I - COMPLEMENTARY INVESTMENTS, ORGANIZATIONAL CHANGE AND SPILL OVER FROM KNOWLEDGE ACCUMULATION

Direct and Indirect Complementarity between Workplace Reorganization and New Technology

Annalisa Cristini - Alessandro Gaj - Riccardo Leoni*
University of Bergamo

We link survey and balance sheet data to investigate the extent of complementarity between the introduction of new technology and changes in workplace practices. Across all firms, we find that new technology is complementary with higher work intensity. Similarly, changes in work techniques yield diffuse complementarity gains, particularly in firms undergoing extensive restructuring. Changes in work organization yield, on average, complementarity gains in terms of productivity growth. Substitutability between new technology and specific workplace changes is sometimes found, consistently with the presence of costs associated to learning functions or resistance to changes. [JEL Classification: D23, L23, O33, J24, M54]

Key words: workplace practices, ICT investments, complementarity.

1. - Main Issues and the Existing Literature

It is widely recognized that the traditional work organization, based on extensive hierarchy, low levels of delegation and narrow skills, is inadequate to fully exploit the potentials of the general-

* <annalisa.cristini@unibg.it>; <alessandro.gaj@unibg.it>; <riccardo.leoni@unibg.it>; Department of Economics "Hyman Minsky". This research is supported by internal funds of University of Bergamo. Previous versions of this paper have been presented at International Workshops held respectively in Oslo, Norway (January 2006, on the Use and Analysis of Employer-Employee Data, at the Institute for Social Research) and in Lucca, Italy (January 2007, on Internal Organization, Cooperative Relationships among Firms and Competitiveness). We are grateful to all participants and in particular to Eliana Baici, Francesca Bettio, Alex Coad, Anna Grandori, Lisa Lynch, Federica Origo, Mario Pianta, Kjell Salvanes and an anonymous referee for their very useful comments. Usual disclaimers are applied.

purpose computer-based technology. The diffusion of the latter is expected to have a pervasive impact on the firm's life as it is likely to imply both technical and organizational changes. The higher speed of computation allows the processing of large quantity of data and enables new work techniques based on sophisticated machines and equipments. To exploit the increased amount of computer-processed information more employees are empowered and given some decisional control (Brynjolfsson *et* al., 2002; Breshnan *et* al., 2002). Communication is facilitated, information sharing among employees and between employees and managers is encouraged and this enhances employees' involvement, autonomy and discretion. On the whole, these events are expected to trigger major processes of re-organization within the firm: middle and line managers are crowded out, flattening the hierarchical structure; new workplace practices entailing employees' involvement are adopted and competencies in technical, relational and cognitive skills are upgraded.

The new technology and the newly designed workplace are expected to raise factors' productivity, allow costs reduction, endorse knowledge creation and eventually spur innovations and firm growth. If the net gain to the firm's payoff is positive, investments in computer technology and the workplace re-design are said to be complements.

This broad brush progression of events is quite commonly observed and documented by the empirical literature[1]; still, the latter equally recognizes that the firm specificities make each re-design process a peculiar one; a fully standard re-organization scheme cannot be conceived for various reasons: firm characteristics like size, age, technical aspects of the production may determine different extent of complementarity gains; for given firm characteristics the reorganization process still involves some discretionary actions on the part of the managers, particularly if different strategies are possible. Consequently, complementarity between introduction of ICT and firm re-organization is ultimately

[1] BLACK S. - LYNCH L. (2001, 2004); BRYNJOLFSSON E. *et* AL. (2002); BRESHNAN T. *et* AL. (2002); BAUER T.H. (2003); LAURSEN K. - FOSS N.J. (2003); CRISTINI A. *et* AL. (2003); ZWICK T. (2004).

idiosyncratic and the complementarity-induced gains are firm specific.

The distinctiveness of each firm renovation process explains why the empirical analysis is essentially micro, based either on case studies or on survey firm-level data. At this regard, the latter type of data, if available for representative samples, allows more general conclusions than those obtained from case studies but usually provides less detail on qualitative and non-accountable information. This is particularly limiting for the analysis in object since the reorganization of the workplace entails complex interactions of practices regarding various aspects of the firm's life like the working time, the forms of employees' involvement, the work organization, the incentive schemes.

There is also a time dimension, in addition, which is very important. Any redesign of the workplaces can be viewed as a process that evolves along time and takes some time to be completed[2]. In particular, we expect investments in general-purpose ICT to be relatively low cost whereas other changes, specifically those related to human resource practices are both costlier and slower to activate. Therefore, the complementarity between contemporaneous ICT and organizational changes may not emerge or may even be negative, signalling, for example that the process of adjustment has not yet be completed or that adjustment costs outweigh the gains. Indeed, where investigations can rely on panel data, a considerable time lag between adoption and productivity results is usually observed. The Danish Ministry of Business and Industry (1996), for example, documents that the implementation of both ICT investments and organizational changes deploys a positive and rising impact on productivity from the fourth year after adoption; Brynjolfsson *et* al. (2002) find that the performance

[2] According to some evidence, the diachronic nature of firm reorganizations implies that practices are adopted sequentially, stepping from those most largely diffused and easy to adopt to those more difficult and costly to implement (FREEMAN R. *et* AL., 2000). If this is the case, and hence if it is possible to identify a single, though imperfect, reorganization meter, then the set of practices in existence in a firm at a point in time also indicate the firm's advancement in the reorganization process itself.

effect of the interacted ICT-reorganization term rises appreciably in the third year[3].

Moreover, adjustment costs may depend on the extent of reorganization: a situation in which the workplace is undergoing an extensive renovation (many dimensions are being changed) differs considerably from a situation in which only one or two changes are introduced. For example, one expects that where many changes are being undertaken potential complementarity gains are higher[4] although employees, in this case, may need more time to learn and adapt to the new environment or may even resist the changes thereby reducing the benefits of the restructuring.

In this paper we make use of linked balance sheet-survey data for a sample of 100 firms. Balance sheet data are avaiable from 1990 to 1999 whereas the survey data are from the retrospective section of a questionnaire on workplace practices, addressed in 1999 to the universe of industrial firms with more than 50 employees located in the province of Bergamo in the North of the Italy. These survey data provide information on the occurrence, in the triennium preceding the survey, of various organizational changes and on the adoption of new technologies. The details obtainable from the survey allow us to address the multiple dimensions of the redesign of the workplace; moreover, the three year retrospective information, linked with the balance sheet panel data, attenuate the usual limits of a cross-sectional survey and allow to account for some time evolvement. We carry out complementarity tests between the introduction of new technology and the changes in the workplace. We consider both direct and

[3] With regard to bundles of workplace practises the time lag appears to be even longer: KATO T. - MORISHIMA M. (2002) find that complementary participatory human resource management practices lead to a significant increase in productivity only seven years after their introduction; similarly BAUER (2003) shows that the productivity effect of implementing high performance workplace practices rises over time and has a positive impact on labor efficiency only in the long run.

[4] MILGROM P. - ROBERTS J. (1990) cite various literature according to which «the full benefits are achieved only by an ultimately radical restructuring» (page 513).

indirect complementarity (Athey and Stern, 1998) and check for the assumption of exogenous organizational and technological changes. The paper proceeds as follows: the next section describes the data; section 3 illustrates the basic model and section 4 discusses the corresponding empirical findings; the last section concludes.

2. - The Data

We use a sample of 100 industrial firms with more than 50 employees located in Lombardy, Italy's most industrialized area; the data come from two sources: longitudinal 1991-1999 balance sheets from the "Balance Sheet Register" of Turin and a survey providing detailed information on the workplace practices existing at the date of the survey — year 1999 — and, retrospectively, on the introduction, in the triennium preceding the survey, of new technology and of various changes regarding the workplace organization. Specifically, the respondent is asked whether the firms has introduced the following changes:

1. introduction of new technology
2. changes in working hours
3. changes in work organization
4. changes in work techniques
5. introduction of new initiatives of employees' involvement

A second question asks the respondent whether the firm has increased:

6. the employees' autonomy in carrying out their job (job autonomy)
7. the flexibility of moving employees from one task to another (job rotation)
8. the subordinates' loads of work (work intensity).

