IT and work organisation: beyond technological complementarity and social interaction

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Abstract

We propose a unified analytical framework to understand both the complementarity between computer use and innovative organisational practices and the selection principles that guide their diffusion at the work post level. We show that the common selection principles governing the allocation of IT and the organizational design *of the work posts are connected with the choice of the network configuration of social interactions within the firm. This interactive social structure is analysed with reference to the concept of "social capital". We then identify in the complementarity between technology and organisation, what comes from the pure co-ordination of choices in these two dimensions and what comes from the selection of workers. We conducted econometric tests, based on the labour force section of the survey on "Organisational Change and Computerisation" conducted in 1997. They allow us to verify four propositions.* First of all*, we show that the social capital of workers favours their access to computers and more generally to Information and Communication Technologies (ICTs). This selective allocation of equipment seems specific to ICT since it does not drive the allocation of automated machines.* Second*, the same selection mechanism drives the access of employees to work posts with innovative productive and informational characteristics.* Third*, ICTs are correlated with innovative organizational characteristics of work posts resulting from the diffusion of new types of organization. However, this relationship is not uniform within the different occupational groups.* Finally*, innovative organizational characteristics involving a relational dimension generate a complementarity with ICT which main source is in the way workers have been selected to occupy a modernized work post.*

Key words*: Computerisation, work organisation, complementarity, social capital.*
JEL classification : L23 – M54 – O33 – Z13

Introduction

For the last two decades, the industrial enterprise landscape has been transformed by major reorganisations and the spread of Information and Communication Technologies (ICT). This spread of ICT is often viewed as a major phenomenon due to the massive and transversal way in which ICT have been adopted by business firms. These generic technologies impact communication, affect co-ordination within the firm (Caby and Alii (1999), Brousseau and Rallet (1997)) and satisfy the logic of rationalising the production of knowledge (Benghozy and Cohendet (1998)). As for business reorganisations, they are founded on the diffusion of innovative organisational practices such as quality management, just-in-time production systems, project teams, out-sourcing or even re-engineering. The extent, duration and persistence of the adoption of these practices leads us to consider them as reflecting real structural changes within organisations (Osterman (2000)). These new practices favour the development of work logic of a more horizontal nature where decision taking is decentralised, where the employee becomes more autonomous, polyvalent and multi-skilled, and where collective dynamics are encouraged.

How do these changes in the domains of technology and work organisation fit together? Observations made by economists tend to show that IT is complementary to these more horizontal modes of co-ordination. It would be more efficient for firms to adopt ICT conjointly with new organisational practices rather than separately. It would therefore be more in their interests to co-ordinate their technical and organisational choices (Milgrom and Roberts (1990)). On the other hand, studies focussing on the uses of IT in firms, emphasise the vertical logic applied in the allocation of computers to employees. Managers are the first to be equipped and are provided with equipment of a more advanced nature even if their daily use of it is not very intensive (Gollac and Kramarz (2000), Cezard, Gollac and Rougerie (2000)). The fact of being equipped results from important effects of selection reflecting the ways in which firms differentiate between employees. IT is thus not allocated in a random way within firms. Similar effects of selection may be observed for certain innovative characteristics in the organisation of the work station such as autonomy or the fact of participating in a dense communication network (de Coninck (1991)).

How does the vertical logic, applied in selecting the users of technology, conjugate with the horizontal logic that seems to influence the co-ordination of the technological and organisational choices made by firms? The object of this article is to propose a unified framework for analysing both the complementarities between computer use and innovative organisational practices and the selection principles that guide their diffusion at work-station level. More precisely, we identify the common elements that generate selection in the distribution of IT and in the organisational design of work stations. This common logic acts as a hidden factor that generates complementarity between the technical and organisational characteristics of work stations. We will demonstrate that this component of complementarity is a product of the network of social relationships within the firm rather than of purely technical factors and we interpret this with reference to the role of the "social capital" of individuals in the context of technical and organisational changes.

This analytical framework enables us to formulate propositions that we test empirically on a sample of 4,067 stable employees (all having at least one year's seniority) in French manufacturing firms of more than 50 employees. This sample comes from the matched employer/employee French survey C.O.I (Changement Organisationnel et

Informatisation, i.e. Organisational Change and Computerisation) carried out in 1997 by the DARES (section "employees"), the SESSI and the SCEES (section "business enterprises"), that we have matched with the Données de Déclaration Annuelle de Données Sociales (DADS – i.e.Data from the Annual Declaration of Social Data).

This study is structured as follows. In the first section, we expose the analytical framework with regard to the relationships between technology and organisation. In the second section, we present the.C.O.I survey together with the indicators used for measuring the use of technology at work-station level, the organisational characteristics, and the variables occurring in the selection process of employees whose work station is modernised. The third section concentrates on identifying the effects of selection on the modernisation of work stations. The fourth section measures the complementarities between the use of technology and the organisational characteristics of work stations while discussing the influence of the selection principles they have in common.

I The relationships between computerisation and organisation: an analytical framework

Relationships between computerisation and the organisation of firms have been covered by numerous works since the end of the 1990's. For economists, the idea of complementarity between the two has henceforth become the consensus. We develop this in the first section. In sociology, a different approach has been favoured, emphasising the social determinism influencing the allocation to employees of computers and work stations having innovative organisational characteristics. The latter is presented in the second section. Finally, in the third section, we formulate the hypothesis that "social capital" is a hidden factor behind the choices in IT equipment and reorganisation made by the firm.

I.1 Complementarity: an economic determinism triggered by the reduction in the price of computers

In micro-economic studies, organisation for a long time remained "embedded" in technique. Organisation has progressively evolved towards a full field of research by becoming less dependant on technical approaches of economists. Today, the idea of complementarity between computerisation and organisation dominates economic literature. This relationship of complementarity has been formally defined by Milgrom and Roberts (1990). Any two productive activities or practices in a firm are said to be complementary if the development of one increases the productivity of the other. In this case, the choices made by the firm in these two domains must be co-ordinated.

In a standard production function, the firm essentially chooses the quantities of its production factors. In addition to these operational choices, there is a set of strategic choices of products, equipment, and organisational practices. The standard production function must thus be added to an "organisational design" production function to summarise the discrete choices made by the firm in strategic domains (Athey and Stern (1998)). If the complementary variables of the production function increase simultaneously, the value of that function increases by more than the sum of the value of the changes induced by the increase in each of the variables when taken separately.

Technical determinism is substituted by economic determinism insofar as the search for performance leads firms to co-ordinate their technical and organisational choices. The impulse for change still comes however from the technical side in that the reduction in the price of computers induces firms to invest in IT and then co-ordinate their choice of organisational practices with their choice of IT equipment.

Which choices in "organisational design" are complementary to IT equipment? Milgrom and Roberts (1990, 1992) mention a model of "industrial excellence" where Computer-Aided Drafting, Computer-Aided-Design, Computer-Aided Design and Manufacturing, and Computer Aided Production Management software, as well as programmable automated machines and robots are complementary to the rapid renewal of products, to small-batch production, to the polyvalence and multiple skills of employees, as well as to just-in-time production and delivery practices, outsourcing and sub-contracting.

Theoretical literature on organisation describes several dimensions of work organisation as being "modern". Greenan (2001) makes a synthesis of these while distinguishing the organisational choices affecting the firm's system of production from those affecting its information system. In all these models, the alternative forms of organising the firm depend on market conditions; i.e., uncertainty in the market for goods and property, the supply of skills in the labour market, as well as the availability and price of the technology, etc. The changes described most often lead to substituting a logic of horizontal co-ordination for a vertical-coordination logic. As far as the production system is concerned, employees become more versatile and/or multi-skilled (Carmichael and Mac Leod (1993) ; Lindbeck and Snower (1996) ; Janod and Pautrel (2002)), more autonomous (Greenan and Guellec (1994) ; Caroli, Greenan and Guellec (2001)) and more interdependent in their work (Kremer (1993) ; Kremer and Maskin (1996) ; Crifo-Tillet, Diaye and Greenan (2002)). As regards the IT system, information used by the firm becomes more decentralised, linked to local knowledge, partially tacit (Aoki (1986) ; Carter (1995)), and its processing takes place on a network basis relying on horizontal communication (Aoki (1990) ; Bolton and Dewatripont (1994) ; Kennedy (1994)). Certain theoretical models distinguish themselves however in describing an accentuation of hierarchical logic rather than "decentralisation" (Williamson (1967); Keren and Levhari (1989) ; Otani (1996)), which may be corroborated by certain observations (Brousseau and Rallet (1998)).

A certain number of empirical studies have sought to test the complementarity between IT equipment and decentralisation of the firm[1]. Bresnahan, Brynjolfsson and Hitt (2002) draw some significant correlations from the data of individual firms, between the indicators of ICT use and those of the decentralisation of work organisation as measured by the importance of autonomous work teams. They also verify that the association between IT equipment and decentralisation is a source of productivity gains over and above the effect of each variable taken seaparately. In mobilising a sample of French industrial firms, Greenan (1996, 2002) draws a correlation between the use of advanced manufacturing technologies and reorganisations involving decentralisation of decision-taking at operator level, reduction in the number of management levels and an increase in the competencies required in the workforce. Gollac, Greenan and Hamon-Cholet (2000) show that in the French industry, the degree of computerisation has a very marked correlation with that of new organisational structures. It would seem also that the co-ordination of firms' technical and organisational choices was prevalent

1 Numerous recent studies seek to test these links of complementarity on samples of very diverse origins. We do not attempt here to do a review of all the literature.

throughout the 1990's, based on issues of quality, differentiation and product renewal. However, at the end of the decade, a new logic emerged in a context of financial restructuring with firms favouring cost control through their IT networks and practices such as outsourcing, sub-contracting and just-in-time. Finally, Caroli and Van Reenen (2001) encountered some difficulties in identifying, from data on firms in France and England, any complementarity between IT use and a reduced number of hierarchical levels, that they use as a synthetic indicator of organisational change.

I.2 Common selection principles resulting from social determinism?

Studies carried out by economists on the theme of complementarity between IT and organisation, favour the firm as the level of analysis and observation. Certain economists and sociologists have also used "complementarity" to position themselves at work-station level for analysing the impact of IT use on wages. The complementarity in question relates to the links between IT use and employee's skills. The underlying ideas are that either the ICT will increase employees' productivity as soon as they use it, or they receive higher pay, because they present skills or attitudes, not statistically measurable, but known by their employer, that render them more capable of using the new technology efficiently. These studies, centred on employees rather than firms, have contributed to thinking on "technological bias".

Krueger (1993) was the first to attempt evaluating the link between IT use and wages. According to his estimations, the wage premium associated with using IT would be between 10% and 15%. His estimations have been taken up and refined by a certain number of authors; for example, Entorf and Kramarz (1994), Gollac and Kramarz (1999), Di Nardo and Pischke (1997). They show that taking organisational variables into account in cross-section estimations considerably reduces the wage premium while the use of longitudinal data results in estimations considerably less optimistic, to the order of 2%.

The progressive disappearance of the "IT effect" measured by Krueger, once one introduces cross-section controls or even based on temporal data, demonstrates that computers are not allocated randomly to employees by chance. Using IT supposes a minimum of educational capital, in spite of appearing to be a tool of secondary importance, because this tends to be less used by those with a higher level of education (Faguer and Gollac (1997)). Using IT also supposes that the employee has a minimum of seniority; firms allocate computers in priority to employees it knows, in whom it can have trust (Moatty (1993)). Finally, it is apparently those already the best paid employees, who benefit first from IT equipment (Entorf, Gollac and Kramarz (1999)). If the links between IT and organisation reflect the spread within firms of working logic of a more horizontal nature, the distribution of computer equipment to employees tends to follow a logic that is quite hierarchical. This vertical logic is persistent. In spite of the mass phenomenon of access to IT in firms (passing in France from 24% of users in 1987 to 51% in 1998), it does not seem that any democratisation is starting since the distribution of the more advanced generations of computers remains very selective (Gollac, Greenan and Hamon-Cholet (2000)). Gender, education, experience, seniority and occupational category constitute as many criteria that guide the allocation of technology.

Di Nardo and Pischke (1997) have identified, in the same way as Krueger, the wage premium linked to other attributes of employees' work stations like use of the pencil, the telephone or even the fact of working while seated. They have obtained wage primes

of the same order as those calculated for IT. De Conninck (1991) shows that age and gender strongly influence the organisational characteristics of work stations when these relate to "post-Taylor" logic. If computers are not allocated randomly to employees, matching between work station and employee is not the fruit of chance either, but the result of recruiting procedures, internal mobility and work-station "design choices".

From that point on, we can ask ourselves whether the correlation / complementarity observed, at firm level, between IT equipment and the organisational characteristics of work stations does not result from some "hidden" factor that is a common selection principle in allocating to employees computers and work stations with innovative organisational characteristics. What is this "hidden" factor?

I.3 Social capital: a hidden determinant in the work of modernised employees

We propose to analyse the effects of selection in access to a modernised work station, while taking into account the reconfiguration of social relationships between the employees in a context of organisational changes. Within the firm, employees are in relationships of productive interdependence and social interaction. Thus the quality of the social interaction has an effect on productive activity, and conversely, the productive activity can contribute to the development of social interaction. It may therefore be in the firm's interest to manage the social interaction between its employees.

The origin, role and dynamics of social relationship networks are today widely analysed, in sociology and economics, based on the notion of social capital. An individual's social capital includes his/her belonging to groups or networks from which he/she derives a benefit. One can distinguish an employee's social capital (Bourdieu (1980, 1986)) from the internal social capital of a firm or organisation (Coleman (1988, 1990)). Within the firm, social capital designates the social structure of the organisation that exists through the complex network of formal and informal relationships among the employees. This constitutes a resource for employees and firms in their more or less durable social relationships (Adler and Kwon (1999)).

As underlined by Turner (1999), while the organisational structure of work refers to the distinction by skills between employees, the relational structure of work (the social capital) covers the social distinction of employees by groups belonging to the same community. If the belonging were uniquely based on skills acquired in the educational system, and corresponded exactly to the division of labour, the two structures would coincide perfectly. But, memberships are built by society. Turner (1999) makes reference to age, gender, localisation, religion, ethnic group, social class and social origins as being determinants of social capital.

In a hierarchical or centralised firm, the downwards and upwards circulation of information takes place along the whole length of the hierarchy line. The firm's communication network is thus structured around the line managers. Elsewhere, as shown by Rosen (1982), outside his/her role in the circulation of information, the line manager plays a role in the productive activity by neutralising, through his/her supervision, any effects that the heterogeneity of employees in terms of skills and membership might have on production. This activity contributes to "individualising" the work of direct producers in the sense that it eliminates sources of direct interdependence between individuals. The only interactions that influence the quality of productive

activity are thus those that direct producers maintain with their hierarchical superiors. Productive and informational interdependence passes in this way via the line manager[2] and it is their social capital that the firm seeks to manage via tools of human resources management such as recruitment procedures, promotion and involvement.

In a decentralised firm, direct connections between employees not in a line management position increase, and/or the strength of hierarchical control is reduced. The development of non-hierarchical networks of communication is a consequence of the increased interdependency between direct workers resulting from new forms of organisation favouring quality, just-in-time resource management, tighter lead-times and reduction in the numbers of management levels (Aoki (1990), Kremer (1993), Kremer and Maskin (1996), Crifo-Tillet, Diaye and Greenan (2002)). In organisations of this type, the network of interactions with productive consequences is wider and denser. This is shown, for example, by work of Gant, Ichniowski and Shaw (2002, 2003) on the iron and steel industry. In firms that have been reorganised, operators are much more closely in contact with each other because, in communicating with their colleagues, they succeed in resolving the operational problems they encounter, without the aid of a hierarchical superior.

