 000 (e)	13 800
From three to six years schooling after baccalauréat (high school graduate), number of persons (Y)	27 000	23 200 (d)	32 000 (f)	87 500
Working population, number of persons (Z)	24 320 000	28 508 000	29 779 000	62 700 000
Inflow rate (ratio of bac+5/6 graduates against Working Pop.) (X/Z) (per thousand)	0,67	0,39	0,30	0,22
Inflow rate (ratio of bac+3/6 graduates against Working Pop.) (Y/Z) (per thousand)	1,11	0,81	1,07	1,39

(a) OECD (Edition 1991), Population 1989
(b) Inflow of "diplômés de la commission des titres d'ingénieurs"
(c) Inflow of chartered Engineers and equivalent
(d) Chartered+Graduates non chartered (estimation)
(e) Technishen Hochschulen+Technischen Universitäten
(f) Technishen Hochschulen+Technischen Universitäten+Fachochschulen

Source: Académie des Sciences. Comité des Applications de l'Académie des Sciences Mars 1992.

neers" is very different from one country to another.

Great Britain produces proportionally many fewer engineers who have spent at least three years in higher education than do the others countries. By contrast, Japan and France make more of an effort to develop the technical human potential in educational system: the young qualified with more than three-years of schooling in higher education represent 1.39 per thousand of the working population in Japan and 1.11 in France. But the most significant thing is that the latter puts a strong priority on the production of engineers with a long initial training period (more than five years after baccalauréat) through the Grandes Ecoles. This French situation contrasts with the Japanese one, where a four-year period of university formation (bachelor's degree) remains predominant, although it has seen a rapid increase of students in Master courses (six-year training) in the most famous universities. Similarly, there is a considerable difference between the number of scientific doctoral theses produced annually: 0.20 doctors per thousand of the working population in France for 1989, but only 0.05 in Japan[4].

These indicators show that France heavily invests, with high cost, in the human capital of high potential, while Japan seems to opt for a mass production of engineers rather undifferentiated.

I-2 Educational Training systems in France and in Japan

In France, various routes to qualification may be taken within higher education. There exist both engineering schools (Grandes Ecoles) and university science faculties. The former adopts a system of entrance examination (numerus clausus) and screens students mainly by mathematics, while the latter accepts all the students holding the baccalaureate but selects them progressively by annual examination. Each is designed to "grade" and

[4] It excludes the Japanese students (some hundreds by year) which obtain the doctoral theses in foreign countries, in particular in USA.

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, for example "Ecole Polytechnique", tend to embark quickly on careers as State Technocrats (Corps d'Etat) or in higher management in private sector. The rationale behind training and qualification opportunities corresponds to a French way of management characterised by marked distinctions of employees via hierarchical order of status. Furthermore, a very fine distinction has to be made between engineers who have graduated from engineering schools with various technical specialities (software, robotics, aeronautics etc.) and those from university with a more academic background. Those graduated 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 these distinction is based on the strength of the educational frame of reference and leads to distinct professional identities. The latter themselves serve to legitimise hierarchically ordered functions or "territories" within the firm.

In Japan contrary to France, the 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 formation rather than professional specialization[5]. In this sense, labour supply is not very differentiated. On the other hand, this educational system is characterised by a hierarchical order of establishments. Such hierarchy works as a filter for grading 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 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 and company seniority are considered as equals; 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 progress. Nonetheless, whist qualifications are accepted as equivalent at the beginning of professional career in Japan, the effects of the hierarchy of universities remain. They are revealed only slowly during the graduate's career, in contrast with the almost immediate effect of the hierarchy of the French "Grandes Ecoles".

[5] It is a sort of paradox, because the Japanese scientific formation historically is dominated by the engineering faculty. The engineering faculties enrol 461000 students and the natural science faculties solely 73000 (year 1992). The engineering education in Japan doesn't give much importance to student specialization.