The first group of items captures general and across the board changes which signal reorganization processes along the lines sketched above. The items listed in the second group, being more specific, have the advantage of looking into the reorganization but can be potentially detached from a coherent process of reorganiza-

tion; they could still complement with introduction of new technologies if they are part of larger bundles (Ichniowsky *et* al., 1997). Job rotation and job autonomy, for example are usually regarded as practices typical of an innovative system; work intensity, on the contrary, is associated with management by stress which some literature views as a possible byproduct of the high performance workplace (Green, 2004).

Table 1 reports the diffusion of reorganizations for the whole

TABLE 1

INTRODUCTION OF NEW TECHNOLOGIES AND ORGANIZATIONAL CHANGES IN THE TRIENNIUM 1997-1999 *(percentages)*

	all firms	small firms	large firms
Introduction of new technologies	80.81	85.42	76.47
Changes in work organization	70.71	68.75	72.55
Changes in work techniques	58.16	62.50	54.00
Introduction of initiatives of employees' involvement	54.55	50.00	58.82
Changes in working hours			
Increase in:	all firms	small firms	large firms
Job rotation	61.00	51.02	70.59
Work intensity	49.00	44.90	52.94
Job autonomy	44.44	36.73	52.00

Note: For convenience small (large) firms are defined as those with a number of employees smaller (larger) than the median (168 employees). The number of observation is 100 (or 99) when all firms are considered, 49 (or 48) for the small firm group and 51 (or 50) for the large firm group.

group of firms (first column) and for two subgroups defined according to the firm's employment being below (second column) or above (third column) the median employment (168 employees). On average, more than 80% of the firms introduced new technologies during the triennium 1997-99; changes in work organization, though quite spread, are not as common and involve

71% of the firms: 58% of the firms, changed worktechniques 54%, introduced initiatives of employees' involvement; changes in working hours regarded 46% of the firms (column 1). The ranking of these organizational changes is essentially the same for the two subgroups although we find that a larger percentage of smaller firms introduced new technology (85% *versus* 76% of the larger firms) and changed work techniques (68% *versus* 54% of the large firms). On the contrary, the smaller firms changed the work organization comparatively less (69% *versus* 73%), were less prone to introduce initiatives of employees' involvement (50% versus 59%) and made much less use of changes in working hours (35% versus 57%). On the whole, small firms seem to have paid attention more to the techniques than to the organization of the system.

The same conclusion holds when looking at single practices. The flexibility in moving employees across jobs (job rotation or multitasking), a practice aimed at involving employees by enhancing their knowledge of the production process and their familiarity with the organization, increased in 61% of the firms on average (70% in large firms and 50% in small firms). A comparatively smaller percentage of firms, 44%, declared to have increased employees' autonomy, a practice signalling an advanced stage of employees' empowerment; again, the percentage is lower for small firms. Half of the firms declared an increase in the loads of work and this case the incidence is similar between large and small firms.

It is not easy to say how this picture compares with the existing evidence for Italy since the workplace surveys available for the same period tend to group all types of workplace changes under the generic heading of firm reorganisation. Trento and Warglien (2001), on the basis of a representative sample of 1500 manufacturing firms, document — in line with our study — that over 80% of the firms introduced some form of new technology although they left hierarchical levels unchanged. Bugamelli and Pagano (2001), using a sample of over 2000 firms, report that in the period 1995-97, only about 30 percent of the firms claimed some form of reorganization mainly related to process innovation;

this percentage, quite smaller than our figures, is probably due both to the inclusion of smaller firms in their sample (their median size being 48 employees) and, perhaps even more importantly, to the time period they use since the principles of the so called "lean production" were only starting, at that time, to be introduced: they had been little known from the business practice in Italy until the second half of the nineties[5]. In the European countries, according to the EPOC survey (European Foundation for the Improvement of Living and Working Conditions, 1997), over the triennium 1993-1996, initiatives of involvement of lower level employees, of team-based work reorganization and of job rotation took place, respectively, in 33%, 27% and 15% of the firms. Again this figures are smaller than our evidence although we must consider that these data also relate to a previous triennium and that the situation within southern European countries is quite heterogeneous. For the US, Freeman *et* al. (2000) find that employee involvement in various activities (the design of compensation systems, of productivity enhancing methods and of performance evaluation systems) is present in almost 70% of the firms, a much larger percentage than the figure we record for general initiatives of employee involvement; autonomous team working is adopted by 50% of the firms: this is a higher percentage than the one we record for employees' autonomy in their job though we do not have figures on changes regarding the extent of team working.

3. - The Organisational Production Function

We are interested in testing which type of organizational changes a firm investing in new technology should undertake in order to gain efficiency. The relevant concept is one of

[5] Until the beginning of the 1990s the driving model of production in Italy has been the flexible specialization of the industrial districts (PYKE F. *et* AL., 1990). VIESTI G. (1992) raised questions about the possibility of protracting the advantages of the flexible specialization model, while MARIOTTI S. (1994) was one of the first scholars to signal first sporadic implementations of lean production principles among Italian big and medium size firms.

complementarity according to which two variables are complements if having more of one increases the returns of having more of the other (Topkis, 1978; Milgrom and Roberts, 1990, 1995). The empirical test of complementarity is based on a general specification that allows for both direct and indirect complementarity where the latter is enabled by specific variables which act as conditioning variables (Athey and Stern, 1998). In our specification we allow these conditioning variables to be time varying or time invariant. Examples of the first type are the production inputs (labour input or the capital-labour *ratio*); examples of the second type are firm size and other firm characteristics assumed given in the period under consideration.

Let Ω_{it} be the vector of time varying conditioning factors, Φ_i be the vector of time invariant conditioning factors, Z_{tec} be a dummy equal 1 if the firm has introduced new technology in a given period of time and Z_λ be a vector of m dichotomic workplace changes undertaken by the same firm in the same period. Then, the firm's return to a joint adoption of new technology and of any λ reorganization practice is defined as follows:

$$\begin{aligned}\rho_{tec-\lambda,it} = {} & (\gamma_{00} + \alpha_{00}\Omega_{it} + \beta_{00}\Phi_i)(1 - Z_{tec})(1 - Z_\lambda) + \\ & (\gamma_{10} + \alpha_{10}\Omega_{it} + \beta_{10}\Phi_i)Z_{tec}(1 - Z_\lambda) + \\ & (\gamma_{01} + \alpha_{01}\Omega_{it} + \beta_{01}\Phi_i)(1 - Z_{tec})Z_\lambda + \\ & (\gamma_{11} + \alpha_{11}\Omega_{it} + \beta_{11}\Phi_i)Z_{tec}Z_\lambda\end{aligned} \qquad (1)$$

where $\lambda=1,\ldots,m$ are the organizational changes of interest and ρ is the system-specific return. Given the return specified as in equation *(1)*, the introduction of new technology and the reorganization λ are said to be complements if the following inequality holds:

$$\begin{aligned}&(\gamma_{11} + \alpha_{11}\Omega_{it} + \beta_{11}\Phi_i) - (\gamma_{10} + \alpha_{10}\Omega_{it} + \beta_{10}\Phi_i) \geq \\ &(\gamma_{01} + \alpha_{01}\Omega_{it} + \beta_{01}\Phi_i) - (\gamma_{00} + \alpha_{00}\Omega_{it} + \beta_{00}\Phi_i)\end{aligned} \qquad (2)$$

Our objective, carried out in the following empirical investigation, is to test inequality *(2)* using $\hat{\alpha}$, $\hat{\beta}$, and $\hat{\gamma}$ estimated from equation *(1)*.

