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TECHNOLOGICAL AND ORGANIZATIONAL CHANGES AS DETERMINANTS OF THE SKILL BIAS: EVIDENCE FROM A PANEL OF ITALIAN FIRMS [*]

by

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Abstract
Recent empirical literature has introduced the "Skill Biased Organizational Change" hypothesis, according to which organizational change can be considered as one of the main causes of the skill bias (increase in the number of highly skilled workers) exhibited by manufacturing employment in developed countries. In this paper, a specific branch of the Italian capital goods industry is analyzed, that producing specialized industrial machinery; from the estimation of a transcendental logarithmic firm cost function it turns out that skill upgrading is not a consequence of technological change alone, but is also an effect of the overall reorganization of the firm, which in turn may be linked to technological change.

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1. Introduction

In the most highly developed countries the share of skilled workers has increased over time. The economic literature has proposed for this secular trend an explanation based on the so-called Skill Biased Technological Change (SBTC) hypothesis, according to which the reason for the upskilling of the labor force is to be found in the non-neutrality of technological change (TC), which benefits skilled labor more than other production factors (*factor bias*). Being technology complementary to skills, acceleration in the rate of TC determines an increase in the demand for skilled labor an increase in the supply of skills induces faster TC (see among others, Greiner, Rubart and Semmler, 2001; Acemoglu, 2002).

While SBTC appears to be a long-term historical trend (see Nelson and Winter, 1982; Goldin and Katz, 1998), recently the diffusion of Information and Communication Technologies (ICT) seems to have fostered a new impetus in the substitution of unskilled workers with skilled ones. Accordingly, Wood (1995) and Michel and Bernstein (1996) argue that, in contrast with previous decades, the acceleration of SBTC has also resulted in rising skill premia[1] in many countries. However, since at the industry level the evidence for this acceleration is somewhat mixed, with some industries characterized by higher skill premia than others (see Autor, Katz and Krueger, 1998), one might conclude that, within a multi-sector framework, it is mostly the *sector bias* of TC that is in operation, rather than the *factor bias*. This explanation is consistent with empirical evidence supporting the SBTC hypothesis at the macroeconomic level for countries in which high-tech industries account for larger shares of GDP (such as the US and the UK) but not for medium or low-tech ones (including other European countries).

Given that the literature is inconclusive about whether TC favors a certain factor of production or is more likely to occur in certain industries than in others (see Haskel and Slaughter, 2002) some researchers have attempted to explore other possible complementary explanations of the skill-bias. Among trade economists, these alternatives are related to *globalization*[2], whereas among industrial and managerial economists they are related to *reorganization of production*.

In this paper, following the approach put forward by industrial and managerial economists, attention will be focused on the role of organizational change as a factor associated to with skill-upgrading within a branch of the capital goods industry (that producing specialized industrial machinery) in Italy. It is organized as follows. In Section 2 we discuss the economic literature

[1] Defined as the ratio of the wages earned by high-skilled workers and the wages earned by low-skilled workers.

[2] This strand of literature supports the hypothesis that increased volumes of world trade and FDI cause a reallocation of the labor force, shifting activities involving unskilled workers towards the least developed countries, while activities involving the production of skill-intensive goods remain in developed countries (Wood, 1994). Due to lack of data, an empirical test of this hypothesis is very challenging and the few studies on the subject have not found any strong support for this explanation of the skill-bias, see Slaughter (2000) and Piva and Vivarelli (2002).

covering the role of technological and organizational changes as possible explanations for the skill bias. In Section 3 we present an overview of the capital goods industry in Italy, whereas in Section 4 we put forward our empirical analysis based on a panel of 25 Italian (large) firms in the capital goods industry. Finally, in Section 5 some conclusive considerations are presented.

2. The SBTC and SBOC hypotheses

2.1 Skill-biased Technological Change

The Skill-biased Technological Change (SBTC) hypothesis is based on the well-established idea that there is a strong complementarity between new technologies and skilled workers as far as the latter are the only ones able to fully implement the former. Empirical studies testing this hypothesis, at both the firm and the industry level, have been carried out with regard to manufacturing sectors in different developed countries. Most of these studies focus on the *factor bias* of SBTC.