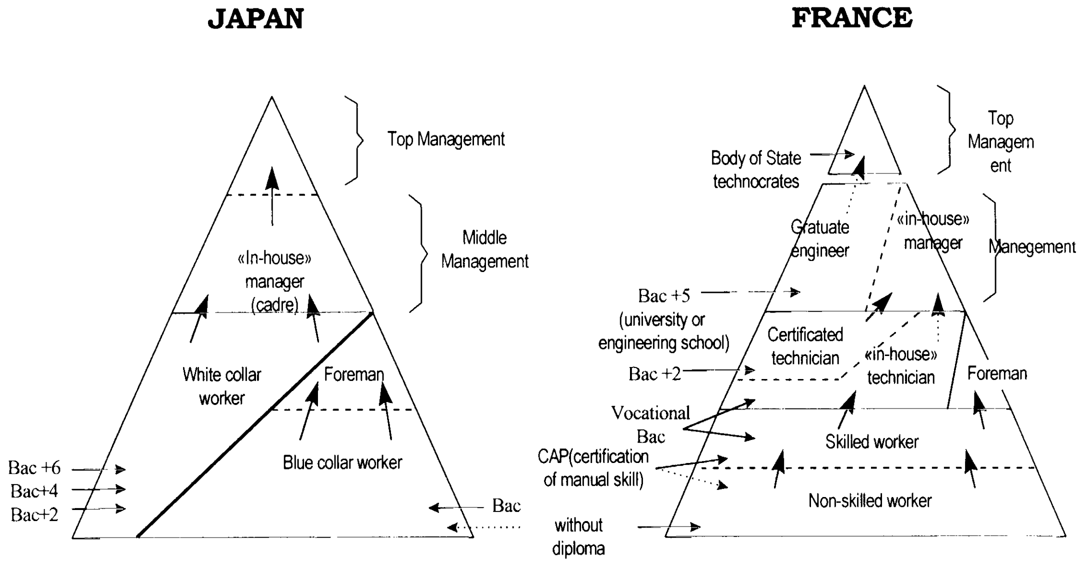
I-3 transition between the educational system and the labour market

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

On the contrary, there is no formal recognition of the title of engineer, in Japan, as a prerequisite to 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 the 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 the French engineer negotiates the conditions of his contract and professional commitment with the firm on an individual basis. The latter is chosen by the employer both in relation to the school from which he graduated and because of his 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[6]. Both parties commit themselves to a strict relationship involving mutual obligations. The firm invests in training, taking its chance on the long-term graduate's potential. As for graduate, he consents to learn the art of engineering and waits for deferred recognition in terms of salary and promotion to the management position. Such a tacit contract on the basis of mutual commitment shapes a particular form of internal labour market in Japan and structures learning behaviour of the Japanese engineers which constitutes the base of firm's capability.

II-Construction of Engineer's capacity; division of labour, hierarchy and career pattern

Innovative capacity depends on the way that the career patterns of engineers are managed-at both the national and the firm level-to create the linkage between individual leaning and the collective accumulation of knowledge. The organization of career patterns is, never-



Nota:The level of education corresponds to a number of schooling years after the baccalauréat(high school graduate)

Figure I Comparison of hierarchy between Japan and France

[6] The introduction of students by the university professor to the company plays a very important role as a first job search channel, because the mechanism of individual signalling doesn't work well in the Japanese labour market. This channel of communication constitutes a main tie organising the relations between University and Industry in the case of Japan.

theless, very closely associated with the structure of labour market, the social division of labour and the hierarchy in the firm. In other words, the learning attitude of engineers and the way that they coordinate each other and create the shared knowledge are dependent on the form of incentive system within which they are inserted (Aoki 1988). To this regard, France and Japan show different institutional frameworks (see figure I). In particular, the French firm elaborates, through interactions with the educational system, a very specific form of combination between incentive and coordination mechanisms which can not be at all assimilated to the typology developed by Aoki[7].

II-1 Access to the Hierarchy

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 by adopting a range of different 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 people promoted from the lower levels exist alongside each other. It is as if these two categories of actors are constantly competing with each other for vacant jobs by enhancing, in their own particular ways, the human capital they possess.