In order to define the empirical counterpart of equation *(1)*, we need to decide on a measure of ρ and choose Ω and Φ. With regard to the firm's return, we use the firm's productivity defined as value added *per* employee. Value added accounts for most of the costs of organizational changes (for example: external consultants, services, training) as well as other potential costs, like a loss in production in the initial period of adoption of a new technology or of a new practice and it is therefore a suitable net measure. As far as the choice of the variables which might indirectly enable complementarity, we choose the firm's capital intensity as and indicator of the firm's production function; we expect some organizational changes to be more effective, *ceteris paribus*, in labour intensive firms (for example changes directly involving the employees' amount of work), and others to be more effective in capital intensive firms, for example changes in the techniques of work).

As time invariant indicators we choose the firm's size, age and extent of reorganization. Although there isn't a precise *a priori* on the expected role of these firm characteristics in enabling complementarity with the introduction of new technology, according to the existing evidence organizational changes are relevant and feasible only above a certain size (Millward, 2001). Older firms are usually less dynamic and prone to changes, so that we expect young and old firms to differ in their reorganization strategies. Likewise, the extent of reorganization can also have ambiguous effect on the complementarity gains. On the whole we expect the empirical analysis to highlight, on the one hand, those workplace changes which easily complement technology across all type of firms and, on the other, those changes which are complementary only for particular firm types.

The empirical organizational production function is specified as follows:

$$
\begin{aligned}
y_{tec-\lambda,it} = {} & (1-Z_{tec})(1-Z_{\lambda})(\gamma_{00}+\beta_{00}\Phi_i) + Z_{tec}(1-Z_{\lambda})(\gamma_{10}+\beta_{10}\Phi_i) + \\
& (1-Z_{tec})Z_{\lambda}(\gamma_{01}+\beta_{01}\Phi_i) + Z_{tec}Z_{\lambda}(\gamma_{11}+\beta_{11}\Phi_i) + \\
& (1-Z_{tec})(1-Z_{\lambda})\alpha_{00}k_{it} + Z_{tec}(1-Z_{\lambda})\alpha_{10}k_{it} + \\
& (1-Z_{tec})Z_{\lambda}\alpha_{01}k_{it} + Z_{tec}Z_{\lambda}\alpha_{11}k_{it} + \\
& \tau' X_{it} + \omega_{it}
\end{aligned}
\qquad (3)
$$

where y is the log of value added per employee, k is the log of the capital labour *ratio*, X is a vector of controls which includes: time dummies, sector dummies, and the log of capital to allow for non constant returns to scale[6], ω is an error term comprising a random component $IN(0,\sigma_\omega)$ and some unobservable fixed effects. Since the survey does not ask for the exact year of introduction of both new technology and organizational changes but only if such changes have occurred during the triennium prior the survey, we assume that each observed change (both organizational and technological) is uniformly introduced during the period 1997-1999 so that each dummy extends from 1997 to 1999. Therefore each organizational production function in *(3)* has a three-year panel structure and is separately estimated.

The estimation of equations *(3)* has to account for two usual problems.

One problem is the endogeneity of the regressors. Employment and capital, since simultaneously decided with output, should be treated as endogenous; moreover measurement problems may be relevant especially for the capital stock.

More debatable is the extent to which the organizational changes and introduction of new technologies are endogenous (Athey and Stern, 1998; Osterman, 2006); there are two reasons why they may be so. The potential reverse causality is relevant as long as the decision to introduce organizational changes or new technology is affected, among other things, by the firm's VA and the latter is, in turn affected by the system of adopted practices. Indeed, if we think of workplace practices as 'special factor inputs', then they are choice variables and hence endogenous in the organizational production function. A second reason why work-

[6] Equation *(3)* is clearly obtainable from a generalized Cobb Douglas production function of the following type: $Y=AN^aK^b$ where A is the multifactor productivity and a, b are the shares of labour and capital. Diving by N and using logarithms the production function can be written as follows: $\log(Y/N)=\log A+(1-a)\log(K/N)+(1+b-a)\log K$ where the last term is zero if returns to scale are constant. Since we look at a short period of time (three years) we allow non constant returns to scale and therefore include log K as a control variable.

place practices may be endogenous is that there may be a common unobserved factor that drives the choice to adopt new practices/-technology and the firm's productivity. Such common factor may be a productivity shock or a demand shock and as long as it is unobservable, being also time variant, the error term in equation *(4)* is not orthogonal to *Z*.

The existing literature on the adoption does not find clear cut results and recently Osterman (2006) reinforces the conclusion of not significant endogeneity. Still, since in presence of endogeneity OLS estimates are biased and inconsistent, we first estimate equations 4 using IV which also take care of the usual endogeneity of employment and capital, test for endogeneity using Hausman specification test and use OLS only if the latter does not reveal an endogeneity bias.

Another typical problem arises if unobservable fixed effects are correlated with the regressors; to obtain consistent estimates of the α'*s* we use the within estimator. However such estimator implies that the time invariant effects, and in particular the parameters of interest γ'*s* and β'*s*, capturing the impact of practices on the multifactor productivity, cannot be directly estimated; however they can be recovered. The empirical organizational production functions therefore look as follows:

$$\begin{aligned}\tilde{y}_{tec-\lambda,it} = {} & (1-Z_{tec})(1-Z_{\lambda})\alpha_{00}\tilde{k}_{it} + Z_{tec}(1-Z_{\lambda})\alpha_{10}\tilde{k}_{it} + \\ & (1-Z_{tec})Z_{\lambda}\alpha_{01}\tilde{k}_{it} + Z_{tec}Z_{\lambda}\alpha_{11}\tilde{k}_{it} + \\ & \tau' \tilde{X}_{it} + \tilde{\omega}_{it}\end{aligned} \tag{4}$$

where ~ indicates the within transformation. Since the observable and unobservable fixed effects drop from the regression, equations *(4)* is used to estimate the α'*s* which are used to test for indirect complementarity through the capital intensity. Then, in order to test for overall complementarity, we recover the fixed effects of equation *(4)* and run the following OLS regressions:

$$\begin{aligned}u_i = {} & (1-Z_{tec})(1-Z_{\lambda})(\gamma_{00}+\beta_{00}\Phi_i) + Z_{tec}(1-Z_{\lambda})(\gamma_{10}+\beta_{10}\Phi_i) + \\ & (1-Z_{tec})Z_{\lambda}(\gamma_{01}+\beta_{01}\Phi_i) + Z_{tec}Z_{\lambda}(\gamma_{11}+\beta_{11}\Phi_i) + \delta\Theta_i + \upsilon_i\end{aligned} \tag{5}$$

where u_i is the firm time-average of the retrieved fixed effects and

Θ is a vector of strictly exogenous variables containing: sector dummies and the firm year of birth. Using the estimated γ*'s* and β*'s*, the overall complementarity can be tested.

In practice, the available degrees of freedom oblige us to estimates four different types of equations *(5)*, depending on the Φ. In one case (equation *(6)* below) Φ=0; β=0 and the estimated γ*'s* then allows us to compute the across-firm-average complementarity gain working through the multifactor productivity. The other three equations, from *(7)* to *(9)*, differ according to Φ being, alternatively, the class of the firm size (*Size*), the firm's age (*Age*) or the extent of reorganization (*Change*). The coefficients estimated from these last three equations allow to disentangle the across-firm-average complementarity gain associated to each possible couple Z_{tec}–Z_{λ}, by firm characteristics.