In selecting employees occupying interconnected work stations, firms keep a control over the network of social relationships affecting productive activity[3]. Indeed, the personal characteristics of the employee and his/her environment are liable to affect his/her individual social capital and the way in which this crystallises at firm level. First of all, if employees have to co-ordinate in a horizontal manner, it is necessary that persons placed in the network by virtue of the choice in work organisation, should want and be able to communicate, speak the same language, and understand one another. The social capital of an employee and its adequacy with that of the organisation may thus serve as a criterion of selection for the firm when matching employees to work stations and/or deciding which work stations are to be reorganised. This choice can facilitate reorganisations in generating trust in spite of the uncertainty inherent in all process of change (Leana and Van Burren (1999)). Beyond the selection process, certain human resources management tools such as evaluation interviews, company seminars, and use of long-term contracts can contribute to the maintenance and/or development of the firm's social capital.

The use of IT also interacts with social capital. First of all, as demonstrated by Goshal and Nahapiet (1998), social capital favours the conditions necessary for combining and exchanging knowledge to sustain the creation of new knowledge. Now, Gollac and Kramarz (2000) show that using IT is not simply an obligation for the employee, but also a taste for acquiring knowledge. Moreover, Gollac (1996), Gollac and Kramarz (2000) emphasize that employees, equipped with computers, use this equipment even more efficiently when they belong to social communication networks. It is in taking advantage of their social relationships that IT users succeed in configuring their tool so that it really meets their needs. Finally, the very nature of IT which is part of communication technology explains why it can influence the configuration of social

[2] This description of the hierarchy confirms the definition of social capital proposed by Burt (1992, 1995) according to which the manager's social capital is high because he serves as an intermediary in a "structural hole"; i.e., he provides a bridge between different networks of communication that do not exchange directly between each other. A manager plays this role in connecting different departments of the firm, enabling him to access more relevant information.

[3] The selective modernisation of employees' work stations may also result from a process of self-selection among the employees.

capital. In equipping employees with computers, firms provide them with a new means of communication that can be used in maintaining social relationships as well as creating new ones.

All together, the relationships of complementarity identified at firm level, between IT equipment and innovative forms of work organisation, result in part from common principles of selection, that we interpret as if they were part of a single process of selection by social capital[4], in the allocation of computers and in the matching between "modern" work stations and employees.

We will now test this hypothesis by using the survey on C.O.I carried out in 1997. This survey, with two sections on "employers" and "employees", enables us to match together a detailed description of work-station characteristics with rich information on the firm and the personal characteristics of its employees.

Even if C.O.I is a rich source of data on employees, it does not describe in detail the graph of social relationships that employees maintain amongst themselves. We are thus unable to evaluate directly the social capital of the employees questioned and study its distribution as a function of technological and organisational work-station characteristics. Thus, our use of the concept of social capital will remain relatively limited, as a reading grid to guide us in building the list of selection variables and interpreting our results.

II The data and measurement

The data base used groups together three sources of information: (1) The "employees" section in the C.O.I survey, (2) The "firms" section in the C.O.I survey, (3) The Data from the Annual Declaration of Social Data (DADS). The C.O.I survey was carried out at the end of 1997, covering the period 1994-1997. The field considered is industrial firms with more than 50 stable employees (i.e. with at least one year of seniority). The sample covers 2,330 firms and 4,067 employees of those firms.

II.1 Presentation of data

The C.O.I survey was designed and co-ordinated by the Centre d'Etudes de l'Emploi (Centre of Employment Studies) on behalf of the DARES, the SESSI, the SCEES and the INSEE. It covers industry (including the F.P.I; i.e. Food Processing Industries,), a branch of services (that of chartered accountancy) and a branch of trade (the do-it-yourself trade). Firms have been randomly selected from the files of the Annual Surveys of Industry (EAE, or Enquêtes Annuelles d'Entreprise). The statistical administrative services of these surveys, the SESSI for industry, the SCEES for the F.P.I, the INSEE for the independent auditors and the do-it-yourself trade, have conducted the surveys in the field. The surveys in industry and the F.P.I, representing the bulk of the sample of firms, have been carried out by post using a simple questionnaire of four pages. The manager being questioned was asked to describe the choices made by the firm in terms of IT and organisational practices between 1994 and 1997, to specify the difficulties

[4] Of course, the process of selection in the modernisation of work stations is not limited to selection by social capital. The dimensions of the selection are multiple (economic and cultural capital, in particular). Nevertheless, concentrating on the single dimension of the selection processus enables us simply to expose its underlying logic.

encountered in their implementation as well as the general strategy followed by the firm.

The lists of firms, produced by the EAE, have subsequently been matched to the file of the DADS for the year 1996. Small samples of employees have been selected within each firm. The criterion of random selection of employees, "being born in the month of October in an even-numbered year", guaranteed their presence in the population constituted each year by the INSEE from the DADS.

The "employees" section was prepared by the network of INSEE surveyors on behalf of the DARES, by telephone and home visits. The survey procedure involved questioning employees one year after being surveyed in the DADS. If they are successfully located and still in the same firm, they have at least one year's seniority. This means that the employees must be stable. The "employees" questionnaire comprises three parts. The first provides socio-demographic data, the second takes an interest in employees' work-station characteristics in terms of scope for initiative, communication, working speed, and work evaluation, while the third produces a set of information dealing with the use of IT, telecommunications and modern industrial technologies.

In the work carried out by economists, the question of complementarity is in general analysed at the level of the firm which is supposed to coordinate, in the context of its general strategy, its choice of equipment and organisational practices. Greenan, Gollac and Hamon-Cholet (2000), mentioned in Section I.1, have mobilised C.O.I to identify complementarities at firm level. In our work, we treat this question of complementarity at a finer level, that of work-station "design". Do work-station designers co-ordinate their choice of technical equipment with their choice of organisational characteristics? If yes, we should be able to observe regularities at work-station level, in exactly the same way as we can observe it at the level of the whole firm. The starting point for our empirical analysis is thus the "employees" section of the C.O.I, from which we measure the technical and organisational characteristics of work stations. As the employees who occupy these posts are stable with 90% of them on a fixed-term contract, it is clear that we can have a particular interest in the design of work stations in the "primary" sector or the firm's "core activity".

We will use the "firms" section of the C.O.I to identify the productive context in which employees' work stations are set, by basing ourselves on the results obtained by Greenan, Gollac and Hamon-Cholet (2000).

Finally, the DADS file of 1996 constitutes a basis for the survey in the "employees" section of the enquiry, providing indicators on the composition of the work force as a function of profession, age, gender and nationality. Moreover, the employees questioned also belonged to the DADS5 population constituted by the INSEE each year. We can thus identify employees' previous career path at the date of the survey.

[5] For a presentation and treatment of the DADS population, see Le Minez and Roux (2002).

II.2 Measuring the technological and organisational work-station characteristics

Indicators of work-station computerisation

Three indicators enable us to understand computerisation of the work station. Their construction is detailed in Appendix 1[6].

The first measures whether the work station has been computerized or not ("use"). A "computerized" employee uses a terminal and/or PC (which might be a laptop computer) in the context of his/her main task. 60% of stable employees in industrial firms with more than 50 employees use a computer. Even if IT concerns direct more often than indirect employees, it is distributed throughout all the occupational groups: 92% of executives, 92% of white-collars, 84% of middle management (technicians and supervisors), 38% of skilled blue-collars and 21% of unskilled blue-collars use IT.

The more advanced uses of IT often involve more than one computer. Our second indicator measures this type of use by the coexistence of several technologies on the same work station ("NBOI"). The survey identifies nine technologies: terminal, desktop PC, laptop computer, intranet connection, Internet connection, EDI (Electronic Data Interchange), fax, minitel, mobile telephony.

Finally, we measure the duration of IT use ("duration"). Greater duration of use may be a sign of work on computer that is repetitive or even Taylorised.

In this study, we seek to focus on the specifics of IT. One way of identifying these consists in examining the relationships between IT and the organisational characteristics of work. It is however also interesting to compare IT with another technology. C.O.I employees are questioned about their use of automated machines or installations. In contrast to ICT, automated machines concern only direct employees: 58% of unskilled workers, 48% of skilled workers and 22% of middle management use them, against only 6% of executives and 3% of white-collars. The use of ICT may thus be compared to that of automated machines in the sample of direct employees.

As for ICT, the use of automated machines is defined by three indicators: indicators of use and duration of use ("use" and "duration") are comparable to those built for ICT. On the other hand, the advanced uses of automated machines are not measured by the diversity of technologies employed but by the diversity of functions performed by the machine concerned ("NBMO"). The survey identifies nine different functions: 1) tooling, casting, laminating and the other transformations of materials, 2) assembly-mounting-welding 3) painting and other surface treatments, 4) mixing, curing and other chemical transformations of materials, 5) proof testing and controls, 6) conditioning and packing, 7) handling and stocking, 8) printing and copying, 9) cutting out, laundering, sewing and manufacturing.

[6] For complementary descriptive statistics on the indicators of computerisation and organisation that we measure, see Greenan, Hamon-Cholet and Walkowiak (2003).

Innovative organisational characteristics of work stations

We measure the "innovative" organisational characteristics of work stations by distinguishing the characteristics linked to the system of production from those linked to the information system. Appendix 2 details the questions used in the survey for constructing these variables.

The organisational characteristics associated with the system of production that we measure are: autonomy ("autonomy"), hierarchical responsibilities ("to be chief"), training new or temporary staff on looking after their work stations ("to train"), respecting quality standards, participation in group working ("working in a group") and the intensity of the work ("intensification").

These characteristics may be related to organisational dimensions identified as innovative in the theoretical literature. In the new forms of organisation functioning according to more horizontal or decentralised co-ordination logic, employees will be more autonomous and management positions rarer. If management constraints tend to diminish, other constraints take over, linked to interdependency of a more horizontal rather than vertical nature. Like the different components of a product are immovably attached to each other in the finished product, definition of quality objectives renders the work of some workers more sensitive to the work of others. If individuals belonging to work collectives have to adjust to each other and transfer their knowledge, then the work of an individual is more closely dependent on that of his/her colleagues.

Finally, the indicator of work intensity measures the accumulation of industrial constraints (linked to machines and to the production process) and commercial constraints (linked to clients) influencing the rhythm of work[7]. These two constraints are horizontal but the first, centred on the equipment, is traditional while the second is more modern and linked to the principle of managing just-in-time production according to downstream criteria[8]. A high level of work intensity may also indicate a preference by the firm, for higher levels of effort, which is another dimension of the new forms of organisation.

The intensity of communication with managers ("vertical"), close work colleagues ("horizontal"), more distant work colleagues ("other departments"), and persons outside the firm ("with outside"), as well as the frequency of meetings ("meetings") and the transmission of information or directives in writing ("paper") all characterise the organisation of the work station from the point of view of its information system.

Indeed, according to the theoretical literature, the new forms of organisation are characterised by a more decentralised information and by a non-hierarchical network system of information processing. From this point of view, innovative work stations are those located at the heart of a dense network of communication involving rich exchanges of information with different persons. Clearly, these characteristics are less innovative for stations associated with a hierarchical position. The frequency of meetings indicates the intensity of another form of communication, more formal and multilateral than that measured by the other indicators. *A priori*, if co-ordination is more decentralised, the costs of co-ordination increase and the probability for an employee of participating in meetings should increase.

[7] This indicator has been proposed by Gollac and Volkoff (1996).

Our last measurement enables us to know if the important information received by the employee is in writing. The latter is an indicator of the formalisation of communication, but also a step of initial codification required for the use of information technologies. We should note that, as with writing, the use of quality standards also generate formalisation, but with respect to the production system. Even though more often associated with bureaucracy than new forms of organisation in the theoretical literature on organisations, empirical work shows that formalisation tends to develop in firms that reorganise their processes.

II.3 Measuring selection criteria

We seek to identify the effects of selection underlying the allocation of technology and the matching between employees and work stations. We distinguish between the variables characterising the employee and those characterising the firm, and within each of these two categories, the variables that may play a role in the formation of social capital (of, respectively, employee and firm). The detail of these variables is presented in Appendix 3.

The employee's personal characteristics

Most personal characteristics of employees contribute to measuring his/her social capital. The literature on social capital gives us information on the role played by gender, nationality, place of residence, age and seniority. It is more difficult for women, foreigners or employees living in a rural area, to take advantage of their social relationships in their professional activities. For example, Burt (1998) shows that women do not benefit from social capital as men in their work, since women face legitimacy problems. The influence of age on social capital is *a priori* indeterminate. Older employees may not accept new forms of communication as easily as younger generations. But the converse is equally conceivable. Finally, seniority, because it is a vector of trust, is a dimension of individual social capital that favours integration and mobilisation of social networks of communication.

To these traditional variables, we add indicators of human capital held by the employee: their age on completing their education[9]. enables us to evaluate the educational level of the employee, and the fact of receiving a general training on the work station is an indicator of human capital specific to the firm. We know that educational degrees are an important determinant in the allocation of computers and that, besides, access to training in firms is very selective. These two variables are thus *a priori* selection criteria that must be investigated. We should add that, according to Coleman (1990), human capital is favourable to the formation of social capital.

The employee's family context gives a measure of his/her social environment, important in that social capital is built up partially outside the firm. Three qualitative indicators relate to the family context. The first identifies the employee's marital status as single, married to an employed person, or married to an unemployed or inactive person. According to us, the fact of being married must be favourable to the employee's capital

[9] A part of the tests we make in Section III consist in verifying the persistence of the effects of selection and complementarity within occupational groups. That leads us to work on samples of reduced size. We thus privilege nomenclatures rich in meaning but economical in the number of categories and continuous variables. This is why we prefer age on completing education to a detailed list of educational degrees.

(in any case for men), contrary to the single status, and social capital should be even greater if the spouse has an important professional situation. The two other indicators enable us to assess the employee's social origins according to his/her father's and mother's professions. On the one hand, if the father holds or held an executive position (as an executive or in middle management), the employee's favourable social origin must be an asset to his/her social capital. On the other hand, having a father in a less-skilled occupation (blue-collar or white-collar), or even who has worked in another sector (craftsman, or farmer), is generally unfavourable to social capital. Finally, the mother's professional situation is described by using two categories: active, or inactive. This variable's influence on the employee's social capital is more ambivalent since the employment activity of women has evolved a great deal during the 20th century. In our sample, an inactive mother is a sign of belonging to well-off social categories, in itself favourable to social capital. But the influence of this variable could have changed for the younger employees in our sample.

Finally, the DADS panel enables us to construct synthetic indicators describing employees' career path for the period 1976-1996. We thus have elements of appreciation for the whole career path of employees answering the C.O.I. Only older employees and those having exercised a part of their professional activity outside the scope of DADS are not covered for the whole of their professional lives. We retain two indicators of career path: number of occupational categories and number of firms in which the employee has worked. The occupational category used is that produced by INSEE from processing the DADS, coded automatically from the post title as supplied by the firm, from the payroll file. When we take changes of firm into account, the number of occupational categories the employee has belonged to, illustrates his/her professional mobility within the firm. This latter is favourable to social capital in that the employee knows and is known by an extended number of other employees in different departments. For a given degree of professional mobility, the number of changes of firm is rather an indicator of instability, destructive of social capital, since the employee is unable to stabilise his/her relationships within the firm.

In our empirical work, we suppose that social capital plays a role when the employee's personal characteristics intervene significantly in the allocation of a modernised work station.