As far as the US is concerned, evidence supporting the SBTC hypothesis is abundant. Among the most representative papers, Berman, Bound and Griliches (1994) - at the industry level - and Dunne, Haltiwanger and Troske (1996) - at the firm level - found a positive and significant relationship between R&D and skilled labor in the US. Doms, Dunne and Troske (1997) - for firms in some US manufacturing sectors - showed that the use of the most advanced industrial technologies leads to a greater utilization of workers with higher qualifications. Moreover, Siegel (1998) found evidence of upskilling in certain Long Island manufacturing plants that had introduced new technologies. Finally, dealing with US chemical firms, Adams (1999) showed the skill-bias nature of R&D expenditure and innovative investments.

In Canada, both Betts (1997) focusing on manufacturing and Gera, Gu and Lin (1999), focusing both on manufacturing and service sectors (1981-94), showed a connection between several different measures of technology and the growing demand for skilled workers.

For the UK, Machin (1996) - using both sector-level and firm-level data in the '90s - and Haskel and Heden (1999) - at the firm level - showed respectively a positive relation between R&D intensity, number of innovations produced and used, and skilled labor (in the sector analysis), and between the use of computers and skilled labor in the case of firms for both the studies.

In studies regarding other countries, results generally confirmed the SBTC hypothesis, but less robustly than in British and North American economies. For example, in France, Mairesse, Greenan and Topiol-Bensaïd (2001) obtained results similar to those of Machin for firm data where the technological variables were ICT capital and ICT workers; however, only the negative relation between ICT and less-qualified labor was robust in time-series. This confirmed the results of Goux and Maurin (2000), which showed how an increased spread of new technology explained only 15% of the change in labor demand in France between 1970 and 1993.

2.2 Skill-biased Organizational Change

The Skill-biased Organizational Change (SBOC) hypothesis relies upon a recent idea that there is a progressive transformation within firms moving from rigid, Tayloristic-style, segmented organizations towards more flexible and "holistic" ones (see Lindbeck and Snower, 1996). This phenomenon first appeared in the US and Japan and has since spread through Europe (see Aoki, 1986; Greenan and Guellec, 1994; OECD, 1999). It is impossible here to give a full account of the vast literature on organizational change and its impact on a firm's structure and performance[3]; it will be sufficient to remind that economic, management and sociological studies on the subject seem to agree in singling out three main trends: i) *Decentralization and delayering*, implying "lean production" associated with new firms' functions such as just-in-time, management of breakdowns and quality control which in turn imply both the decentralization of decision-making and more involvement, responsibility and autonomy on the workshop floor (see Brynjolfsson and Mendelson, 1993); ii) *Collective work*, that is new work practices such as work teams and quality circles require collective efforts from the manpower (see Osterman, 1994); iii) *Multi-tasks*, as a consequence of which workers are now requested both to perform a greater variety of tasks within a given occupation and to rotate among different jobs (see Greenan and Mairesse, 1999; Ichniowski and Shaw, 2003).

These organizational innovations imply a need for upskilling of the manufacturing workforce; thus, the "skill biased organizational change" (SBOC) hypothesis has been put forward and tested. In this connection, the empirical literature revealed that most organizational changes occur at the same time, assuming the form of "clusters" of organizational innovations. For instance, Ichniowski, Shaw and Prenushi (1997) showed the complementarity of the introduction of teamwork, flexible job assignment and intensive worker-management communication in US steel manufacturing. As far as the direct test of the SBOC hypothesis is concerned, using a French survey on work organization, Greenan and Guellec (1998) found that organizational changes - such as a larger workers' autonomy and an increase in between workers communication - were positively correlated with skill upgrading. Moreover, Caroli and Van Reenen (2001), comparing two panels of French and British firms, focused on organizational change, measured with a dummy. Their results, supporting the SBOC hypothesis, turned out to be econometrically significant in both the panels. In

Italy, Piva, Santarelli and Vivarelli (2003) identified a super-additive effect of technological and organizational change[4] on the skill composition of Italian manufacturing employment in the 1990s. In particular, they have shown *a)* that the alleged role of R&D alone in determining skill bias is not confirmed by econometric estimations, *b)* that significant organizational changes made by a firm to its structure and functions are major factors affecting skill composition, and *c)* that combining the R&D and the organization variables yields higher and more significant coefficients, even in comparison with the organization variable in previous estimates.