(6)
$$u_i = (1-Z_{tec})(1-Z_{\lambda})\gamma_{00} + Z_{tec}(1-Z_{\lambda})\gamma_{10} + \\ +(1-Z_{tec})Z_{\lambda}\gamma_{01} + Z_{tec}Z_{\lambda}\gamma_{11} + \delta\Theta_i + \upsilon_i$$

(7)
$$u_i = (1-Z_{tec})(1-Z_{\lambda})(\gamma_{S00} + \beta_{S00}Size_i) + Z_{tec}(1-Z_{\lambda})(\gamma_{S10} + \beta_{S10}Size_i) + \\ (1-Z_{tec})Z_{\lambda}(\gamma_{S01} + \beta_{S01}Size_i) + Z_{tec}Z_{\lambda}(\gamma_{S11} + \beta_{S11}Size_i) + \delta\Theta_i + \upsilon_i$$

(8)
$$u_i = (1-Z_{tec})(1-Z_{\lambda})(\gamma_{A00} + \beta_{A00}Age_i) + Z_{tec}(1-Z_{\lambda})(\gamma_{A10} + \beta_{A10}Age_i) + \\ (1-Z_{tec})Z_{\lambda}(\gamma_{A01} + \beta_{A01}Age_i) + Z_{tec}Z_{\lambda}(\gamma_{A11} + \beta_{A11}Age_i) + \delta\Theta_i + \upsilon_i$$

(9)
$$u_i = (1-Z_{tec})(1-Z_{\lambda})(\gamma_{C00} + \beta_{C00}Change_i) + Z_{tec}(1-Z_{\lambda})(\gamma_{C10} + \beta_{C10}Change_i) + \\ (1-Z_{tec})Z_{\lambda}(\gamma_{C01} + \beta_{C01}Change_i) + Z_{tec}Z_{\lambda}(\gamma_{C11} + \beta_{C11}Change_i) + \delta\Theta_i + \upsilon_i$$

Finally, using the estimated coefficients, we can compute the estimated complementarity gain between the introduction of new technology and any specific workplace change λ:

(10)
$$(a)\ \ \hat{\alpha}_{11} - \hat{\alpha}_{10} - \hat{\alpha}_{01} + \hat{\alpha}_{00}$$
$$(b)\ \ \hat{\gamma}_{11} - \hat{\gamma}_{10} - \hat{\gamma}_{01} + \hat{\gamma}_{00}$$
$$(c)\ \ (\hat{\gamma}_{S11} - \hat{\gamma}_{S10} - \hat{\gamma}_{S01} + \hat{\gamma}_{S00}) + Size_i(\hat{\beta}_{S11} - \hat{\beta}_{S10} - \hat{\beta}_{S01} + \hat{\beta}_{S00})$$
$$(d)\ \ (\hat{\gamma}_{A11} - \hat{\gamma}_{A10} - \hat{\gamma}_{A01} + \hat{\gamma}_{A00}) + Age_i(\hat{\beta}_{A11} - \hat{\beta}_{A10} - \hat{\beta}_{A01} + \hat{\beta}_{A00})$$
$$(e)\ \ (\hat{\gamma}_{C11} - \hat{\gamma}_{C10} - \hat{\gamma}_{C01} + \hat{\gamma}_{C00}) + Change_i(\hat{\beta}_{C11} - \hat{\beta}_{C10} - \hat{\beta}_{C01} + \hat{\beta}_{C00})$$

The complementarity gains listed in equations *(10) (a)-(10)(e)* are only partial while equations *(11)(a)-(11)(d)* refer to overall complementarity. Equation *(10)(a)* indicates the indirect complementarity working through the capital/labour *ratio*, *(10)(b)* is the direct complementarity through the total factor productivity, and each *(10)(c)-(10)(e)* allows the complementarity working through the total factor productivity to depend, alternatively, on firm's characteristics.

The formulas *(11)(a)-(11)(d)* below define various measures of overall complementarity: *(11)(a)* is the complementarity gain on the assumption that the multifactor productivity channel conveys only a direct effect, *i.e.* an effect that is independent of specific firm characteristics. In this sense this complementarity gain is the sample average one; still it varies with the capital labour *ratio*. The formulas *(11)(b)-(11)(d)* are analogous to *(11)(a)* but split the complementarity working through the multifactor productivity into a direct effect and an indirect effect enabled by, alternatively, firm size, age and extent of reorganization. In all cases the precise value of the complementarity gain associated to the joint adoption of new technology and any workplace changes λ, depends on the firm's capital labour *ratio* and other firm characteristics: size, age or extent of reorganization.

$$
\begin{aligned}
&(a)\quad (\hat{\gamma}_{11}-\hat{\gamma}_{10}-\hat{\gamma}_{01}+\hat{\gamma}_{00})+\eta_{it}(\hat{\alpha}_{11}-\hat{\alpha}_{10}-\hat{\alpha}_{01}+\hat{\alpha}_{00})\\
&(b)\quad (\hat{\gamma}_{S11}-\hat{\gamma}_{S10}-\hat{\gamma}_{S01}+\hat{\gamma}_{S00})+Size_i(\hat{\beta}_{S11}-\hat{\beta}_{S10}-\hat{\beta}_{S01}+\hat{\beta}_{S00})+\\
&\qquad +\eta_{it}(\hat{\alpha}_{11}-\hat{\alpha}_{10}-\hat{\alpha}_{01}+\hat{\alpha}_{00})\\
(11)\quad &(c)\quad (\hat{\gamma}_{A11}-\hat{\gamma}_{A10}-\hat{\gamma}_{A01}+\hat{\gamma}_{A00})+Age_i(\hat{\beta}_{A11}-\hat{\beta}_{A10}-\hat{\beta}_{A01}+\hat{\beta}_{A00})+\\
&\qquad +\eta_{it}(\hat{\alpha}_{11}-\hat{\alpha}_{10}-\hat{\alpha}_{01}+\hat{\alpha}_{00})\\
&(d)\quad (\hat{\gamma}_{C11}-\hat{\gamma}_{C10}-\hat{\gamma}_{C01}+\hat{\gamma}_{C00})+Change_i(\hat{\beta}_{C11}-\hat{\beta}_{C10}-\hat{\beta}_{C01}+\hat{\beta}_{C00})+\\
&\qquad +\eta_{it}(\hat{\alpha}_{11}-\hat{\alpha}_{10}-\hat{\alpha}_{01}+\hat{\alpha}_{00})
\end{aligned}
$$

The role of the enabler factors and the presence of different sources of complementarity imply that complementarity gains between new technologies and workplace changes may be found even if the "partial" complementarities do not all hold.

Finally, notice that a negative complementarity gain implies substitutability.

4. - Results

Table 2 reports the main results of the analysis, that is the estimated complementarity gains corresponding to the formulas *(11)(a)-(11)(d)*. These values are computed from coefficients estimated using OLS fixed effects, after Hausman test excluded the presence of significant endogeneity. In the Appendix we report the production function estimates, the Hausman tests, the one tail tests on the partial complementarity and the regressions using the retrieved fixed effects. In the following, for convenience, results are reported in a two entry table, by capital-labour *ratio* quartiles and by firm characteristics. Along each row, the capital labour *ratio* is fixed either at the first quartile, at the median or at the last quartile, while firm characteristics change across columns. The first column corresponds to the formula *(11)(a)*, hence it gives the average overall complementarity gain; columns (2) and (3) are based on the formula *(11)(b)* and report the complementarity gain for large and small firms[7]. Columns (4) and (5) are based on the formula *(11)(c)* and report the complementarity gain for old and young firms[8]. Finally, columns (6) and (7) are based on the formula *(11)(d)* and report the complementarity gains for firms that have undergone a significant restructuring in the three years before the survey and for firms that have not undergone extensive reorganisations[9].

The most interesting result is that the increase in work intensity is the only change that shows positive complementarity

[7] *Size* is a 1-4 categorical variable; column (2) takes *Size*=4 and column (3) takes *Size*=1.

[8] The median age of the firms in the sample is 19 years, the 90th decile of the distribution is 60 years and the 10th decile is 6 years. Column (4) takes *Age*=6 and column (1) takes *Age*=60.

[9] We construct an indicator of the extent of restructuring on the basis of the number of changes the firm states to have undertaken in the three years before the survey. We consider the following changes: changes in working hours, in work techniques, in the pay system, organizational changes, introduction of new initiatives of employee involvement, introduction of new technology, reduction in hierarchical levels. The maximum score is 7, the top 10th deciles of the distribution is 6, the median is 4 and the bottom 10th decile is 1. Column (6) assumes 6 changes, column (7) assumes 1 change.