Characteristics of the firm

Four variables describe, in general terms, the productive context in which the firm operates: size, number of hierarchical levels, the technological intensity of its sector, and localisation.

Size is measured by the logarithm of the number of the firm's employees. Since the quantity of information processed by the firm increases with its size, this can play a role in the process of computerising the firm, as in the adoption of innovative forms of organisation for the information system. The number of management levels gives a complementary indication of the complexity of the firm's internal structure. For a given size, new forms of organisation have a flatter pyramid structure, incorporating fewer levels of hierarchy.

Since the beginning of the 1980's, the OECD has been producing classifications of manufacturing industries (outside the F.P.I) according to their technological level. The classification that we use groups the sectors into four categories, low, low median, high

median and high, according to the firms' ratio of R&D expenditure to added value. The firms related to sectors investing a greater part of their resources in R&D, need to renew their products, processes and, in consequence, the design of their work stations more often than other firms.

Finally, a control variable indicates the firm's localisation as rural or urban. The effect of localisation on a firm's use of IT and internal organisation is much debated. On the one hand, these firms ought to have greater needs for remote communication, while on the other they may be less well integrated in the fabric of social relationships that develop more easily in an urban environment. They would thus have a more restricted social capital.

Six variables, constructed from the "firms" section, contribute to describing the reorganisations that have affected firms in the 1990's on the basis of the new organisational and technical practices used. These variables, from two analyses of multiple correspondences, are precisely explained in Gollac, Greenan, Hamon-Cholet (2000) and Greenan and Mairesse (2003). The first variable measures the intensity of recurring to new organisational structures. The three following variables contribute to defining the orientation of organisational changes made by the firm. The first two position it in relation to the model "of industrial excellence" inspired by the Japanese model, the third in relation to the Anglo-Saxon model of "corporate governance". The two variables related to the model of industrial excellence identify any tensions between the practices of just-in-time and the mechanisms of working in groups or teams on the one hand, and the mechanisms of quality management on the other. One variable thus indicates if the firm practices group working that exclude downstream just-in-time, and another identifies the mechanisms of quality with this same property. The variable attached to the "corporate governance" model measures the degree of recourse to mechanisms such as organisation in profit centres, internal client-supplier contracts, outsourcing, and sub-contracting. This variable is called "intensity of the commercial logic". Two other variables describe computerisation of the firm, the first measuring the degree of recourse to ICT, and the second stating if the firm's IT is structured around a large system or even a network of PC's.

The intensity of organisational changes and computerisation enables us above all to characterise the magnitude of the transformations that have taken place within the firm. Among the different orientations of possible organisational changes, orientation towards work in groups, in underlining the work's collective character, should be linked to activation by the firm of a denser network of social relationships. *A contrario*, strength of the commercial logic, which induces competition between employees, may lead to a less rich network of social interaction and hence weaken its intra-organisational social capital. Finally, the network architecture of the IT system, in diversifying the connections between work stations, should be more favourable to social capital than a structure around a large system.

Organisational demography is equally an important dimension of the productive context. The DADS file, survey base for the "employees" section of C.O.I, enables us to measure the diversity in the firm's work force as a function of four criteria: occupational category, gender, nationality and age. For each of these criteria, we have constructed an index of diversity D measuring the probability of two observations, taken at random in the population, belonging to different categories. This indicator varies between 0 and 1, the two extreme values corresponding respectively to a situation of perfect homogeneity (0) and to a situation of maximum mix (1).

We measure the diversity of occupational categories (executive, employee, middle management, skilled or unskilled blue-collar), gender (man or woman), nationality (French or foreign) and ages (less than 26 years, 26-30 years, 30-38 years, 38-50 years, 50 years and over). The occupational category used comes from the designation in the payroll file, as does that used for measuring the employee's career path.

These indicators pick up certain characteristics of the productive context. In this way, as our work is set in the industry, the firms principally in a production activity will have a workforce that is essentially working class, that will appear to be more homogeneous than for a firm also having a tertiary activity like sales, administration, or even design.

From the social capital point of view, indicators of diversity in the workforce enable us to examine two hypotheses debated in this literature.

According to Bourdieu (1980) and Coleman (1990), closed social networks with strong social proximity between individuals favour the development of social capital, since information flows better and trust is higher. In this way, employees close to each other in terms of identity characteristics, communicate more easily and stick more closely together. In this perspective, homogeneity of employees within the same firm may thus influence the extent and nature of the social relationships built up there and hence favours the development of social capital. Conversely, firms in which networks of social interaction extend and become stronger as a result of decentralisation may seek a more homogeneous workforce in order to facilitate the development of their social capital. Reorganisations can in this way be a source of greater segregation of the workforce according to types[10]. On the contrary, according to Burt (1992), the social capital is larger for the individuals who know how to build bridges between the different communities. Indeed, communication is more efficient in this case because each individual obtains non-redundant information. The interaction of heterogeneous employees may then favour the development of social capital. In this perspective, reorganisations can favour the integration of heterogeneous employees. These two views of social capital[11] may be associated in the modernisation of firms. On the one hand, the homogeneousness of employees creates the cohesion and collective action facilitating the acceptance of change. On the other, the diversity of employees stimulates creativity that is favourable to innovation.

Clearly, the criteria that we measure are sparse. We seek to know, for example, the educational diversity of the workforce, or the diversity in family and/or geographical origins. If we have some of this information available for employees answering the C.O.I, it is not available for the whole of the firm's workforce.

[10] In this paper, we do not test this hypothesis because we do not have information on the evolution of homogeneity in the work force.

[11] Godechot and Mariot (2003) show how these two forms of social capital correspond to two modes of organising competition; "on the one hand, the search for individual advantages within a given group and, on the other, the collective mobilisation of this group in the competition against other groups". They measure social capital according to the network mobilised during the constitution of the jury and characterise the degree of interconnection between the thesis supervisor and the other members of the jury invited to the thesis defence. The cohesion of the links between researchers within a given university favours "local" behaviour in internal recruitment of doctoral students, that we may interpret as a segregation of doctoral students according to their university of origin. However, diversity of links favours the placements of these latter in other universities.

II.4 The empirical method

At the end of Section I, we state our central hypothesis in the following way: the relationships of complementarities, identified at the level of the firm, between IT equipment and innovative forms of work organisation, would result partly from common principles of selection by the "social capital", particularly, in the allocation of computers and matching between "modern" work stations and employees. This may be broken down into four propositions, illustrated by Figure 1.

Complementarity 1 : ICT are linked to innovative organisational characteristics of work stations resulting from the spread of new organisational forms.

Selection 1: As a function of their social capital, employees are allocated with ICT and/or offered work stations with innovative organisational characteristics.

Selection 2: This principle of selection by social capital is specific to ICT and not observed for other technologies.

Complementarity 2: The links of complementarity that we can measure on the work station, between ICT use and innovative organisational characteristics, are explained partly by this principle of common selection by social capital.

To test Selection 1 empirically, we explain the technological and organisational characteristics of work stations according to the set of selection variables we have identified, and verify if the variables we think to be correlated to social capital, work in the way we expect. We test Selection 2 by confronting the results obtained for IT use with those obtained for the use of automated machines.

To test Complementarity 1, we correlate[12] the variables describing the use of technologies with those describing innovative work station characteristics. To test Complementarity 2, we use two different methods aiming to check the effects of selection on the measurement of complementarity.

We conduct these tests on an overall sample of employees (4,067 individuals), on sub-samples of executives (529), white-collars (325), middle management (1,021), skilled blue-collars (1,478), and unskilled blue-collars (714), and on the sub-sample of "direct" employees grouping together middle management and blue-collars (3,213). The skill variable we use for dividing up employees in this way, is not the same as that produced by DADS. It is the result of manual coding carried out by the INSEE network of surveyors on the basis of the job title given by the employee in the C.O.I survey. This is therefore the perception that the employee has of his/her professional activity that determines its skill and not, as in the case of the DADS variable, the view built by the firm's human resources department that is partly linked to methods of fixing wages.

Empirical work on the wage premium linked to computers, shows that skill is a central determinant of employees' equipment. Besides, work station characteristics are also contingent on the skill exercised by the employee. In carrying out our estimations within occupational categories, we seek to verify if the mechanisms in operation are comparable from one category to another; do we observe the same effects of selection in

[12] Several methods allow testing of the complementarity between two factors. The approach by correlations is one of the methods possible. We justify this choice in Section IV.

the allocation of a computer to an executive as to a workman? Do we observe relationships of complementarity of same nature between IT use and organisational characteristics of work stations?

III Identifying the effects of selection

III.1 The models used

N is the overall number of employees in the sample considered (i= 1, 2, …N); Yi is a technological or organisational characteristic of the work station for which we analyse the distribution; $x_{1i},\ldots, x_{p-1,i}$, are the p-1 criteria of selection envisaged; $b_{1i}, \ldots b_{pi}$, are the p parameters for estimation; and u_i is a random error factor which contains the set of the determinants of Y_i that do not figure in the list of explanatory variables, the model that we are going to estimate is expressed as:

$$Yi= b_{1i}\, x_{1i} + b_{2i}\, x_{2i} +\ldots+ b_{(p-1)i}\, x_{ki} + b_p + u_i$$

We define the matrix containing N observations of p explanatory variables, noted as $\underset{(N,k)}{SELECT} = \left[\underset{(N,1)}{x_1} \quad \underset{(N,1)}{x_2} \quad \ldots \quad \underset{(N,1)}{x_{p-1}} \quad e_N \right]$. This model may then be written in the following matrix form:

$$\underset{(N,1)}{Y} = \underset{(N,p)}{SELECT} . \underset{(p,1)}{b} + \underset{(N,1)}{u}$$

All the continuous independent variables that we use in the estimations have been standardised. These include the firm's size, the number of management levels, the intensity of the change in organisation, the strength of the commercial logic, and degree of computerisation, the four indicators of workforce diversity, age, seniority, age on completing education, the number of professions exercised and the number of firms in each individual's career path. The coefficients associated with these variables thus measure the effect of a difference in a standard deviation, in relation to the mean calculated for the total sample. To the other variables, of a qualitative type, the mode has been chosen as the reference category. We thus position ourselves at the mean point in the overall sample of employees, and keep this same mean point for all our regressions, whatever the sub-sample used (Table A32 in Appendix 3).

The dependent variables Y examined, are successively for technology, then for work-organisation. The majority of these variables are dichotomous Y_i=0 or 1 such as, for example, "using a computer". Variables of this type are in general modelled according to a continuous latent variable (Y_i* such that Y_i* > 0 if Y_i=1), which leads to non-linear logit or probit estimations. Our regressions are simpler because they are linear. Even if logistic regression is more satisfactory for giving an account of a dichotomous variable, the results obtained by a linear regression at the mean point of the sample are not very different (Lesne and Mairesse, 2001). We thus realise a linear approximation of the model of logistic regression at the mean point of the overall sample of employees[13]. The only continuous dependent variables are NBOI, NBMO, as well as the durations of computer and automated machine use. We have also standardised these.

[13] We have verified that the residuals of the model were between [0,1]

In Table 1, we study the determinants of IT use, accumulation of technologies (NBOI), and duration of IT use representing different facets of work-station computerisation. Then we study the determinants of machine or automated installation use, diversity of functions used on machines (NBMO), and duration of machine use. In Table 2, we concentrate on the fact of using a computer or automated machine, and analyse its determinants within five occupational categories (executives, white-collars, middle management, skilled, and unskilled blue-collars) and within 3 automated-machine categories of manpower (middle management, skilled, and unskilled blue-collars). The twelve work organisation variables are subsequently considered successively, as dependent variables (Y). The results of these regressions are shown in Table 3. In order to avoid overloading the presentation, the regressions of different organisational variables for the different sub-samples of occupational groups are not included[14].

III.2 IT and automated machines are not allocated according to the same rules.

The estimations shown in the Table 1 show that IT and automated machines are not allocated according to the same rules, to stable employees of industrial firms with more than 50 employees.

IT and automated machines: a contrasting relationship with skills

The first central difference concerns the role of occupational category. If executives do not constitute the occupational group that uses IT the most often or the longest, they do accumulate the most ICT. At the opposite extreme, unqualified blue-collars represent the category that uses IT the least. Thus, with the exception of white-collars, the allocation of IT seems to follow the line drawn by the hierarchical division of labour. The categories making a more intensive use of IT and more widely of ICT, have the most senior positions in the hierarchy of occupations. This result is confirmed by the regressions for each occupational group (Table 2). Indeed, the constants of the models indicate that, when we situate ourselves at the mean point in the overall sample of employees, the probability of an executive using IT is 0.87, and amounts respectively to 0.75 for white-collars, 0.71 for middle management and only 0.33 for blue-collars. In the case of white-collars, such frequent use of IT is accompanied by a longer daily usage that is greater than that of other categories of manpower (Column 4 in Table 1), a sign of a different type of IT use that it probably more routine and/or Taylorised.

For automated machines in the sample of direct employees (blue-collars and middle management), this logic of distribution according to skills is reversed. Unqualified blue-collars are the most frequently equipped, followed by skilled blue-collars, then by middle management. At the mean point in the global sample of employees, the probability of an unskilled workman using an automated machine rises to 0.57, to 0.45 for a skilled workman and only 0.23 for someone in a middle management position (Table 2). Qualified and unqualified blue-collars do not stand out for duration of automated-machine use, but middle management works less time on them, and it is the employees with weaker skills that make the most complex use of this category of equipment.

14 Indeed, that would lead to presenting the results of 60 supplementary regressions. These are nevertheless available on demand, from the authors.

Machines are allocated to a work station, computers to a person

Let us examine the role of employees' personal characteristics in the allocation of technology. IT and automated machines have two determinants in common: age and the fact of having received training specific in looking after the work station. The first effect is negative. Older employees use the computer and automated machine less often and for a shorter time. They also make less advanced use of IT. The second effect is positive. Employees to whom their firm has given special training for their main task, also use technical tools more often and in a more advanced way (Table 1). In the case of direct employees (middle management and blue-collars) the direct effect of the training is greater for IT than for automated machines (Table 2).

Gender is another important criterion for use of technical tools, but its effect varies according to the type of tool. In the global sample of employees, we observe that women use automated machines less often and in a less advanced way. For IT, *a contrario*, gender only interacts positively on the duration of use, women's use of IT being more routine than men's (Table 1). To observe the impact of gender on the probability of using a computer, we must look at occupational categories (Table 2). As for automated machines, female blue-collars in fact use IT less often than their male counterparts. However, when women hold executive, white-collar or middle management positions, they are more likely than men to use IT.

IT reacts more than automated machines to the other personal characteristics of employees. Hence, we conclude that computers are allocated more to persons, while automated machines are allocated to work stations independently of the personal characteristics of the individuals occupying them. In this way, seniority, skills, social origin, place of residence and career path influence computer use much more than for automated machines. A typical "computerised" employee has a skill and seniority, his/her father is an executive or in a middle management post, he/she lives in an urban area and is on an ascending career path within the firm. All together, he/she is an employee well endowed in social capital.

Machine use is not linked to personal criteria of this type. However, among the users of automated machines, certain personal characteristics may help discriminate between long use and short use. The operators of automated machines with the greatest duration of use have fewer diplomas, live more often in a rural area and have professional trajectories that are more precarious. They thus contrast with IT users in their endowment in social capital.

Different productive contexts

The firm's general characteristics differentiate equally between use of IT and automated machines (Table 1).