3. The capital goods industry in Italy

Italian manufacturing is to a large extent characterized by the employment of intermediate technologies, more related to embodied technological change than to internal R&D. From this viewpoint, the capital goods industry - particularly the branch specialized in the production of industrial machinery - is one of the main sources of new technology for most of the other industries using capital equipment embodying new knowledge usefully employable in the development of new products or the improvement of existing ones. Besides driving technological change and innovation in those traditional consumer goods industries that constitute the bulk of the Italian economy, this industry is also among the few manufacturing industries in which Italy holds a competitive advantage mostly based on the technological strength of its firms. As a result, the country is among the top exporters worldwide of specialized industrial machinery, with a share of world exports almost always above 10% during the 1990s (with a peak of 11.51% in 1996), and a share of EU exports ranging between 21% and 22 %over the same period (with a peak of 22.6% again in 1996).

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[3] This literature has focused more on the consequences of organizational change on productivity than on its effects on skill-composition. See, among others, Colombo and Delmastro (2002).

[4] The possible interaction between technological and organizational change has been also investigated in case-study analyses; for example, Fernandez (2001) - analyzing the retooling of a food processing plant in the US - shows that organizational and human resources factors have strongly mediated the impact of changing technology, whereas Pavitt (2002) – analyzing the development of “innovating routines” inside the firm – shows the importance of the matching of specific corporate competencies and organizational practices to the market opportunities offered by specific technologies..

Table 1 – Structure and economic performances of Italian firms in the specialized industrial machinery industry*

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Number of firms	2,339	2,328	2,316	2,304	2,292	2,481	2,671	2,861	3,051	3,240
- Δ No. of firms (%)		-0.47	-0.52	-0.52	-0.52	8.25	7.66	7.11	6.64	6.19
Number of employees	283,314	272,345	260,618	261,090	267,679	272,691	272,380	272,943	269,796	287,735
- Δ No. of employees (%)		-3.9	-4.3	0.2	2.5	1.9	-0.1	0.2	-1.2	6.6
Average firm size	12.112	11.701	11.253	11.333	11.679	10.989	10.196	9.539	8.843	8.879
Total sales (M €)	33,683	35,236	36,653	39,936	47,511	50,333	52,184	54,219	54,495	60,020
- Δ Total sales %		4.6	4.0	9.0	19.0	5.9	3.7	3.9	0.5	10.1
Gross operating surplus (%)	9.7	9.9	10.6	10.7	10.1	9.4	9.8	9.9	10.1	10.5
Net income (%)	2.5	2.1	2.3	2.8	3.3	2.5	2.3	2.5	2.5	2.0
Fixed investments (%)	3.2	2.6	2.5	2.6	4.8	3.8	3.2	3.1	3.4	5.0
Fixed capital intensity ((%)	16.3	17.0	16.8	15.9	14.6	15.6	16.7	17.5	18.5	18.7
Total capital intensity (%)	76.2	75.6	72.8	68.7	65.0	67.2	68.4	70.2	73.1	69.5
Leverage (%)	1.13	1.09	1.04	1.00	0.96	1.04	1.03	1.06	1.07	0.95
ROE (after tax)	10.7	8.4	9.4	12.1	15.5	11.7	10.6	11.4	10.7	8.3

Source: Prometeia Srl.
* All monetary values are in current prices.

The data reported in Table 1 for the 1991-2000 period provide an overview of the structure and the performance of this industry[5]. First of all, the data shows that a significant process of new firm formation and entry has characterized the Italian capital goods industry in the last decade, with the total number of firms increasing by nearly 39%. In particular, net entry has become stronger over the second half of the decade, when the number of active firms in the industry increased at a rate of between 6.19% (in 2000) and 8.25% (in 1996). However, Italian firms in this industry have also been characterized by an aggressive investment strategy (with total fixed investments increasing by an average yearly rate of more than 3% during the relevant period). Taking into account that new firm formation and accelerating investments generally imply both embodied technical change and reorganization of the workshop floor, these are indirect indications that technical progress and organizational change might have played an important role in reshaping the composition of the sectoral workforce in favor of skilled workers, at least in the second half of the 1990s.

From Table 1 only one direct indication concerning employment arises, namely a general stability of total employment during the 1990-2000 period, with a significant reduction in the early 1990s and a marked increase from 1999 to 2000.