TABLE 2

COMPLEMENTARITY GAINS IN TERMS OF PRODUCTIVITY

		Size		Age		Restructuring	
	Average (1)	Large (2)	Small (3)	Old (4)	Young (5)	Yes (6)	No (7)
log(K/N)	Increase in work intensity						
1st quartile	0.32	0.03	0.62	0.05	0.47	0.39	0.14
2nd quartile	0.37	0.08	0.67	0.09	0.51	0.43	0.19
3rd quartile	0.42	0.13	0.72	0.15	0.57	0.49	0.24
	Increase in job rotation						
1st quartile	0.05	0.15	-0.08	0.55	-0.24	-0.58	0.24
2nd quartile	-0.02	0.09	-0.15	0.49	-0.30	-0.64	0.17
3rd quartile	-0.10	0.01	-0.23	0.41	-0.38	-0.72	0.10
	Increase in job autonomy						
1st quartile	-0.21	-0.24	-0.22	-0.13	-0.36	-1.11	0.19
2nd quartile	-0.23	-0.25	-0.23	-0.14	-0.37	-1.13	0.18
3rd quartile	-0.24	-0.27	-0.25	-0.16	-0.39	-1.14	0.17
	Changes in working hours						
1st quartile	0.09	1.34	-1.23	0.06	-0.02	1.64	-2.07
2nd quartile	-0.15	1.10	-1.47	-0.17	-0.26	1.40	-2.31
3rd quartile	-0.43	0.82	-1.74	-0.45	-0.54	1.12	-2.59
	Organisational changes						
1st quartile	-0.18	-0.04	-0.57	-0.86	0.05	-0.83	-0.16
2nd quartile	-0.03	0.11	-0.42	-0.72	0.20	-0.68	-0.01
3rd quartile	0.14	0.28	-0.25	-0.54	0.37	-0.51	0.16
	Changes in work techniques and methods						
1st quartile	0.19	0.28	0.15	0.28	0.15	1.20	-0.21
2nd quartile	0.26	0.35	0.22	0.35	0.22	1.27	-0.14
3rd quartile	0.34	0.43	0.30	0.43	0.30	1.35	-0.06
	Introduction of initiatives of employees involvement						
1st quartile	-0.01	-0.75	0.59	-0.31	0.01	0.13	-0.26
2nd quartile	0.07	-0.68	0.67	-0.24	0.09	0.20	-0.19
3rd quartile	0.15	-0.59	0.75	-0.15	0.17	0.29	-0.10

Note: The complementarity gain is defined according to formula 11; it is the increase in value added per employee due to the introduction of new technology and workplace change additional to the increase due to the introduction of either new technology alone or the workplace change alone. Recall that in the triennium under consideration, value added per employee has a mean of 4.6 and a standard deviation of 0.41.

gain across all firm characteristics. Increasing work intensity, in conjunction with the introduction of new technology, produces a net gain in terms of VA per employee which rises slightly with the capital labour *ratio*. The gain is, on average, around 1 standard deviation (column 1) which implies, for a median firm, a rise to the third quartile or to the 90th decile, depending on the capital-labour *ratio*. Changes in work techniques also complements rather diffusely across firm characteristics with the exception of firms that are not undergoing other changes (last column). The impact of the capital labour *ratio* is in this case more important and again the gains rise with the intensity of capital. The complementarity gain is above average in presence of extensive changes (column 6): the extra gain can shift the firms from the 25th percentile to the median position.

Increase in job autonomy scores worst in terms of complementarity gains: in fact they are negative for all capital labour *ratios* and for all firm characteristics except those which are not undergoing a restructuring; on the contrary, firms that are undergoing extensive restructuring suffer the largest loss of productivity when jointly adopting new technology and increasing job autonomy; the loss is larger than 3 standard deviations and would drag a firm from median position to the bottom 5th percentile. A similar loss in productivity arises when combining introduction of new technology with job rotation, in presence of firm restructuring. The loss is slightly lower in this case but still sufficient to drag a median firm to the bottom 10th percentile of the productivity distribution. On the other hand, job rotation is complementarity for old firms. The overall small or nihil complementarity gain from job autonomy and job rotation supports the idea that practices which are essentially based on the employees' participation, like job rotation and job autonomy, may need longer time to produce positive effects because they need to discount longer adjustment costs in the form of learning or resistance to changes.

The pattern that emerge for the changes in work organization is not clear cut; on average the gains become positive for high capital intensive firms but of these only young

firms and large firms can gain a good productivity increase from complementarity. Initiatives of employees' involvement is, instead, a particularly good complementarity practice for small firms and again the gain rises with capital intensity. Finally, the gain from complementing new technology with changes in working hours is rather small, on average, and positive only for low capital intensive firms; however it may be particularly effective for firms undergoing other changes (column 6) and for large labour intensive firms (column 2).

Reading the results of Table 2 by column we can see that for large firms the best complementary practise is changes in working hours; for small firms as well as for young firms it is the increase in work intensity; for firm under restructuring it is either changes in working hours or in working techniques; for firms that are not under restructuring, the complementarity gains are all relatively small and obtainable through an increase in work intensity or, for labour intensive firm, from job rotation.

4.1 *Complementarity Gains and the Productivity Growth*

The issue of whether the complementarity gains should be measured on the firm's productivity level or on its productivity growth is an interesting one as in the first case complementarity affects the firm's efficiency and, in the latter case, it affects the firm's dynamic efficiency thereby making complementarity between new technology and organizational changes a vehicle for innovation. This is not a new issue, various authors have investigated the links between the firm's degree of innovation in terms of new product or R&D and new workplace practices (see for example Michie and Sheehan, 2003; Laursen and Foss, 2003).

In the following we take the increase in productivity between 1996 (the year at the beginning of the triennium during which organizational changes and new technology have been adopted) and 1999, the final year. By working on the changes in productivity, we reduce the three year panel to a cross section

TABLE 3

COMPLEMENTARITY GAINS ON THE PRODUCTIVITY GROWTH, FOR A GIVEN CAPITAL-LABOUR *RATIO*

		Size		Age		Restructuring	
	Average (1)	Large (2)	Small (3)	Old (4)	Young (5)	Yes (6)	No (7)
Increase in:							
Work intensity	-0.07	0.57	-0.96	-3.01	1.00	0.62	-0.06
Job rotation	-0.31	0.53	-1.22	0.23	-0.51	0.03	-0.43
Job autonomy	-0.48	-0.45	-0.77	0.1	-0.82	1.18	-1.56
Changes in:							
Working hours	-0.37	-0.42	-0.25	1.36	-1.19	-0.42	-1.35
Organization	0.47	1.26	0.00	1.36	-0.16	-5.19	1.02
Work techniques	0.09	-0.87	1.11	-0.23	0.30	0.03	-0.04
New initiatives of employees involvement	-0.04	-0.41	0.24	-0.52	0.19	1.82	-1.00

Note: Recall that in the triennium under consideration, the growth of the value added per employee has a mean of -0.025, a median of 0.066 and a standard deviation of 0.36.

but avoid potential bias from unobservable fixed effects. The estimated equation neglects the indirect effect working through the capital labour *ratio*, essentially for the limited number of observations and on the account that, as shown in Table 4 in the Appendix, the average results on the level of productivity do not change substantially when averaging the role of the capital-labour *ratio*. The estimated equation is therefore of the following type:

$$d_3 y_{tec-\lambda,it} = (1-Z_{tec})(1-Z_\lambda)(\gamma_{00}+\beta_{00}\Phi_i) + Z_{tec}(1-Z_\lambda)(\gamma_{10}+\beta_{10}\Phi_i) + (1-Z_{tec})Z_\lambda(\gamma_{01}+\beta_{01}\Phi_i) + Z_{tec}Z_\lambda(\gamma_{11}+\beta_{11}\Phi_i) + d_3 k_{it} + \tau' d_3 X_{it} + \omega_{it} \quad (12)$$

where d_3 indicates the three year difference and the rest of the variables are as previously defined. Table 3 reports the results in a two entry table; the single production functions, in the case of no indirect effect in the fixed effects, are reported in the appendix; those with indirect effects are available from the author on request. Looking at the average effect (column 1) the most interesting result is that changes in work organization now turn out to be the only change that produce a complementarity gain in terms of productivity growth. By reading across columns, again we see that changes in work organization are particularly profitable for large firms and for old firms but also for firms that have not undertaken many other changes. Small firms gain most by complementing new technology with changes in work techniques while increases in work intensity produce large gains in young firms. New initiatives of employees' involvement turns out to be the best complements to new technology in firms under restructuring.