Automated machines are more often used in low technology-intensive sectors, albeit in firms that tend to be located in an urban environment. In terms of organisational characteristics, firms with automated installations have less recourse to "corporate governance" measures such as profit centres, internal client-supplier contracts, outsourcing, or sub-contracting. This confirms a result obtained by Greenan and Mairesse (2003) from other data in the survey, and translates the fact that firms strongly motivated by commercial logic tend to "export" industrial constraints to their sub-contractors and suppliers. We observe also that the incidence of new organisational

measures here favours more complex uses of automated machines. Finally, automated machines are used more often in firms with a workforce that is more homogeneous in terms of occupational categories, with a large proportion of blue-collars even though mixed from the point of view of gender[15]. The homogeneity of occupational categories could indicate that firms whose employees use automated machines, depend on collectives structured around a small number of skills.

On the other hand, IT use is more frequent in medium/high technology-intensive sectors, and in firms located in rural areas. The intensity of organisational change reinforces the distribution of computers but reduces the duration of their use. Unsurprisingly, the intensity of computerisation in the firm favours the use and accumulation of ICT, as well as duration of use. This also goes for the diversity of occupational categories and homogeneity of ages within firms. The most advanced uses of technology occur in large firms and, for any given size, in firms with fewer levels of management and a change in organisation oriented towards group work rather than just-in-time. Thus, firms whose employees work with IT seem more decentralised. Diversity of occupational categories implies a certain heterogeneity of the workforce favourable to creativity and innovation, while homogeneity of ages may facilitate networks of exchanges around the technical tool, that play a central role in learning a technology like IT (Gollac (1996)).

What happens now when we place ourselves within the different occupational categories? Do we find the same criteria of selection in terms of productive context? Or do we observe any differences from one category to another? Globally, we don't see any marked contrast in the logic of selection between the occupational categories except for executives (Table 2). The computerisation of executives is more frequent in high-technology sectors, when computerisation of firms is structured around a large system and the workforce is homogeneous in terms of occupational categories but heterogeneous in terms of age and nationality. Finally, diversity of nationality does not appear to be significant in the global sample because its influence is variable from one profession to another. It favours IT equipment for indirect employees (executives as well as white-collars) and penalizes IT for blue-collars, while favouring the equipment of middle management in automated machines.

Overall, the variables that appear to favour the development of social capital, are important determinants of IT equipment for work stations, as suggested by the proposition Selection 1. This principle of selection does not seem to operate in the allocation of automated machines that depends more closely on work-station characteristics rather than personal characteristics, which supports the proposition Selection 2.

III.3 Work organisation and IT: a common logic in selective diffusion

We now examine the determinants of innovative organisational characteristics in work stations, by comparing these results with those concerning the allocation of computers. More precisely, we attempt to verify the hypothesis of Selection 1, according to which the diffusion of IT and new forms of work organisation would operate in a similar way.

[15] This result is surprising because we expected to find homogeneity of gender. It would be desirable to examine things more finely in order to understand what is happening and particularly to evaluate these situations of mix according to the sector the firm belongs to, and activity.

The results from models estimating the effects of selection on employees' work organisation are shown in Table 3. In the columns, the variables explained may be related to organisation of the firm's production and information systems, while the independent variables are indicated in the rows.

We begin by identifying two innovative configurations in work-station organisation: the executive and the production-worker models (Greenan, Hamon-Cholet and Walkowiak (2003)). Then we analyse the factors affecting the diffusion of each of these models.

The executive and production- worker models

Exactly like for IT, the employee's occupational category is a structuring criterion for the organisational characteristics of his/her work station. We observe that the innovative organisational characteristics, measured in the survey, appear associated to either executive positions, or production skills. Thus, we extract two innovative work-station "configurations", the models for the executive and the production-worker. The organisational characteristics attached to each model have determinants in common.

The higher the employee's position in the vertical division of labour, the greater his/her autonomy, management responsibilities, range in communication (with other departments or persons external to the firm), as well as the number and frequency of meetings. We may thus say that these identify a relationship with work based on the executive model. One trend in the evolution of work is thus the spread of this executive model to all the other professions.

On the other hand, following quality standards, working in groups or teams, communicating with colleagues and receiving instructions in writing are innovative features of direct production skills. The spread of the production-worker model constitutes a second trend in the evolution of work.

Two models closely linked to the personal characteristics of employees …

The innovative organisational characteristics of work stations react very strongly to the personal characteristics of employees.

First of all, the executive and production-worker models have a set of determinants in common. The typical employee in a work station with innovative organisational characteristics has been trained by the firm for performing his/her main task. This is a married man of French nationality, and there is little chance of his father having exercised the activity of farmer or craftsman.

Gender and nationality are criteria traditionally examined in studies on recruitment discrimination. It is striking to observe here that women and foreigners are also excluded from the more advanced forms of work. Women are less autonomous, have fewer management responsibilities, train new employees less often, work to quality standards less often, work less often in groups, have a less intensive job, communicate less frequently with close or distant colleagues as well as the outside, participate less often in meetings, and receive less information in writing than men. Foreign employees are less autonomous, have fewer management responsibilities, work to quality standards less often, and participate in meetings less often than employees of French nationality.

It is a common idea that new forms of organisation bring a more "feminine" relationship with work; i.e., the importance of managing interpersonal relationships, communication, and less room for authority in the face of collective dynamics (Lindbeck (1999). If this were so, these new forms of organisation would offer new professional opportunities to women. We observe that this is far from being the case, in any event within the stable workforce of firms with more than 50 employees in manufacturing industry, where women are excluded from work stations with innovative organisational characteristics. This could be explained by women's lower value in terms of social capital in the professional domain as demonstrated by Burt (1998). Their skills in the domain of maintaining social links is not made use of, or legitimised in professional life where maintaining networks appears above all to be a matter for men.

The executive and production-worker models also have their own determinants: level of skills, and an ascending career path are more favourable to the executive model, while seniority, age and a stable career path in the firm favour the production-worker model. Both these sets of determinants are linked to the employee's endowment in social capital, but the endowment's source is different, external to the firm and more linked to profession for the executive model, but internal to the firm and linked to professional stability for the production-worker model. The first form of accumulation in social capital may be associated with Burt's definition (1992) while the second is closer to that by Bourdieu (1980) or Coleman (1990). In the first case, employees accumulate social capital by making a bridge between several communities not otherwise interconnected while, in the second, they count more on the solidarity that exists within their community of membership.

Overall, the place of the employee's personal characteristics in the allocation of a work station with innovative organisational characteristics, as well as the role of his/her endowment in social capital, bring closer together the logic of selection underlying the organisation and that influencing the allocation of computers. This supports the proposition Selection 1. These results persist within the occupational categories.

… and specific to contexts of innovative work

If we consider the firm's characteristics, an initial result stands out clearly: the work-station organisational characteristics measured are for the most part positively linked to firm using new organisational structures. We selected these characteristics, referring to recent theoretical literature on the choice of organisation by firms. Thisresult tends to support the idea that these characteristics are highly innovative. The other variables of reorganisation in firms interact little with the organisational characteristics of work stations. Nonetheless, we note that recourse to organisational "corporate governance" principles has a negative correlation with following quality standards and meeting frequency, while the extent of computerisation in the firm is associated with more intensive internal communication and more developed use of written communication.

The executive and production-worker models are less frequent in some sectors, but not in the same sectors. The executive's work characteristics do not extend to other professions in high technology-intensive sectors, while the renewed production-worker model occurs infrequently in low technology-intensive sectors, marked by direct supervision and intensification of work.

Finally, we observe that organisational characteristics associated with the executive model are positively linked to diversity of occupational categories and age homogeneity

within the firm, while the production-worker model is associated with workforce homogeneity, be this in terms of occupational category, gender, nationality, or age. This is particularly marked for the intensity of communication between close colleagues. This result echoes two forms of social-capital accumulation, identified for employees attached to the executive and production-worker models. The heterogeneity of occupational categories and homogeneity of ages, within firms where employees work according to the "executive model", favour the development of bridges between communities not otherwise interconnected, while homogeneity of the workforce, where employees work according to the "production-worker model", favours group cohesion.

If we now confront the determinants of "firm" level technology use and innovative organisational work-station characteristics, we observe similarities between the executive model and computer use in the role played by organisational changes, diversity of occupational categories, and homogeneity of ages. The similarity is less marked between the production-worker model and automated machine use, but the homogeneity of occupational categories contributes to the spread of these two work-station characteristics.

IV Relationship of complementarity or common principles of selection?

IV.1 Three measures of complementarity

In the literature, two different methods are implemented for measuring productive complementarities in data from individual firms. First, the "CORR" approach, consists of verifying whether a positive correlation exists between computerisation variables, on the one hand, and variables describing organisational practices, on the other, conditional on a certain number of observable variables. Second, the "PROD" approach consists of estimating, as a function of production, the parameters associated with the terms of interaction between technological and organisational variables. Athey and Stern (1998) show, while working on different error configurations in the measurement of variables, that neither of these two approaches is entirely satisfactory and that they only measure "presumptions" of complementarity.

Our approach is original in that we do not work directly on data of firms but rather on data of employees. This being the case, our question is not so much about the co-ordination of technological and organisational choices at the level of the entire firm, but rather about the co-ordination of these choices in the design of work stations. At this finer level, the information gathered is more objective and of better quality, enabling us to set aside fallacious sources of correlation like the desire that managers of firms may have to display a certain "modernity" in their choices. The control variables we have are many, and the problem of "social capital" leads us to extend the list traditionally used for explaining the characteristics of work stations.

Formally, we note our measures of technology as $TECH_j$, with j designating successively the use of IT by the employee, and the use of an automated machine. We note our indicators of organisation as ORG_z, z indexing each of the twelve dimensions in work organisation. Our first measurement of complementarity is simply the coefficient of linear correlation $\rho(TECH_j, ORG_z)$, which enables us to test the proposition Complementarity 1.

The two other measurements we use are conditional on criteria of selection that we have identified. They contribute to controlling the possible effects of social capital in the allocation of a computer and organisational design of the work station, and thus to testing the proposition Complementarity 2.

An initial way of controlling the effects of selection in IT use and work organisation, consists of using the residues from models estimated in Section III.1, such as the balanced indicators of the effects of selection and, especially, the effect of social capital that we measured indirectly according to certain characteristics of the firm and employee. We subsequently calculate the coefficient of linear correlation of these residual indicators, that we note as $\rho'(\hat{u}_{TECH_j}, \hat{u}_{ORG\,z})$.

The second is based on a model of selective matching. Stemming from work by Rubin (1974), these models were originally used for investigating the effectiveness of medical treatments on non-experimental samples. These methods have subsequently been applied in economics (see Appendix 4). For example, Duguet (2003) uses a model of selective matching for analysing the effects of research tax credits[16]. In our estimations, the fact of using a computer may be compared with that of following a medical treatment. The organisational characteristics of the work station are, in turn, comparable with performance indicators of treatment. To avoid any selection bias, we do selective matching, which amounts to building, from the population of employees not equipped in IT, a twin population of users; i.e., undergoing the same effects of selection. As matching criteria, we use the selection criteria listed in the preceding Part. Table 4 presents the results of these estimations.

IV.2 IT and work organisation: relationship of complementarity

In each cell in Table 4, the first line gives the correlation between the "primary variables" of work organisation and technology use, the second gives the correlation between the "residual" variables and the third, the kernel estimator of the selective matching model. This last coefficient is read as the difference in the frequency of occurrence of a given organisational characteristic between users of IT and their non-user opposite numbers. Its level may thus not be compared with the correlations.

These estimations are made on the global sample of employees, the sub-sample of direct employees and the sub-samples of executives, white-collars, middle management, skilled and unskilled blue-collars. For automated machine use, only direct-employee sub-samples are considered (middle management, skilled blue-collars and unskilled blue-collars).

We begin by identifying the links between organisation and IT, seeking to zero in on the specifics of IT as compared with automated machines. We then verify if the complementarity between IT and work organisation occurs for all the sub-samples considered.

[16] We thank Emmanuel Duguet for having put his programmes so willingly at our disposition. Written under SAS IML, these programmes calculate the kernel estimators proposed by Heckman, Ichimura and Todd (1998).

IT – a privileged tool for enriching working methods and communication

Correlations between IT use and work-station organisational characteristics are always positive[17]. Use of IT goes hand in hand with more autonomy, indirect tasks and communication, which indicates an enriching of the work of IT users. The idea according to which digitizing, consisting of encoding production plans in IT programmes, enables senior managers to transfer conceptual work to programmers and engineers, and limit the tasks of operators to manipulation of data and machines, is thus rejected by the evidence. On first analysis, the proposition Complementarity 1 thus seems well verified, the ICT being positively linked to innovative work-station characteristics resulting from the spread of new organisational forms.

Does IT represent a break, as compared with automated machines? En 1974, Braverman upheld the argument, widely debated in work sociology, whereby the automation of machines tended to confine skilled workers to semi- or unskilled work while developing a need for managers and professionals to choose the projects and supervise the work. This was not the most widespread form of use in 1997 for stable employees in industrial firms. Like IT, the use of automated machines has a positive correlation with variables measuring work enrichment. We note however that the use of an automated machine is negatively linked to the autonomy of middle management and that, in the sub-sample of direct employees, it is negatively correlated to communication with other departments and the outside, and to meeting frequency. These last results are, however, fragile as they are no longer observed within the occupational categories, or when we use the kernel estimator of the selective matching model. Deskilling of the workforce seems linked to exclusion from the use of IT and automated machines, rather than to their use.

Innovative work-station characteristics react more frequently to the use of IT than to that of an automated machine. For example, with skilled blue-collars, the use of IT reinforces all the twelve organisational characteristics retained, while the use of an automated machine affects only eight. Moreover, IT is distributed throughout all the categories in workforce, while automated machines have not penetrated the world of white-collars and executives in industry. IT is thus the privileged tool for transforming the work organisation.

IT differs from automated machines mainly in its effect on the variables of communication. While the use of an automated machine reinforces the intensity of horizontal and vertical communication only for direct production employees, IT affects all forms of communication for middle management and blue-collars, with the exception of vertical and horizontal communications for unskilled blue-collars.

IT affects the activity of blue-collars more than executives

We observe that the links between IT and work organisation depend greatly on the occupational group considered. The correlations between the use of IT and work organisation, obtained in the global sample of employees, only apply in a limited way to the work of executives and white-collars. For executives, IT favours the training of new personnel in looking after their work stations, group work, horizontal communication, and the frequency of meetings although these effects are no longer significant once we mobilise the kernel estimators of selective matching models. The role played by

[17] We observe a small exception: intermediate management occupies an executive position less often when using IT, but this result is not maintained as soon as we introduce control variables.

executives in the work organisation is somewhat independent of their use of IT. On this basis, IT becomes simpler to implement for executives than in the professions where IT correlates with work organisation. This may help explain why this technology spreads best among executives. The organisational characteristics of work stations respond more to IT use for white-collars than for executives. But some of the effects observed lose their significance as soon as we introduce control variables (work intensification, communication with other departments, meetings, use of written communication) while others appear only with the method of kernel estimators (being autonomous, a manager and communicating with his/her superior).

The links between IT use and organisational characteristics of the work station are more extensive and persistent with direct employees, and especially with blue-collars. From the moment they use IT, they become more autonomous, take on greater management responsibility, perform more indirect tasks like training new employees or following quality standards, and communicate more and in very diverse forms.