Analysis of the economic performance of Italian producers of specialized industrial machinery gives a generally positive picture. The dynamics of total sales is particularly favorable throughout the 1990s, with a peak in 1995 when total sales in current prices grew by nearly 20% compared with the previous year. Also gross operating surplus, net income, and ROE were positive, again with a peak around the mid-1990s[6].

4. Data and empirical estimates

4.1 Data

Our empirical analysis started with the identification of the 200 largest firms in the capital goods industry that produce specialized industrial machinery. These firms, located mostly in Northern and Central Italy, were interviewed via e-mail and, when an e-mail address was not available or replies were not forthcoming after four weeks, via a postal questionnaire. Although only 25 of them (12.5%) returned the questionnaire, it was possible to construct a panel database covering the six-year period between 1996 and 2001.

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[5] Based on ISIC rev.3 sectors interested are 291 (Manufacture of general purpose machinery) and 292 (Manufacture of special purpose machinery).

[6] To some extent, the positive performance of the Italian capital goods industry is probably linked to the long-standing tradition (dating back to the mid-1960s) of investment subsidies in Italy. In this respect, empirical work (for a survey, see Goolsbee, 2003) has shown that capital investment responds less to investment subsidies than basic models predict, probably because some of the benefits of the subsidy are passed on to the capital suppliers through higher prices.

Besides standard information on their size, sales, capital, and the belonging/not belonging to an industrial group, firms were requested to provide detailed data and information on the composition of their workforce, labor costs, number of patents registered with either USPTO or EPO, R&D expenditures, purchases of embodied (machinery, etc.) or disembodied (licenses) technological innovations. In the concluding section of the questionnaire, firms were requested to indicate the type of organizational innovations introduced in each of the years considered and, if they had introduced such innovations, to quantify the percentage of the workforce that was involved. With reference to skills, our data allow for the identification of only two broad categories of homogeneous workers: white-collars (WC, including the entrepreneur and family assistants, senior and junior managers, and office workers) and blue-collars (BC, manual workers).

4.2 Methodology

The econometric specification was conducted within a theoretical framework based on the transcendental logarithmic (or translog) firm cost function originally introduced by Kmenta (1967) to approximate the CES production function, and formally developed by Christensen, Jorgenson and Lau (1971 and 1973). One of the main advantages of the translog cost function is that it does not impose *a priori* restrictions on the admissible patterns of substitution between inputs and outputs. Nevertheless, since it has a number of unknown parameters, some restrictions must be imposed.

Accordingly, we estimated a restricted function of total variable costs, which were given only by the cost of labor, while other input variables were assumed to be quasi-fixed factors. In this context, in our econometric specification the alternate dependent variables were the logs of the ratio of WC to total employment and BC to total employment, representing upskilling within the firms. The aim was to test the role of the two possible determinants of skill-bias - measured as variables indicating the intensity of activities related to technological innovation (TEC[7]) and organizational changes (OC[8]) - checking for all the factors, such as output, capital and labor cost, which might influence the causative link that we wanted to study[9]. Also the interaction between technological innovation and organizational change (TEC*OC) was taken into account, to test the hypothesis that the characteristics of technology lead to experimentation in organizational practices, and viceversa (cf. Pavitt, 2002). In addition, to control for the dynamic path of the dependent variable, which turned out to be quite persistent in its time dimension (for both WC and BC), the lagged dependent

[7] TEC is measured each year as the total expenditure on innovation.
[8] OC is measured each year as number of employees involved in organizational change connected to the production activity of the firm.
[9] Sample summary descriptive statistics are reported in the Appendix (table A1).

variable was included in the right hand-side of each of the two equations for WC (equation 1) and BC (equation 2), which therefore assumed the following specifications:

$$(1)\ln(WC)_{it} = C + \alpha\ln(WC)_{i,t-1} + \beta\ln(Y_{it}) + \gamma\ln(K_{it}) + \delta\ln(W_{WC}) + \eta\ln TEC_{it} + \lambda\ln OC_{it} + \\ + \vartheta\ln TEC * OC_{it} + u_{it}$$

$$(2)\ln(BC)_{it} = \tilde{C} + \tilde{\alpha}\ln(BC)_{i,t-1} + \tilde{\beta}\ln(Y_{it}) + \tilde{\gamma}\ln(K_{it}) + \tilde{\delta}\ln(W_{BC}) + \tilde{\eta}\ln TEC_{it} + \tilde{\lambda}\ln OC_{it} + \\ + \tilde{\vartheta}\ln TEC * OC_{it} + \tilde{u}_{it}$$

where C denotes the constant, Y total sales, K capital, W wages, TEC technological change, and OC organizational change.