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

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 pupils for its various levels and courses, thereby preparing them for specific occupational categories: those with five years' higher education are graduate engineers (or cadres), those with two years' higher or further education are technicians, those with the vocational baccalauréat or CAP (certificat d'aptitude professionnelle, or vocational training certificate) are manual workers, and so on. This labour supply, which is already extremely hierarchised, is also finely graded 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 technical functions, and holders of lower-grade qualifications (brevet de technicien supérieur or the two-year university formation) 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 segmented situation gives rise to a certain imbalance of power in the organization of creativity in manufacturing industry: those engaged directly in manufacturing (i.e. technicians and manual workers) are not allowed to play as full a role as possible in the technical aspects of product design and manufacturing, since engineers tend to "parachute" their ideas on to the shop floor without any consultation. In other words, the existence of hierarchised "territories" hinders the development of wide-ranging dialogue between the design and

[7] Based on a theoretical comparison of A-type firm (American firm) and J-type firm (Japanese firm), his approach is very stimulating and coherent as a theory of firm, but it appears mechanical from the empirical standpoint. Our interpretative view consist rather of supposing the deep embeddedness of firms (incentive and coordination mechanisms) in the social structure, as a consequence of supporting the national diversity of firm organizations and its evolution. This position is much more in line with the evolutionary theory.

manufacturing functions and of sufficiently rigorous compromises between technical "inventiveness" and manufacturing feasibility.

> "Graduate engineers design a 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 technical design service are so concerned with the fundamental functions of product that they attach greater importance to the conceptual 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... (Manager of industrialization).

Faithful to the doctrine of scientific management, France tends to produce a hierarchy characterised by a clear split between design (thinking) and production (manufacturing) (Boyer 1990). The former function is overvalued, while the latter is not given sufficient consideration.

Over and above the influence over organizational structures exerted by educational qualifications, firms also have some scope 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 the firm and employees is based on highly personal strategies. The ambition of semi-skilled manual workers is to be promoted to the skilled worker category, while that of technicians is to become engineers or cadres. The system of internal promotion between the various categories serves as an incentive mechanism for those wishing to become involved in their work or to invest in continuing training. Thus this mechanism creates groups of self-taught employees, such as the so-called "in-house" technicians or engineers, who coexist with their formally qualified colleagues but are unable to transfer the standing they have acquired within the firm to the external labour market.

To sum up, the French engineering graduates get 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, though 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 doesn't last vary long. Their entry into the first job is just 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 in resolving empirical problems. We can cite many examples showing a clear-cut division of labour between engineers and technicians which exists everywhere across the firm; at laboratory level, at manufacturing level and in a project team...[8]

[8] According to the French survey of employment in 1997 (Enquête Emploi, Insee), the category of engineers and technical managers amounts to 292000 persons and the category of technicians to 408000 persons in Industry. As far as the former is concerned, 44% are engineers graduated from the engineering schools, 11% graduated from universities, and the others are considered "in-house" engineers. For the technician category, the one third of them have a diploma superior to two-year formation in higher education, the another one third have manual workers' certificates.

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

"When I arrived here, I abandoned the practical part carried out by the technicians. I only attached myself to the theoretical part. I divided the competencies, theory is my domain, at the practical, they (technicians) are better. I leave it to them . . ." (Researcher in the central laboratory).

"It's not technical competence that makes an engineer. Rather it's his overall abilities . . . They're more generalists than experts . . . On the technical level, engineers rely on the know-how of technicians . . ." (Project leader).

"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 the superiority of intellectual work leads the engineers, from the beginning of their career, to fulfil control functions which make them take initiatives and identify themselves as a manager. Indeed, young French engineers 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 men, isn't taught in engineering school . . ." (young project leader)

But they aren't faced with the problem of gaps between the management function and the technical function, as is frequently reported in a case study of English industry (Lam 1998). The engineers' role in French organization naturally integrates these two functions.