Concerning the production process, there does not seem to be any substitution of the logic of horizontal co-ordination for that of vertical co-ordination, associated with the use of technology (IT or automated machine), but, on the contrary, a simultaneous reinforcement of these two logics. In fact, if blue-collars using IT are more autonomous (horizontal co-ordination) than non-users, they also have more management responsibilities (vertical co-ordination). In the same way, middle management and blue-collars using automated machines are more often managers and work more often in groups than non-users. Nevertheless, increasing the hierarchical logic follows a very different line, depending on whether the employee uses IT or an automated machine. The correlation between management responsibilities and automated machine use is stronger for middle management than for skilled blue-collars, but not significant for unskilled blue-collars. In other words, the increase in responsibilities associated with the use of an automated machine respects the hierarchy of skills. With IT, it is blue-collars (skilled and unskilled) rather than middle management that have more management responsibilities.

Concerning the information system, once we accept that the effort of communication is the same, whatever the type of communication (vertical, horizontal, with other departments, or with the exterior), we may attempt to organise into a hierarchy, the magnitude of transformations in modes of communication induced by IT for skilled blue-collars. The intensity of communication with the exterior is most affected by IT, followed by communication with other departments, then by horizontal communication. In other words, for skilled blue-collars, IT reinforces the intensity of communication proportionately more when it concerns relationships between persons who are distant.

When we examine the simple correlations between IT use and organisational characteristics of the work station for unskilled blue-collars, we observe effects of the same nature and magnitude as for skilled blue-collars, with four exceptions. First of all, IT does not reinforce the communication of unskilled blue-collars with their manager or between close colleagues, whereas this link is significant for skilled blue-collars. Furthermore, the link that IT maintains to communication with other departments and use of written communication, is distinctly more marked with skilled than unskilled blue-collars. We observe also that the relationships examined are a lot more sensitive to control variables with unskilled than with skilled blue-collars.

IT interacts with the work of middle management more distinctly than for executives, but less so than for skilled blue-collars. In this occupational category, variables relative

to the system of production hardly react at all to IT use. Hence, only those variables relative to the information system exhibit these effects. If the latter are comparable to those observed for skilled blue-collars, they are also more sensitive to control variables, like for unskilled blue-collars.

In a certain way, IT leads the work stations of blue-collars to "catch up" the work stations of other professional categories, particularly those of executives and middle management in terms of their organisational characteristics[18]. In other words, blue-collars using IT are led to develop a relationship with their work until then restricted to positions with management responsibility, and/or to adapt to an enrichment of their work in production. In this way, the spread of IT contributes to blurring the frontiers between the occupational categories. Finally, we observe that IT transforms even more when the work is less skilled.

IV.3 Two facets of complementarity between IT and organisation

The comparison of estimations without control variables (correlation between the primary variables) with controlled estimations (correlations between the residual variables and kernel estimators of selective matching models), enables us to appreciate the impact of the effects of selection on the links maintained by IT and work organisation.

This comparison aims to isolate two components of complementarity between IT and organisation. The first is only defined in the space of work stations. It represents the "technological" complementarity that would come from a function of organisational design (Milgrom and Roberts (1990)) that only integrates two arguments: the choices of work-station organisation and technical equipment. The second component of the complementarity is measured in the space of work-station occupants. It isolates, in the complementarity between IT and organisation, what comes from the common principles in the selection of employees whose work station is modernised.

If we compare the correlations between primary variables with correlations between residual variables, we observe that the introduction of control variables expressing the effects of selection, affects the estimated coefficients quasi- systematically.

The estimated correlations may not be compared in level with the kernel estimators of selective matching models. However, the significance of results can be. We will successively envisage the cases where the links recorded remain stable or are reinforced, as opposed to the cases where they disappear or are attenuated.

The direct effect of the technology

When the effect of technology is reinforced or remains stable once control variables are taken into account, we may conclude as to it's having a direct effect.

We observe, first of all, much greater stability in coefficients estimated for using an automated machine than for using IT. Being in charge of training new workers is , following quality standards, working in groups and communicating with their manager,

[18] To have an order of magnitude of the distribution of organisational characteristics of work stations within the occupational categories, see Table A2 of Appendix 2.

is more frequent when employees use an automated machine. In the preceding section, we have shown that automated machines are allocated to work stations rather than individuals. Our results complement this observation by showing the structuring character of automated machines use on work-station organisation. The links between automated machine use and organisational characteristics of the work station thus reflect "technological" complementarity.

IT occurs, however, in a quite different configuration. The estimated coefficients are for the most part sensitive to controls. One single relationship seems stable when we take the effects of selection into account, that linking IT use to intensification of the work. This result confirms observations made on the basis of other sources by Gollac and Volkoff (1996) and by Askenazy and Gianella (2000). The intensification of work appears as a direct effect of using IT for middle management, skilled blue-collars and unskilled blue-collars. This result echoes the report according to which work under industrial and commercial constraints is little dependent on identified selection variables, particularly in the case of occupational category. It is common to all the skills and professions. It is simply a little more frequent in low technology-intensive sectors, within firms characterised by intensive organisational changes and along the professional trajectories of young men who have already changed employers several times. We note however that the work under double constraints associated with IT spares the executives and white-collars, as it is an organisational characteristic of computerised direct-production stations. We should note finally that intensification marks the use of IT more strongly than automated machines, the latter being complementary to work under double constraints only for unskilled blue-collars.

When measured complementarity comes from common principles of selection

On the other hand, when the effect of technology on work organisation is alleviated or disappears, we conclude as to a complementarity reflecting the common principles of selecting employees with modernised work stations. This complementarity finds its origin in social interaction rather than in the properties of the technology.

Organisational characteristics where the link with IT use is the most sensitive to the introduction of control variables include: work in groups, and the set of variables relative to the information system. All these variables directly reference the employee's communication. In this way, the organisational characteristics involving exchanges of information between employees, are more subject to the effects of selection. In other words, the correlations that we have identified between IT use and these organisational characteristics, should not be interpreted as a direct effect of the technology but rather as a reflection of the similarity of the effects of selection in operation in the allocation of computers and work stations with innovative characteristics.

In a large number of cases, the persistence of correlations and the significance of the kernel estimator nevertheless bear witness to the existence of an alleviated complementarity in relation to our first estimation based on correlation between primary variables. The variables for which complementarity persists may be organised into a hierarchy according to the strength of the effects of selection. On the global sample and for variables relative to the information system, it is remote communication (with the outside, then with other departments) followed by the frequency of meetings that are most sensitive to the effects of selection. For variables relative to the production system, variables complementary to the use of IT, that are the most sensitive to the effects of selection are autonomy, followed by management responsibilities.

Finally, we observe that sensitivity to the effects of selection is not uniform from one occupational category to another. For the least skilled employees, blue-collars, but above all unskilled blue-collars, positive correlations between IT use and innovative organisational characteristics tend to disappear as soon as we introduce control variables. Within these professions, IT has only a few direct effects. For white-collars, none of the five positive correlations initially identified persist, as soon as we introduce control variables[19] while, for unskilled blue-collars, out of ten significant correlations, only three remain once we apply the controls.

Conclusion

Compared to automated machines, IT is special for two reasons. On the one hand, computers are allocated in function of the personal characteristics of the employees who use them, while automated machines are allocated to work stations. Employees' social capital thus plays an essential role in accessing IT tools. On the other hand, IT use is positively correlated to organisational characteristics specific to the "executive model" (autonomy, management responsibilities, remote communication and participating in meetings) as well as to the innovative features of direct production skills (quality standards, group working, communication with colleagues, use of written communication) while the use of automatic machines is correlated only with the second group of variables. By the magnitude of these links measured in a representative sample of stable employees of industrial firms with more than 50 employees, IT appears as a tool that contributes strongly to changes in the work. This result may be interpreted as bearing witness to a strong complementarity between IT use and innovative organisational characteristics of the work station.

We verify however that variables which appear favourable to the social capital of employees are also important determinants of innovative organisational characteristics in work stations. This being the case, the correlation between technology and work organisation reflects the principles of selection at work in the allocation of computers and work stations with innovative characteristics as much as the properties intrinsic to the technology.

Insofar as the links between IT and work organisation are concerned, interpretation in terms of "technological" complementarity predominates only in one single case: the intensification of work. For all the professions with the exception of executives, work under double commercial and industrial constraints accompanies computerisation of the work station, whatever the productive environment and the personal characteristics of the employee. Beyond technological complementarity, it is the link between productive and social interactions that guides the association between IT use and innovative organisational characteristics of the work station. However, the effects observed in the case of automated machines are, for the most part, direct effects of the technology.

For all the variables involving a relational dimension (group working, remote communication, meetings, and written communication), correlation with the use of IT reflects the common principles of selection clearly.

[19] Employees are the only occupational category for which the kernel estimator reveals complementarities not identified by the correlations between primary variables: they associate the use of IT with autonomy and management responsibilities.

Finally, the effect of IT on work organisation is not homogeneous within occupational categories. The role played by executives in work organisation is independent of their use of IT, while the activity of blue-collars is drastically changed by use of IT. Transformation of the work induced by IT appears thus all the stronger when the workforce has few skills. But we observe also that the less the workforce is qualified, all the more the common principles of selection play a central role in the correlation between IT use and innovative characteristics of work stations.

What are the possible consequences of the selection mechanisms that we have observed in the access to modernised work stations? These work posts offer more professional opportunities than others. The employees who have access to them therefore have a higher probability of having an ascending professional evolution. They, thus, not only contribute to explain the growing inequality linked to difference in skills but could also play a role in the increase in "residual" inequality (Lemieux, 2003), observed within same skills, and in the persistence of inequalities linked to gender, age or nationality. These mechanisms could also generate a preference by firms for the renewal of their workforce rather than to train it: the level of skill of an employee can be changed by providing training, but it is more difficult to change his personal characteristics. Finally, these phenomenon introduce a certain inertia within firms: social interactions change slowly and are sensitive to the quality of social climate.

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Figure 1 : summary of tests carried out

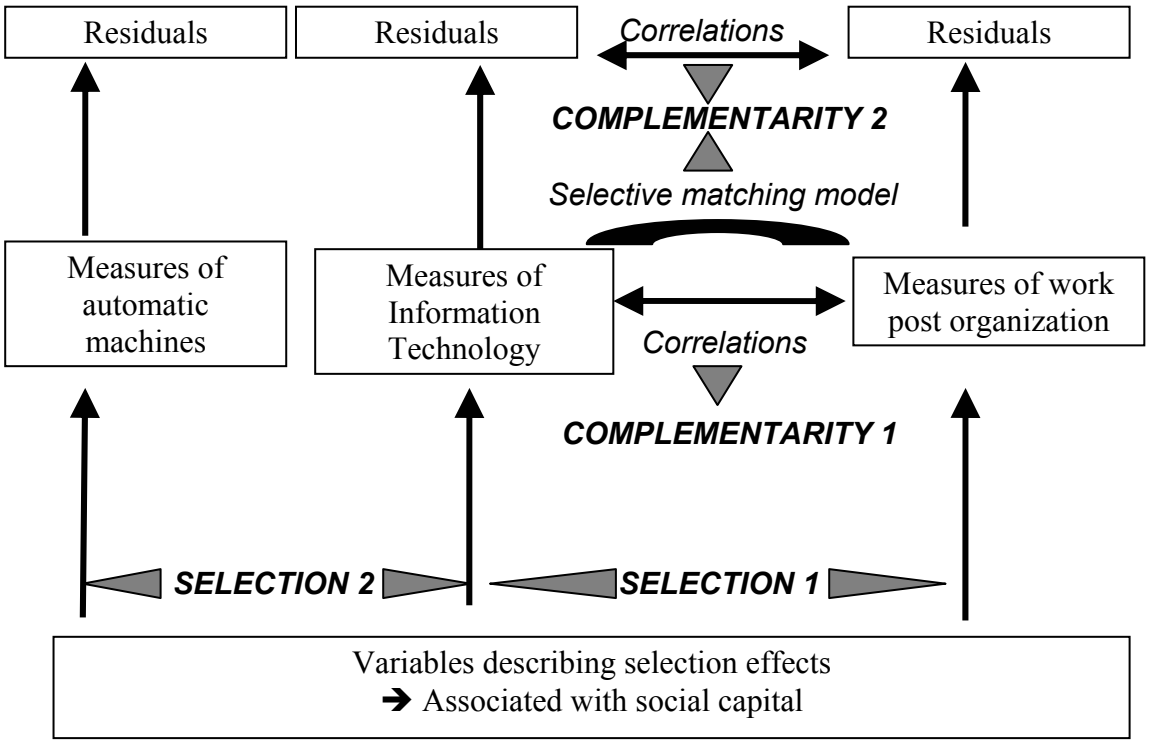

Table 1 : Selection effects caused by the use of information and industrial technology

	IT			Automatic machines		
	Use	**NBOI**	**Time of use**	**Use**	**NBMO**	**Time of use**
	All workers		*Users*	*Direct employees*		*Users*
Constant	0,35**	-0,69**	ns	0,46**	0,16**	1,3**
Occupational Groups *(ref : qualified workers)*						
Executive	0,39**	1,32**	0,45**	-	-	-
White collar	0,51**	1,08**	0,89**	-	-	-
Middle Management	0,35**	0,93**	0,41**	-0,24**	-0,34**	-0,55**
Unskilled blue collar	-0,1**	-0,15**	ns	0,08**	0,13**	ns
Personal characteristics of the worker						
Woman *(ref : man)*	ns	ns	0,35**	-0,05**	-0,16**	ns
Foreigner *(ref : French)*	ns	ns	ns	ns	ns	ns
Rural inhabitant *(ref : urban)*	-0,03*	ns	ns	ns	ns	0,14**
Age	-0,03**	-0,05**	-0,09**	-0,04**	-0,08**	ns
Seniority	0,02**	ns	ns	ns	ns	ns
Age at end of studies	0,06**	0,13**	ns	ns	ns	-0,07*
General training for the work post	0,12**	0,19**	ns	0,06**	0,16**	-0,12**
Marital status *(ref : single)*						
Married to an active person	ns	ns	ns	ns	ns	ns
Married to an inactive person	ns	ns	ns	ns	0,1*	ns
Occupation of father *(ref : unskilled)*						
Farmer or craftsman	ns	ns	-0,12**	ns	ns	ns
Executive or intermediate occupation	ns	0,12**	ns	-0,08**	-0,1*	ns
Active mother *(ref : inactive)*	ns	ns	0,08*	ns	ns	ns
Number of company changes	-0,01*	ns	ns	ns	ns	0,06**
Number of occupational groups	0,02**	0,03**	ns	ns	ns	-0,05*
General characteristics of the firm						
Size	ns	0,04**	-0,06**	ns	ns	ns
Hierarchy levels	ns	-0,02*	ns	ns	ns	ns
Technological intensity of the sector *(ref :low median)*						
Food processing industry	ns	ns	ns	ns	ns	ns
Low	ns	ns	ns	0,04*	ns	0,15**
High median	0,08**	0,07**	ns	ns	ns	ns
High	ns	ns	ns	ns	ns	ns
Rural localization *(ref : urban)*	0,03*	ns	ns	-0,05**	ns	-0,16**
Organizational characteristics of the firm						
Intensity of organizational change	0,02**	ns	-0,05*	ns	0,05*	ns
Work in group vs JIT (*ref* : *JIT)*	ns	0,05**	ns	ns	ns	ns
Quality vs JIT (*ref* : *JIT)*	ns	ns	ns	ns	ns	ns
Intensity of trading logic	ns	ns	ns	-0,02**	-0,06**	ns
Intensity of computerization	0,05**	0,07**	0,07**	ns	ns	ns
PC vs large systems (*ref : Large systems)*	ns	ns	ns	ns	ns	ns
Labor force diversity						
Occupations	0,02**	0,04**	0,06**	-0,02**	ns	-0,06**
Sex	ns	ns	ns	0,02**	0,04*	ns
Nationality	ns	ns	ns	ns	ns	ns
Age	-0,01*	-0,03**	-0,04*	ns	ns	ns
Number de employees	*4067*	*4067*	*2241*	*3213*	*3213*	*1300*
Number of firms	*2330*	*2330*	*1256*	*1860*	*1860*	*732*

Legend : * significant to 10%, ** significant to 5%, - the variables are not introduces in the regressions, ns the coefficient is not significant. Direct employees are the intermediate occupations and blue collars.
Source : C.O.I survey 1997, « labor force » section (DARES) and « employer » section (SESSI, SCEES) matched with DADS.
Perimeter : Stables employees (at least one year of seniority) of manufacturing industries of more than 50 employees.