5. - Conclusions

We link survey and balance sheet data to analyze the complementarity between the introduction of new technology and changes in workplace practices; specifically, we investigate the relevance of direct and indirect complementarity on the firm's

payoff measured both in the terms of productivity level and in terms of productivity growth. From the estimated average gains (column 1 Table 2 and column 1 Table 3), two specific results emerge: regarding the gain in terms of productivity, we find that increases in work intensity is a general effective practise to follow in presence of introduction of new technology, since it is complementary across all types of firms. The complementarity gain is around one standard deviation and slightly larger for capital intensive firms. Changes in work techniques have a similar impact but the gain is smaller, particularly for labour intensive firms. The average complementarity gains in dynamic efficiency, measured by the growth of the firm's productivity since the introduction of the changes (column 1 Table 3), are largest when changes in work organization complement the introduction of new technology. However, both in terms of productivity and even more in terms of productivity growth, the distribution of the gains by firm characteristics is rather heterogenous and indeed we are able to identify a set of "best practices" by firm characteristics.

On the whole, our results indicate that work intensification is a "safe" practice to yield productivity gains when new technology is introduced, although it is not equally efficient in terms of productivity growth. This result is consistent with the literature pointing to work intensification as a likely situation in the new workplace (Green, 2004) with worrying consequences in terms of quality of work (Askenazy and Caroli, 2006). In fact, changes in work techniques emerge as an alternative route which, though not as profitable for small firms, it is largely more efficient in presence of an extensive reorganization process; if one considers that the median firm undergoes four changes in the sample period, increases in work intensity can be relatively less profitable. The presence of more than one change implies, in addition, that the overall complementarity gain should consider not only the sum of the gains from the various changes but also their possible interplay, extending the concept of complementarity to workplace changes. Unfortunately the number of observations in this sample prevented an analysis of this type.

Finally, the evidence of some negative gains indicates in-

stances of substitutability between introduction of new technology and some particular workplace changes; substitutability could be viewed either as structural condition, depending on firm's characteristics, or as a transitory state which reverts to complementarity on a longer horizon when reorganization costs have been paid. In this sense, it could be argued that the substitutability between the introduction of new technology and increases in job autonomy, being diffused across all firm types except those that are not undergoing adjustments, is consistent with the presence of costs of learning and resistance to change.

APPENDIX

TABLE 4

COMPLEMENTARITY GAINS FOR A GIVEN CAPITAL-LABOUR *RATIO*

		Size		Age		Restructuring	
	Average (1)	Large (2)	Small (3)	Old (4)	Young (5)	Yes (6)	No (7)
Increase in:							
Work intensity	0.37	-0.02	0.71	-0.17	0.63	0.48	0.18
Job rotation	-0.07	-0.05	-0.17	0.63	-0.41	-0.93	0.22
Job autonomy	-0.35	-0.36	-0.44	-0.20	-0.54	-1.17	0.05
Changes in:							
Working hours	-0.16	1.65	-2.17	-0.11	-0.30	2.02	-3.13
Organization	-0.02	0.63	-0.59	-0.34	0.13	-0.51	-0.02
Work techniques	0.33	0.45	0.27	0.45	0.28	1.58	-0.16
New initiatives of employees involvement	0.04	-1.07	0.96	-0.05	-0.01	0.13	-0.22

Note: The corresponding production function estimates are available on request.

TABLE 5

PRODUCTION FUNCTION, OLS FIXED EFFECTS

	(1) Work intens	(2) Job rot	(3) Job auto	(4) Ch hours	(5) Ch w org	(6) Ch w tec	(7) New involv
α_{11}	0.29*	0.24*	0.13	0.12	0.21	0.31**	0.31**
	(0.15)	(0.14)	(0.16)	(0.16)	(0.14)	(0.15)	(0.14)
α_{01}	0.48	0.54*	0.38	0.58*	0.36	0.48	0.48
	(0.43)	(0.3)	(0.38)	(0.31)	(0.32)	(0.41)	(0.35)
α_{10}	0.26*	0.34**	0.36**	0.35**	0.41**	0.24	0.22
	(0.15)	(0.16)	(0.14)	(0.14)	(0.17)	(0.15)	(0.16)
α_{00}	0.55*	0.49	0.59	0.3	0.88*	0.56	0.55
	(0.33)	(0.54)	(0.36)	(0.47)	(0.47)	(0.34)	(0.38)
lk	-0.22**	-0.22**	-0.18*	-0.18*	-0.20*	-0.22**	-0.20*
	(0.1)	(0.1)	(0.11)	(0.1)	(0.1)	(0.1)	(0.11)
Constant	87.83***	88.75***	91.61***	89.74***	82.81***	87.80***	86.72***
	(28.65)	(28.61)	(28.9)	(28.36)	(28.66)	-29	(28.7)
Sector dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time dum	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R sq.	0.09	0.09	0.11	0.11	0.11	0.09	0.09
N	252	252	249	252	252	249	252
Hausman test							
Chi (7)	1.27	1.18	1.64	1.17	0.79	0.66	1.22
Complementary test	0.98	0.99	0.98	0.99	0.99	0.99	0.99
F(1,154)							
pval	0.03	0.05	0	0.81	0.3	0.08	0.1

Note: Standard errors in parenthesis. The regressions correspond to equation *(4)* in the text. The IV regression used to test for endogeneity uses the following instruments: number of average reorganization changes in the other firms of the sector, the firm's year of birth, three year MA of: leverage, export sales and operative profits, all lagged four periods, log of capital and log labour all lagged three and four periods, size dummies. Complementarity tests are one tail tests.

TABLE 6

REGRESSIONS USING RETRIEVED FIXED EFFECTS FROM PRODUCTION FUNCTION ESTIMATES; NO INDIRECT EFFECTS, OLS

	(1) Work intens	(2) Job rot	(3) Job auto	(4) Ch hours	(5) Ch w org	(6) Ch w tec	(7) New involv
γ_{11}	7.11	8.27*	8.69**	9.64**	8.15*	7.54*	7.96*
	(4.27)	(4.49)	(4.12)	(4.37)	(4.52)	(4.33)	(4.25)
γ_{01}	6.14	7.08	7.81*	7.83*	7.55*	6.74	7.23*
	(4.28)	(4.46)	(4.11)	(4.35)	(4.51)	(4.33)	(4.24)
γ_{10}	7.26*	7.89*	7.63*	8.63*	7.26	7.76*	8.41*
	(4.27)	(4.48)	(4.12)	(4.37)	(4.51)	(4.34)	(4.25)
α_{00}	6.24	7.26	6.64	8.79**	5.31	6.6	7.08
	(4.26)	(4.5)	(4.13)	(4.38)	(4.54)	(4.33)	(4.26)
Sector dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time dum	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R sq.	0.72	0.72	0.86	0.82	0.86	0.7	0.74
N	83	83	82	83	83	83	83
Compl. test							
F(1,70)	0.06	6.33	0.25	72.01	29.80	2.56	8.19
pval	0.41	0.01	0.31	0.00	0.00	0.06	0.00

Note: Standard errors in parenthesis. Regressions correspond to equation *(6)* in the text. Complementarity tests are one tail tests.