"Engineers are polyvalent. 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 gratuates enter directly managerial positions, Japanese engineers integrate a rank-and-file position[9]. 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 will be selected. In other words, the entire population of new recruits is treated, at least formally, 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 to 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 foremen, as well as to university graduates with six-year 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) 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.

[9] The starting salary of young Japanese graduates is at the very similar level of the salary of production workers having the same age, while the French graduate engineers start their salary career at the level which is twice that of manual workers and equal to that of the highest paid technicians. See NOHARA H (1995), "the comparaison France-Japon des Salaires" in Travail et Emploi N°62, Documentation Française, Paris.

"I have been concerned, for few years, with the technical transfer of IC chips manufacturing between Japan and France. I think the French engineers are very conceptual, I mean they are firstly preoccupied by the conceptual framework and much less interested in technical details... I'm rather a research engineer but I had to often solve the 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 that 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, demonstrate to the technicians how we could find out 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 responsible of IC promotion section).

"... The most important thing is that process engineers have real experience of operation. They are really capable of decoding the manufacturing language of operators, if they learned to operate themselves. The most experienced operators often can identify a serious problem by experience... The role of engineers is solely to formalise the operational skills..." (Head of production)

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, by the level of university formation, to different functions: holders of master degree to R/D function; bachelor degree graduates to development and design functions; those having two-year university formation to design and manufacturing functions etc.

"I learned my work, my task on the job, guided by my boss and senior colleagues. This initial period of my apprenticeship lasted, at least, for two years after my recruitment. In this period, I was much aided when confronted with technical problems. My boss even organised, after the normal time of work, the six-month study meetings in our section which allowed me to master some basic technological knowledge about the crystallisation equipment. From the third year, I had to find out myself the problems and the best solutions with some indications from the others..." (Young bachelor degree engineer)

"In this laboratory, all young graduates, independently of the level of their degree, have the status of "apprentice" for two years. For this period, each one is, although integrated in a research team, given his particular study theme and works on it. At the end of this period, they present the result in front of jury composed by senior researchers. According to this evaluation, their allocation to a post become definite. Some of them remain in laboratory, the others go to the design section or the development centre and so on" (Young research engineer)

"I was introduced to this company by my professor with whom I had do a master course. I studied the chemical engineering and I 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 domain. I did never work so hard in my life, during the first four years... I used to do 100 or 150 hours of overtime by 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 carrying little responsibility, gradually extending their sphere of competence by moving on to related tasks. Given the quasi-absence of the technician category in Japanese organization, all young graduates are assigned to concrete technical tasks to resolve problems or to develop the minor applications under the control of senior engineers and in cooperation with different categories of workers. Such collaboration or cooperation seem 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 organization and the ill-defined responsibility of each member generate multiple interaction, mutual adjustment and sharing of information and knowledge (Ishida 1986). This way of learning, orientated toward empirical problem-solving, contributes to developing a tacit knowledge and to sharing it collectively.

"In our company, there are many formal training programs for the young graduates. But it is not these programs which make the engineer. The young engineers are initiated to the work by doing 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 detail designs of equipment. They are guided by the head of section, but more frequently seconded by the senior colleagues in the team... When they made a stupid error on the blueprint, I said them to go to hear from the operators in the workplace... Anyway, they learn informal or unwritten technical knowledge throughout a sort of osmosis with their working environment..." (Head of design section)

Nevertheless, these tasks become more complex and comprise more managerial functions in line with professional advancement. This kind of organisation-controlled learning puts the young employees in a situation of dependence and long-term competition with colleagues in the same entrance group. Such a slow rate of progression does not encourage initiative and may weaken the originality of individuals, and even sap their creativity. But this kind of "apprenticeship", just like in Germany, forces employees to learn how to work together (mutual adjustment) and to keep up the idea of overall performance.

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

As for the formation of a "typical" career pattern, the external labour market is of little importance to Japanese engineers. Some comparative studies (Ishii 1993, Shapira 1995) as well as our own support the fact that they experience much less external mobility than do European or American engineers. Most of them follow their career 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.