Tableau 2 : Selection effects of use of technology within occupational groups

	Use a computer					Use an automatic machine		
	Executive	*WC*	*MM*	*SBC*	*USBC*	*IO*	*SBC*	*USBC*
Constant	0,87**	0,75**	0,71**	0,33**	0,33**	0,23**	0,45**	0,57**
Personal characteristics of the worker								
Woman *(ref : man)*	0,06*	0,12**	0,08**	-0,09**	-0,09**	-0,09**	-0,06*	
Foreigner *(ref : French)*	ns	ns	ns	ns	ns	ns	ns	0,15**
Rural inhabitant *(ref : urban)*	ns	ns	ns	-0,05*	ns	ns	ns	ns
Age	-0,03*	-0,07**	-0,06**	ns	ns	ns	ns	-0,07**
Seniority	ns	0,07**	0,05**	ns	ns	ns	-0,05**	ns
Age at end of studies	ns	0,1**	0,08**	0,07**	0,07**	ns	ns	ns
General training for the work post	0,08**	0,08**	0,06**	0,15**	0,15**	ns	0,05**	0,08*
Marital status *(ref : single)*	ns	ns	ns	ns	ns	ns	ns	ns
Married to an active person	ns	ns	ns	ns	ns	ns	ns	ns
Married to an inactive person	ns	ns	ns	ns	ns	ns	ns	ns
Occupation of father *(ref : unskilled)*								
Farmer or craftsman	ns	ns	ns	ns	ns	ns	ns	ns
Executive or intermediate occupation	ns	ns	ns	ns	0,12**	-0,06*	ns	ns
Active mother *(ref : inactive)*	ns	ns	ns	ns	ns	ns	ns	ns
Number of company changes	ns	ns	ns	ns	ns	ns	ns	ns
Number of occupational groups	ns	ns	ns	0,05**	ns	ns	ns	ns
General characteristics of the firm								
Size	ns	ns	0,03*	ns	ns	ns	ns	ns
Hierarchy levels	ns	ns	ns	ns	ns	ns	ns	ns
Technological intensity of the sector *(ref :low median)*								
Food processing industry	0,1**	-0,11**	ns	ns	ns	ns	ns	ns
Low	ns	ns	ns	ns	-0,1**	ns	ns	ns
High median	ns	ns	0,08**	0,11**	ns	ns	ns	ns
High	0,12**	ns	ns	0,12**	ns	ns	ns	ns
Rural localization *(ref : urban)*	ns	0,15**	ns	ns	ns	ns	ns	-0,1*
Organizational characteristics of the firm								
Intensity of organizational change	ns	ns	0,03*	ns	ns	ns	ns	0,05*
Work in group vs JIT (*ref* : *JIT)*	ns	ns	ns	ns	ns	ns	ns	ns
Quality vs JIT (*ref* : *JIT)*	ns	ns	ns	ns	ns	ns	ns	ns
Intensity of trading logic	ns	ns	ns	ns	ns	ns	-0,04**	ns
Intensity of computerization	0,06**	ns	0,05**	0,07**	0,03*	ns	ns	ns
PC vs large systems (*ref: large systems)*	-0,06**	ns	0,06**	ns	ns	ns	ns	ns
Labor force diversity								
Occupations	-0,03*	ns	ns	0,03**	0,04**	-0,03*	ns	ns
Sex	ns	ns	ns	ns	ns	ns	0,04**	ns
Nationality	0,03*	0,02*	ns	-0,02**	-0,02*	0,04**	ns	ns
Age	0,03*	ns	-0,02*	ns	ns	-0,02**	ns	ns
Number de employees	*529*	*325*	*1021*	*1478*	*714*	*1021*	*1478*	*714*
Number of firms	*326*	*144*	*603*	*869*	*388*	*603*	*869*	*388*

Legend : * significant to 10%, ** significant to 5%, ns the coefficient is not significant. . Abbreviations: WC for white collar, MM for middle management, SBC for skilled blue collar, USBC for unskilled blue collar.
Source : C.O.I survey 1997, « labor force » section (DARES) and « employer » section (SESSI, SCEES) matched with DADS.
Perimeter : Stables employees (at least one year of seniority) of manufacturing industries of more than 50 employees.

Table 3: Selection effects in the work organization

	Production system						Information systems					
							Intensity of communication					
	Autonomy	To be chief	Train	Quality standards	Work in group	Intensi-fication	Verti-cal	Hori-zontal	Other depart.	With outside	Meetings	Paper
Occupation Group *(ref : qualified worker)*												
Executive	0,38**	0,55**	ns	-0,17**	ns	ns	0,08**	ns	0,33**	0,41**	0,47**	ns
White collar	0,09**	ns	ns	-0,27**	-0,29**	ns	ns	-0,13**	0,09**	0,18**	0,07**	0,06**
Mid. Manag..	0,25**	0,31**	ns	-0,07**	-0,05*	ns	0,08**	Ns	0,22**	0,3**	0,3**	0,07**
Uns. blue collar	-0,1**	-0,05**	ns	ns	ns	ns	0,04*	-0,04*	ns	ns	ns	-0,12**
Personal characteristics of the worker												
Woman *(ref :M)*	-0,11**	-0,12**	-0,08**	-0,08**	-0,06**	-0,03*	ns	-0,05**	-0,05**	-0,09**	-0,04**	-0,06**
For. *(ref : Fr.)*	-0,06**	-0,05**	ns	-0,08**	ns	ns	ns	ns	ns	ns	-0,05**	ns
Rural in. *(ref : U)*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	-0,04*	ns
Age	ns	ns	-0,02*	-0,02**	-0,05**	ns	-0,03**	-0,07**	ns	ns	ns	ns
Seniority	0,02*	0,03**	0,03**	ns	0,03**	ns	ns	ns	ns	ns	ns	ns
Age at end of stu.	0,04**	ns	ns	ns	ns	ns	ns	ns	0,03**	0,04**	0,04**	0,02**
Trained for WP	0,05**	0,05**	0,1**	0,08**	0,1**	ns	0,1**	0,1**	0,08**	0,08**	0,11**	0,11**
Marital status *(ref : single)*												
Married / active	0,04*	0,06**	0,05**	0,04*	ns	ns	ns	ns	ns	ns	0,04**	ns
Married / inac.	ns	0,08**	0,05**	0,05**	ns	ns	ns	ns	ns	ns	0,04*	ns
Occupation of father *(ref : unskilled)*												
Farmer / craftsman	-0,04**	ns	ns	ns	-0,05**	-0,05**	ns	-0,03*	-0,04*	ns	ns	ns
Executive / IO	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	-0,03*
Act. mother *(ref : I)*	ns	-0,03**	-0,03*	ns	ns	0,04**	ns	0,03*	ns	ns	ns	ns
Num. comp. chg	ns	-0,02**	ns	ns	-0,02**	0,02**	ns	-0,02**	ns	0,02*	ns	ns
Num of occup. groups	ns	0,03**	ns	ns	ns	ns	ns	0,01*	0,01*	ns	0,02**	ns
General characteristics of the firm												
Size	ns	ns	ns	-0,02*	0,04**	ns	ns	ns	ns	-0,02**	0,03**	ns
Hierarchy levels	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Technological intensity of the sector *(ref :low median)*												
FPI	ns	0,07**	0,07**	ns	0,07**	ns	ns	ns	ns	ns	ns	ns
Low	ns	0,04**	ns	-0,05**	ns	0,04**	ns	ns	ns	-0,04*	ns	-0,03*
High median	ns	ns	ns	0,04*	ns	ns	ns	ns	ns	ns	ns	ns
High	-0,07**	-0,07**	ns	ns	ns	ns	ns	ns	ns	-0,07**	ns	ns
Rural *(ref : U)*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	0,03*	
Technical and organizational characteristics of the firm												
Intensity of OC	ns	ns	0,02**	0,04**	ns	0,02**	0,02*	ns	0,02*	ns	0,06**	0,03**
Work in group vs JIT (*ref* : *JIT)*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	0,03**	ns
Quality vs JIT (*ref* : *JIT)*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Intensity of TL	ns	ns	ns	-0,02**	ns	ns	ns	ns	ns	ns	-0,02**	ns
Intensity of comp.	ns	ns	ns	ns	ns	ns	ns	0,02**	0,02*	ns	ns	0,02*
PC (*ref: LS)*	ns	ns	ns	ns	ns	ns	ns	ns	-0,03**	ns	ns	ns
Labor force diversity												
Occupations	ns	-0,02**	0,02**	-0,02**	ns	ns	0,02**	ns	ns	0,03**	0,02**	0,02**
Sex	ns	ns	ns	ns	-0,02*	ns	ns	-0,02**	ns	ns	ns	ns
Nationality	ns	0,01**	ns	ns	ns	ns	ns	-0,01*	ns	ns	ns	-0,01*
Age	ns	-0,01**	-0,03**	ns	ns	-0,01**	ns	-0,02**	ns	ns	-0,02**	-0,02**

Legend: * significant to 10%, ** significant to 5%, ns the coefficient is not significant. These regressions have been carried out on a sample including 4 067 et 2 330 firms. FPI: Food Processing Industry

Source: C.O.I survey 1997, « labor force » section (DARES) and « business » section (SESSI, SCEES) matched with DADS.

Perimeter: Stables employees (at least one year of seniority) of manufacturing industries of more than 50 employees.

Table 4: The correlations between the use of technology and work organization

	Use of computers							Use of automatic machines			
	Total	*Exec.*	*WC*	*Direct Workers*	*MM*	*SBC*	*USBC*	*Direct Workers*	*MM*	*SBC*	*USBC*
Variables relative to the production system											
Autonomy	0,28**	ns	ns	0,26**	ns	0,14**	0,11**	-0,12**	-0,06**	ns	ns
	0,07**	ns	ns	0,15**	ns	0,10**	0,07*	-0,09**	-0,07**	ns	ns
	0,07**	ns	0,27*	0,10**	ns	0,09**	ns	-0,04**	ns	ns	ns
To be boss	0,25**	ns	ns	0,23**	-0,07**	0,13**	0,15**	-0,03*	0,11**	0,06**	ns
	0,07**	ns	ns	0,17**	ns	0,12**	0,11**	ns	0,06**	0,05*	ns
	0,06**	ns	0,08**	0,06**	ns	0,09**	0,08*	0,04**	0,08*	0,04*	ns
Train	0,10**	0,11**	ns	0,13**	ns	0,16**	0,13**	0,12**	0,19**	0,12**	0,14**
	0,07**	0,11**	ns	0,06**	ns	0,10**	ns	0,13**	0,17**	0,11**	0,11**
	0,08**	ns	ns	0,06**	ns	0,11**	ns	0,12**	0,19**	0,10**	0,10**
Quality standards	ns	ns	ns	0,06**	ns	0,10**	0,14**	0,17**	0,22**	0,17**	0,10**
	0,04**	ns	ns	ns	ns	0,06**	ns	0,17**	0,19**	0,16**	0,09**
	ns	ns	ns	ns	ns	0,08**	ns	0,16**	0,22**	0,16**	0,08**
Work in group	ns	0,13**	ns	ns	ns	0,05*	0,07*	0,12**	0,21**	0,08**	0,11**
	ns	0,09**	ns	ns	ns	ns	ns	0,11**	0,17**	0,08**	0,09**
	0,07**	ns	ns	ns	ns	ns	ns	0,13**	0,20**	0,10**	0,12**
Intensification of work	0,10**	ns	0,10*	0,12**	0,10**	0,11**	0,11**	0,03*	ns	0,05*	0,09**
	0,10**	ns	0,13**	0,11**	0,11**	0,11**	0,08**	0,04**	ns	ns	0,09**
	0,10**	ns	ns	0,11**	0,16**	0,10**	0,10*	0,05**	ns	ns	0,08*
Variables relative to the information system											
Vertical communication	0,09**	ns	0,12**	0,10**	0,07**	0,05**	ns	0,04**	0,08**	0,05*	0,10**
	0,03*	ns	ns	0,05**	ns	ns	ns	0,05**	0,07**	0,05*	0,09**
	0,06**	ns	0,32*	ns	0,09*	ns	ns	0,06**	0,08**	0,06**	0,08*
Horizontal communication	0,10**	0,12**	ns	0,12**	0,11**	0,13**	ns	0,05**	0,09**	0,07**	ns
	0,06**	0,10**	ns	0,06**	0,09**	0,06**	ns	0,04**	ns	0,06**	ns
	0,09**	ns	ns	0,07**	0,11**	0,07**	ns	0,05**	0,07*	0,06**	ns
Communication with other depart.	0,26**	ns	0,12**	0,25**	0,10**	0,17**	0,07**	-0,06**	ns	ns	ns
	0,07**	ns	ns	0,14**	0,06**	0,11**	ns	-0,04**	ns	ns	ns
	0,09**	ns	ns	0,09**	ns	0,12**	ns	ns	ns	ns	ns
Communication with outside	0,30**	ns	ns	0,29**	0,07**	0,16**	0,13**	-0,12**	ns	ns	ns
	0,06**	ns	ns	0,16**	ns	0,11**	0,07*	-0,07**	ns	ns	ns
	ns	ns	ns	0,07**	ns	0,11**	ns	ns	ns	ns	ns
Meetings	0,35**	0,16**	0,15**	0,33**	0,16**	0,17**	0,17**	-0,10**	ns	ns	ns
	0,09**	0,12**	ns	0,17**	0,10**	0,09**	0,08**	-0,07**	ns	ns	ns
	0,12**	ns	ns	0,10**	0,17**	0,09**	ns	ns	ns	ns	ns
Paper	0,22**	ns	0,09*	0,25**	0,06*	0,21**	0,17**	ns	ns	0,05*	ns
	0,09**	ns	ns	0,12**	ns	0,14**	0,08**	ns	ns	0,05*	ns
	0,04*	ns	ns	0,08**	ns	0,15**	0,09*	ns	ns	ns	ns
No. employees	*4067*	*529*	*325*	*3213*	*1021*	*1478*	*714*	*3213*	*1021*	*1478*	*714*
No. firms	*2330*	*326*	*144*	*1860*	*603*	*869*	*388*	*1860*	*603*	*869*	*388*

Legend: * significant to 10%, ** significant to 5%, ns the coefficient is not significant. Abbreviations are : exec. For executives, WC for white collars, MM for middle management, SBC for skilled blue collars, USBC for unskilled blue collars. The three latter categories constitute the sample of direct workers. For each organization dummy three correlations are reported: the first is the correlation between primary variables (use the technology and the organizational trait); the second is the correlation between the residuals of primary variable when taking into account the selection effects. The third is core estimator of the matching model

Source: C.O.I survey 1997, « labor force » section (DARES) and « employer » section (SESSI, SCEES) matched with DADS.

Perimeter: Stables employees (at least one year of seniority) of manufacturing industries of more than 50 employees.