TABLE 7

REGRESSIONS USING RETRIEVED FIXED EFFECTS FROM PRODUCTION FUNCTION ESTIMATES; INDIRECT EFFECTS THROUGH SIZE, OLS

	(1) Work intens	(2) Job rot	(3) Job auto	(4) Ch hours	(5) Ch w org	(6) Ch w tec	(7) New involv
(mean) birth	-0.00*	-0.00*	-0.01**	-0.00**	-0.00*	-0.00*	-0.00*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
γ_{S11}	0.73	0.71	0.55	0.78**	0.01	0.56	0.26
	(0.50)	(0.52)	(0.57)	(0.38)	(0.55)	(0.51)	(0.70)
γ_{S01}	-0.61	-0.25	0	0.96	0	0	-0.58
	(0.74)	(0.77)	(0.00)	(1.01)	(0.00)	(0.00)	(0.78)
γ_{S10}	0.90*	0.61	-0.19	0.03	-0.45	0.76	0.39
	(0.49)	(0.53)	(0.59)	(0.38)	(0.64)	(0.54)	(0.71)
γ_{S00}	0	0	-0.85	0	-2.37**	-0.25	0
	(0.00)	(0.00)	(0.73)	(0.00)	(0.99)	(0.73)	(0.00)
β_{S11}	0.30***	0.33***	0.31***	0.32***	0.30***	0.28***	0.24***
	(0.07)	(0.05)	(0.06)	(0.06)	(0.05)	(0.05)	(0.06)
β_{S01}	0.44**	0.23	0.17	-0.45	0.07	0.17	0.28*
	(0.21)	(0.21)	(0.20)	(0.36)	(0.20)	(0.21)	(0.15)
β_{S10}	0.29***	0.20**	0.18***	0.20***	0.11	0.29***	0.38***
	(0.06)	(0.09)	(0.06)	(0.07)	(0.12)	(0.09)	(0.08)
β_{S00}	0.23	0.19	0.03	0.29*	0.06	0.22	-0.02
	(0.22)	(0.23)	(0.19)	(0.15)	(0.42)	(0.20)	(0.29)
Constant	6.48	6.98	9.62**	8.60*	8.26*	6.78	6.74
	(4.52)	(4.58)	(4.24)	(4.37)	(4.52)	(4.64)	(4.30)
Sector dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time dum	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R sq.	0.72	0.73	0.87	0.84	0.87	0.7	0.75
N	83	83	82	83	83	83	83
Compl. Test							
direct	0.33	0.20	0.02	0.04	3.58	0.34	0.30
pval	0.29	0.33	0.45	0.42	0.03	0.28	0.30
indirect	0.40	0.06	0.00	4.77	0.13	0.02	1.81
pval	0.27	0.40	0.49	0.02	0.36	0.45	0.09

Note: Standard errors in parenthesis. Regressions correspond to equation *(7)* in the text. Complementarity tests are one tail tests.

TABLE 8

REGRESSIONS USING RETRIEVED FIXED EFFECTS FROM PRODUCTION FUNCTION ESTIMATES; INDIRECT EFFECTS THROUGH AGE, OLS

	(1) Work intens	(2) Job rot	(3) Job auto	(4) Ch hours	(5) Ch w org	(6) Ch w tec	(7) New involv
(mean) birth	-0.01	-0.01	0.01	-0.00	0.01	0	0.01
	(0.02)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)
γ_{A11}	0.61***	0.97***	0.56*	0.77**	2.49***	0.80***	0.56*
	(0.23)	(0.28)	(0.31)	(0.29)	(0.35)	(0.26)	(0.32)
γ_{A01}	-0.43	0	0	-0.80*	1.97***	0.11	-0.08
	(0.47)	(0.00)	(0.00)	(0.42)	(0.41)	(0.36)	(0.41)
γ_{A10}	0.90***	0.72**	-0.60*	-0.27	1.53***	1.10***	1.19***
	(0.23)	(0.31)	(0.33)	(0.30)	(0.39)	(0.28)	(0.32)
γ_{A00}	0	-0.06	-1.44***	0	0	0	0
	(0.00)	(0.41)	(0.37)	(0.00)	(0.00)	(0.00)	(0.00)
β_{A11}	-0.35	-0.16	1.07	0.45	1.82	0.58	1.72
	(1.81)	(1.56)	(0.94)	(1.30)	(1.53)	(0.86)	(1.55)
β_{A01}	0	-0.96	0	-0.28	1.47	0.13	1.34
	(0.00)	(1.68)	(0.00)	(1.48)	(1.65)	(1.25)	(1.68)
β_{A10}	-0.92	-0.67	1.42	0.58	2.04	0.21	0.98
	(1.83)	(1.59)	(0.95)	(1.36)	(1.62)	(0.96)	(1.56)
β_{A00}	-1.35	0	0.78	0	0	0	0
	(1.91)	(0.00)	(1.23)	(0.00)	(0.00)	(0.00)	(0.00)
Constant	20.99	14.68	-14.29	0.44	-29.68	-2.35	-18.78
	(35.94)	(30.49)	(17.75)	(25.36)	(29.83)	(16.31)	(30.25)
Sector dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time dum	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R sq.	0.73	0.73	0.86	0.83	0.86	0.7	0.75
N	83	83	82	83	83	83	83
Compl. Test							
direct	0.09	0.19	0.51	17.13	4.77	1.07	1.57
pval	0.39	0.34	0.24	0.00	0.02	0.15	0.11
indirect	0.16	0.71	0.10	0.01	0.93	0.03	0.12
pval	0.35	0.20	0.38	0.46	0.17	0.44	0.37

Note: Standard errors in parenthesis. Regressions correspond to equation *(8)* in the text. Age is divided by 100. Complementarity tests are one tail tests.

TABLE 9

REGRESSIONS USING RETRIEVED FIXED EFFECTS FROM PRODUCTION FUNCTION ESTIMATES; INDIRECT EFFECTS THROUGH EXTENT OF REORGANIZATION, OLS

	(1) Work intens	(2) Job rot	(3) Job auto	(4) Ch hours	(5) Ch w org	(6) Ch w tec	(7) New involv
(mean) birth	-0.00	-0.00	-0.00**	-0.01***	-0.00	-0.00	-0.00*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
γ_{C11}	0.38	1.28***	1.23**	0.62	2.59***	1.13***	0.61*
	(0.39)	(0.36)	(0.52)	(0.40)	(0.42)	(0.35)	(0.32)
γ_{C01}	-0.20	0	0	1.74	2.10***	0.71	0.15
	(0.40)	(0.00)	(0.00)	(1.15)	(0.46)	(0.47)	(0.40)
γ_{C10}	0.86**	0.94***	0.24	-0.18	1.68***	1.46***	1.39***
	(0.34)	(0.34)	(0.48)	(0.30)	(0.44)	(0.29)	(0.29)
γ_{C00}	0	0.58	-0.43	0	0	0	0
	(0.00)	(0.40)	(0.49)	(0.00)	(0.00)	(0.00)	(0.00)
β_{C11}	1.24	-0.56	1.34	0.05	-0.42	1.14	0.26
	(1.12)	(1.07)	(1.02)	(1.61)	(1.19)	(1.38)	(1.07)
β_{C01}	0.23	0	2.71*	-7.09**	-0.63	0	-0.14
	(1.61)	(0.00)	(1.60)	(3.10)	(1.49)	(0.00)	(1.42)
β_{C10}	0.52	-0.62	1.24	-0.29	0	0.94	-0.38
	(1.06)	(1.09)	(0.93)	(1.58)	(0.00)	(1.46)	(1.08)
β_{C00}	0	-1.69	0	0	-1.56	2.62	0
	(0.00)	(1.48)	(0.00)	(0.00)	(2.64)	(1.63)	(0.00)
nrpr	-0.45	0.89	-0.93	0.56	0.75	-0.94	0.53
	(0.96)	(0.97)	(0.85)	(1.51)	(1.11)	(1.28)	(0.95)
Constant	6.42	5.89	8.01*	11.07**	5.05	5.61	6.67
	(4.66)	(4.72)	(4.25)	(4.45)	(4.74)	(4.55)	(4.43)
Sector dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time dum	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R sq.	0.73	0.73	0.87	0.84	0.86	0.71	0.75
N	83	83	82	83	83	83	83
Compl. Test							
direct	0.35	3.74	0.99	0.62	4.44	3.53	3.73
pval	0.28	0.03	0.16	0.22	0.02	0.03	0.03
indirect	0.08	1.09	2.33	5.46	0.23	2.59	0.26
pval	0.39	0.15	0.07	0.01	0.32	0.06	0.31

Note: Standard errors in parenthesis. Regressions correspond to equation *(9)* in the text. The number of practices is divided by 10. Complementarity tests are one tail tests.