"... to allocate such an engineer to such a post is a matter decided principally by the mutual consultation between the supervisors and the department of human resources. The supervisors naturally have to be careful of the desiderata of each engineer, but they don't negotiate about it... We can't take in consideration the desire of all persons. It is absolutely the company which has a right of final decision on the transfer, the change of post.. The individual can not refuse the company decision..." (Manager of human resources)

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

From the organisational point of view, such mobility tends both to form a hybrid but highly consistent competence focused on managing the various interfaces and 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 take 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 chain among different jobs, Japanese engineers could be more likely to have a variety of work experience that covers a wide range of technical areas and to share such experience with others. This would enable the engineers to overcome the communication impedance and to transfer tacit as well as explicit knowledge based on their shared experience. In this sense, the mobility among narrowly linked tasks they experiment at the first stage of theirs careers could contribute to build up an important organizational capability to enhance cross-functional integration.

The hierarchy of educational levels and university degrees remains in abeyance during this period of apprenticeship. However, its effects make themselves felt as individuals advance along their career paths, and particularly when it comes to promotion up 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 begins increasingly to emerge. Thus 35–40 is a pivotal age, since it is then that selection to the first rung of the management ladder takes place. This selection is based not on a shot in the dark or on a gamble on any particular individual. It is based rather on the system of assessment that constantly evaluates, on an annual basis, not only each individual's output but also his/her progress in the learning process and his/her ability to cooperate and contribute to the collective effort (koike and Inoki 1987). This encourages employees to incorporate long-term considerations into their career strategies. Nevertheless, sustained and exacting competition of this kind finishes by producing a hierarchy at around age 35–40 and leads to the differentiation of university graduates into managers and non-managers. This competition continues subsequently, in an extremely selective way, as employees progress towards the upper echelons of the hierarchy. This structuring of internal career paths might finally correspond to the principle of "tournament competition" outlined by Rosenbom (Rosenbom 1982). However, the question remains as to why and how Japanese firms manage to organise such a slow selection process which combines collective cooperation and individual competition, two largely contradictory elements from the European point of view.

Compared with the Japanese situation, individual strategies play a major role in the career pattern of French engineers. There exist, as we saw, two types of engineers. One is composed of "in-house" engineers promoted from the technician category who cultivate the allegiance to the firm. Just like the Japanese colleagues, they develop a contextual skill, but their empirical expertise, considered as inferior to the conceptual one, is undervalued. Their career paths tend to be limited to low-level technical function or production management in the firm.

> "There is a cultural demarcation between engineers and technicians ... so there is a identity problem for those who cross the barrier ... In any way, technicians do not have access to posts of high responsibility, even when I've got the title of cadre..." (Technician passing the test for access to management "cadre")

Those graduated from the engineering school can draw a bargaining power from their nationally recognised "title". They negotiate, at every stage of their career, the condition of contract (retribution, condition of work etc.) and their professional commitment to the firm: the nature of contract appears here explicit and limited in content and in time, while the Japanese one is more implicit or ambiguous. Anyway, the firm rapidly puts these engineers to the test and channels them into different careers. Thus, the most competent engineers 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, we put them on a fast track to the hierarchy. And we don't check frequently 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, it always faces the risk of their departure, which represents a loss of technical expertise and organisational knowledge.

The mobility of these engineers both in the internal and external labour market seems to be motivated fundamentally by individual strategic choices, whereas in Japan, the internal transfer of engineers is closely controlled by the organisation. Moreover, the internal mobility occurs more frequently amongst French engineers and covers a larger range of functions than amongst Japanese engineers. It corresponds to a progression between functions which are organised according to a notion of "territory". This territorial rationale leads to a segmentation of organisation (research, marketing, production etc.), to the difficulty of coordination between them and to the relative weakness of collective learning. Moving from one to another is a sign of the engineer's ability to fulfil different functions, master them and adapt to them. In France, therefore, career paths followed by engineers appear discontinuous, with breaks between various types of technical or managerial responsibilities.

"The most brilliant career consists of changing the product department or shifting from the production function to the marketing, to the strategic planning, to the purchasing one and so on every three years, as the X guys (graduates of Ecole Polytechnique) used to do. If you have such a profile, you surely are going straight to an executive post..." (Product Department head).