Appendix 1: Measure of technology use

1- The measure of ITC utilization

The survey distinguishes 9 types of different ITC:

1. The PC or the workstation
2. The terminal or the computer console
3. Internet
4. The internal computer communication network (Intranet)
5. The fax
6. The minitel
7. The pager, pocket messager, mobile phone, tatoo, tam-tam, etc…
8. The laptop computer? (yes/no)
9. Electronic links to customers or suppliers of the firm by e-mail or computer networks (for example EDI)

For each of these equipment, the worker is asked whether he uses the technology (even occasionally), in the frame of his work. Basing ourselves on answers to these questions, we characterize the computerization of the work by two variables.

The first variable indicates if the worker is computerized. **For computers, USE(computers) = 1** when the worker declares the use of either a terminal or a PC, or a laptop. On the contrary, USE(computers) = 0

The second variable NBMO gives the total number of ITC used by the employees. Each time that the worker declares that he uses one of the nine ITC equipment studied by the survey, NBOI is incremented by 1. NBOI can be interpreted as the diversity of use of computer equipment by the employee. The plurality of these technologies at the work post level can also be interpreted as the intensity of having recourse to computers by the worker.

Besides, the survey provides information on the time spent by the employee working with IT, all types of equipment being considered. The daily IT utilization time expressed in hours per day is our third variable.

2- The measure of use of automatic machines

In the same way, workers have been questioned on the use of automatic machines. When the workers declares that he uses a machine or an automatic appliance, the variable USE(an automatic machine) = 1. On the contrary, USE(an automatic machine)=0.

When the worker declares that he uses a machine or an automatic appliance, he precises the functions of the machine. Nine functions are distinguished in the survey:

1. Tooling, casting, laminating and other transformations of materials
2. Assembly- mounting – welding
3. Painting and surface treatments
4. Mixing, curing and other chemical transformation of materials
5. Proof testing and controls
6. Conditioning and packing

7. Handling and stocking
8. Printing and copying
9. Cutting, laundering, sewing, manufacturing

The **NBMO** variable represents the cumulated functions of the automatic machines that the worker uses. For each itemized function, when the worker declares that he uses a function of an automatic machine, NBMO is incremented by 1. As NBOI, NBMO can be interpreted as the diversity of automatic machines use by the worker, or as an intensity of utilization of automatic machines.

Like for the utilization of computer equipment, the surveys provides information on the daily time utilization of automatic machine, expressed in hours per day. This time utilization is the third variable describing the use of automatic machines of the worker.

Table A1 gives the distribution of these variables within the different sub-samples used.

Table A1 : Distribution of technology indicators

	COMPUTER				AUTOMATIC MACHINE			
	Use (%)	**NBOI**	**NBOI**	**Time**	**Use (%)**	**NBMO**	**NBMO**	**Time**
	All workers		*Workers using a computer*		*All workers*		*Workers using an automatic machine*	
Whole sample	60	2,53 (2,35)	4,01 (1,84	3,04 (2,39)	33	0,64 (1,17)	1,92 (1,29)	5,51 (2,97)
Executives	92	5,10 (1,79)	5,35 (1,61	3,15 (2,30)	6	0,13 (0,65)	2,18 (1,56)	1,71 (2,25)
White Collars	92	3,81 (1,53)	4,05 (1,31	4,88 (2,15)	3	0,04 (0,23)	1,22 (0,50)	2,45 (2,32)
Direct workers	50	1,88 (2,09)	3,50 (1,74	2,67 (2,31)	42	0,80 (1,26)	1,92 (1,29)	5,65 (2,90)
Middle Management	84	3,88 (1,84)	4,38 (1,50	3,09 (2,24)	22	0,51 (1,23)	2,31 (1,65)	3,80 (3,06)
Skilled blue collars	39	1,09 (1,49)	2,53 (1,40)	2,17 (2,26)	48	0,90 (1,22)	1,86 (1,15)	5,84 (2,79)
Unskilled blue collars	22	0,49 (0,99)	1,99 (1,13)	2,14 (2,42)	58	1,04 (1,29)	1,80 (1,22)	6,41 (2,52)

Lecture : Pourcentage of users of a computer and of automatic machines. For the accumulation of ICT (NBOI) and the accumulation of the functions of automatic machines (NBMO), and for the times of use, the mean is followed by the standard deviation between brackets. These statistics are weighted to adjust for sampling rates and non response.
Source: C.O.I survey 1997, « labor force » section (DARES) and « business » section (SESSI, SCEES) matched with DADS.
Perimeter: Stables employees (at least one year of seniority) of manufacturing industries of more than 50 employees.

Appendix 2: measure of work organization

We have chosen to concentrate on questions of the labor force section of the C.O.I survey allowing us to appraise, at the work post level of the workers, the decentralization of the production and information system of the firm.

1- Production system

Autonomy or control of work definition

The survey includes 4 questions allowing the appraisal of the degree of control that the worker has on the definition of his work content:

Q1 : You receive orders, assignments, instructions. In order to perform your work correctly, which of the following applies (if it applies)? 1) You carry the assignments to the letter. 2) In certain cases, you act differently. 3) You act differently most of the time 4) irrelevant (no orders, no directives, no directions for use)

Q2 : Instructions given by your superiors in the company tell you what must be done. 1) In general do they also tell you how to do the work? or 2) do they tell you the objective of your work, but leave you to decide how to achieve this objective?

Q3 : Do you have occasion to modify the nature and quantity of the work which you will have to do, or the manner of proceeding?

Q4 : In general, when in the course of your work, something unforeseen occurs, what happens? 1) You fix the problem on your own. 2) You manage it with the colleagues around you. 3) You call on other people (a superior, a colleague, a specialist department).

We have set up the following score from the answers to the above questions:

SCORE1=(Q1=2 or 3)+(Q2=2)+(Q3=yes)+(Q4=1)

This score varies between 0 and 4. The variable has been dichotomized after observing its distribution on the totality of the workers. If SCORE1 is equal to 3 or 4 then the worker is considered as being autonomous (AUTON=1) and moderately autonomous in other cases (AUTON=0)

The hierarchy framework

Q5 : Do you have one or more employees follow your orders or are under your authority? (yes/no) CHIEF=1 if Q5=yes, 0 otherwise.

Train new workers

Q6 : Do you train new workers or interim workers to hold their work post ? (yes/no) TRAIN=1 if Q6=yes, 0 otherwise.

Follow quality norms

Q7: Do you personally have to meet precise quantified quality standards (for example: wastage rates, measurable characteristics of the product)? (yes/no)

QUAL=1 if Q7=yes, 0 otherwise.

Work in group

Q8: Do you sometimes do your work in group or collectively? (yes/no)

GROUP=1 if Q8=yes, 0 otherwise.

Work intensification

The intensification of work of the employees is a synthesis of two types of work intensity: intensity of industrial constraints and of commercial constraints.

The intensity of industrial constraints synthesizes the answers to the following questions:

Q9 : Is your work rhythm imposed by the following :

a. Automatic moving of a product or a part? (yes/no)
b. Automatic pace of a machine? (yes/no)
c. Immediate dependence of one or more colleagues in the work done? (yes/no)
d. Production norms or deadlines to meet in an hour at most? (yes/no)
e. Production norms or deadlines to meet in a day at most? (yes/no)

The indicator of intensity of industrial constraints is given by the variable IINDUS:
IINDUS=1 if (Q9a=yes or Q9b=yes or Q9c=yes or Q9d=yes or Q9e=yes), 0 otherwise.

To determine the indicator intensity of commercial constraints we have used the following questions:

Q10: Is your work rhythm imposed by the external demand (customers) needing an immediate response? (yes/no)

Votre rythme de travail vous est-il imposé par une demande extérieure (clients) obligeant à une réponse immédiate ? (oui/non)

Q11: Are you in direct contact (face to face or by phone) with customers? 1) All the time, 2) regularly, 3) occasionally or 4) never

The indicator of intensity of commercial constraints is given by the variable IMAR
IMAR=1 if (Q10=yes or Q11=1 or Q11=2), 0 otherwise.

Finally, we observe an intensification of work when the worker cumulates the industrial and commercial constraints.
INTENS=1 if (IINDUS=1 and IMAR=1), 0 otherwise.

2- Information system

Four synthetic indicators of intensity of communication have been defined and which express: the communication with superiors (vertical communication), with colleagues (horizontal communication), with colleagues from other departments (communication with other departments)with persons outside the firm (communication with outside the firm). The variables are built as follows:

Intensity of vertical communication

Q12: Do you have occasion to modify the nature and quantity of the work which you will have to do, or the manner of proceeding? (yes/no)
Q12a: while discussing with your superiors alone? (yes/no)
Q12b: while discussing with your superiors in the presence of your colleagues? (yes/no)

Q13: If you have a temporary excess workload or if you are uneasy with a difficult or tricky task are you helped by …?
Q13a: By your superiors? 1) yes, 2) no, 3) irrelevant, no excess workload

With the answers to the above questions we have set up the following score:
SCORE2= [(Q12a=yes) +(Q12b=yes)+(Q13a=yes)]/[2* (Q12=yes) + (Q13=yes or no)].
This score takes 5 modalities between 0 and 1. The variable has been dichotomized after observing its distribution on all the workers. If SCORE2 ≥ 0,5, then the worker has a very intense vertical communication (CVERT=1), and weakly intense in other cases.

Intensity of horizontal communication

Q12: Do you have occasion to modify the nature and quantity of the work which you will have to do, or the manner of proceeding …? (yes/no).
Q12c: while discussing between colleagues, without your superiors being present (if it applies)? (yes/no)

Q13 : If you have a temporary excess workload or if you are uneasy with a difficult or tricky task are you helped by …?

Q13b : colleagues you usually work with ? 1) yes; 2) no; 3) not relevant, no excess workload or colleagues who are close.

Q14 : Do you have one or more employees under your orders or authority? (yes/no) If yes, do you give indications to other persons on what they have to do?
Q14a : to colleagues you usually work with? 1) yes, sometimes; 2) no; 3) not relevant.

Q15 : Apart from your superiors, are there other persons that give you indications on what you have to do?
Q15a : to colleagues you usually work with? 1) yes, sometimes; 2) no; 3) not relevant.

With the answers to the above questions we have built the following score :
SCORE3=[(Q12c=yes)+(Q13b=yes)+(Q14a=yes)+(Q15a=yes)]/[(Q12=yes)+(Q13b=1 or 2)+(Q14a=1or 2)+(Q15a=1 or 2)].

SCORE3 includes 7 modalities on the interval [0,1]. After observing the distribution of this variable on the totality of the employees, we have dichotomized it. CHORI is equal to 0 value when the worker communicates half of the time or less (SCORE ≤0.5), which corresponds to the case of employees communicating moderately with their colleagues. CHORI is equal to 1 otherwise, when the employees communicate a lot with their colleagues.

Communication intensity with other departments of the firm

Q12: Do you have occasion to modify the nature and quantity of the work which you will have to do, or the manner of proceeding? (yes/no)
Q12d: while discussing with colleagues from other departments? (yes/no)

Q13: If you have a temporary excess workload or if you are uneasy with a difficult or tricky task are you helped by…?
Q13c: persons in the firm other than the colleagues you usually work with?? 1) yes, 2) no, 3) not relevant, no excess workload or colleagues from other departments.

Q14 : Do you have one or more employees under your orders or authority? If yes, do you give indications to other persons on what they have to do…? (yes/no)
Q14b : other persons or departments in the firm? 1) yes, sometimes, 2) no, 3) not relevant.

Q15: Apart from your superiors, are there other persons that give you indications on what you have to do?
Q15b : other persons or departments in the firm? 1) yes, sometimes, 2) no, 3) not relevant.

With the answers to the above questions we have built the following score :
SCORE4=[(Q12d=yes)+(Q13c=yes)+(Q14b=yes)+(Q15b=yes)]/[(Q12=yes)+(Q113c=1 or 2)+(Q14b=1 or 2)+(Q15b=1 or 2)].

SCORE4 has 7 modalities on the interval [0,1]. After observing the distribution of this variable on the totality of the employees, we have dichotomized it. CATUSER variable is equal to 0 when the worker communicates one time out of four or less (SCORE ≤0.25), which corresponds to the case of employees communicating moderately with their colleagues from other departments of the firm. On the contrary, (CAUTSER = 1), when the employees communicate a lot with other departments.

Intensity of communication with outside the firm

Q13: If you have a temporary excess workload or if you are uneasy with a difficult or tricky task are you helped by…
Q13d: persons from outside the firm? (yes/no)

Q14: Do you give indications to other persons on what they have to do…
Q14c : persons from outside the firm (customers, suppliers, order-givers…)? (yes, sometimes / no)

Q15: Apart from your superiors, are there other persons that give you indications on what you have to do…?
Q15c: persons from outside the firm (customers, suppliers, order-givers…), etc.…? (yes, sometimes / no)

With the answers to the above questions we have built the following score :
SCORE5=[(Q13d=yes)+(Q14c=yes)+(Q15c=yes)]/[2+(Q13=yes)].
SCORE5 has 7 modalities between 0 and 1. After observing the distribution of this variable on the totality of the employees, we have dichotomized it. If SCORE5=0, then the employee does not communicate with outside the firm (CEXTER=0). When the worker communicates with outside the firm, CEXTER=1.

The frequency of meetings

We have in the survey the number of meetings attended by the employee. The variable REUI=1 when the worker has at least one meeting per month. It is equal to 0 otherwise. Whereas the previous indicators reflect bilateral communication, REUI corresponds to a a multilateral exchange in a formal framework.

The written formalization of instructions

Q16: Are instructions, procedures or important indications provided by written paper documentation (including faxes and listings) ? (yes/no) PAPER=1 if Q16=yes, 0 otherwise.

The distribution of the variables characterizing work organization within the different sub-samples used are reported in table A2.

Table A2 : Distribution of organization variables

	Total sample	Executives	White collars	Direct workers	Intermediate occupations	Skilled blue collars	Unskilled blue collars
PRODUCTION SYSTEM							
Autonomy	49	84	45	43	65	37	21
To be boss	28	68	7	23	44	14	7
Train	66	63	60	68	70	67	63
Quality Standards	42	32	15	47	46	49	45
Work in groups	58	78	32	57	64	56	48
Intensification of work	30	28	35	30	35	29	25
INFORMATION SYSTEM (intensity of communication)							
Vertical	54	58	50	54	61	50	51
Horizontal	50	55	33	50	56	50	41
Other services	42	70	39	37	57	29	22
Outside	39	72	36	32	58	21	15
Meeting	48	87	35	41	68	31	21
Paper	71	77	72	70	83	69	50
Sample size	*4067*	*529*	*325*	*3213*	*1021*	*1478*	*714*

Lecture : Distribution in percent of organizational methods within occupations. These statistics are weighted to adjust for sampling rates and non response.
Source: C.O.I survey 1997, « labor force » section (DARES) and « business » section (SESSI, SCEES) matched with DADS.
Perimeter: Stables employees (at least one year of seniority) of manufacturing industries of more than 50 employees.

Appendix 3 : The control variables

1- *Personal characteristics of the worker*

- **Gender** (man/woman)
- **Nationality** (French/foreigner)
- **Housing location** (urban/rural)
- **Age**
- **Seniority**
- **Age at the end of studies**
- **Training for the work post** (to be trained or not)

The reference individual in our analysis is a man of French nationality, living in an urban region, aged 42, with 17 years of seniority and who ends his studies at an age slightly higher than 18 and who has not been trained by his firm to occupy his work post.

We have completed this base information with information on the familial context, his social origins and his professional career path.