TABLE 10

PRODUCTION FUNCTION USING PRODUCTIVITY GROWTH AS DEPENDENT VARIABLE. NO INDIRECT EFFECTS. OLS; INDIRECT EFFECTS THROUGH EXTENT OF REORGANIZATION, OLS

	(1) Work intens	(2) Job rot	(3) Job auto	(4) Ch hours	(5) Ch w org	(6) Ch w tec	(7) New involv
(mean) birth	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
γ_{11}	-0.25	-0.20	0.02	-0.24	-0.10	-0.24	-0.22
	(0.19)	(0.24)	(0.20)	(0.18)	(0.16)	(0.19)	(0.20)
γ_{01}	-0.01	0.12	0.46*	0.14	0	-0.10	0
	(0.28)	(0.28)	(0.26)	(0.27)	(0.00)	(0.28)	(0.00)
γ_{10}	-0.17	-0.00	0.03	-0.01	-0.07	-0.24	-0.31
	(0.19)	(0.25)	(0.20)	(0.18)	(0.18)	(0.19)	(0.20)
γ_0	0	0	0	0	0.51	0	-0.13
	(0.00)	(0.00)	(0.00)	(0.00)	(0.32)	(0.00)	(0.26)
$d_3$lkn	0.40*	-0.56***	-0.66***	-0.63***	-0.62***	-0.60***	-0.60***
	(0.21)	(0.21)	(0.21)	(0.20)	(0.21)	(0.21)	(0.21)
$d_3$lk	-0.29	0.69***	0.74***	0.74***	0.74***	0.71***	0.74***
	(0.18)	(0.17)	(0.17)	(0.17)	(0.17)	(0.18)	(0.18)
Constant	3.21	3.31	2.27	3	3.97	3.28	2.83
	(5.29)	(5.18)	(5.15)	(5.21)	(5.17)	(5.28)	(5.26)
Sector dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R sq.	0.25	0.44	0.44	0.46	0.44	0.41	0.42
N	64	64	64	64	64	64	64
Compl. Test							
direct	0.06	1.06	2.82	1.58	1.91	0.10	0.02
pval	0.41	0.16	0.05	0.11	0.09	0.38	0.45

Note: Standard errors in parenthesis. Regressions correspond to equation *(12)* in the text. Complementarity tests are one tail tests.

BIBLIOGRAPHY

ASKENAZY P. - CAROLI E., «Innovative Work Practices, Information Technologies and Working Conditions: Evidence for France», *IZA, Discussion Paper*, no. 2321, Bonn, 2006.

ATHEY S. - STERN S., «An Empirical Framework for Testing Theories About Complementarity in Organizational Design», *NBER, Working Paper*, no. 6600, June, 1998.

BAUER T.K., «Flexible Workplace Practices and Labor Productivity», *Discussion Paper*, IZA n. 700, Bonn, 2003.

BLACK S. - LYNCH L., «How to Compete: The Impact of Workplace Practices and Information Technology on Productivity», *Review of Economics and Statistics*, vol. 83, no. 3, 2001.

BLACK S. - LYNCH L., «What's Driving the New Economy? The Benefits of Workplace Innovation», *Economic Journal*, 114, February, 2004, pages F97-F116.

BRESNAHAN T. - BRYNJOLFSSON E. - HITT L.M., «Information Technology, Workplace Organization, and the Demand for Skilled Labor: Firm-Level Evidence», *Quarterly Journal of Economics*, vol. 117, February, 2002.

BRYNJOLFSSON E. - HITT L.M. - YANG S., «Intangible Assets: Computers and Organizational Capital», *Brooking Papers on Economic Activity*, 1, pages 137-181, 2002.

BUGAMELLI M. - PAGANO P., «Barriers to Investment in ICT», *Temi di Discussione*, Banca d'Italia, no. 420, 2001.

CRISTINI A. - GAJ A. - LABORY S. - LEONI R., «Flat Hierarchical Structure, Bundles of New Work Practices and Firm Performance», *Rivista Italiana degli Economisti*, no. 2, 2003, pages 313-341.

DANISH MINISTRY OF BUSINESS AND INDUSTRY, «Technological and Organisational Change. Implications for Labour Demand», *Enterprise Performance and Industrial Policy*, Copenhagen, 1996.

EUROPEAN FOUNDATION FOR THE IMPROVEMENT OF LIVING AND WORKING CONDITIONS, *New Forms of Work Organisation: Can Europe Realise its Potential?*, Office for Official Publications of the European Communities, Luxembourg, 1997.

FREEMAN R. - KLEINER M. - OSTROFF C., «The Anatomy of Employee Involvement and its Effects of Firms and Workers», *NBER, Working Paper*, no. 8050, 2000.

GREEN F., «Why Has Work Effort Become More Intense?», *Industrial Relations*, vol. 3, Issue 4, 2004.

ICHNIOWSKI C. - SHAW K. - PRENNUSHI G., «The Effects of HRM Systems on Productivity: A Study of Steel Finishing Lines», *American Economic Review*, no. 87, 1997 pages 291-313.

KATO T. - MORISHIMA M., «The Productivity Effects of Participatory Employment Practices: Evidence from New Japanese Panel Data», *Industrial Relations*, vol. 41, no. 4, 2002, pages 487-520.

LAURSEN K. - FOSS N.J., «New Human Resource management practices, complementarities and the impact on innovation performance», *Cambridge Journal of Economics*, no. 27, 2003, pages 243-263.

MARIOTTI S., *Verso una nuova organizzazione della produzione. Le frontiere del post-fordismo*, [Toward a New Organization of Production. Frontiers of Post-Fordism], Etas Libri, Milano, 1994.

MICHIE J. - SHEEHAN M., «Labour Market Deregulation, "Flexibility" and Innovation», *Cambridge Journal of Economics*, vol. 27, no. 1, 2003, pages 123-143.

MILGROM P. - ROBERTS J., «The Economics of Modern Manufacturing: Technology, Strategy, and Organization», *American Economic Review*, no. 80, 1990, pages 511-528.

——— - ———, «Complementarities and Fit: Strategy, Structure and Organizational Change in Manufacturing», *Journal of Accounting and Economics*, no. 19, 1995, pages 179-208.

MILLWARD N., *Threats to the Validity of International Comparisons: Units of Analysis, the Operationalisation of Constructs and Some Analysis Issues*, Paper presented at the International Conference on Organisational Design, Management Styles And Firm Performance, University of Bergamo (Italy), 22-23 June, 2001.

OSTERMAN P., «The Wage Effects of High Performance Work Organisation in Manufacturing», *Industrial and Labor Relations Review*, no. 59, 2006, pages 187-20.

PYKE F. - BECATTINI G. - SENGENBERGER W. (eds.), *Industrial Districts and Inter-firm Co-operation in Italy*, International Institute for Labour Studies, ILO, Geneva, 1990

TOPKIS M.D., «Minimizing a Submodular Function on a Lattice», *Operations Research*, no. 26, 1978, pages 305-321.

TRENTO S. - WARGLIEN M., «Nuove tecnologie e cambiamenti organizzativi: alcune implicazioni per le imprese», *Temi di discussione*, no. 428, Banca d'Italia, Roma, 2001.

VIESTI G., «Crisi ed evoluzione dei distretti industriali», [Crisis and evolution of industrial districts], in ONIDA F. - VIESTI G. - FALZONI A. (eds.), *I distretti industriali: crisi o evoluzione?*, [Industrial Districts: Crisis or Evolution?], Egea, Milan, 1992.

ZWICK T., «Employee Participation and Productivity», *Labour Economics*, vol. 11, no. 6, 2004, pages 715-740.