II-3 Work Patterns, Communication and Coordination

Incentive mechanisms and career formation maintain a sort of interdependence with work organisation for engineers. We can observe the contrasting forms of information flow and coordination associated with the diferent patterns of career formation in two countries.

The characteristic of French organisation consists of more bureaucratic control which produces a formal project management and a rigorous scheduling in the work. The mode of communication between project members is more supported by the formal procedures and the written documents; information is more codified and stored in detailed specifications for reducing "territory" 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 (Aoki 1986). This coordination method is straightforward and puts less demands on the information processing capacity of the organisation and the individuals.

"The project management is rather linear in this company ... It is essential to pass as cleanly 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... One shouldn't have to go back to a previous phase... This means that the various phases must not overlap...." (Project leader)

Faced with the economics of variety which imply the necessity of flexible adjustments at the most decentralised level of organisation, this mode of coordination seems to be less efficient, because it is much difficult de introduce retroactive and corrective actions. But it demonstrates the capacity to organise big scientific projects such as the nuclear national project, aerospace programme etc. which need an important information processing and a huge coordination ability. The competence of French engineers, especially that of the most elitist group of engineers (Corps d'Etat), matches rather the organisational requisites of hierarchy-based coordination.

The Japanese organisational approach seems to be quite different: coordination is less based on the formal procedure. On the contrary, it is more dependent on intensive human interaction and information sharing. Project management is organised through reciprocal communication and mutual adjustment between members. It depends less heavily on formal planning and hierarchical control but requires team members' full engagement in the project. Direct communication between them enriches the stock of non-coded information and encourages continuous mutual adjustment throughout the problem solving process. Nevertheless, such intensive human interaction imposes a heavy work load on the individuals. Here, we can point out the same kind of finding as Nonaka and Takeuchi have yet mentioned.

"Phases are not always very clear-cutting in our project, although we must pass the project review at each step... I think these reviews can not check completely all technical problems which appear later. The process is much more erratic and non-linear. For example, we must continue to complete some functional details, while the product is on trial line. It is normal that we, all development engineers, have to go to the factory in order to find out practical solutions to a technical default, modify the specification, even few days before the date of commercialisation of product... It is very often anarchic at the end step of project, you know... Each member adjusts himself to the others in a chaotic way under the pressure of the deadline, we do it but we consume lot of energy..." (Project manager)

This form of coordination is fundamentally based on common corporate experience of members which creates mutual trust and a willingness to share knowledge. It generates also intensive human networks through which the tacit know-how is transferred. This human-network approach (Ito 1988) is facilitated by the absence of rigid task divisions, job rotation for the engineers and interfunctional transfer (Kusunoki and Numagami 1997). These characteristics are, more generally, sustained by the practice of long-term employment and the mode of career formation which generate both the long-term competition around internal promotions and the cooperation based on shared values. Of course, the human network is one of elements which facilitates the coordination within French firm too. But the same concept doesn't mean the same reality. In the case of France, the human network is considered more as a tool for a strategic power game: non-disclosed or restricted information is a source of power in negotiations (Crozier 1973). Segmented by professional groups and weaken by a logic of "territory", the human network doesn't necessarily serve as a vehicle for disseminating the knowledge within the French firm. In particular, tacit knowledge accumulated by technicians is seldom shared by engineers and remains latent or under-utilised. By contrast, the high mobility of French engineers in the labour market helps to spread the interfirm human networks and to diffuse the new ideas and knowledge at the sector or national level.

Anyway, such two different modes of coordination and information flow have also an another origin.