- **The marital status**

Two questions allows us to identify the marital status:
Q1) Do you live as a couple? (yes/no)
Q2) Is your spouse …?:

a- Salaried employee
b- Unwaged employee (storekeeper, craftsman, professions,…)
c- unemployed
d- retired
e- in training or in military service
f- at home or inactive

The variable which allows us to identify the marital status of the worker is made up of three modalities. If Q1=no, then the worker is single. If (Q1=yes) and (Q2=a or Q2=b), then the worker is married and active. If (Q1=yes) and (Q2=c or Q2=d or Q2=e or Q2=f), then the worker is married to an unemployed person. In 61% of the cases, the worker is a married active person. This modality thus constitutes the reference.

- **Occupation of the father**:

The question asked to the employees is:
Q3) When you left school or university what was the occupation of your father (including tutor or adoptive father)? The answers of the employees have been coded by using the occupational group nomenclature of INSEE.
Our indicator which identifies the occupation of the father has three modalities. The first characterizes employees who are in a situation of structural mobility, in other words those whose father is a farmer or a craftsman. The second one characterizes workers whose father belonged to managerial staff (executive or intermediate occupation) and the last one refers to employees whose father is a blue collar, white collar or inactive. This last modality is used as our reference in our analysis.

- **Occupation of the mother**

Similarly, the occupation of the mother can be identified. The distribution of this variable is very different since the majority of the workers declared that their mother is inactive, in other words is a housewife, when they end their studies. This first case thus constitutes the reference modality. In the case when the employee declares an active mother, the occupation of the mother is very closely correlated to that of the father. The second modality thus describes the case of employees whose mother are active.

- **The number of firms for which the employee has worked** (mean 3.7)
- **The number of changes in occupational group** (mean 2.6)

2- General characteristics of the firm

The variables characterizing the firm are provided by the business section of the COI survey:

- The logarithm of the **size** of the firm
- The **number of hierarchical levels** between the operator and the head of the company
- Knowing the sector of the company, the firms have been grouped according to the **technological intensity of their sector**: high/high-median/low-median/low/FPI. The nomenclature used has been set up by OCDE from the ratio of R & D expenses and the production of each industry at a detailed level (OCDE (1994)). The firms to which the employees of our sample belong are mainly classified in the low-median in terms of technological intensity whatever the occupational group f the workers. This modality thus constitutes or reference.
- The COI survey gives the **localization of the firm** to which the employee belongs according to the typology set up by INSEE and INRA. This parameter allows to distinguish between the companies based in urban poles, suburbs, rural poles, isolated rural regions. The localization variable that we have introduced separates the companies located in the urban zones (the first three modalities of the typology) from those situated in rural zones(the last three modalities). The workers constituting our sample are in most cases, whatever their occupational group, situated in urban zones (reference).

3- Organizational characteristics of the firm

The labor force section of the COI survey allows us to understand the organizational systems set up by the firms. The management tools have been chosen because they have been qualified as “new” or “modern” when the survey has been carried out. Some of these organizational mechanisms aim at managing quality problems (ISO certification, total quality control, value analysis, functional analysis or AMDEC), deadlines (just-in-time production systems and delivery, preventive maintenance procedures), internal transactions of the company (profit center organization, formal in-house customer-supplier contracts), boundary of the company (self managed teams, problem solving groups and project teams). The business section of the survey also allows to evaluate the number of hierarchical layers and the sharing of responsibilities between operators and

their hierarchy. Gollac, Greenan and Hamon-Cholet (2000) have carried out a multiple correspondence analysis using this large set of questions.

The coordinates of the companies on the first four factorial axes, synthesizes the principle dimensions of organizational practices of firms in 1997:

- The first synthetic variable resulting from this analysis is the **intensity of use of the new organizational mechanisms**
- The second variable compares the orientation of organizational practices towards **work in group** to an industrial logic oriented towards the control of costs thanks to **just-in-time processes**. Since this variable is interpreted as an opposition between two polar forms, we have dichotomized it. The orientation towards just-in-time characterizes the majority of the firms to which the workers of our sample belong, whatever their occupational group. This variable is the thus the reference modality.
- The third variable opposes an industrial logic centered on quality of just-in-time production practices. We have also dichotomized this variable and we have chosen the orientation towards just-in-time as the reference modality.
- The fourth variable measures the intensity of recurring to the commercial logic, that is the formalization of in-house transactions of the firm, of externalization transactions and of outsourcing activities.

The business section of the COI survey also allows to understand the computerization and technological equipment strategy followed by the firm: the type of equipment used by the management and production departments of the firm, intensity of data transfer through a computer interface internally and externally, use of the Internet, the level of equipment of the blue collar and non blue collar labor force, the sharing of responsibilities between the IT department, the users, the project teams and the external providers for the systems architectural design, the choice of software and computer applications, maintenance and administration of the IT system, assistance and training to users. The two variables that are retained in our analysis result from a second multiple correspondence analysis that includes all these variables (Gollac, Greenan et Hamon-Cholet (2000)).

- The first indicator measures the **intensity of computerization** and conveys the accumulation of equipment at the level of the firm.
- The second indicator indicates if c the computerization is based on large systems (with or without interconnected PCs) or on a computer **network**. As it expresses the opposition between two polar forms of computerization, the variable has been dichotomized. In almost all cases, the firms to which the workers of our sample belong structure their IT systems on large systems (reference)

4- Diversity of the labor force

The DADS shows the social composition of the labor force in the firme. Indeed, this data provides information on:

- The proportion of different occupational groups: executives/intermediate occupations/blue collars
- of man and woman
- of French and foreign workers

- of different generations of workers: less than 26 years old/26 to 30 years old/ 30 to 38 years old/38 to 50 years old/more than 50 years old

For each of these criteria, we have set up a synthetic indicator of diversity *D* measuring the probability that two observations taken at random in the population belong to different modalities. If N represents the total number of workers in a firm, K the total number of modalities of the variable considered and n_k, the size of the modality k (k=1,…..,K), then *D* can be expressed as:

$$D = \frac{1 - \sum_{k=1}^{K} \left(\frac{n_k}{N} \right)^2}{D_{\max}}$$

The numerator measures the diversity but its value depends on the number of modalities K taken by the variable considered. The denominator, D_{max} neutralizes this effect, thus allowing the comparison of different diversity indicators. D_{max} measures the case of maximum diversity where the N workers are distributed with equal probabilities in the K modalities. In this case, we have N/K workers by modality, thus:

$$D_{\max} = 1 - K\left(\frac{N/K}{N} \right)^2 = \frac{K-1}{K}$$

The diversity indicator varies between 0 and 1, illustrating a continuum of cases ranging from a perfect homogeneity of the labor force to the maximum possible diversity. The indicators set up allows to evaluate the diversity of the occupational groups, ages, genders and nationalities within the firm.

The distribution of these variables within the different samples used are given in table A32.

Table A32 : Distribution of socio-organizational variables

	Total Sample	Exec.	WC	Directs Workers	IO	SBC	USBC
PERSONAL CHARACTERISTICS OF WORKER							
- Gender : *man* (versus *woman*)	71	79	19	75	80	80	54
- Nationality *French* (versus *foreign*)	91	96	94	89	94	87	86
- Habitation *urban* (versus *rural*)	74	88	75	72	81	68	65
- Age	41,63 (9,26)	43,95 (9,52)	41,73 (9,46)	41,15 (9,11)	41,46 (9,04)	41,15 (8,99)	40,68 (9,47)
- Seniority	16,69 (9,63)	15,54 (10,42)	16,38 (9,96)	16,95 (9,41)	16,67 (9,76)	17,40 (9,19)	16,39 (9,31)
- Age at the end of studies	18,23 (3,70)	22,46 (3,60)	18,43 (2,81)	17,35 (3,15)	19,23 (3,02)	16,64 (2,69)	15,95 (2,92)
- Not be trained (/to be trained)	39	24	41	42	23	46	64
- marital status : (ref) *married to a salaried worker*	61	62	69	60	61	62	56
Married to an unemployed worker	23	25	10	23	22	24	23
Single	16	13	21	17	17	14	21
- Occupation of the father: (ref =) *Unskilled*	61	34	62	67	59	71	72
Farmer or craftsman	19	19	20	19	18	20	20
Executive or intermediate occupation	19	46	18	14	24	09	08
- Mother: *inactive* (versus *active*)	59	62	53	59	57	59	59
- Number of firms for which worker has worked	3,69 (2,67)	4,11 (2,83)	3,54 (2,67)	3,61 (2,62)	3,79 (2,61)	3,62 (2,70)	3,31 (2,46)
- Number of changes of occupational groups	2,62 (1,00)	2,86 (1,09)	2,39 (1,07)	2,59 (0,96)	2,83 (1,01)	2,50 (0,91)	2,40 (0,94)
GENERAL CHARACTERISTICS OF THE FIRM							
- Log (size)	6,41 (1,38)	6,79 (1,22)	6,14 (1,25)	6,36 (1,41)	6,44 (1,31)	6,38 (1,50)	6,16 (1,35)
- Number of hierarchical levels	4,16 (1,48)	4,44 (1,39)	4,11 (1,43)	4,11 (1,50)	4,24 (1,43)	4,09 (1,53)	3,96 (1,53)
- Technological intensity of the sector (ref) *median-low*	38	37	32	39	34	43	39
FPI	10	7	12	10	7	10	15
Low	23	19	26	24	18	26	28
Median- High	17	19	16	17	24	15	12
High	11	17	14	10	17	06	5
- Firm localization : *urban* (vs *rural*)	76	86	79	74	84	72	64
ORGANIZATIONAL CHARACTERISTICS OF THE FIRM							
- Intensity of organizational change	0,21 (0,49)	0,31 (0,49)	0,10 (0,47)	0,20 (0,49)	0,25 (0,46)	0,20 (0,51)	0,14 (0,48)
- Orientation toward *JIT* (versus *work in group*)	54	55	56	53	51	54	55
- Orientation toward *JIT* (versus *quality*)	46	42	46	46	40	50	48
- Intensity of the commercial logic	0,01 (0,24)	0,04 (0,25)	0,03 (0,25)	0,01 (0,24)	0,01 (0,25)	0,00 (0,23)	0,00 (0,25)
- Intensity of compterization	0,49 (0,96)	0,78 (0,83)	0,38 (0,97)	0,44 (0,97)	0,55 (0,89)	0,42 (1,00)	0,30 (1,01)
- *Large system* (versus *network of computers*)	52	46	55	53	52	53	57
DIVERSITY OF THE LABOR FORCE							
- occupational groups	0,69 (0,19)	0,75 (0,18)	0,74 (0,16)	0,67 (0,19)	0,74 (0,17)	0,65 (0,19)	0,60 (0,19)
- Age	0,76 (0,09)	0,78 (0,07)	0,77 (0,09)	0,76 (0,09)	0,77 (0,09)	0,76 (0,09)	0,74 (0,10)
- Gender	0,66 (0,27)	0,69 (0,25)	0,70 (0,25)	0,65 (0,27)	0,65 (0,26)	0,61 (0,27)	0,74 (0,26)
- Nationality	0,18 (0,19)	0,15 (0,16)	0,17 (0,19)	0,19 (0,20)	0,16 (0,18)	0,19 (0,20)	0,21 (0,22)
Sample size	*4067*	*529*	*325*	*3213*	*1021*	*1478*	*714*

Lecture : Frequencies in % for qualitative variables, mean followed by standard deviation for quantitative variables. For dichotomous variable we only report the modality of reference. Abbreviations: WC for white collar, IO for intermediate occupation, SBC for skilled blue collar, USBC for unskilled blue collar.

Source: C.O.I survey 1997, « labor force » section (DARES) and « business » section (SESSI, SCEES) matched with DADS.

Perimeter: Stables employees (at least one year of seniority) of manufacturing industries of more than 50 employees.

Appendix 4: the Rubin model

In this appendix, we rely to a large extent on the presentation of selective matching models realized by (Brodaty, Crépon et Fougère (2002)). These models resulting the work of Rubin (1974), were originally used to study the effectiveness of medical treatments on non experimental samples. They have then been applied in economics.

When the impact of a treatment variable on individual performance is evaluated, the general performance of individuals receiving the treatment is compared to that of individuals receiving no treatment. The question is then the selectivity bias: individuals who choose to follow a treatment take a rational decision which is not independent from the state (the health) of the individual in the absence of treatment. Thus a direct comparison between treated and non treated individuals are likely to lead to biased estimations of the effect of the treatment. In other words, when the effects of a treatment are tested, comparing the health of treated and non treated individuals can lead to biased estimations. The selection bias lies in the fact that the individuals who have received the treatment are initially sick, whereas those who have received no treatment are healthy.

The causal framework of Rubin allowing to define the causal effect of a treatment is well adapted to discuss the question of selectivity bias. For each individual, two latent variables y0 and y1 exist, corresponding to potential results of the individual, depending on whether he has received the treatment (T=1) or not (T=0). The result variable observed is:

$$y = Ty1 + (1-T)y0$$

Only the couple (y,T) is observed for each individual. The causal effect of the treatment is given by:

$$C= y1 – y0$$

This causal effect has two characteristics . First of all, it is not observable: for a given individual, it is not possible to know at the same time, the state of his health when he receives the treatment and when he does not receive any treatment. Secondly, the causal effect is individual. The individual character of this causal effect implies that it is heterogeneous within the population. But because it is not observable, this distribution cannot be identified.

Nevertheless, under certain hypothesis of a joint rule between performance and treatment, the causal mean effect within the population or on the population of individuals treated can be identified. Indeed, when the variables of latent results are independent of the assignment to treatment, this identification is possible: $(y0,y1)\perp T$. This means that the assignment to treatment is random. Namely, it does not depend on the state of health of the individual. This can for example be considered in the case of contraceptives.

When the condition for identification is met, the average causal effect can be identified in the population $Cm = E(y1-y0)$, or the average causal effect on the population of treated individuals $Cm,t = E(y1-y0 \mid T=1)$.

But this property of independence is very rarely verified. Indeed, the individuals receiving a treatment are in general sick. Consequently, if they did not receive a treatment, the average state of health of the treated individuals would not be the same as that of untreated individuals.

A natural approach is to build a control group so that the distribution of the group of observable characteristics (for example the blood test) notes x, is the same in the group of individuals receiving the treatment. The selectivity bias can thus be eliminated on the observable characteristics. The identification condition is then less restrictive. Conditionally to this set of observable variables, the property of independence between latent results and assignment to treatment must be verified: $(y0,y1) \perp T \mid x$. In other words, conditionally to this set of observable variables, the individuals are assigned randomly to treatment, the experience is controlled. The average effect of the treatment on the whole of the population and on the population of treated individuals.

Rubin (1977) proposes to match to each worker, a counterfactual worker having exactly the same characteristics. This matching can be difficult to put into practice when the number of characteristics is high. Facing this problem of dimensionality, Rosenbaum and Rubin (1983) have shown that the property of independence conditionally to a set of observable variables implies conditional independence to the score.

Several methods of matching have been proposed (Heckman, Ichimura et Todd (1997, 1998)). The “twin” individual can be the closest neighbor, that is the one who has the closest score to the studied individual. It can also be built by taking the weighted average of the n neighbors who are the closest to i. In particular, Heckman and al (1998) propose the kernel estimator which is convergent and asymptotically normal under certain hypothesis. Under this perspective, each non treated individual participates in the construction of the “twin” of the treated individual. But the weight of non treated individuals in the construction of the “twin” varies according to the distance between their score and that of the considered individual.

In our estimations, the fact of using a computer can be compared to the fact of following a medical treatment (T=UTILISER). As for the organizational characteristics of the work post can be compared to the performance indicators of the treatment (y=ORG). The matching criteria that we use are those we have identified in the previous section ($x \equiv$SELECT).