The inclusion of the lagged dependent variable in a dynamic panel data context requires more sophisticated econometric techniques than traditional ones due to the correlation between the lagged dependent variable and the error term (Baltagi, 2001, p.129). Indeed, this correlation renders the Ordinary Least Squares estimator (OLS) biased and inconsistent and the Within Group estimator turns out to be always biased and moreover inconsistent if the time dimension is not large enough (as in our case). In addition, it is necessary to get rid of at least the individual firms' effects (a component of the error term); therefore first difference transformation is implemented and instrumental variable techniques are used to instrument new regressors correlated with new error terms. In particular, Arellano and Bond (1991) propose the unbiased and consistent GMM-DIF estimator (first differenced) which uses an instrument matrix containing instruments for all the regressors depending on the assumptions made about endogeneity, predetermination and exogeneity[10] of the corresponding instrumented variable.

4.3 Empirical results

We run separate regressions[11] - using the GMM-DIF estimation procedure[12] - for white-collars (equation 1, table 2) and blue-collars (equation 2, table 3), taking into account the SBTC, the SBOC, and the joint SBTC/SBOC hypotheses[13].

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[10] If the generic $x_{i,t}$ variable is assumed to be endogenous, the lagged values $x_{i,t-2}$ and longer lags are valid instrumental variables in the first differenced equations for periods t = 3, …, T. If the variable is predetermined, then $x_{i,t-1}$ is additionally available as a valid instrument in the first differenced equation. If a stronger assumption is made, that $x_{i,t}$ is strictly exogenous, then the complete time series of the $x_{i,t}$ or the contemporaneous first difference are valid instrumental variables on each of first-differenced equations (see Bond, 2002).

[11] In order to have a manageable unbalanced panel, data regarding only 22 firms were used.

[12] One-step GMM-DIF results are presented. DPD 1.00 (Dynamic Panel Data) for Ox is used (see www.nuff.ox.ac.uk/Users/Doornik).

[13] The joint SBTC/SBOC hypothesis has been tested through the inclusion of an interaction variable (see equation (1) above).

As expected, the demand for white-collars (table 2) increases with increase in total sales, and with a reduction of white-collars' wages, while investments do not play a significant role. As far as TEC is concerned, results do not support the SBTC hypothesis, since firms more committed to technological change exhibit a reduction in white-collar workers (column 1). Although we are unable to distinguish between the single components of this broad category of employees it is likely that this result is driven by a reduction in the number of clerical workers and other intermediate figures, whereas that of technicians and scientists should at least remain stable. Conversely, the SBOC hypothesis is confirmed by the estimates, although OC turned out to be barely significant (column 2). Finally, no statistically significant interaction is found between technological change and organizational change, i.e. they do not seem to generate super-additive effects (column 3).

Table 2 – Regression results: WHITE-COLLARS

	(1)	(2)	(3)
White-collars (-1)	0.92***	0.82***	0.83***
	(4.91)	(4.11)	(5.84)
Sales	0.22***	0.23**	0.19**
	(3.89)	(2.61)	(3.29)
Capital	0.04*	0.03	0.03
	(1.92)	(0.71)	(0.87)
Wages	-0.38**	-0.43***	-0.27**
	(2.53)	(4.47)	(2.11)
TEC	-0.20*		-0.11*
	(1.92)		(1.64)
OC		0.04*	0.04*
		(1.91)	(2.19)
TEC*OC			-0.06
			(0.59)
Constant		0.04	0.05
		(1.50)	(1.59)
Time dummies	Yes	Yes	Yes
Sargan test	11.95	4.24	2.15
Observations	83	68	67

Notes:
- the monetary variables are all expressed in constant prices (base = 1995).
- the GMM-DIF estimates are in first differences.
- in brackets: t-statistics in absolute value, robust for heteroscedasticity; *=10% significant, ** =5% significant, ***= 1% significant.
- lagged white-collars, TEC, OC and TEC*OC are considered as endogenous; sales, capital and wages as exogenous.
- the Sargan-test has a $\chi^2(16)$ distribution under the null hypothesis of validity of the instruments in column (1) and (2)
($\chi^2(32)$ in column (3)); the test is not significant therefore the null hypothesis is not rejected.