The information flows through the human network means that knowledge and information are more keenly associated with the complex social relationships and work groups in which engineers work. They are context bounded, idiosyncratic and not immediately portable to outside. It is exactly what Aoki named the specific collective assets (Aoki 1988). This sort of asset is not necessarily divisible into individual property, as the human capital theory supposes. The most impotent point is that it can be mobilised solely by an adequate incentive mechanism which puts the accent not on individual performance but on the collective commitment of members. In the French case, knowledge structure is explicitly managed by written rule, "routinised" procedure and hierarchical coordination. Tacit knowledge and unwritten know-how, based on pregnant practices, are often neglected. Engineers are likely to privilege conceptual and formalised knowledge and to promote the organisational learning on the basis of knowledge objectified scientifically and translated into hard data or formulae. Because the task organisation is characterised by standardised procedure, codified and explicit rules, the competence and responsibility of each engineer can be defined, measured and evaluated on an individual basis. Innovation based on this type of knowledge can not be dissociated from the explicit knowledge database that French firm tends to constitute.

III-Nature of Innovation

Around his territory, the French engineer develops scientific and managerial skills. Such a building-up of capacity based on highly professional expertise encourages inventiveness.

It bears the potential for originality, the possibility of a "breakthrough innovation". It can lead to occasional scientific successes or even a far-reaching "prowess", particularly when the State acts as challenge coordinator. This phenomenon is noticeable in certain sectors such as the nuclear, aerospace and telecommunication industries, where the technocracy composed of "State Engineers" (Corps d'Etat) coordinates and supports a "national project" in the long term, or in the chemical industry, where the scientific performance of research upstream of the production process determines its overall competitiveness. An engineer's confinement within his own territory, however, leads to a certain difficulty in communication, cooperation and collective learning. Likewise, having a markedly different status from that of technicians or production workers tends to make the sharing of knowledge and/or know-how highly sensitive, and to make the collective challenge random. In France, original creativity appears to show itself in exceptional circumstances or through a strong personality of individuals, with its spin-offs being often poorly capitalised upon or consolidated in the industrialisation stage. 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" to manufacturing because of the discontinuity of skills between workers.

In the case of Japan, an engineer does not occupy his own territory right from the start. His skills and recognition as an engineer are built up over time. In a position of apprenticeship, he trains himself by slowly exploring an area of competence collectively covered by a work group to which he belongs. Learning is based essentially on the action of interacting with colleagues or more experienced engineers. His contribution to the group consists in gradually enriching the current stock of knowledge/know-how. This way of collective learning in the organisation generates the same type of engineers having less differentiated cognitive resources and consequently impedes the emergence of individual originality (Sakakibara 1993). The meaning of industrial creativity becomes very different from a French sense: creativity is seen less as the creation of the new than as the consolidation/recombination of existing elements. Thus, the Japanese engineer tends 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 the industrial efficiency. The second refers to the necessity of creating a complementarity with other categories of employee (such as foremen and manual workers) which goes as far as the distribution of shared knowledge or the overlapping of skills. Somehow, both realities are found in the way German industry ensures the continuity of the skill formation process, through its professional training system, ranging from the skilled manual worker to the "Meister" and then again to the "graduate engineer" (Sorge 1994). It is doubtless not by chance that these practices contribute to shaping the Japanese form of "productive intelligence" which efficiently ensures the transition from design to prototype and on to industrialisation. This type of organisational "routine", coherent with "incremental" innovation, 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, telecommunication, pharmaceutics, biotechnology etc.) where creativity is more closely and directly linked to basic research activities or to individual capacity. 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 has a merit of showing the interdependence between the socialisation of actors, the mode of learning, the form of competence and the nature of innovation. It means that the innovation process is deeply embedded in the societal (and national) context. It is doubtless not by chance that France and Japan have a huge potentiality of cognitive resources which can create a variety of knowledge. But at the same time, both countries have construct a particular configuration of national institutions which tends to shape certain form of knowledge creation process through, among other things, the formation of engineers and their utilisation. This institutional environment works as a given vis-à-vis the actors and constitutes a "path dependency" at the national level. The institutional change is not at all impossible but may be gradual and adaptative, as it is stated by the school of evolutionary economics. As for economic competitiveness of a nation, the comparative advantage of each country seems finally to be based on a matching between the industrial/technological requisites of sectors and the dominant form of knowledge that it is capable of promoting.

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