As far as blue-collars are concerned (table 3), their dynamics over time is less affected by total sales than was the case with white-collars; technological change pushes down their relative number (column 1), while organizational change is substantially neutral (column 2). This neutrality of OC is probably linked to the fact that it determines a restructuring of managerial activities but not necessarily (and non simultaneously) a significant modification of the work practices at the shop floor level. Finally, no statistically significant impact arises from the interaction between technological and organizational change (column 3). This implies that no super-additive skill bias effect of reorganization combined with technological change is in operation.

Table 3 – Regression results: BLUE-COLLARS

	(1)	(2)	(3)
Blue-collars (-1)	0.50***	0.57***	0.56***
	(3.69)	(3.43)	(5.54)
Sales	0.17*	0.10	0.11*
	(1.78)	(1.10)	(1.99)
Capital	0.10	0.01	0.03
	(1.18)	(1.19)	(0.52)
Wages	-0.15	-0.08	-0.18
	(0.77)	(0.47)	(1.06)
TEC	-0.33*		-0.20
	(1.75)		(1.55)
OC		-0.0005	-0.04
		(0.01)	(1.63)
TEC*OC			0.11
			(0.73)
Constant	-0.02	-0.005	-0.004
	(0.82)	(0.24)	(0.22)
Time dummies	Yes	Yes	Yes
Sargan test	17.60	6.11	11.10
Observations	84	69	68

Notes:
- the monetary variables are all expressed in constant prices (base = 1995).
- the GMM-DIF estimates are in first differences.
- in brackets: t-statistics in absolute value, robust for heteroscedasticity; *=10% significant, ** =5% significant, ***= 1% significant.
- lagged blue-collars, TEC, OC and TEC*OC are considered as endogenous; sales, capital and wages as exogenous.
- the Sargan-test has a $\chi^2(16)$ distribution under the null hypothesis of validity of the instruments in column (1) and (2)
($\chi^2(32)$ in column (3)); the test is not significant therefore the null hypothesis is not rejected.

5. Conclusions

For a specific branch of the Italian capital goods industry - that producing specialized industrial machinery - it results that skill upgrading is not a direct consequence of technological change, but is rather mainly an effect of the overall reorganization of the firm, which in turn may be linked to technological change. In particular, technological change alone exhibits a labor-saving nature, irrespective of the relative skills of the affected workers. In contrast, organizational change seems to entail an asymmetric effect in favor of skilled workers. Finally, in contrast with results obtained by Piva, Santarelli and Vivarelli (2003) dealing with Italian manufacturing as a whole, this industrial sector seems not to be characterized by any significant super-additive skill-biased effect originating in the joint occurrence of technological and organizational change.

Although these results may be considered specific to the sector examined, they nevertheless suggest some interesting managerial implications. First, at least in some sectors, technological change may have an overall labor-saving impact, involving both blue and white collars, with obvious implications in terms of HRM. Second, organizational change may show a skill-biased nature, implying the need for training and re-training of the labor force both on and off the job. Third, although no clear evidence of a super-additive effect emerges from this study, the interaction between technological and organizational change should be monitored carefully both in terms of its impact on a firm's performance and on the level and structure of employment within the firm.

Appendix

Table A1 – Summary statistics

	Mean	Standard Deviation
Employment	278	559.56
White-collars	90	119.46
Blue-collars	188	447.79
Sales (millions of Euro)	67.95	117.31
Capital (millions of Euro)	39.04	101.72
White-collars wages (000 Euro per employee)	70.70	8.83
Blue-collars wages (000 Euro per employee)	50.60	7.48
TEC (millions of Euro)	2.75	3.26
OC	48.76	95.59

Notes:
- Sales, capital, white-collars' wages, blue-collars' wages and TEC are expressed at 1995 prices.
- OC represents the number of employees involved in organizational change related to the production activity of the firm.

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